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**BONGA UNIVERSITY**

**COLLEGE OF NATURAL AND COMPUTATIONAL SCIENCES**

**DEPARTMENT OF BIOLOGY**

**Lecture note on the course Principle of Taxonomy (Biol 3063)**

**For 3rd year regular students**

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# COURSE DESCRIPTION

The course deals with the historical development of taxonomy as a science, principles, procedures and rules of taxonomy, rules of botanical and zoological nomenclatures and the hierarchy of classification, with examples from both plant and animal kingdoms. Classification systems, taxonomic structures, taxonomic evidences, code of nomenclature and purpose of giving names to organisms and nomenclatural codes, taxonomic techniques and the application of taxonomic result in different disciplines are discussed in details

COURSE OBJECTIVE**:-**Dear learner after attending this course, each student will be able to:

* Review how the science of taxonomy grew through time
* Discuss the rules and procedures in taxonomic classification
* Enumerate the types and sources of characters used in taxonomic classification
* Describe how species are hierarchically arranged into different taxonomic groups
* Explain various species concepts
* Employ herbarium and museum techniques in taxonomy

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# CHAPTER ONE

# 1. INTRODUCTION

Dear Learners! Welcome to module of principle of Taxonomy, we hope that you have prior knowledge on diversity of life forms and the need for grouping and classification and different hierarchies of classification. Also details of the related terminologies above are briefly explained under this module.

## 1.1. Definition of Taxonomy

Dear learner! Under this section of the module you are expected to define the term taxonomy with its narrower and broader explanation and try to avoid confusion between taxonomy, systematics, classification, nomenclature, identification and description, as each of these terms are widely used throughout the module.

**Self- test exercise**

* Define Taxonomy in its narrower and broader sense.
* Differentiate between classification, Description, Identification, Nomenclature, and Classification?
* Differentiate between taxonomy and systematics?

**Taxonomy**: Taxonomy is derived from the Greek words- taxis="arrangement/to classify;" nomos =“law” or “science”

**Taxonomy:** the science of classification of organisms (from its origin = narrow definition)

**Taxonomy:** the study of variation, sources of variation, consequences of variation, classification/the principles underlying classification, discovering & naming of organisms/groups of organisms.(Broad definition)

**Taxonomy** is the branch of biology that names and groups organisms according to their characteristics and evolutionary history. In a broader sense, consists of four separate but interrelated disciplines: classification, nomenclature, identification, and description. Classification refers to the arrangements of Organisms into groups or taxa (sing, taxon) on the basis of their mutual similarity or evolutionary relatedness. Nomenclature is the discipline concerned with the assignment of names to taxonomic groups as per published rules. Identification represents the practical side of taxonomy, which is the process of determining that a particular organism belongs to a recognized taxon, and Description is the assignment of features or attributes to a taxon.It is to mention here that the term systematics often is used for taxonomy. But, systematics bears broader sense than taxonomy and is defined by many as the scientific study of organisms with the ultimate objective of characterizing and arranging them in an orderly fashion. Systematics therefore encompasses disciplines such as morphology, ecology, epidemiology, biochemistry, molecular biology, and physiology of organisms.

How the taxa are ordered into classiﬁcations deﬁnes the particular approach to taxonomic classiﬁcation. The rules for naming are outlined in various Codes of Nomenclature, and these codes are now being challenged in new ways by those who seek to redeﬁne taxonomy.

**Practices of Taxonomy**

* **Description**: assignment of features to an organism
* **Identification:** assignment of one single organism or specimen to an existing classification (taxa produced)
* **Classification:** ordering of organisms into groups on the basis of their r/ship.
* **Nomenclature**: naming of taxonomic groups or taxa according to some standardized system (i.e. allocation of name of the taxa produced)

. **Taxonomy and Systematics**

* **Taxonomy:** the science that deals with description, identification, classification & nomenclature of taxa.
* **Systematics:** taxonomy + study of evolutionary relatedness among various groups of organisms/phylogenetic analysis

The term systematics is derived from Latinized Greek word-systema-as applied to the systems of classification developed by early naturalists, notably Linnaeus.According to Simpson, Systematics is the scientific study of kinds and diversity of organisms and of any and all relationships among them. Systematics includes taxonomy, identification, classification and nomenclature and all other aspects of dealing with different kinds of organisms and data accumulated about them is also included in systematics.

