e-Pathshala पाठशाला

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Stream	**BIO-GROUP**
Faculty	**SCIENCE**
Department/ Subject	**ZOOLOGY**
Course	ZOOL202- Systematics, Biodiversity & Evolution
Course Duration	IISemester (CBCS)
Sub Topic	**Biosystematics & Taxonomy**
Content	Scope & Significance of Biosystematics, Experimental Taxonomy, Experimental & Classical Taxonomy
Search KeyWords	Genecology, phylogenetic or omega, Turreson categories

Biosystematics & Taxonomy

Introduction

Biosystematics is simply known as "the study of biodiversity and its origins" and it is an art as much as science. In a broader sense, it is a science through which organisms are discovered, identified, named and classified with their diversity, phylogeny, spatial and geographical distributions. It is a science that provides indispensable information to support many fields of research and beneficial applied programmes. Biosystematics is a synthetic branch which uses the characters and data from many disciplines like morphology, anatomy, cytology, genetics, palynology, embryology, ecology, plant geography, phylogeny, physiology, phytochemistry, evolution and paleobotany. Hence, biosystamatics is an integrative and unifying science.

The experimental taxonomy is also known as 'Biosystematics', which was first advocated by the ecologist F.E. Clements (1905). In 1920 the Swedish botanist Turresson laid foundation to it. Camp and Gily (1943) coined the term '**Biosystematics**'. It is originally coined from the word 'biosystematy'.

Biosystematics is the taxonomic application of the **genecology**, is the study of the genotypic and phenotypic variation of species in relation to the environments in which they occur. It is the union of taxonomy and genetics. The biosystematics mainly concerned with genetical, cytological and ecological aspects of taxonomy and it must involve the studies in the experimental gardens.

Is taxonomy in crisis?

It is very important to know the living organisms around us, and careful and accurate identification and classification are of vital importance (Kapoor, 1998). Without taxonomy, nobody would be sure of the identity of organisms they were interested in, or whether they belonged to the same or different species as the organisms studied by others. Without taxonomy, there would be no meaningful genome projects, and medical science, for example, would be seriously compromised. Without taxonomy, we could not begin to understand biodiversity and the related issue of conservation (Nature, 2002). As Kapoor (1998) pointed out, taxonomy is essential in theoretical and applied biology (agriculture and forestry, biological control, public health, wild life management, mineral prospecting through the dating of rocks by their enclosed fauna and flora, national defence, environmental problems, soil fertility, commerce, etc).

About 1.7 million species have been named since Linnaeus and it is generally estimated that only around 10% of the world's biota has so far been described (Wilson, 2000; Disney, 2000). Obviously, taxonomy plays the major role, and its importance as basic science for the remaining sciences should be taken into consideration. However, although society has a growing need for credible taxonomic information in order to allow us to conserve, manage, understand, and enjoy the natural world, support for taxonomy and collections is failing to keep pace (Wheeler *et al*., 2004) and passing through a world crisis (Boero, 2001).

Scope and Significance of Biosystematics

Biosystematics has broad **scope** in the following branches to generate fundamental knowledge of living organisms.

i. Experimental taxonomy: In the sense of experimental taxonomy it provides data on variations, adaptations, and evolutionary dynamics of populations and species.
ii. Biodiversity: To make an inventory of diversity of life forms.
iii. Biological Resources: For management and conservation of plant, animal and microbial genetic resources and their sustainable use.iv. Ecology and Environment: For protection and conservation of natural habitats and ecosystems of the earth.
vi. Evolution and Biogeography: to demonstrate the evolutionary implications and its effects on phylogeny. To provide information on distribution patterns of various organisms of universe.
v. Agriculture & Forestry: To develop sustainable practices in agriculture, forestry, industry, urban development to ensure health and wealth of environment.
vi. Biotechnology: By using genetic diversity of organisms developing new varieties in crops, new strains for medicines and analyzing DNA patterns for forensic uses.
vii. Politics: To give information to make laws acts and national policies on biodiversity, environment and forests.

