ZL-101: Biosystematics and Taxonomy

Unit I
- Definition and basic concepts of biosystematics taxonomy and classification.
- History and theories of biological Classification.
- Trends in biosystematics: Chemotaxonomy, cytotaxonomy and molecular taxonomy
- Dimensions of speciation. Species concepts: Typological, Nominalistic and Biological species concepts. Subspecies and other infra-specific categories.

Unit II
- Taxonomic Characters and different kinds.
- Origin of reproductive isolation, biological mechanism of genetic incompatibility.
- Taxonomic procedures: Taxonomic collections, preservation, curetting, process of identification.

Unit III
- Taxonomic keys, different types of keys, their merits and demerits.
- International code of Zoological Nomenclature (ICZN): Operative principles, interpretation and application of important rules: Formation of Scientific names of various Taxa.
- Synonyms, homonyms and tautonomy.

Unit IV
- Evaluation of biodiversity indices.
- Evaluation of Shannon Weiner Index.
- Evaluation of Dominance Index.
- Similarity and Dissimilarity Index.

Suggested Reading Material (All latest editions)
1. M. Kato. The Biology of Biodiversity, Springer.
2. J.C. Avise. Molecular Markers, Natural History and Evolution, Chapman & Hall, New York.
3. E.O. Wilson. Biodiversity, Academic Press, Washington.
4. G.G. Simpson. Principle of animal taxonomy, Oxford IBH Publishing Company.
5. E. Mayer. Elements of Taxonomy.
6. E.O. Wilson. The Diversity of Life (The College Edition), W.W. Northem& Co.
7. B.K. Tikadar. Threatened Animals of India, ZSI Publication, Calcutta.

Practical **Module – I**

- Composition assessment of the taxonomic diversity / biodiversity in a habitat (e.g. grassland, arid land, wet land, etc.).
- Influence of climatic conditions on taxonomic diversity in a given habitat.
- Preparation of models showing the status of certain taxa or species in a particular habitat.

Unit I

- Definition and basic concepts of biosystematics, taxonomy and classification.
- History of Classification
- Trends in biosystematics: Chemotaxonomy, cytotaxonomy and molecular taxonomy
- Dimensions of speciation.
- Species concepts: species category, different species concepts, subspecies and other infra-specific categories.
- Theories of biological classification: hierarchy of categories.

Definition and basic concepts of biosystematics, taxonomy and classification

Biosystematics:

- Systematics: In biology, systematics is the study and classification of living things; in other words, grouping organisms based on a set of rules (or system).
- The science of classifying organisms.
- Thus, biosystematics may be defined as 'taxonomy of living populations'.
- The word systematics is derived from the Latinized Greek word '*systema*' applied to the system of classification developed by Carolus Linnaeus in the 4th edition of his historical book *Systema Naturae* in 1735.

Kinds of Systematics

- Systematics can be divided into two closely related and overlapping levels of classification: **taxonomic** (known as the Linnaean System) and **phylogenetic**.
- Taxonomic classifications group living things together based on shared traits - usually what they look like or what their bodies do.
- For example, animals that lay eggs and have scales we call reptiles, and animals that give births and have fur or hair we call mammals.
- More specifically, all humans share the same characteristics and so belong to a group, or taxon, of the genus *Homo*, and species *sapien*.
- Phylogenetic classifications use the taxonomic names, but further group organisms by how evolutionarily related they are to one another.
- By looking at each organism's genes, we know that gorillas (taxonomic term) are more closely related to humans than they are to cockroaches.

Taxonomy:

- Taxonomy is the theory and practice of identifying plants and animals. In fact, taxonomy deals with the principle involved in the study of classification of organisms.

- It is the <u>functional science which deals with identification, nomenclature and classification of different kinds of organisms all over the world</u>.
- The word 'taxonomy' is derived from the Greek words *taxis* (= arrangement) and nomos (= law) and the term 'taxonomy' was coined by <u>A. P. de Candolle in 1813</u>.

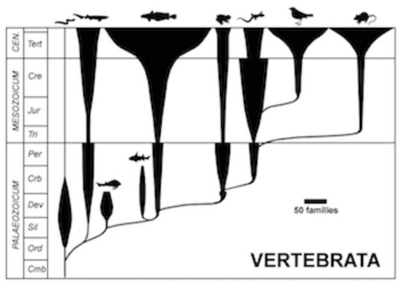
There are several stages of taxonomy such as:

- ***Alpha taxonomy***: In this stage species are identified and characterized on the basis of gross morphological features.
- ***Beta taxonomy***: In this stage species are arranged from lower to higher categories, i.e., hierarchic system of classification.
- ***Gamma taxonomy***: In this stage intraspecific differences and evolutionary history are studied.

- The nomenclatural and taxonomic system for botany introduced by Linnaeus and improved by many generations of later botanists as its first goal to make possible <u>information storage and retrieval concerning plants and plant products</u>.
- While Linnaeus originally believed the systematic pattern he recognized in nature to

divine creation, post-Darwinian botanists have mostly interpreted it as resulting from evolution.

- Many botanical taxonomists of today therefore regard systematics as the art of tracing similarities between taxa, combining them into larger groups, and hypothesizing about their evolution.
- While the number of taxonomic features available to Linnaeus was very limited, the gradual refinement of technical equipment has both widened the scope of morphological studies and facilitated the introduction of ancillary sciences like anatomy, embryology, serology, cytotaxonomy, genetics, palynology, and chemotaxonomy.

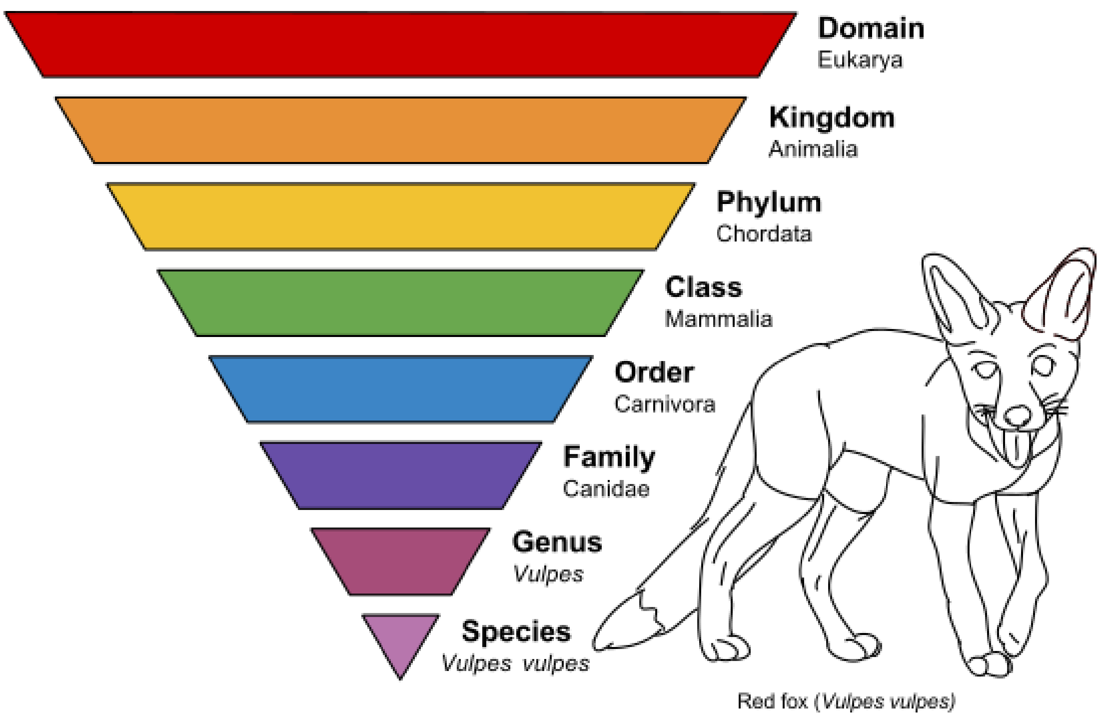


- Those have provided a number of new character sets, the incorporation of which has been facilitated by methodologies such as numerical taxonomy, cladistics and DNA hybridization.

Biological Classification:

Biological classification is a critical component of the taxonomic process. Biological classification uses taxonomic ranks, in order from most inclusive to least inclusive: Domain, Kingdom, Phylum, Class, Order, Family, Genus, and Species.

Rank	Fruit fly	Human	Pea	*E. coli*
Domain	Eukarya	Eukarya	Eukarya	Bacteria
Kingdom	Animalia	Animalia	Plantae	Bacteria
Phylum or Division	Arthropoda	Chordata	Magnoliophyta	Proteobacteria
Class	Insecta	Mammalia	Magnoliopsida	Gammaproteobacteria
Order	Diptera	Primates	Fabales	Enterobacteriales
Family	Drosophilidae	Hominidae	Fabaceae	Enterobacteriaceae
Genus	*Drosophila*	*Homo*	*Pisum*	*Escherichia*
Species	*D. melanogaster*	*H. sapiens*	*P. sativum*	*E. coli*



History of Classification:

The Greeks and Romans

Aristotle (384–322 BC):

In Western scientific taxonomy, the Greek philosopher Aristotle was the first to classify all living things, and some of his groups are still used today, like the vertebrates and invertebrates, which he called animals with blood and without blood. He further divided the animals with blood into egg-bearing and live-bearing, and formed groups within the animals without blood that we recognize today, such as insects, crustacea and testacea (molluscs).

Theophrastus (370–285 BC):

Theophrastus was a student of Aristotle and Plato. He wrote a classification of all known plants, *De Historia Plantarum*, which contained 480 species. His classification was based on growth form. Carolus Linnaeus accepted many of his generic names.

There are two surviving botanical works by Theophrastus – The Enquiry into Plants and On the Causes of Plant Phenomena. In his Causes Theophrastus looks at plant physiology and considers different methods of cultivation. In the Enquiry Theophrastus turns his attention in a more taxonomical direction. In this work he was one of the first authors to attempt to classify plants into different types, dividing them into 'trees', 'shrubs', 'undershrubs' and 'plants'. These two books give Theophrastus a good claim to the title of 'the grandfather of botany'.

Dioscorides (40–90 AD):

Dioscorides was a Greek physician and a medic in Roman Army, who travelled widely in the Roman and Greek world to gather knowledge about medicinal plants and wrote *De Materia Medica*, which contained around 600 species. *De Materia Medica* was used in medicine until the 16th century, and was copied several times. One famous copy from the 6th century is kept in Vienna. The classification in his work is based on the medicinal properties of the species.

Plinius (23–79 AD):

Plinius was involved in the Roman army and wrote many books, but the only one that has survived is his '*Naturalis Historia*', a work of 160 volumes, in which he described several plants and gave them Latin names. Many of these names we still recognize, like *Populus alba* and *Populus nigra*, and since Latin was later kept for botanical science, we may call him the Father of Botanical Latin.

Early taxonomists

Until the end of the 16th century, the taxonomic works of ancient Greeks were not replaced. One of the reasons for this was the development of optic lenses, which made it possible to study details in the different species. Collection of specimens became part of the growing sciences, and the emphasis turned from medical aspects to taxonomic aspects.

Caesalpino (1519–1603):

Caesalpino in Italy, who is sometimes called "the first taxonomist". In 1583 he wrote *De Plantis*, a work that contained 1500 species. His classification was based on growth habit together with fruit and seed form, as was that of Theophrastus.

Bauhin (1541–1631) and **Bauhin (1560–1624)**

Two Swiss brothers (Bauhin) wrote the work '*Pinax Theatri Botanici*' in 1623. The work is a listing of 6000 species. The Bauhin brothers included synonymes, which was a great necessity of the time. The Bauhin brothers recognized genera and species as major taxonomic levels. Linnaeus honored the Bauhin brothers Gaspard and Jean in the genus name *Bauhinia*.