In general, systematic includes an aspect of evolutionary relatedness among various groups of organisms (phylogenetic relationships). That is, it deals not only with identifying, describing, naming, and classifying organisms (taxa), but also with investigating the evolutionary relationship between them. Thus, according to this perspective, systematic includes both the traditional activities of taxonomy and investigations of evolutionary relationships, variations and speciation (formation of new species).

However, the two terms, taxonomy and systematic, are often used interchangeably in different textbooks and research papers. In this Course, taxonomy is dealt with as the sub-part of systematic.

## 1.2. The scope of taxonomy and that of systematics

1. It works out a vivid picture of the existing organic diversity of our earth and is the only science that does so.
2. It provides much of the information, making it possible for the reconstruction of the phylogeny of life.
3. It reveals various interesting evo­lutionary phenomena, making them avai­lable for casual study by other branches of biology.
4. Almost entirely, it supplies information needed by the various branches of biology.
5. It provides names for each kind of organism, so that all concerned can know what they are talking about and such infor­mation can be recorded, stored and retrieved when needed.
6. It differentiates the various kinds of organisms and points out their characteris­tics through descriptions, keys, illustrations etc.
7. It provides classification, which are of great heuristic and explanatory values in most branches of biology like evolutionary biochemistry, immunology, ecology, genetics, ethology, historical geology etc.
8. It is important in the study of eco­nomically or medically important organisms.
9. It makes important conceptual con­tributions in population thinking, thereby making it accessible to experimental bio­logists. It thus contributes significantly to the broadening of biology and to a better balance within biological science as a whole.

**Importance of Taxonomy**

* *Taxonomy* is an important science, and is basic to all biological disciplines since each requires the correct names and descriptions of the organisms being studied. It is also dependent on the information provided by other disciplines, such as genetics, physiology, ecology and anatomy.
* Classification systems serve four important roles:

1. They do aid to memory.
2. Classification systems greatly improve our predictive powers.
3. Improve our ability to explain relationships among organisms.
4. Provide relatively stable, unique, and unequivocal names for organisms/taxa.

**Objective of Taxonomy**

Dear students under this section you should underline and identify the major objective mainly why it is needed the science taxonomy, and its need of studying. Therefore you are provided here with three different objective that you to know.

1. Taxonomy aims at classifying organisms into taxa on the basis of similarities in phenotypic (phenetic) characteristics i.e. the characteristics which are expressed in an organism and can be examined visually or can be tested by other means. As each phenotypic characteristic is controlled by one or a group of genes, two individuals which possess similar phenotypic characteristic must have similar genes. Large number of similar phenotypic characteristic, therefore, reveals a genetic closeness between organisms. Genetic closeness is also often linked with phylogenetic relatedness, because organisms having many common genes among them must have originated from a common stock during evolution. For instance, if two organisms, A and B, are phylogenetically closer than to another organism, C, it means that A and B have branched off from a common stock in more recent times than C which branched off earlier. Obviously, A and B will have more common genes between them than they will have with C.
2. The second objective of taxonomy is to assign each taxon a name. This naming of a taxon is known as nomenclature. Assigning a name to an organism is necessary for identifying it without confusion throughout the scientific world. Therefore, nomenclature needs to be made following certain internationally accepted rules.
3. The third objective of taxonomy is to serve as an instrument for identification of bacteria. A newly isolated organism can be assorted to its nearest allies or can be identified as a new hitherto unknown taxon. This makes taxonomy a dynamic branch of biology, because discovery of new organisms constantly demands changes in the existing classification.Also, adoption of new techniques for classifying organisms often necessitates changes, sometimes thorough changes in the existing framework. For example, the developments in the molecular biological techniques, like DNA hybridization, have made a great impact on the taxonomy of bacteria taxonomy.

## 1.3. Levels of Taxonomy

**α (alpha), β (beta) and Ƴ (gamma) taxonomy:**

**Alpha (α) taxonomy:**

Alpha (α) taxonomy is the analytic phase in which the species are identified, characte­rised and named. At this level when a new species is discovered it is named in accor­dance with Linnaeus system of binomial nomenclature. Here priority is given to the one who publishes his work first. All prob­lems relating to species are dealt here.