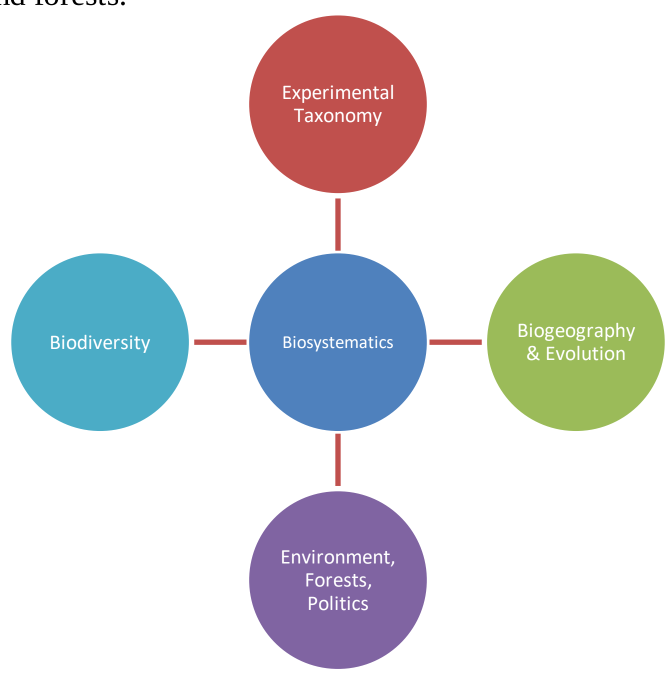

Figure represents the scope of Biosystematics in broader sense

Significance of Biosystematics:

The significance of biosystematics spreading to the following aspects-

1. Biosystematics provides a foundation of information about the incredible diversity of the life.
2. Biosystematics is useful to understand the evolutionary history and relationship of the different groups of organisms.
3. The study of biosystematics gives the fundamentals for defining and delimiting species and infraspecific texa.
4. It provides information to determine whether a species or infraspecific texon is common, rare, threatened and endangered. This data may aid in conservation, protection and management of such taxon.
5. The biosystematic studies are helpful to better understanding on the natural relationships of organisms, particularly those of the rank of genus and below.
6. It promotes cooperative research between taxonomists and other biological specialists and provides impressive data for biological research.
7. In biosystamatics, transplant experiments could provide important clues to the relationship between similar plants (Hall, 1932).
8. The experimental techniques used by biosystamatists are potential, fruitful methodology for improving classification.
9. The research in biosystematics emphasized the previously little explored problems such as variation, adaptation, and evolutionary dynamics of population.
10. The biosystematics will give route map for restoration of degraded or damaged ecosystems such as forests, wetlands and other habitats.

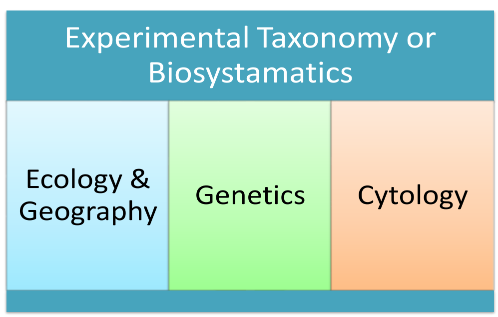

Figure represents the scope of biosystamatics in the sense of experimental taxonomy

Practical applications of experimental taxonomy or biosystematics

1. Babcock (1926) studied the cytogenetics of genus *Crepis* and produced a 'classical model' with combined applications of cytology, genetics and taxonomy.
2. The experimentalist Jens Clausen has studied taxonomy and cytogenetics of genus *Viola* and published fruitful results.
3. In *Phleum pratense* L. (Poaceae) there are diploid and hexaploid groups which are practically intersterile and occupy ecologically different habitats. The cytogenetics study revealed that

these two groups may correspond to var. *typicum* Beck., and var. *nodosum* (L.) Richt. and together fall within the subspecies *vulgare*.

4. T. G. Tutin has studied the different races of *Poa annua* L. (Poaceae) a remarkable species which is capable of growing different habitats and found several cytogenetic variants.
5. A.A. Maassoumi (2009) has published the experimental taxonomy of the genus *Salix* L. (Salicaceae) in Iran. He recognized 31 species (earlier 12 species were reported in Iran) and 7 hybrids with the help biosystematics studies.

Principles and Procedures

The following general principles are proposed by various biosystematists by experimenting different techniques.

1. Selection of plant groups: In this stage we have to select the plant groups for study of variations and micro-evolution.

2. Collection of samples: Targeted plant groups samples should be collected from its geographical and ecological ranges.

3. Cultivation of samples: Collected samples should be cultivated in experimental gardens, where the polymorphy and characters of races can be studied under uniform conditions, and various statistical methods to be followed.

4. Observation of variations and collection of data: The samples should be observed on the grounds of their geography and ecology and note down the continuous and discontinuous variations.