John Ray (1627–1705):

John Ray, the English naturalist wrote several important works through his life. His most important contribution was the establishment of species as the ultimate unit of taxonomy. In 1682 he published ‘*Methodus Plantarum Nova*’, which contained around 18000 plant species, a result of a relatively narrow species concept.
He published important works on botany, zoology, and natural theology. His classification of plants in his *Historia Plantarum*, was an important step towards modern taxonomy.
Ray rejected the system of dichotomous division by which species were classified according to a pre-conceived, either/or type system, and instead classified plants according to similarities and differences that emerged from observation. He was the first to give a biological definition of the term species.
In his 1686 History of Plants:
"No surer criterion for determining species has occurred to me than the distinguishing features that perpetuate themselves in propagation from seed. Thus, no matter what variations occur in the individuals or the species, if they spring from the seed of one and the same plant, they are accidental variations and not such as to distinguish a species. Animals likewise that differ specifically preserve

their distinct species permanently; one species never springs from the seed of another nor vice versa".

Joseph Pitton de Tournefort (1656–1708):

Joseph Pitton de Tournefort from France constructed a botanical classification that came to rule in botanical taxonomy until the time of Carolus Linnaeus. In 1700, he published *Institutiones Rei Herbariae*, in which around 9000 species were listed in 698 genera. He put primary emphasis on the classification of genera, and many genera were accepted by Linnaeus and still in use today. Tournefort's plant classification was exclusively based on floral characters.

Linnaean era

Starting point of modern taxonomy

For nomenclatural reasons two works of Carolus Linnaeus (1707–1778) are regarded as the starting points of modern botanical and zoological taxonomy: the global flora '*Species Plantarum*', published in 1753 and the tenth edition of '*Systema Naturae*' in 1758 including global fauna. Linnaeus introduced a binary form of species names called "trivial names" for both plants and animals in these books. The trivial names were intended for fieldwork and education, and not to replace the earlier phrase names.

Linnaeus counted 8,530 species of flowering plants in 1753. The simplicity of Linnaeus' trivial names revolutionized nomenclature, and soon binary nomenclature.

Linnaeus published several books that would transform botany and zoology into sciences of their own. Until then, these two disciplines had merely been a fringe of practical medicine. With the works of Linnaeus, botany and zoology transformed into a *Scientia*, a science surrounded by philosophy, order and systems.

Post-Linnaean taxonomy

Natural system emerging in France

One of the few countries in which the Linnaean systematics did not make success was France. Four French scientists emerged that made an impact on future biological sciences.

Georges-Luise Leclerc de Buffon (1707–1788) was a strong critic to Linnaeus work, and he found it wrong to impose an artificial order on the disorderly natural world. His approach was for an evolutionary theory.

Michel Adanson (1727–1806) wrote Familles des Plantes already in 1763. He launched the idea that in classification one should not put greater emphasis on some characters than on others. He critized Linnaeus' works, and considered Tournefort's classification far superior.

Antoine Laurent de Jussieu (1748–1836) changed the system of plants with his *Genera Plantarum* in 1789, in which he launched a natural system based on many characters that came to be a foundation of modern classification. He divided the plants into acotyledons and monocotyledons.

Jean-Baptiste de Lamarck (1744–1829) launched an evolutionary theory including inheritance of acquired characters, named the "Lamarckism".

The French scientific work, the development of anatomy and physiology and improved optical instruments made way for a new era of taxonomy, which was trying to cope with an increasing number of species in a rapidly expanding flora and fauna of the world.

Theories of biological classification: hierarchy of categories.

Biological classification is defined as a process of giving hierarchy of categories by scientific procedure based on features of organisms and arranging them into different groups. The very purpose is to establish the relationship among different organisms and to know about their evolution. Further, to study and include each organism along with its identification and habitat.

Artificial Classification

Artificial Classification uses form, shape as prominent features for grouping organisms. Animals were also classified on basis of red blood cells, habitat such as land, water or air. They were also classified on their basis to fly or not to fly. This system is relatively easy to follow.

Artificial System of Classification has many disadvantages. It relies just on form and shape of organisms and does not take into account other features. So it is difficult to understand the evolution of organism. It leads to misunderstanding of any relationship among organisms. The different types of organisms are arranged in same groups like birds, insects, bats they fly and they are grouped in same criteria. The form and shape of organism is not permanent and it changes with time.

Natural System of Classification

It takes into account multiple features such as anatomy, physiology, pathology, biochemistry, reproduction and cytology to compare the organisms and establish a relationship between them. It overshadows all the disadvantages of artificial system of classification. It helps to understand the evolution of organism by knowing the relationship between them.

The features undertaken in this classification are constant. In this bird, reptiles and mammals are placed in the different groups based on the multiple features. For example humans have 4 chambered hearts, warm blooded nature and denucleated erythrocytes. Fishes have 2 chambered hearts, cold blooded and respire through gills.

Phylogenetic System of Classification

It is defined as a relationship based on the evolutionary aspect of organisms. It is based on Darwin's Concept of Natural Selection. It tells us about the original relationship among organisms. The foremost phylogenetic system of classification was given by Engler and Prantl. They divide the plants into primitive and modern types.

Hierarchy Categories

Taxonomic Hierarchy Categories were also introduced by Linnaeus. They are also known as Linnaean hierarchy. It is defined as sequence of categories in a decreasing or increasing order from kingdom to species and vice versa. Kingdom is the highest rank followed by phylum, class, order, family, genus and species. Species is the lowest rank in the Hierarchy.

The hierarchy has two categories which are obligate and intermediate. Obligate means they are followed strictly and range from kingdom to species as said above. Intermediate are not followed strictly and they are added in obligate list such as subdivision, super family, super class, suborder, subspecies etc.

Species:

Group of population which is similar in form, shape and reproductive features so that fertile sibling can be produced. Some siblings can be sterile when a hybrid is produced. A hybrid can be product of female horse & male donkey (Mule). Or male tiger & female lion known as Tigon. Sexual reproduction is present in eukaryotes. Species is followed by subspecies, varieties and races. These categories are inferior as compared to species.

Genus:

It is defined as group of similar species. But it is not mandatory to have many species. Some genera have only one species known as Monotypic. If there are more than one species it is known as polytypic. For example lion, tiger are quite similar species placed under the genus *Panthera*.

Family:

It is defined as collection of similar genera. For example, cats and leopard are included in the family Felidae.

Order:

One or more than one similar families constitute order. Family felidae are included in the order Carnivora.

Class:

One or more than one order makes a class. Class Mammalia includes all mammals which are bats, rodents, kangaroos, whales, apes and man.

Phylum:

It is a term used for animals while its synonym ‘Division’ is used for plants. It is a collection of similar classes. Phylum Chordata of animals has class Mammalia along with birds, reptiles and amphibians.

Kingdom:

The top most taxonomic category. Example all animals are included in Kingdom animalia.

Trends in biosystematics: Chemotaxonomy, Cytotaxonomy and Molecular taxonomy.

Chemotaxonomy

The chemotaxonomy or chemical taxonomy is used for the classification of plants on the basis of their chemical constituents. Plants produce thousand types of chemicals. Some of the organic compounds like carbohydrates, fats, proteins, nucleic acids, chlorophylls are required for their basic metabolic processes and found throughout the plant kingdom. These organic compounds are called 'primary metabolites' or 'biomolecules'. These are produced in large quantities and can easily be extracted from the plants.

Many plants, fungi and microbes of certain genera and families synthesize a number of organic compounds which are not involved in primary metabolism (photosynthesis, respiration, and protein and lipid metabolism) and seem to have no direct function in growth and development of plants. Such compounds are called 'secondary metabolites' (secondary plant products or natural products).

These compounds are accessary rather than central to the functioning of the plants in which they are found. These compounds are produced in small quantities only in specific parts of plants and their extraction from the plant is difficult and expensive.

These are derivatives of primary metabolites. Secondary metabolites are not directly involved in the normal growth, development, or reproduction of an organism. They are used for protection and defence against predators and pathogens. Usually, secondary metabolites are specific to an individual species.

The phenolics, alkaloids, terpenoids and non-protein amino acids are the four important and widely exploited groups of compounds utilized for chemotaxonomic classification. These groups of compounds exhibit a wide variation in chemical diversity, distribution and function. The system of chemotaxonomic classification relies on the chemical similarity of taxon.

Examples: Pigments – carotenoid, anthocyanin etc; Alkaloids – morphine, codeine etc; Terpenoides – monoterpene, diterpene, etc; Essential oils – Lemongrass oil; Toxins – abrin, ricin, etc; Lectins – concanavalin A; Drugs – vinblastine, curcumin etc; Polymeric – rubber, gum, cellulose etc.

Cyanogenic glycoside in chemotaxonomy

The cyanogenic glycosides are the compounds responsible for providing defensive mechanism to plants. Plant species have ability to produce hydrogen cyanide (HCN) by enzymatic hydrolysis of cyanogenic glycosides by the process called cyanogenesis. Different amino acid like phenyl alanine, tyrosine, valine, leucine, and isoleucine are precursor for the biosynthesis of cyanogenic glycosides, but they are restricted to families: a cyanogenic glycoside synthesized from leucine commonly occurs in the subfamily Amygdaloideae (almond) and Maloideae (apple) of family Rosaceae.

Cytotaxonomy

It is the branch of biology dealing with the relationship and classification of organism using comparative studies of chromosomes. The structure, number and behaviour of chromosomes is of great value in taxonomy, with chromosome number being the most widely used and quoted character. Chromosome numbers are usually determined at mitosis and quoted as the diploid number (2n). Another useful taxonomic character is the position of the centromere.

The cytotaxonomy is more significant over physiological taxonomy because cytotaxonomy is dealing with the comparative study of chromosome and with this method minute variation among the individuals can be detected. DNA are present in the chromosome and the variation in DNA are responsible for the variation among the individuals, species, genus and so on. The difference in physiological variation are too less among the individuals of same species and other higher taxa.

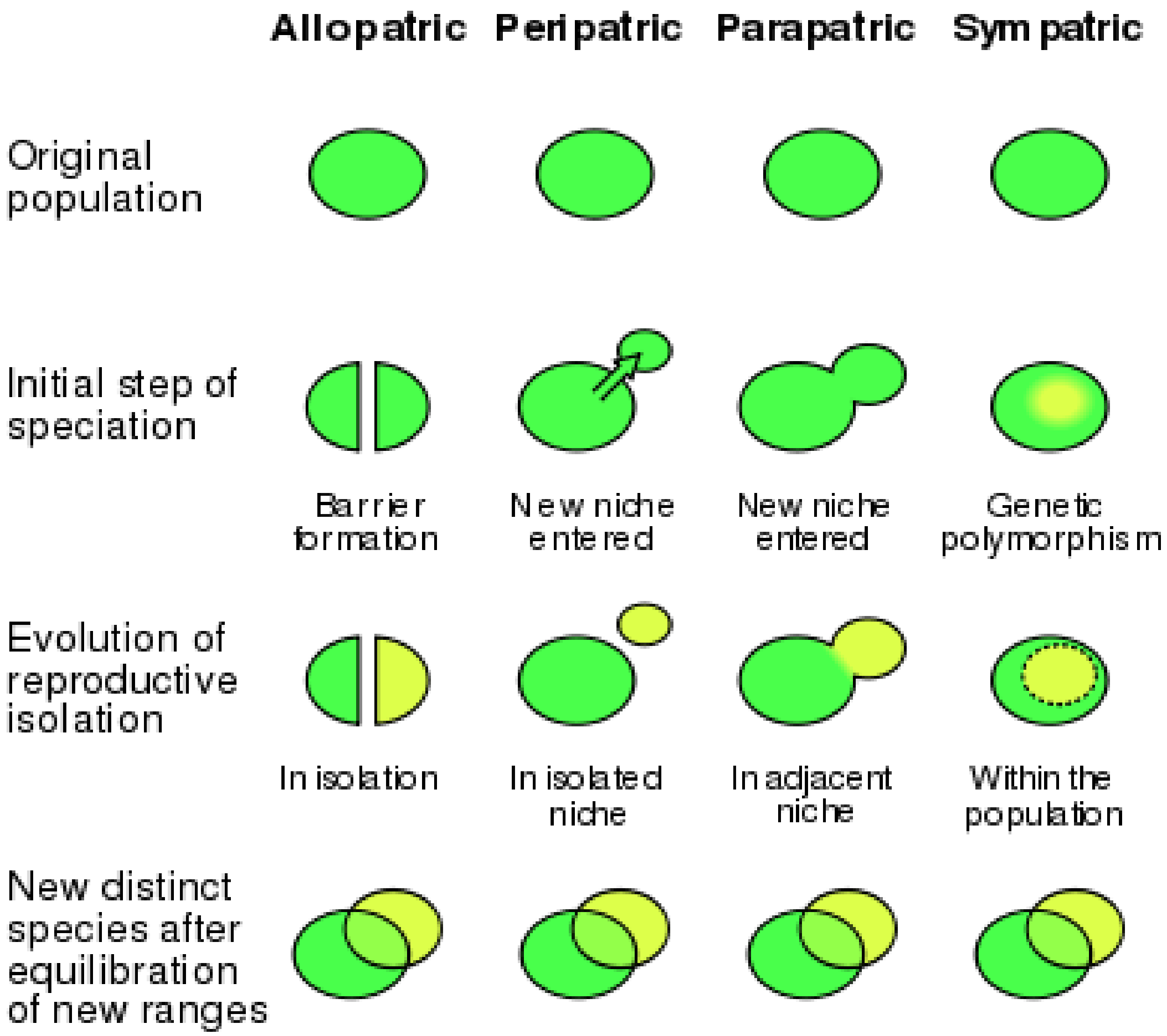
Molecular Taxonomy

Molecular Taxonomy is the classification of organisms on the basis of the distribution and composition of chemical substances in them. Molecular techniques in the field of biology have helped to establish genetic relationship between the members of different taxonomic categories. DNA and protein sequencing, immunological methods, DNA-DNA or DNA-RNA hybridization methods are more informative in the study of different species. The data obtained from such studies are used to construct phylogenetic trees.