**Beta (β) taxonomy**:

Beta (β) taxonomy refers to the arrange­ment of the species into a natural system of hierarchial categories. This is done on the basis of easily observable, shared, structural features and evaluation of numerous charac­ters. Thus, β-taxonomy relates to the search of a natural system of classification. Each taxon would thus possess diagnostic fea­tures unique to that taxon.

**Gamma (Ƴ) taxonomy:**

Gamma (Ƴ) taxonomy designates the analysis of intraspecific variations and evolutionary studies. Much attention is paid to a causal interpretation of organic diversity — study of speciation. But in actual practice it is rather difficult to dissociate them because these overlap and integrate. There are only a few groups of animals (some vertebrates, especially the birds and a few insect orders like Lepidoptera etc.) where the taxonomy has reached up to the gamma level. Otherwise, in almost majority of the groups, the Works are still at the alpha and beta level.

**Chapter one: Review questions.**

**Answer the following questions properly**

1. Explain Taxonomy, classification, identification, description and nomenclature.
2. Briefly differentiate taxonomy and systematics.
3. What is a need for taking course taxonomy as independent course for you?
4. Discus the major steps that you should follow if you have been given with new taxa?
5. What are the major objectives of taxonomy?
6. Suppose you are assigned to investigate some unknown taxa as a based on procedural principle of taxonomy,discus the steps in light of α (alpha), β (beta) and Ƴ (gamma) taxonomy.

# CHAPTER TWO

# 2. HISTORY AND DEVELOPMENT OF TAXONOMY

Self –test Exercise

* + Name some biologist who contributed for the development of taxonomy?
  + Discus the similarity and difference between Aristotelian and Carolus Linnaeus classification type?

The taxonomic classifications also portray our understanding of the evolution and relatedness of life, the phylogenetic classification. Humans have a natural tendency to classify things, biodiversity being no exception. Classification depends upon what we can observe and what we think it means (often inﬂuenced by social, political and religious attitudes).

Classifications of life have changed over time, but even ancient systems can show precise methodologies and criteria. Taxonomic classifications of life have varied throughout time. Changes reflect use of increasingly small scale, internal features (internal organs, internal cell organelles, internal organelle RNA), and use of genetic materials. As time period passes number of philosophers put their contributions in the development of taxonomy, and the gradual development in the field includes from external observational characteristics or morphologic feature to internal genetic materials. On the other hand classification and taxonomy of organisnms growth from simpler type of comparetional to most advanced way which includes gene level, by rebooting the genetic materials of the organisms.

* Taxonomy has passed different stages of developments similar to other sciences**.** Different scholar variously divided the developmental stages of taxonomy mainly based on some important occasions and events (such as well-known discoveries, publications, theories forwarded, etc) which contributed to the science of taxonomy.
* Generally, we can divide the phases of developmental stages of taxonomy into ***Pre-Linnaean taxonomy*, *Taxonomy during the Linnaean Era & Post-Linnaean taxonomy.***

The following are some of the pioneers in the development of the science of taxonomy.

## 2.1. Phases of Developmental Stages of Taxonomy

1. **Pre-Linnaean Taxonomy**
2. **Ancient taxonomy**

* Ancient people have grouped or categorized living things into groups & gave common or vernacular names. e.g. Identifying edible plants & animals and non-edible ones, useful and harmful organisms, and aggressive and non-aggressive wild animals in their environment, and giving names are as old as human races.
* This system is called **folk taxonomy**.
* It is important for communication of the people.
* In such system of classification, organisms that were obvious (common) or more important (useful or harmful) to the people got names while the others might not.
* The system is characterized by **existence & non-existence o**f vernacular names for organisms/groups of them.
* Folk taxonomy is characterized by **existent & no-existent** of common names.
* One can say that taxonomy is as old as the language skill of mankind

1. ***Taxonomy during the Greek and Roman Philosophers*-***Essentialists*

**Aristotle (384–322 BC)**

**Greek Aristotle**, in Historia Animalia(486 BC), classified animals by clearly stated criteria for grouping animals together: (1) ‘With regard to animals there are those which have all their parts identical . . . speciﬁcally identical in form’; (2) ‘When other parts are the same but differ from one another by more or less, then they belong to animals of the same genos. By genos mean for example bird or fish. (3) ‘There also exist animals whose parts are neither the same by form but by analogy’.Organisms were grouped into land dwellers, water dwellers, and air dwellers.Plants were placed into three categories based on the differences in their stems.As new organisms were discovered, his system became inadequate.