5. Study of fertility relationships and investigation of cytology: The samples should be studied in the view of their breeding behavior, barriers and cytology.

6. Synthesis of results: This also called as synthetic or encyclopaedic phase of principle. This phase aims to synthetize or coordinate the evidences and information derived from the above prinicples in order to express the taxonomic and evolutionary relationships of plants at different levels of hierarchy. The results especially give more details on levels of species, subspecies, varieties, ecotypes, ecophenes, etc.

Procedure and methods in the study of biosystematics

The experimental methods are supplementary to herbarium and other classical methods of taxonomy. The methods followed in the experimental taxonomy will enrich the existing system of taxonomy and act as complementary, mutually helpful. These methods give all the essential data in separating and solving a number of problems which may develop in the recognition of plants at the level of species and its real position.

The general technical procedure of experimental taxonomy includes the following steps as proposed by W.B. Turrill (1952). They are

i. Planning: Select taxonomic groups with few taxa and collect the available literature. While selecting, annuals, perennial herbs or shrubs are preferable than woody plants.

ii. Collection of material: The material should be collected ideally from wild and make a fair analysis of wild populations. The samples should be planted in the form of seeds or vegetative propagators in the experimental garden.

iii. Labelling: Label all the stocks and samples which are using for experiment.

iv. Attention: Attention should be made in all the stages of experiments

v. Scoring & Analysis: Record the qualitative and quantitative characters and abiotic factors with the help of scoring sheets. The obtained scores should be analyzed and preserved.

vi. Harvesting: The dry fruits and seeds of the samples can be collected and stored for future experiments.

Methods: The following methods are covering all the aspects of experimental taxonomy:

Method 1: It includes careful sampling and analysis of the taxonomic species. The population of taxon, its geographical range, palynology, anatomy, cytology, chromosomal number, phytochemistry, and natural behavior of taxon should be observed and studied for finding genetic variations that may arise between different populations.

Method 2: It involves determination of capability of dissimilar populations to interbreed between one another to form a variant species with vigor and fertility of it. This will reveal the existence or absence of breeding barriers among taxa at several levels.

Method 3: It includes the study of likeness of chromosomes in the hybrids throughout meiosis.

The information acquired from the above studies is compared with the data acquired by comparative morphology and geographical distribution resulted in the identification and recognition of a total range of species.

Relationship between experimental and classical taxonomy

In classical taxonomy, the relationship between the taxa is typically based on morphological characters. It is also known as **alpha, descriptive, formal** and **orthodox taxonomy.** Classical taxonomy was predominantly practiced during the Darwinian and pre-darwinian period. The artificial systems of classifications (Classification of Theophrastus & Sexual system of classification of Linnaeus) and natural systems of classifications (Classifications of de Jussieu, de Candolle and Bentham & Hooker) are the best examples for the classical taxonomy. The classical taxonomy not much reflected the genetical and evolutionary relationships among the taxa. Realization of this has led, the botanists attempted **phylogenetic or omega taxonomy** after the publication of 'Origin of species' and the announcement of 'theory of evolution' by Charles Darwin (1859). This has resulted the 'Synthetic systems' or 'Post-Darwinian systems of classifications' (eg. Classifications by Eichler, Engler & Prantal, Bessey, Hutchinson and more recent ones Takhtajan (1980), Cronquist (1981) and Thorne (1992). To acquire the large amount of data the systematists have experimented different fields such as cytology, anatomy, genetics, palynology, embryology, ecology, plantgeography, physiology, phytochemistry, evalution and paleobotany. Such a multidisciplinary approach has led to discover a great many new important taxonomic characters, and provides the data to phylogenetic classifications, numerical taxonomy, cladistics and **experimental taxonomy or biosystematics.** The classification of organisms on the basis of experimental facts has been termed as 'Experimental taxonomy'. In 1920 the Swedish botanist Turresson laid foundation to it. The experimental taxonomy studies the organisms from the stand point of populations rather than individuals, and evolutionary processes which occur within populations.

The experimental taxonomy concerned with genetical, cytological and ecological aspects of taxonomy and must involve the studies in the experimental gardens, whereas classical taxonomy more often depends on morphological data and can be carried out to a much extent in the herbarium and laboratory. The results of classical taxonomy explained only in the form of classifications whereas the phylogenetic and experimental taxonomy have illustrated its opinions not only in new classifications, but also by the construction of phylogenetic charts or trees which shows the lineage.