Dimensions of speciation

Speciation is the evolutionary process by which biological populations evolve to become distinct species. Charles Darwin was the first to describe the role of <u>natural selection</u> in speciation in his book ‘The Origin of Species’ (1859).

There are four geographic modes of speciation in nature, based on the extent to which speciating populations are isolated from one another:



allopatric, peripatric, parapatric, and sympatric. All forms of natural speciation have taken place over the course of evolution.

Allopatric

During allopatric speciation, a population splits into two geographically isolated populations (e.g., habitat fragmentation due to geographical change such as mountain formation). The isolated populations then undergo genotypic or phenotypic divergence as: (a) they become subjected to dissimilar selective pressures; (b) they independently undergo genetic drift (variation in the relative frequency of different genotypes in a small population, owing to the chance disappearance of particular genes as individuals die or do not reproduce); (c) different mutations arise in the two populations. When the populations come back into contact, they have evolved such that they are reproductively isolated and are no longer capable of exchanging genes.

Peripatric

In peripatric speciation, a subform of allopatric speciation, new species are formed in isolated, smaller peripheral populations that are prevented from exchanging genes with the main population. It is related to the concept of a founder effect, since small populations often undergo bottlenecks.

Genetic drift is often proposed to play a significant role in peripatric speciation.

Parapatric

In parapatric speciation, there is only partial separation of the zones of two diverging populations afforded by geography; individuals of each species may come in contact or cross habitats from time to time (but behaviours or mechanisms prevent their interbreeding).

Parapatric speciation may be associated with differential <u>landscape-dependent selection</u>. Even if there is a gene flow between two populations, strong differential selection may impede assimilation and different species may eventually develop. Habitat differences may be more important in the development of reproductive isolation than the isolation time.

Sympatric

Sympatric speciation refers to the formation of <u>two or more descendant species from a single ancestral species all occupying the same geographic location</u>. Often-cited examples of sympatric speciation are found in insects that become dependent on different host plants in the same area. However, the existence of sympatric speciation as a mechanism of speciation remains highly debated.

Species concepts: species category, different species concepts, subspecies and other infra-specific categories

The species concept

- Under the currently accepted Biological Species Concept (BSC), species exist only in sexually reproducing organisms as a consequence of the mechanisms of genetic shuffling and recombination during meiosis and in zygote formation.
- Species do not exist in asexually reproducing organisms except as an artificial classificatory convenience.
- The BSC is usually defined as: groups of actually or potentially interbreeding populations in nature which are reproductively isolated from other such groups (Mayr, 1942, 1963).
- By reproductive isolation, evolutionists mean that no gene flow exists between different species, not necessarily that members of different species cannot interbreed and produce hybrids.
- Evolutionists actually use the criterion of lack of gene flow between different species, rather than lack of reproduction.
- Thus, Bock (1986) modified definition of the BSC, namely: *a species is a group of actually or potentially interbreeding populations of*

organisms which are genetically isolated in nature from other such groups.

- The distinction between these two definitions is clarified in the classification of intrinsic isolating mechanisms (Mayr, 1963), as follows:
- 1. Mechanisms that prevent interspecific crosses (<u>premating mechanisms</u>)

  (a) Potential mates do not meet (seasonal and habitat isolation)

  (b) Potential mates meet but do not mate (ethological isolation)

  (c) Copulation attempted but no transfer of sperm takes place (mechanical isolation)

2. Mechanisms that reduce full success of interspecific crosses (<u>postmating mechanisms</u>)

  (a) Sperm transfer takes place but egg is not fertilized (gametic mortality)

  (b) Egg is fertilized but zygote dies (zygote mortality)

  (c) Zygote produces an F1 hybrid of reduced viability (hybrid inviability)

  (d) F1 hybrid zygote is fully viable but partially or completely sterile, or produces deficient F2 (hybrid sterility)

- All of these intrinsic isolating mechanisms serve to prevent exchange of genetic materials between members of different species taxa and achieve genetic isolation.

Species possess three individual sets of properties that separate them from one another:

1. **Genetic coherence**: the members of a species form a genetic community which is genetically isolated from other species. Genetic material from reproduction thus will flow between members of a single species, but not from one species to another under natural conditions. Genetic isolation is maintained by the possession of intrinsic genetic isolating mechanisms.
2. **Reproductive coherence**: the members of a species form a breeding community which is reproductively isolated from other species. Members of one species do not interbreed or attempt to interbreed with members of another species under natural conditions, regardless of the barriers to gene flow between them. Interbreeding between members of different species would be prevented by particular intrinsic reproductive isolating mechanisms.
3. **Ecological coherence**: the members of a species have similar ecological requirements that differ from those of other species. Competition between sympatric members of different species is thus greatly reduced and separated.

- In fully evolved species, all three sets of properties are developed such that the species are completely genetically isolated, completely reproductively isolated and largely ecologically separated from other sympatric species.

Types of species concepts:

Typological species concept

Typological species concept defines as species that "*a group of individuals that differ from other groups by possessing constant diagnostic characters*". Nearly all of the older definitions of the species, including those of Buffon, Lamark and Cuvier refer to the morphological similarities of individuals of the same species.

Typological species concept is also called as Essentialist, Morphological, Phenetic species concept. Typology is based on morphology/phenotype. Still applied in museum research where a single specimen (type specimen) is the basis for defining the species. In paleontology all you have is morphology: typology is practiced and species are defined as *morphospecies* (e.g. snail shells in fossil beds).

Problems: what about sexual dimorphism: males and females might be assigned to different species. Geographic variants: different forms viewed as different species? What about life stages: caterpillars and butterflies? If typology is let run it can lead to over splitting taxa: each variant is called a new species.

Nominalistic species concept

Occan, the proponent of this concept and his followers (Buffon, Bessey, Lamarck, etc.) believed that only individuals exist but did not believe in the existence of species.

Species are man's own creations and have no actual existence in nature. They are mental concept and nothing more. Therefore, such mental concept (i.e. species) of man has no value.

Biological species concept

An entirely new species concept has begun to emerge in the seventeenth century. John Ray believed in the morphological definition of species and his species characterization also contained the germ of *biological species concept*, which considers the reproductive relationship to be a principle species criterion.

The biological species concept was clearly formulated by Jordan, Dobzhansky and Mayr. According to Mayr a species is a group of potentially or actually interbreeding natural population which are reproductively isolated from other such groups.

Dobzhansky added the term gene pool, and defined species as "*a reproductive community of sexually reproducing individuals which share in a common gene pool*". The biological species concept is the most widely accepted.

In the biological species concept, interbreeding among the individuals of the same species and reproductive isolation from other species are the principal criteria.

Evolutionary species concept

Simpson proposed the evolutionary species concept and defined the species as a lineage (an ancestral–descendent sequence of populations) evolving separately from others and with its own unitary evolutionary role and tendencies.

Mayr has criticized the evolutionary species definition saying that it is the definition of a phyletic lineage, but not of the species. The evolutionary species concept ignores the core of the species problem and thus, Mayr did not accept the evolutionary species concept and he strongly advocated for the biological species concept in spite of certain difficulties in its application.

Subspecies and other infra-specific categories

Subspecies:

Subspecies is actually a category below species. Linnaeus used the term "subspecies" when he classified subgroups of man. He recognised four subgroups such as (i) the American-Indians (*Homo sapiens americanus*), (ii) the Europeans (*Homo sapiens europaeus*), (iii) the Orientals (*Homo sapiens asiaticus*) and the African Negroes (*Homo sapiens afers*).

Early taxonomists applied the term 'variety' indiscriminately for any variation in the population of a species. In the 19th century the term subspecies replaced 'variety' and the term 'variety' is obsolete today.

When a population of a species splits up by natural barriers such as mountains, islands, climate, etc., each isolated group may evolve different characteristic features, so as to become recognizable as a separate geographical race or subspecies.

The scientific name of the race (subspecies) of Indian lion is *Panthera leo persica*, and the name of the African lion (race) is *Panthera leo leo*. The distinguishing features of Indian race are - (i) scantier mane than that of the African race (ii) a longer tassel of hair at the tip of the tail than that of the African race (iii) a well-pronounced tuft of hairs on the elbow joints and (iv) the abdomen bears a fuller fringe of hairs.

Two subspecies (races) of the same species can interbreed if they meet and professional taxonomists can only recognise the differentiating features of the subspecies of a species.

If species which contain two or more than two subspecies, are called ***polytypic*** species and the species which is without subspecies is called ***monotypic*** species. With the establishment of polytypic concept (Beckner, 1959), it is well accepted that some species are distributed in different geographical areas and form different local populations.

It is widely accepted that genotypic variation within allopatric species occurs. It is widely accepted that these populations become different from each other in morphology, biochemical or genotypic variations that help to mark a taxonomic level sufficient to designate them as subspecies.

Types of Species:

(i) Allopatric species:

The two or more related species that have separate geographical ranges are called allopatric species. Examples of such species are Indian lion

(*Panthera leo persica*) and African lion (*Panthera leo leo*).

(ii) Sympatric species:

Two or more species are said to be sympatric when their geographical distributions overlap, though they may segregate into different ecological niche. Examples of this type are the fig-frog (*Rana grylio*) and the gopher frog (*R. areolata*). The former is extremely aquatic, while the latter species is restricted to the margins of swampy areas.

(iii) Parapatric species:

These are the species which have the geographical ranges with a very narrow region of overlap. Example of this type is the flightless Australian grass-hoppers, *Moraba scurra* and *M. viatica*. (Parapatric species are formed in nature mostly through chromosomal rearrangements)

(iv) Sibling species:

Two or more than two closely related species which are morphologically alike but behaviourally or reproductively isolated from each other. Examples are *Drosophila persimilis* and *D. pseudoobscura*. The sibling species can interbreed and are incapable of producing fertile hybrids.

(v) Cryptic species:

The species which are alike on the basis of observed features but are genetically and sexually they are different are cryptic species. There is a confusion between the terms sibling species and cryptic species. The cryptic species are incapable of interbreeding.

(vi) Monotypic species:

When a genus includes a single species but does not include any subspecies, e.g., *Vampyroteuthis*, a vampire squid which is a single monotypic genus and also contains a single species, *V. infernalis* (monotypic species).

(vii) Polytypic species:

When a species contains two or more subspecies, it is called polytypic species. Examples are tiger, *Panthera tigris* which has several subspecies; such as - (i) Indian tiger, *Panthera tigris tigris*, (ii) the Chinese tiger, *P. t. amoyensis*, (iii) the Siberian tiger, *P. t. altaica*, (iv) the Javan tiger, *P. t. sondaica*, etc.

(viii) Endemic species:

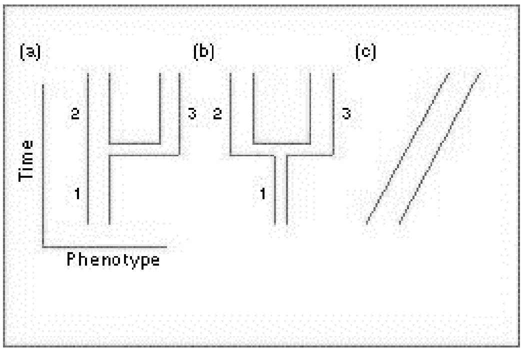
The species which are found in a particular region, called endemic species. Usually the species of oceanic islands which are found in a limited geographic area are called endemic species. The Darwinian finches are the endemic species of Galapagos Islands.

(ix) Agamo species:

Species are those which consist of uniparental organisms. They may produce gametes but fertilization does not take place. They reproduce by obligatory parthenogenesis. In case of bees, wasps, rotifers the haploid eggs develop into haploid individuals and the haploid eggs are not fertilized by sperms.

The species category

- During the process of sexual reproduction, recombination of genetic materials takes place between parental individuals which leads to new combinations of genes in the progeny.
- However, there are many examples which do not come under the biological species category such as hermaphroditism, parthenogenesis, gynogenesis and vegetative reproduction which show uniparental reproduction. There are numerous examples of such uniparental reproduction in invertebrates and vertebrates. Mayr has given a new terminology to such uniparental lineages, i.e. *paraspecies*.
- Most workers have assumed that the species category is the same as the species concept, and hence that the biological species concept (BSC) is the species category. This assumption is invalid because the species category must apply to all organisms, including asexual ones, and the biological species concept applies only to sexually reproducing organisms.
- A broader definition of the species category is needed, concordant with the BSC.
- Defining the species category for all organisms is awkward, but can be summarized as: the fundamental level in the Linnaean hierarchy for



describing the diversity of biological organisms that is based on the biological species concept for sexually reproducing organisms or on the equivalent of the ecological unit of biological species for groups of asexual organisms.

- Survey of taxonomic literature shows that there are a large number of species categories which have been suggested by naturalists, taxonomists and evolutionary biologists from time to time.

Agamo species: Agamo species are those which consist of uniparental organisms. They may produce gametes but fertilization does not take place. They reproduce by obligatory parthenogenesis. In case of bees, wasps, rotifers the haploid eggs develop into haploid individuals.

Cladistic Species: In the cladistic species concept, a species is a lineage of populations between two phylogenetic branch points (between speciation and extinction events). The cladistic concept recognizes species by branch points, independently of how much change occurs between them. Because of this, the two patterns in the figure are cladistically identical: in both there are three species and species 1 gives birth to two new species at the branch point. On the non-temporal species concepts, such as the biological, recognition and ecological species concepts, there are two species in Figure (a) and three in (b).

(a) The ancestral species does not change phenetically (or reproductively or ecologically) after a daughter species evolves. Species 1 and 2 are phenetically identical but cladistically different. (b) The ancestral species changes after the evolution of the new species; species 1 and 2 are both phenetically and cladistically different. (c) Phenetic change in one lineage with no speciation.

Cohesion Species: According to the cohesion species concept (Templeton 1989) a species is the largest delimited population that has internal mechanism, and maintains mutual phenotype cohesion among its members. Phenotype cohesion of a population occurs when mutual similarity observed among the members of the population even when the average appearance of individuals in the population changes in time.

Composite Species: All organisms belonging to an internodon and their descendants until a subsequent internodon (internodon is a set of organisms whose parent-child relations are not split).

E.g. the composite species concept defines a species is a lineage between two temporal occurrence of new characters.

Ecological Species: A lineage which occupies an adaptive zone, minimally different from that of any other lineage in its range and which evolves separately from all lineages outside its range.

Evolutionary Species: A lineage (ancestral-descendent sequence of populations) evolving separately from others and with its own unitary evolutionary role and tendencies.

Geological concordance (similarity): Population subdivisions concordantly identified by multiple independent genetic units constitute the population units worthy of recognition as phylogenetic taxa.

Genetic Species: Group of organisms that may inherit characters from each other, common gene pool, reproductive community that forms a genetic unit.

Genotypic cluster definition: Clusters of monotypic or polytypic biological entities, identified using morphology or genetics that have few or no intermediates when in contact.

Hennigian species: A tokogenetic community that arises when a stem species is dissolved into two new species and ends when it goes extinct or speciates.

Morphological species: Similar to typological species concept of Linnaeus; species are the smallest groups that are consistently and persistently distinct and distinguishable by ordinary means.

Nominalistic species: Only individuals exist and nothing more. Species have no actual existence in nature.

Nothospecies: Species formed from the hybridization of two distinct parental species.

Phenetic species: A class of organisms that share most of a set of characters. A family resemblance concept is possession of most characters which required for inclusion in a species but not all.

Phylogenetic species: A species is the smallest diagnosable cluster of individual organisms within which there is a parental pattern of ancestry and descent.

The concept of a species as an irreducible group whose members are descended from a common ancestor and who all possess a combination of certain defining, or derived, traits.

Recognition species: The recognition species concept is a concept of species, according to which a species is a set of organisms that recognize one another as potential mates: they have a shared mate recognition system (behavioural, physiological or morphological).

Biological Species: Population of sexually reproducing organisms, interbreeding natural populations isolated from other such groups, depending upon reproductive isolating mechanisms.

Unit II

- Taxonomic Characters and different kinds.
- Origin of reproductive isolation, biological mechanism of genetic incompatibility.
- Taxonomic procedures: Taxonomic collections, preservation, curetting, process of identification.

Taxonomic Characters and different kinds

- Taxonomic character is a distinguishing feature of taxa – a characteristic of one kind of organism which will distinguish it from another kind. Example, serrated leaves may distinguish one species of plant from another and hence called a *character*. Similarly, punctate elytra may differentiate between two species of beetles.
- Mayr et al (1953) define a taxonomic character, as "<u>any attribute of an organism or of a group of organisms by which it differs from an organism belonging to a different taxonomic category</u> (or resembles an organism belonging to the same category)".
- The taxonomic characters can be roughly grouped into:

  a) Morphological characters.
  b) Physiological characters.
  c) Behavioural characters.

d) Ecological and distributional characters.

Morphological Characters

- Structural attributes of organisms at the cellular level or above.
- External, internal, microscopic, including cytological and developmental characters.

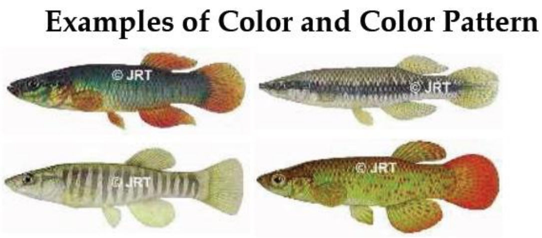
Characteristics:

1. Not subject to wide variation among specimens.
2. Not readily modified by the environment.
3. Consistently expressed.
4. Available in specimens you are using.
5. Effectively recorded.

- Characters that do not vary or vary randomly between groups are of no use.

External Morphology:

- Most characters are useful. May be single or complex shape, size, colour, colour pattern, counts of various repeated or comparable structures.



Sexual Dimorphism

- Frequently species differ sexually in characters so that the mature individuals appear different. May occur only during breeding season.

Embryonic Character

- Characters have an ontogeny and this may be continuous or discontinuous where there are discrete body forms which undergo metamorphosis. Because of these changes we must use equivalent forms.

- Ontogenetic characters are useful in establishing relationships.

Chromosomes

- Chromosomal changes may accompany or provide speciation, reduced fecundity, and sterile.
- Three levels are analyzed commonly for chromosomes:
- <u>Alpha Karyology</u> - Number and size of chromosomes.
- <u>Beta Karyology</u> - Number and location of centromere to allow for comparison of chromosomes between species.
- <u>Gamma Karyology</u> - Number, centromere & stains for various regions of chromosomes to identify homologous parts of chromosome.
- Chromosome number expressed as haploid or diploid.
- Compare number of metacentrics, acrocentrics and telocentrics.

Physiological characters

<u>Body secretions</u>:

- Morphology, numbers, size and structures of secretory glands. E.g. waxy secretion of scale insects and mealy bugs.

Molecular characters

- Immunological information
- Electrophoretic differences
- Amino acid sequences of proteins
- DNA hybridization
- DNA and RNA sequences

Behavioral characters

- ***Courtship and other ethological isolating mechanisms:***
- Matting and reproducing behaviour of species.
- Help in taxonomic classification.
- Result in reproductive isolation and consequent speciation.
- Living, eating and nesting behaviour.

Ecological characters and distributional characters

- Habit and habitats
- Food and Seasonal variations
- Parasites and hosts
- Geographic characters, General biogeographic distribution patterns
- Sympatric-allopatric relationship of populations

Origin of reproductive isolation: biological mechanism of genetic incompatibility

The origin of reproductive isolating mechanisms

- In the origin and maintenance of race and species, isolation is an indispensable factor and its role and importance have been recognized for a long time.
- Even Lamarck and Darwin pointed out that interbreeding of different populations may result in swamping of the differences acquired during the process of evolutionary divergence.
- During the process of speciation the diverging populations must acquire some means of isolation so that the genes from one gene pool are prevented from dispersing freely into foreign gene pool.
- Reproductive isolating mechanisms prevent exchange of genes between populations by genetically conditioned mechanisms which are intrinsic to the organisms themselves.
- The mechanism of reproductive isolation is a collection of evolutionary, behavioural and physiological processes critical for speciation.
- Thus, the origin of reproductive isolating mechanisms is an important event in the process of cladogenesis (speciation).

Isolating mechanisms:

- The species specific reproductive characteristics prevent different species from fusing. The reproductive isolating barriers maintain the integrity of a species by reducing gene flow between related species.
- Different types of reproductive isolating mechanisms have been studied in *Drosophila* such as gametic isolation, ethological (sexual or behavioural) isolation, hybrid inviability and hybrid sterility.
- Two broad kinds of isolating mechanisms between species are typically distinguished, together with a number of sub-types (Mayr 1970):

Pre-mating isolating mechanisms:

Pre-zygotic isolation mechanisms are the most economical in terms of the natural selection of a population, as resources are not wasted on the production of a descendant that is weak, non-viable or sterile. These mechanisms include physiological or systemic barriers to fertilization.

a) ***Temporal isolation***. Individuals of different species do not mate because they are active at different times of day or in different seasons or difference in the time of sexual maturity or flowering.

b) ***Ecological isolation*****:** Individuals mate in their preferred habitat, and therefore do not meet individuals of other species with different ecological preferences.

c) ***Behavioural isolation*****:** Potential mates meet, but choose members of their own species. The potential mates exhibit species specific courtship display.

d) ***Mechanical isolation*****:** Copulation is attempted, but transfer of sperm does not take place. Mating pairs may not be able to couple successfully if their genitals are not compatible.

Post-mating isolating mechanisms:

a) ***Gametic incompatibility*****:** Sperm transfer takes place, but egg is not fertilized. The synchronous spawning of many species of coral in marine reefs means that inter-species hybridization can take place as the gametes of hundreds of individuals of tens of species are liberated into the same water at the same time. Approximately a third of all the possible crosses between species are compatible, in the sense that the gametes will fuse and lead to individual hybrids. This hybridization apparently plays a fundamental role in the evolution of coral species. However, the other two-thirds of possible crosses are incompatible.

b) ***Zygotic mortality***. A type of incompatibility that is found as often in plants as in animals occurs when the egg or ovule is fertilized but the zygote does not develop, or it develops and the resulting individual has a reduced viability. This is the case for crosses between species of the frog genus, where widely differing results are observed depending of the species involved.

c) ***Hybrid inviability*****:** Hybrid embryo forms, but of reduced viability.

d) ***Hybrid sterility*****:** Hybrid is viable, but resulting adult is sterile. A hybrid has normal viability but is deficient in terms of reproduction. This is demonstrated by the mule. In all of these cases sterility is due to the interaction between the genes of the two species involved; to chromosomal imbalances due to the different number of chromosomes in the parent species.