The classical taxonomy give importance up to the units of species level, whereas the experimental taxonomy transfers the emphasis from the level of species to the local races, and attempt to classify evolutionary groups as they occur in nature. The combination of techniques from cytology and genetics provided a method for determining the evolutionary origins of different plant groups. These innovations led to develop a stable and useful system of classification. The categories or ranks of classical taxonomy are class, order, family, genus, species based on distinct delimitation of morphological characters, whereas the categories or ranks of experimental taxonomy are cenospecies, ecospecies, ecotype and ecophene etc., based solely on the extent of interbreeding possibility among the populations. These are delimited by genetic criteria. These 'units of experimental taxonomy' and its status are not universally applied throughout plant kingdom by some taxonomists. For this J. Heslop-Harrison quoted that the future of experimental taxonomy lay in the study of natural variation without recourse to defining new categories.

The classical taxonomy forms the foundation and produced different classifications. The biosystematics may not form the foundation for a radically new taxonomy because the methods used by experimental taxonomists are largely restricted to studying the lowest taxonomic categories. Theoretically and practically it was focused on populations and species. So that in actuality there is a less chance of producing an all-embrasing classification based on experimental methods. But, it promotes cooperative research between the classical taxonomists and other biological specialists and it also stimulates new discussions. It will be useful to solve the problems of large and complex plant groups. So, both the classical and experimental taxonomy are not separate and opposing, but they are closely interacting, complementary approaches to taxonomy, without either of which taxonomy is incomplete. A backcross of experimental and classical taxonomy gives us the modified classical taxonomy of the future, receptive to data of all sorts, and chiefly concerned, as in the past, with the general system, evolutionary relationship, and definition of taxa at all ranks (J. B. Hagen, 1983).

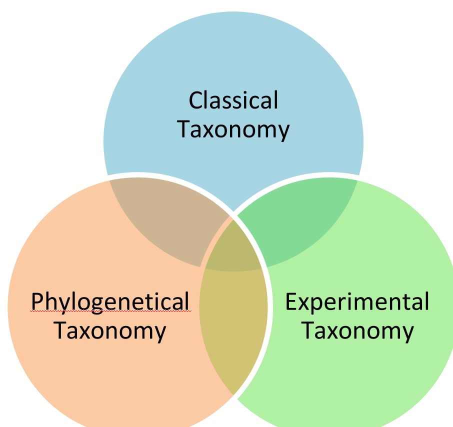

Figure represents the relationship of classical, phylogenetical and experimental taxonomy

Experimental categories

Biosytematists have developed some categories after experimentally investigating natural taxa. These categories are not intended as substitute for the units used in classical taxonomy, and

Classical taxonomy
Experimental taxonomy
Phylogenetical taxonomy

they are not necessarily the equivalent of these, although they may be counter parts of them. The different experimental categories are phyletic in nature and they may not have status in the nomenclature. The most widely accepted experimental categories are given below.

Turreson categories:

The Swedish botanist Gote Turresson (1922) has developed 'the dynamic concept of species' or 'biological species concept' which is a fruitful theoretical construct for twentieth & twenty first century's biologists. He has proposed the experimental categories which are justifiably referred as 'units of experimental taxonomy' (Gregor, 1942; Valentine, 1949).

Initially Turreson has treated the genetical aspect of species (genospeceis which represents all possible combinations of a species genes) and ecological aspect of species (cenospecies) distinctly, in later he combined the both aspects and described as genetic-ecological or 'genecological' aspect of species and established the experimental categories. These categories explained below:

1. Ecotype: The ecotype is the basic unit in biosystematics. It is a phyletic unit "adopted to a particular environment but capable of producing fully fertile hybrids with other ecotypes of the same ecospecies". Ecotype is considered as equal to subspecies of classical taxonomy. The word 'ecotype' coined by Turresson to describe, genetic varieties within the species (Greek *oikos*-house + *typos* – the mark of a blow). So, ecotype is a genetic variant within a species that is adapted to a particular environment yet remains interfertile with all other members of the species.

Gregor et al. (1936) described it as "a population distinguished by morphological and physiological characters, most frequently of a quantitative nature; interfertile with other ecotypes of the ecospecies, but prevented from freely exchanging genes by ecological barriers". The determination of inter fertility among ecotypes of the same ecospecies is usually established by controlled tests on plants transferred from the wild to the experimental ground. Edaphic, climatic and biotic ecotypes are generally recognized by the biosystematists.

2. Ecospecies: Ecospecies is a group of plants having one or more ecotypes, within the cenospecies, whose members are able to interchange their genes without detriment to the offspring. The term 'ecospecies' coined by Turresson. Swingle (1946) described it as " a group of plants comprised whose members are interfertile among themselves but are prevented from free inter crossing with other groups by either complete or partial genetic barriers. When the ecospecies is morphologically distinguishable from others, it corresponds to the taxonomic species". So, ecospecies is also a unit of classification and it is considered as equal to species of classical taxonomy.

3. Cenospecies: Cenospecies is a group of plants that representing one or more ecospecies of common evolutionary origin, so far as morphological, cytological and experimental facts indicate. Cenospecies of similar comparium is separated through genetic barriers and all hybrids among them are sterile. The term 'cenospecies' coined by Turresson. Swingle (1946) described it as "a group of plants that can be linked together by at least slightly fertile hybrids. There is considerable genetic incompatibility and much morphological dissimilarity may exist among its members". If one or more ecospecies are included in a cenospecies, which is frequently equivalent of subgenus or genus of classical taxonomy.

4. Ecophene: Ecophene is the lower term coined by Turresson, which denotes an ecological variant, purely product of environmental modification of the phenotype. At present the term **'ecad'** by F.M. Clements or 'habitat modification' are more often using for such variations.

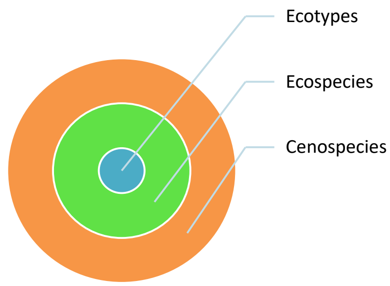

Figure represents the Turreson's Experimental Cotegories

Danser categories: The experimental taxonomist Danser has proposed the following three categories:

1. Comparium: Comparium is created of one or more cenospecies which is not capable of intercross. It is biosystematic unit that often is comparable to the genus of classical taxonomy. Distinct comparia are unable to intercross and complete genetic incompatibility prevails between them. There are, however numerous taxa, accepted by the orthodox systematist as genera, that may contain two or more comparia (Leguminosae). In some families the accepted and conventional genera are not the equivalents of comparia or even of cenospecies (Some taxa of Cruciferae, Crassulaceae and Orchidaceae).

2. Commiscum: It is a group of plants capable of hybridizing with other groups but such hybrids are sterile.

Danser's categories of **comparium** and **commiscum** are the higher and lower aspects of the cenosepecies of Turreson's.

3. Convivium: It is a group of plants capable of hybridizing with other groups to give hybrids showing some or complete fertility. It is the lowest category of Danser's. It covers the definitions of both ecospecies and ecotype of Turreson's.

Other experimental categories which are generally used in biosystematic studies are as follows:

i. Biotype: The biotype consists of all the individuals having the same genotype. Biotypes arise due to mutations, hybridization and isolations. According to Swingle biotype is a population consisting of individuals with identical genetic constitution. Generally ecotypes are developing from biotypes.

ii. Genotype: Genotype is the sum total of all the genes present in the individual. All the first generation progeny of a cross between two completely homozygous individuals have exactly similar genotypes no matter how different are the two parents. But depending on the degree of heterozygosity of one or both parents of any mating, whether within a population, between varieties or between species, the genotypes of the offspring will deffer from each other to a greater or lesser degree.

iii. Phenotype: Phenotye is the form or appearance of an individual and represents, the result of external factors on its genotype. Thus two individuals of the same genotype may appear to be different, if each has grown in an environment different from other. The same way two plants may have the same phenotype but have different genotypes. The study of all these categories are useful especially in understanding the species as a biological unit. According to biosystematists, the species is a group of interbreeding or potentially interbreeding individuals, reproductively isolated from other groups of individuals. It is a unit delimited primarily by genetical criteria and secondarily by criteria derived from ecological and morphological evidence. The biosystematic approach is helpful in the solution of phylogenetic problems, utilizing the knowledge that fertility is usually a more certain indication of close relationships than non-fertility. Biosystematic approaches are useful in the determination of the degree of plasticity of genotypes, the occurrence and constancy of correlation of characters, the occurrence and nature of sterility barriers, the evalution of characters, the recognition of hybrids and the phylogeny of species (Turrill, 1940). So, the biosystematics or experimental taxonomy is a long range research needs more care and attention, with high degree of technical and scientific skills for producing effective results.

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