Hinnies (male horse x female donkey) and mules (female horse x male donkey) are hybrids. These animals are nearly always sterile due to the difference in the number of chromosomes between the two parent species. Both horses and donkeys belong to the genus *Equus*, but *Equus caballus* has 64 chromosomes, while *Equus asinus* only has 62. A cross will produce offspring (mule or hinny) with 63 chromosomes that will not form pairs, which means that they do not divide in a balanced manner during meiosis.

e) ***Hybrid breakdown***. First generation (F1) hybrids are viable and fertile, but further hybrid generations (F2) may be inviable or sterile.

Taxonomic procedures: Taxonomic collections, preservation, curetting, process of identification

Taxonomic collections:

Biological collections are typically preserved plant or animal specimens along with specimen documentation such as labels and notations.

Types of collection

Most biological collections are either dry collections or wet collections. They also may include collections preserved at low temperatures or microscopy collections.

Dry collections

Dry collections consist of those specimens that are preserved in a dry state. Two factors influence decisions about preserving specimens this way:

Rigidity - Some specimens can be preserved naturally (starfish) or artificially with sufficient rigidity to accommodate normal handling. Such specimens often are suitable for dry preservation.

Specific characteristics - Drying may provide the best available means to preserve natural colours (for example, butterflies) or distinguishing features (such as skeletal parts or surface details). Such specimens in a dry state may have great potential for interpretation and research.

Wet collections

Wet collections are specimens kept in a liquid preservative to prevent their deterioration. Certain biological specimens are preserved in a wet form due to: Convenience - an intent to preserve body form and soft parts for a variety of uses. When colour preservation is not critical and dry preservation sacrifices qualities needed for other intended uses, fluid preservation is beneficial.

Biological low-temperature collections

Specimens are maintained at low temperatures to preserve:

- soft parts for various biochemical analyses
- Some algae, Protozoa (especially parasitic strains), Viruses, Bacteria, Bacteriophages, Plasmids
- Animal tissues (dissected organs, muscles),Cell lines
- Blood and blood components (serum, plasma etc)
- Semen, Venom
- Other samples (isolated proteins and nucleic acids, cell suspensions)

Biological microscopy collections:

Scientists preserve certain specimens as microscope preparations to preserve whole or partial organisms for:

- various kinds of microscopic examination

- Biochemical analyses, extraction of DNA.
- Histology
- Karyology
- Scales
- hair

Value of biological collections

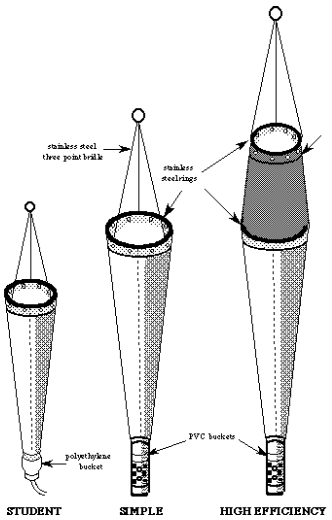
Most biological collections are highly valuable for the following reasons. Museums are only place where extinct species are preserved.

- specimens of special historical value.
- specimens rarely found in any collections.
- Many areas in world are geographically inaccessible. Material from such area are invaluable & are preserved at all costs.

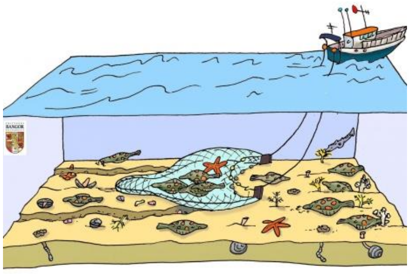


Methods of collections:

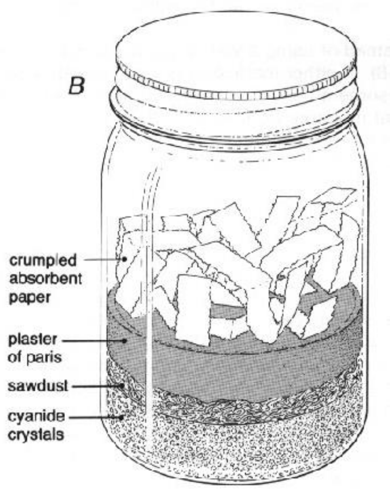
- Mist net collection
- Collection of insects light trap.
- Sweeping net.
- Aquatic insects and other arthropods are collected by using dip-nets & plankton nets.



- Trawling and dredging for collecting deep sea animals



Killing Jar:



Spreading tray:

Carcasses or remnants

Carcasses or remnants of dead animals, scat and other biological material found in the wild may be very useful for obtaining data about wild populations. It can no longer be regarded as ethical to kill threatened wild animals for obtaining skins for collections; carcasses of animals found or confiscated from poachers may serve as a better source of material for reference collections. Skeletal material, skulls, owl pellets may be an interesting source of bones, hair samples; reference hair collection of sympatric species,

Fur and hair

After removing the skin from the animal, as much flesh as possible should be removed, but without damaging the skin with hair roots. Then the skin can be dried in the sun, or if necessary, high over a fire, either hung on a line or stretched between pegs. Salting the skin will speed the drying process and temporarily preserve the skin. Areas that still have flesh or fat should be salted thoroughly. Powdered borax can be put on the skin to further preserve it. When the skin is nearly dry, it should be folded with the hairy sides together.

Preservatives and Fixatives

Formalin: Its use will not harm the specimen, is a better preservative than alcohol. It penetrates more rapidly and internal organs remain in better condition. Commercial formalin (40%) should be diluted with ten volumes of water to a 4% solution. 2% formalin with seawater is an excellent quick preservative for small marine specimens.

Alcohol: It is used in zoology, generally 95% ethyl alcohol (white spirits) which may be diluted with distilled water to strengths of 70% and 80%. At least 70% is required for safe storage of material. Alcohol is a valuable preservative for crustacea, polychaeta and echinoderms with bristles or hard-parts.

A teaspoonful of glycerine mixed with alcohol helps to preserve natural colours and to keep integuments flexible.

Alcohol in jars containing preserved specimens should be changed at intervals once or twice a year and evaporation should be guarded against.

One of the most important fixatives for the general collector of invertebrates is Bouin’s fluid, which is excellent for general structural and histological work, and for preservation of animals for dissection. Fixation time is at least 12 hours for a specimen of l cc. bulk, correspondingly longer for larger material. There is not much danger of over-fixing. Afterwards specimens should be washed in 70% alcohol, to remove excess picric acid, and stored in 70-80% alcohol.

Formula for Bouin's: 75 parts saturated aqueous picric acid; 25 parts 40% formalin; 5 parts glacial acetic acid.

Preservation by cooling or freezing:

Removal of the skin with insulating fur before cooling or freezing may help to cool the carcass down more quickly. Freezing is not recommended if histological examination is planned.

Storage of the Collection

As the collection grows, the greatest need will be for an orderly storage system, with facilities for quick reference to any container, to field notes and any other information.

It may be desired to have the collection visible for permanent display, and with dried material a set of flat cabinet drawers is best for storage.

Most invertebrates, will be kept in bottles, and sets of tubes or jars can be kept together in a small space by placing them in deep cardboard boxes, conspicuously labelled with serial box numbers.

Containers

Uniform sizes of tubes and jars will be preferred.

Jars should be wide-mouthed, and of clear glass, thick enough to withstand knocks. Non-corrodible tops are preferable to metal caps. Alternatively, wide-mouthed bottles may be stoppered with firm, good quality corks.

Preserving jars with rubber washer lids are ideal for larger specimens.

Specimens as a rule may be put straight into the container.

Labelling

The bulk of the information about a specimen should be entered on the record sheet. Labels attached to the container should include the habitat, locality and date, and the collector's initial.

Alternatively specimen labels can be placed in the preservative within the container. They should then be written on stiff, non-absorbent white card, either in pencil or in indian ink.

Ink labels should be allowed to dry, then steeped for a few minutes in a 3% solution of acetic acid, which effectively sets the ink and prevents "running" when placed in preservative.

Recording of data

- Geographic locality
- Date
- Stage (adult male, female or immature form)
- Altitude or depth.
- Host
- Name of collector and other relevant information

Identification:

Identification of collections may be carried out based on published references and museum specimens.

Curating of Collections

Every taxonomist has to take the responsibility of curating collections. This requires a great deal of expertise, knowledge and clear understanding of the function of different collections.

Preparation of Material

- There are certain materials which are ready for study as soon as collected from the field e.g., bird and mammal skins.
- There are certain insects which should never be placed in alcohol or any other liquid preservative, whereas others are useless when dried.
- Most insects are pinned, and the wings are spread if they are taxonomically important as in butterflies, moths and some grasshoppers.
- Certain invertebrates are to be preserved in alcohol or formalin before their study.

Housing

- Research collections should be housed in fireproof and dustproof buildings.
- Most museums keep their collections in air-conditioned buildings.
- Rapid changes in temperature and humidity are harmful to museum cases and specimens.
- Storage cases should be built to be insect-proof. Photographs and films should be stored in air-conditioned rooms.
- Improperly preserved or inadequately labelled specimens should be eliminated by the curator. The most efficient method for the elimination

of useless material is to ask specialists to pull out such specimens while scrutinizing the material during a revision.

Exchange of Material

- The selecting of material for exchanges and keeping its record is time consuming, so the exchanges are not as popular as they used to be.
- A specialist doing a monograph on a certain genus or family can always borrow material from other institutions and return it after completing his work. Exchanges are sometimes necessary to build up complete identification collections.

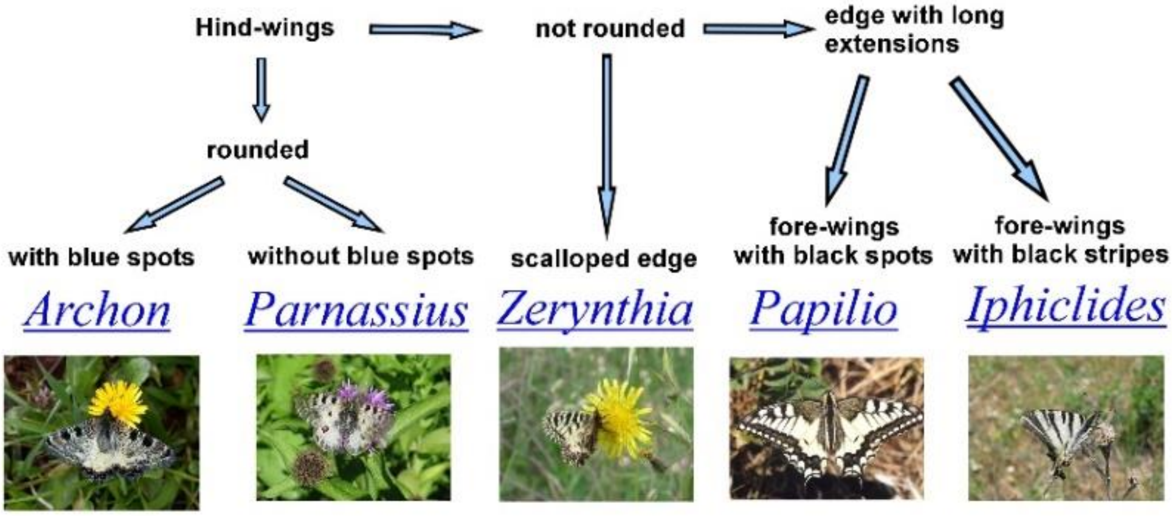
Unit III

- Taxonomic keys, different types of keys, their merits and demerits.
- International code of Zoological Nomenclature (ICZN): Operative principles, interpretation and application of important rules: Formation of Scientific names of various Taxa.
- Synonyms, homonyms and tautonomy.

Taxonomic keys, different types of keys, their merits and demerits

- A key is a device, which constructed properly and used to the identification of unknown species.
- It is a series of contrasting statements required to make comparison and identification.
- The key consists of a series of choices, based on observed features of the specimen. It provides a choice between two contradictory statements resulting in the acceptance of one and the rejection of the other.

Identification key to the genera of the family Papilionidae



- At each point in the decision process, multiple alternatives are offered, each leading to a result or a further choice.
- The alternatives are commonly called **“leads”**, the set of leads at a given point a **“couplet”**. If the entire key consists of exactly two choices at each branching point, the key is called **dichotomous**, otherwise it is described as **polytomous or poly clave**.

Constructive features of taxonomic keys:

1) Constant characteristics rather than variable ones should be used.
2) Proper measurements rather than terms like “**large**” and “**small**” should be used.
3) Characteristics that are generally available to the user of the key rather than seasonal characteristics or those seen only in the field should be used.
4) A positive choice should be made. The term “**is**” instead of “is not” should be used.
5) If possible one should start both choices of a pair with the same word.
6) If possible, different pairs of choices should be started with different words.
7) The descriptive terms should be preceded with the name of the part to which they apply.

Types of Taxonomic Keys

There are basically two types of keys:

A) *Dichotomous* and

B) *Poly clave* (Multiple Access or Synoptic).

A) Dichotomous Keys:

- This is one of the most frequent keys, which are the most common, probably first published by Jean Baptiste-Lamarck in 1778.
- Keys in which the choices allow only two alternative couplets are known as **dichotomous keys**.
- In constructing a key, contrasting characters are chosen that divide the full set of possible species into smaller and smaller groups i.e. the statements typically begin with broad characteristics and become narrower as more choices are required.
- Each time a choice is made, a number of species are eliminated from consideration and the range of possible species to which the unknown specimen may belong is narrowed.
- Eventually, after sufficient choices have been made, their range reduces to a single species and the identity of the unknown species is revealed.
- Couplets can be organized in several forms. The couplets can be presented using numbers (numeric) or using letters (alphabetical). The couplets can be presented together or grouped by relationships.

Example of a numerical key with couplets
1. Seeds round—soybeans 1. Seeds oblong go to—2 2. Seeds white—northern beans 2. Seeds black—black beans
Example of an alphabetical key with same couplets

A. Seeds oblong go to—B
    B. Seeds white—northern beans
    B. Seeds black—black beans
A. Seeds round—soybeans

Types of Dichotomous Keys:

There are two types of dichotomous keys. They differ in the method by which the couplets are organized and how the user is directed to successive choices.

i) Indented Keys (also called yoked)**:**

In indented keys, the choices (leads) of the couplet possess an equal distance from the left margin.

Example of an Indented Key on *Rhododendron*

1a. Flowers in shades of red

  2a. Flowers blood-red, leaves oblong-ovate, leathery and thick matty texture .... *R. sikkimense*

  2b. Flowers crimson-red, leaves broad, oval to elliptic oblong, shiny green above .... *R. fulgens*

1b. Flowers in shades of rose-pink

  3a. Calyx 3-5 mm long, leaf under surface covered with tufts of brown hair .... *R. wallichii*

  3b. Calyx obscure, 1-2 mm long, leaf under surface covered with continuous indumentum

    4a. Corolla in shades of deep rose-pink flushed externally with red-purple, young leaves aeruginose, leaf margins inrolled .... *R. aeruginosum*

    4b. Corolla pale lavender blue, mauve or rose-purple, rarely white, young leaves not aeruginose, leaf margins not inrolled .... *R. campanulatum*

The two choices of the couplet are usually labelled **1** and **1′** or **la** and **lb**. It is not necessary that the choices are numbered, but it helps. The user goes to the next indented couplet following the lead that was selected.

ii) Bracketed Keys:

Provides both choices side-by-side. The choices of the couplet must be numbered (or lettered). It is very helpful if the previous couplet is given. This key has exactly the same choices as the first example. The choices are separated, but it is easy to see the relationships. While this key might be more difficult to construct, it gives more information to the user.

Advantages of dichotomous keys:

a. Similar specimens are grouped together;

b. It is harder to get lost your place;

c. They are faster to use; and

d. It is easier to retrace your steps if you make a "wrong turn".

Disadvantages of dichotomous keys:

A key may be difficult to use at times because:

- The key may not include all potential variations in the species;

Example of a Bracketed Key on *Rhododendron*

1a.	Flowers in shades of red	go to 2
1b.	Flowers in shades of rose-pink	go to 3
2a.	Flowers blood-red, leaves oblong-ovate, leathery and thick matty texture	*R. sikkimense*
2b.	Flowers crimson red, leaves broad, oval to elliptic oblong, shiny green above	*R. fulgens*
3a.	Calyx 3-5 mm long, leaf under surface covered with tufts of brown hair	*R. wallichii*
3b.	Calyx obscure, 1-2 mm long, leaf under surface covered with continuous indumentum	go to 4
4a.	Corolla in shades of deep rose-pink flushed externally with red-purple, young leaves aeruginose, leaf margins inrolled	*R. aeruginosum*
4b.	Corolla pale lavender blue, mauve or rose-purple, rarely white, young leaves not aeruginose, leaf margins not inrolled	*R. campanulatum*

- The key may rely on features not present in that season;
- The key may not include "**all**" species of interest;
- One may misinterpret a feature or make a mistake.

B. Poly clave keys:

- Poly clave keys are tools used to help identify unknown objects or species. The keys are generated using interactive computer programs. Polyclave keys use a process of elimination.
- The user is presented with a series of choices that describe features of the species they wish to identify. The user then checks off a list of character states present in the organism they wish to study.
- The program looks to match those character states with all the species they can possibly match. If a species does not have that character state it is eliminated from the list. The more character states listed the more species that are eliminated.
- This allows the rapid elimination of large numbers of species that the specimen cannot be. The process continues until only one species remains.

Advantages of Poly clave keys:

1) They are easy to use.
2) They allow multi-entry i.e. the user can start anywhere. This is a significant advantage because the user can rely on characters that are most easy to observe, rather than having to deal with characters that may not be present in the specimen or are poorly developed.
3) They are order-free i.e. the user can work in any direction with any character.
4) They are faster.
5) They are easily computerized. In fact, these keys are most commonly used in this form. Paper versions are typically large and unwieldy because each character needs to list all possible taxa.

Disadvantages: It is based on specimen and their availability. They have generally been written only for a limited number of taxonomic groups.

Polyclave Key: Example - Pollination Type

Pollination is the process of transferring pollen from one flower to another. Since plant can't move, they utilize vectors such as wind, water and animals to accomplish this process for them. Flowers are specialized by shape, color, odor, nectar reward in order to maximize the chance that a certain vector will accomplish pollination. These flower adaptations are collectively known as pollination syndromes.

Plants differ in the degree of their specialization for a particular pollination system. For example, many orchids are pollinated by only a single type of bee. Other flowers are not as specialized and may be pollinated by a variety of bees or perhaps beetles. In other cases, insects may visit flowers without actually transferring pollen. These factors make it difficult to determine with absolute certainty the pollination system by the polyclave key.

To illustrate how to use a polyclave key, let's determine the pollination system of a dandelion.

1. Select any one of the FLOWER CHARACTERS in the key.	*Let's choose FLOWER COLOR*
2. Choose the character state (description) that matches the flower you are observing	*Dandelions are* ***Yellow***
3. Write down the possible pollination systems for this feature	*BE,BU,BI*

(*BE-Bee pollination, BU-Butterfly pollination, BI-Bird pollination*)	
4. Select another feature	*NECTAR*
5. Choose the character state description that matches your flower (*WI-wind pollination, FM-fly pollination, BE-bee pollination, BA-bat pollination*)	*b. present...WI,FM,BE,BA*
6. Eliminate from the first character state selected the pollination systems not found on both lists. Continue this process until the pollination system is identified.	*BE,~~BU~~,~~BI~~* *Thus, dandelions are bee pollinated*

Abbreviation Code: **WI** Wind pollination (anemophily); **BT** Beetle pollination (cantharophily); **FM** Fly pollination (syrphid and bee flies; myophily); **FS** Fly pollination (carrion and dung flies; sapromyophily); **BE** Bee pollination (mellittophily); **BU** Butterfly pollination ; (psychophily); **MO** Moth pollination (phalaenophily & sphingophily); **BI** Bird pollination (ornithophily); **BA** Bat pollination (chiropterophily)

International code of Zoological Nomenclature (ICZN): Operative principles, interpretation and application of important rules: Formation of Scientific names of various Taxa

- One of the primary responsibilities of systematic biology is the development of our biological nomenclature and classifications.
- Nomenclature is not an end to systematics and taxonomy but is a necessity in organizing information about biodiversity.
- Nomenclature functions to provide labels (names) for all taxa at all levels in the hierarchy of life.
- Biological nomenclature derives from the binomial nomenclature that was originally codified in the works of Linnaeus, *Species Plantarum* (1753) and *Systema Naturae, 10th Edition* (1758). These publications are the decided starting points for the modern biological nomenclature in most groups of plants and animals.
- Taxa at the level of species are named with binomials, consisting of generic and specific names that together equal the species name.
- Taxa above the level of species are Supraspecific Taxa and are Uninominals.

- Taxa below the level of species are Subspecies or Trinominals.

History of Nomenclature Codes:

1758 Linnaeus' 10th Edition of *Systema Naturae*

1840 Strickland Code of British Association for the Advancement of Science

1867 Set of "laws" at Paris International Botanical Congress

1881 French Code developed

1887 U. S. Code developed

1889 International Zoological Congress adopted Blanchard Code

1894 German Code developed

1901 Regles International Nomenclature of Zoology adopted by 5th Congress, published under the 6th Congress in 1905

1904 International Commission on Zoological Nomenclature (ICZN) formed

1913 Plenary powers granted to ICZN

1952 International Code of Botanical Nomenclature

1953 Publication of Copenhagen Decisions and the Follett Summary (1955)

1958 Rewritten as international code and updated since that time

1976 International Code of Nomenclature of Bacteria
1985 Publication of International Code of Zoological Nomenclature
1994 Most recent Code of Botanical Nomenclature
1999 Most recent Code of Zoological Nomenclature

Parts of International Code of Zoological Nomenclature:

The International Code of Zoological Nomenclature contains three main parts:
(i) The Code proper, (ii) The Appendices and (iii) The Official Glossary

- The code proper includes a preamble followed by 90 articles (grouped in 18 Chapters) which cover mandatory rules without any explanation.
- There are three Appendices, of which the first two cover the status of recommendations and the third part of the Appendices is the constitution of the commission.
- The glossary contains the terms used in the codes with detailed definition.
- The English and French texts of the Code are published on behalf of the Commission by the International Trust for Zoological Nomenclature.

Rules of Zoological Nomenclature:

At present the naming of the animal is governed by the International Code of Zoological Nomenclature. There are many rules (Articles) concerning the Zoological Nomenclature.

Some important ones are cited below:

1. Zoological nomenclature is independent of other system of nomenclature. The scientific name of animals and plants must be different, and the generic name of a plant and an animal may be same, but this system is to be avoided. e.g., the generic name of banyan or fig tree is *Ficus* and the fig shell (a gastropod shell) is *Ficus*. The scientific name of fig tree is *Ficus carica* or *F. indica*, *F. religiosa*, *F. bengalensis* etc., but the scientific name of the fig shell is *Ficus ficus* or *Ficus gracilis*, etc.

2. The scientific name of a species is to be binomial (Art. 5.1) and a subspecies to be trinomial (Art. 5.2).
e.g., the scientific name of Indian bull frog is *Rana tigerina*. It is binomial. The scientific name of Indian lion is *Panthera leo persica*. It is trinomial. Such a system of naming by three Latin or Latinized words is known as trinomial nomenclature.

3. The first part of a scientific name is generic (L. Genus = race) and is a single word and the first alphabet or letter must be written in Capital letter. The genus must be a noun in the nominative singular. The generic part assigns a Latin noun, a Latinized Greek or a Latinized vernacular word.

4. The second part of a name is species (L. species = particular kind) name and may be a single word or a group of words. The first alphabet or letter of the species name must be written in small letter. The species name must be adjective form in nominative singular agreeing in gender with genus name which is in noun form; e.g.:

The specific name indicates distinctness while generic part shows relationship.

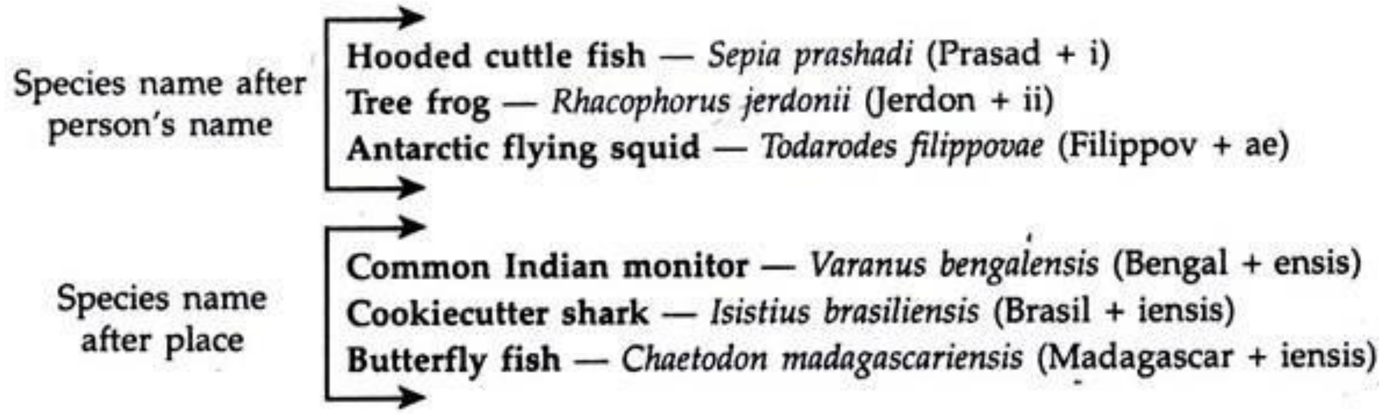
5. If the species names are framed after any person's name, the endings of the species are *i*, *ii* and *ae*, or if the species name are framed after

Ending in species name	Ending in genus name	Full name of the species
Masculine ending (–i)	(–i/–us/–es)	Common mongoose (*Herpestes edwardsi*) River lapwing (*Vanellus duvaucelli*)
Feminine ending (–a/–e)	(–a/–e)	Golden cuttle fish (*Sepia esculenta*) Humpnosed viper (*Hypnale hypnale*)
Neuter ending (–um/–us, etc.)	(–um/–us, etc.)	Tusk shell (*Dentalium elephantinum*) Common crane (*Grus grus*) Lesser black-backed gull (*Larus fuscus*)

geographical place, the endings of the species are ‘*ensis*’, ‘*iensis*’, e.g.:

6. First part of a compound species-group name is a Latin letter and denotes a character of the taxon, connected to the remaining part of the name by a hyphen (-) e.g., Sole (a kind of flat fish)—*Aseraggodes sinus-arabici* L. Sinus = recess

China-rose (a kind of coloured rose) — *Hibiscus*



rosa-sinensis L. rosa = rose

7. If a subgenus taxon is used, it is included within parenthesis in between genus and species part and is not included in binomial and trinominal nomenclature, e.g.:

Name	Genus	Subgenus	Species	Subspecies
Fan shell (Bivalvia)	*Atrina*	(*Servatrina*)	*pectinata*	*pectinata*
Dussumieri's half beak (Osteichthyes)	*Hemirhampus*	(*Reporhampus*)	*dussumieri*	-

8. The person who first publishes the scientific name of an animal, is the original author of a name, may be written after the species name along with the year of publication. The author's name may be in its abbreviated form.

Lion- *Felis leo* Linnaeus, 1758; Lion- *Felis leo* Linn., 1758; *Felis leo* L., 1758

9. Comma is only used between author's name and the year of publication (Art. 22. A. 2.1), e.g., the scientific name of Common octopus is *Octopus vulgaris* Cuvier, 1797. No punctuation marks are considered one to other ends of the name, e.g., "*Octopus vulgaris* Cuvier, 1797" (Not considered). No diacritic mark, apostrophe (i') and hypen (-) are used in names. In German word the umlaut sign is removed from a vowel and the letter 'e' is inserted after the vowel, e.g., Mülleri becomes Muelleri.

10. If the original generic name given by the first author who also reported the species name, transfers the species part from one genus to the

other, the name of the original author is put within parenthesis, e.g.,

Tiger:
Felis tigris Linnaeus, 1758. At first almost all the members of the cat family were placed under the genus-*Felis*.

Later the genus *Felis* was divided into two genera, the genus of the larger cats (tiger, lion, leopard, etc.) is *Panthera* and smaller cats such as jungle cat, fishing cat, golden cat, etc. are placed under the genus *Felis*, e.g.:
Lion- *Felis leo* Linnaeus, 1758 – Lion - *Panthera leo* (Linnaeus, 1758)

Jungle cat- *Felis chaus*

11. The names are not acceptable before the publication of Linnaean treatise, *Systema Naturae* (10^{th} edition) which was published on 1^{st} January, 1758 except the Nomenclature of spiders which starts in 1757. The book *Aranei suecici* was published by C. Clerck in 1757.

12. The scientific names must be either in Latin or Latinized or so constructed that they can be treated as a Latin word.

13. The scientific names must be italicized in printed form, or underlined in hand written or in typed forms, e.g.

Indian leopard- *Panthera pardus fusca* (Meyer)

14. All taxa from subgenera level and above must be uninominal (Art. 4.1, 4.2) and are plural nouns for names above genus, and singular nouns for genus and subgenus. Taxon 'species' may be used as singular or plural.

15. In case of animals some rules and practices are applied on the basis of zoological codes (Art. 29.2) for the formation of supra generic taxa from superfamily to tribe, e.g.

16. A family name should be based on the basis of type-genus, e.g., Chitonidae—Chiton (type genus)

Taxon level	**Endings of the name**	**Examples**
Superfamily	—oidea (for vertebrates) or —acea (for invertebrates)	Hominoidea Genus *Homo* (Latin) = man Genitive *Hominis* Root *Homin*—of *Homo*
Family	—idae	Hominidae [Homin + idae]
Subfamily	—inae	Homininae [Homin + inae]
Tribe	—ini	
Subtribe	—ina	

+ idae = Chitonidae.

17. Two species under a same genus should not have the same name.

18. Nomenclature of a hybrid/hybrids cannot be considered because the hybrids are normally individuals but not population. Thus such names have no status in nomenclature. Hybrids are typically sterile and become synaptic failure during meiosis. They are prevented from back crossing with either parental species.

19. A name published without satisfying the conditions of availability (nomen nudum = naked name) has no standing in zoological nomenclature and is best never recorded, even in synonymy.

20. A scientific valid name which is not used about 50 years in literature, then as per zoological code's provision the unused senior valid scientific name is treated as obliterated name and junior name which is used continuously in literature (at least by 10 authors in 25 publications) becomes the accepted official name.

Remark:
The disadvantage of the binominal system is its instability and the name of a species changes every time and is transferred to a different genus.

21. As per the zoological code's provision, the species and subspecies parts of a name may be same spelling and even the second or the third component of the name repeats the generic name (tautonomy), e.g.: Scandinavian red fox- *Vulpes vulpes vulpes*

22. Synonyms are the different names for a same animal or a taxon (species or genus). If the several scientific names are given to a single animal by different scientists, the senior-most name is selected by law of priority. The senior-most or earliest name is called senior synonym (Art. 10.6) and is considered as valid species and the rest of the names are called junior synonyms and are treated as invalid species.

The leopard cat was named *Felis bengalensis* by Kerr and the same animal was named by Gray, *Felis chinensis*. Again this animal was named as *Prionailurus bengalensis* by Kerr. So the first name is senior synonym and valid and the rest names are junior synonyms and are invalid.

The whale shark was named *Rhiniodon typus* by Smith in 1828 and the same was named *Rhinodon typicus* by Muller and Henle in 1839, *Micristodus punctatus* by Gill in 1865 and *Rhinodon pentalineatus* by Kishinouye in 1891. Here the first name is considered as senior synonym (*Rhiniodon typus*) and valid, the rest are junior synonyms and are invalid.

23. Homonyms mean when identical names are given to two or more different taxa. According to the zoological code (Art. 52.2) when two or more homonyms are found, the senior most (oldest) homonym (Art. 52.2) is used and the junior-most homonyms are replaced with new names, e.g., Cuvier proposed the genus *Echidna* in 1797 for the spiny anteater.

Forster already proposed the genu *Echidna* in 1777 for morey eels. According to Law of Priority, Forsters genus claimed senior homonym and Cuvier's genus considered as junior homonym. *Illiger* replaced the Cuvier's name as *Tachyglossus* for spiny anteater in 1811.

Taxonomic Categories?

Taxonomic Hierarchy Categories were also introduced by Linnaeus. They are also known as

Linnaean hierarchy. It is defined as sequence of categories in a decreasing or increasing order from kingdom to species and vice versa. Kingdom is the highest rank followed by division, class, order, family, genus and species. Species is the lowest rank in the Hierarchy. The hierarchy has two categories which are obligate and intermediate. Obligate means they are followed strictly and range from kingdom to species as said above. Intermediate are not followed strictly and they are added in obligate list such as subdivision, super family, super class, suborder, subspecies etc.

1. Kingdom: The top most taxonomic category. Example all animals are included in Kingdom Animalia. The unit in classification that denotes grouping of organism based on features which are observable is known as Taxon.

The different methods used to identify and classify organisms are referred to Taxonomic aids. Identification of organisms is a tedious process. Keys are used for identification referred as Taxonomic key. It includes a long table of statements with alternative features to identify organisms. The features which are related to organism are chosen.

2. Phylum: It is a term used for animals while its synonym division is used for plants. It is a collection of similar classes. Phylum chordata of animals has class mammalia along with birds, reptiles and amphibians.

3. Class: One or more than one order makes a class. Class mammalia includes all mammals which are bats, rodents, kangaroos, whales, great apes and man.

4. Order: One or more than one similar families constitute order. Family felidae are included in the order Carnivora. Order puts them in a general group of what they are, like the group turtle, which including all turtles.

5. Family: In biological classification, family (**Latin: familia, plural familiae**) is one of the eight major taxonomic ranks; it is classified between order and genus. A family may be divided into subfamilies, which are intermediate ranks above the rank of genus. In vernacular usage, a family may be named after one of its common members. It can be separated from genera by reproductive and vegetative features.

6. Genus: The classification of kingdom is very general and includes the animal kingdom or plant kingdom. In contrast, the division of genus is more specific as the grouping before species and after family. It is defined as group of similar species. But it is not mandatory to have many species.

Some genera have only one species known as *Monotypic*. If there are more than one species it is known as *Polytypic*. For example lion, tiger are quite similar species placed under the genus Panthera.

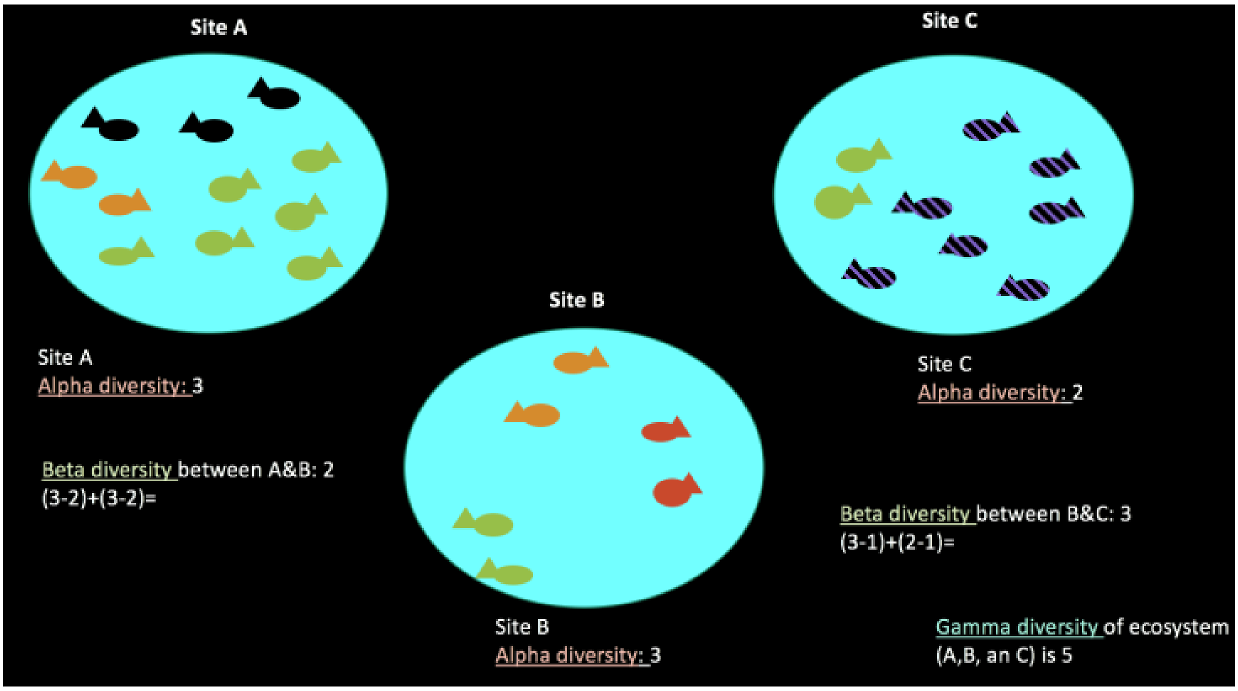
7. Species: The biological species concept defines a species as members of populations that actually or potentially interbreed in nature, not according to similarity of appearance. Although appearance is helpful in identifying species, it does not define species.

Unit IV

Evaluation of biodiversity indices. Evaluation of Shannon Weiner Index. Evaluation of Dominance Index. Similarity and Dissimilarity Index.

The variety of life on Earth is commonly referred as biological diversity or biodiversity. Biodiversity is one of the primary interests of ecologists, but quantifying the species diversity of ecological communities is complicated.

The biodiversity indices aim to describe general properties of communities that allow us to compare different regions, taxa, and trophic levels. They are of fundamental importance for environmental monitoring and conservation, although there is no consensus about which indices are more appropriate and informative.



The spatial component of biodiversity can be termed as alpha, beta, and gamma diversity. Imagine that you have a landscape containing of a number of separate sites and habitats. **Alpha diversity** is just the diversity of each site/habitat (local species pool). **Beta diversity** represents the differences in species composition among sites/habitats. **Gamma diversity** is the diversity of the entire landscape (regional species pool).

Diversity mainly includes two different aspects: species richness and evenness. Species richness, or the number of species, is the simplest measure of diversity and does not consider differences in species relative abundance. That is, each species is not likely to have the same number of individuals. One species may be represented by 1000 birds, another by 200 and a third only a single bird species.

Species evenness is the similarity in species relative abundance in a community. The majority of studies on biodiversity have used species richness to represent diversity on account of its apparent simplicity compared to species evenness.

Diversity indices are mathematical functions that combine richness and evenness in a single measure. The most commonly used diversity indices are: Shannon's diversity and Simpson's diversity indices.

Shannon Diversity Index

The Shannon index increases as both the richness and the evenness of the community increase. The fact that the index incorporates both components of biodiversity can be seen as both a strength and a weakness. It is a strength because it provides a simple, synthetic summary, but it is a weakness because it makes it difficult to compare communities that differ greatly in richness. Typical values are generally between 1.5 and 3.5 in most ecological studies, and the index is rarely greater than 4.

$$H' = -\Sigma\, p_i \,\mathrm{In}\, p_i$$

Where,

H' = Shannon index of diversity

p_i = the proportion of important value of the i^{th} species ($p_i = n_i / N$, n_i is the important value index of i^{th} species and N is the important value index of all the species).

To calculate the index:

1. Divide the number of individuals of species #1 you found in your sample by the total number of individuals of all species. This is p_i
2. Multiply the fraction by its natural log (p_i * ln p_i)
3. Repeat this for all of the different species that you have.
4. Sum all the - (p_i * ln p_i) products to get the value of H'

Example 1:

S. No.	Name of species	N	*pi*	*lnpi*	*pi lnpi*
1	Pigeon	10	0.05	-2.912	-0.158279927
2	Robin	4	0.02	-3.829	-0.083231335
3	Myna	9	0.05	-3.018	-0.147605438
4	Crow	7	0.04	-3.269	-0.124365105
5	House sparrow	11	0.06	-2.817	-0.168410029
6	Grasshopper	15	0.08	-2.507	-0.20436567
7	Butterfly	11	0.06	-2.817	-0.168410029

8	Snake	1	0.01	-5.215	-0.028342042
9	Frog	12	0.07	-2.730	-0.178045377
10	Monkey	10	0.05	-2.912	-0.158279927
11	Owl	4	0.02	-3.829	-0.083231335
12	Chital	18	0.10	-2.325	-0.227403
13	Drango	21	0.11	-2.170	-0.247710216
14	Blue Jay	15	0.08	-2.507	-0.20436567
15	Egret	17	0.09	-2.382	-0.22005044
16	Heron	19	0.10	-2.270	-0.234453472
	Total	184	1	-47.5	**-2.636549012**

H = 2.636

Example 2:

Birds	**N_i**	**P_i**	***ln* P_i**	**- (P_i * *ln* P_i)**
Pigeon	96	.96	-.041	.039
Robin	1	.01	-4.61	.046
Starling	1	.01	-4.61	.046

Crow	1	.01	-4.61	.046
House sparrow	1	.01	-4.61	.046

H = 0.223

High values of H’ would be representative of more diverse communities. A community with only one species would have an H’ value of 0 because p_i would equal 1 and be multiplied by ln p_i which would equal zero. If the species are evenly distributed then the H’ value would be high. So the H’ value allows us to know not only the number of species but how the abundance of the species is distributed among all the species in the community.

Evaluation of Dominance Index (Simpson’s index):

Dominance is one of the most important concepts in the study of animal social behaviour. Dominance hierarchies in groups arise from dyadic relationships between dominant and subordinate individuals present in a social group. In concrete way, dominance is an important indicator of species composition in a habitat. The dominance of a species refers to its relative importance in its habitat, which determines the degree of influence of the species on the ecosystem. Ecologists have spent much effort and imagination to establish and quantify interrelationships among these components, and to identify the underlying biological or physical processes that influence them, e.g., extinction, immigration, colonization, niche segregation, competition, predation, environmental control, disturbances, and historical dynamics.

The Simpson index is a dominance index because it gives more weight to common or dominant species. In this case, a few rare species with only a few representatives will not affect the diversity.

Simpson's index $D = \Sigma (p_i)^2$

Where,

D = Simpson index of dominance

p_i = the proportion of important value of the ith species ($p_i = n_i / N$, n_i is the important value index of ith species and N is the important value index of all the species).

As D increases, diversity decreases and Simpson's index was therefore usually expressed as 1 – D or 1/ D.

Example 1 (site 1)

Order	n	Pi	pi^2	ln pi	pi ln pi
Orthoptera (grasshopper)	6	0.222222	0.049383	-1.50408	-0.33424
Orthoptera (grasshopper)	5	0.185185	0.034294	-1.6864	-0.3123
Lepidoptera (butterfly)	1	0.037037	0.001372	3.29584	0.12207
Lepidoptera (butterfly)	3	0.111111	0.012346	-2.19722	-0.24414
Coleoptera (beetle)	12	0.444444	0.197531	-0.81093	-0.36041
	27	1	**0.294925 =** $\Sigma(p_i)^2$ = D	-9.49447	-1.37315
		1/ $\Sigma(p_i)^2$ = D	**3.390698**		

Number of species = 5

Total number of individuals = 27

$\Sigma (p_i)^2 = 0.294$

$\Sigma p_i \ln p_i = -1.373$

H' = -(-0.334 + -0.312 + -0.122 + -0.244 + -0.360) = **1.373**

D = 1/(0.049 + 0.034 + 0.001 + 0.012 + 0.197) = 1/0.294 = **3.390**

Example 2 (site 2)

Order	(n)	Pi	pi^2	ln pi	pi ln pi
Orthoptera (grasshopper)	99	0.99	0.9801	-0.01005	-0.00995

Orthoptera (grasshopper)	1	0.01	0.0001	-4.60517	-0.04605
	100	1	0.9802 = $\Sigma(p_i)^2$ = D	-4.61522	-0.056
		1-$\boldsymbol{\Sigma(p_i)^2}$ = D	0.020		

Similarity and Dissimilarity Index

In comparing species composition and biodiversity of two or more assemblages in taxonomic and ecological research, similarity (or overlap) or dissimilarity (or distance) indices provide quantitative bases of assessment. A large number of similarity indices based on presence / absence data have been proposed in the literature. The two classic and the most widely used indices are the Jaccard and Sorensen indices.

The **Jaccard index** and **Sorensen index** are the two oldest and most widely used similarity indices for assessing compositional similarity of assemblages (sometimes called species overlap) and hence, its complement, dissimilarity. Both measures are based on the presence/absence of species in paired assemblages and are simple to compute. Many other similarity indices exist that are based on the same information: the number of species shared by two samples and the number of species unique to each of them, and new indices continue to appear.

Jaccard Index:

Uses presence/absence data (i.e., ignores info about abundance)

$$S_J = \frac{a}{a+b+c}$$

Where,

S_J = Jaccard similarity coefficient,

a = number of species common to (shared by) quadrats,

b = number of species unique to the first quadrat, and

c = number of species unique to the second quadrat

Quadrat	sp 1	sp 2	sp 3	sp 4	sp 5	sp 6
I	3	4	2	1	0	0
J	3	3	0	5	2	1

$\Sigma\ _k y_{ki} = 3 + 4 + 2 + 1 + 0 + 0 = 10$

$\Sigma\ _k y_{kj} = 3 + 3 + 0 + 5 + 2 + 1 = 14$

$\Sigma\ _k y_{ki}^2 = 3^2 + 4^2 + 2^2 + 1^2 + 0^2 + 0^2 = 30$

$\Sigma\ _k y_{kj}^2 = 3^2 + 3^2 + 0^2 + 5^2 + 2^2 + 1^2 = 48$

$\Sigma\ _k y_{ki} y_{kj} = 3(3) + 4(3) + 2(0) + 1(5) + 0(2) + 0(1) = 26$

Quadrat	sp 1	sp 2	sp 3	sp 4	sp 5	sp 6	Total		
I	3	4	2	1	0	0	10		
J	3	3	0	5	2	1	14	**26 = a**	
I^2	9	16	4	1	0	0	30 = b	**104 = a+b+c**	
J^2	9	9	0	25	4	1	48 = c	**0.25 (a/a+b+c)**	Similarity
IxJ	9	12	0	5	0	0	26 = a	**0.75** = D_J = 1.0-S_J	Dissimilarity

This index can be modified to a coefficient of dissimilarity by taking its inverse: Jaccard's dissimilarity coefficient = 1–Sj (i.e., $D_J = 1.0 - S_J$)

Sorensen's Index:

- This measure is very similar to the Jaccard measure, and was first used by Czekanowski in 1913 and discovered anew by Sorensen (1948).
- Give greater "weight" to species common to the quadrats than to those found in only one quadrat.
- Indices of similarity and dissimilarity were calculated by using formulae as per Misra (1989) and Sorensen (1948) as follows:

Index of similarity (S) = 2C/A+B

Where,

A = Number of species in the community A

B = Number of species in the community B

C = Number of common species in both the communities.

Index of dissimilarity = 1-S

Example 1:

There are 20 species found in community 1 and 25 in community 2. Between them, they have 5 species in common. The calculation would be:

Sorenson's Coefficient (CC) = $\frac{2*5}{20+25}$ = 10/45 = 0.222

According to Sorenson's coefficient, these communities do not have much overlap or similarity.

Example 2:

There are 15 species found in community 1 and 25 in community 2. Between them, they have 12 species in common. The calculation would be:

Sorenson's Coefficient (CC) = $\frac{2*12}{15+25}$ = 24/40 = 0.6

According to Sorenson's coefficient, these communities have quite a bit of overlap or similarity.