* + Categories were not specific enough.
  + Common names did not describe a species accurately.
  + Names were long and hard to remember.

**Theophrastus** (372-287 BC), the Greek philosopher-scientist, placed this knowledge of plants on a scientific footing. In his “Enquiry into Plants” he dealt with the plants at large and attempted to arrange the plants in several groups.**”. He** classified of all known plants during the time, **De Historia Plantarum**, which contained 480 species. His plant classification was based on **growth form**: tree, shrub or herb Many of his plant genera like *Narcissus, Crocus & Cornus* still in use. He is, therefore, called the **“Father of Botany.**

**Plinius (23–79 AD)**

Pliny compiled a monu­mental work entitled “Historia Naturalis” where he incorporated all information about plants gathered up to that time and added much to the same collected by himself from his travels far and wide.

**Dioscorides (40–90 AD)- Greek physician**

Disocorides was a contemporary of Pliny and like him travelled a lot and gathered information about medicinal plants.

He compiled his famous book “Materia Medica” ≈ 600 plant species. where he described about six hundred species of plants mentioning their local name and classified based on their medicinal properties. Along with descriptions he gave sketches which increased the value of the book very much and gained much popu­larity among the herbalists and plant-lovers in Europe.

1. **Middle Age /Medieval Period** *(5th to 15th C)*

During this period there was a little or no progress in botanical & zoological investigation. Mostly copying & recopying of earlier manuscripts + errors. For a long period there was no contribution in the study of plants worth mentioning till Albert Magnus in the 13th century wrote his “De Vegetabilis” where the difference in the stem structure of dicotyledons and monocotyledons was shown and the two groups were given the terms Tunicate and Corticate.

As in Europe, the study of plants was started by the herbalists in other countries boasting of an ancient civilization. In India the medical men described many plants of medicinal value and classified them in various ways. **Atharva Veda** and **Susruta Samhita** were written before the Christian era.

In his treatise on agriculture **Parasara** in 6th century classified the plants into many “ganas” or families giving clear picture of the morphology of flowers and fruits. Some of his “ganas” correspond to some families of modern taxonomists.

**Sarangadhara** in 12th century in his “Upaban Vinoda”, a book devoted to agriculture and horticulture, dealt with different aspects of plant life and classification of plants.

1. **Herbalists’ time (16 C):** *publications of several books on medicinal uses of plants.*

After the Middle Age, taxonomy was influenced by two occasions:

* **Innovation of printing machine & development of science of navigation.**
* 15th century was the onset of renaissance in Europe.

1. **Innovation of printing machine:**

Printed books on plants were available towards the close of the 15th century and a few German herba­lists carried their enquiries about plants still farther making the study of Botany quite popular.

* eased printing efforts
* Promoted the publication of many medicinal oriented books, particularly in the next century.
* lowered prices of books
* Medicinal oriented book are said to be Herbals & the authors of such books are **Herbalists.**
* 16th century is called the time of great herbalists.

e. g. Otto Brunfels, Jerome Bock & Leonart Fuchs whom named the German fathers of botany

* Herbals exhibit excellent illustrations + detailed descriptions of plants.
* However, didn’t emphasize on any system of classification
* Plants simply arranged in alphabetical/medicinal uses in herbals.

**Otto Brunfels** (1530-1536) who published his book “Herbarium vivae Eiconis” in three volumes which was profusely illus­trated with good figures.

**Jerome Bock** (1498-1554), another German herbalist, pub­lished his “Nue Kreuterbuch” which contained accurate descriptions of about 600 species of flowering plants.In this book the author tried to trace the natural relation­ship of plants while classifying them into 3 major groups, viz., herbs, shrubs, and trees and also noted the original distribution of each species.

**Leonard Fuchs** (1501-1566), Valerius Cordus (1515-1544), Mattias de L’Obel (1538-1616), John Gerard (1545- 1612), and Charles L’Ecluse (1526-1909) were others who also advanced the cause of botanical science by their observations and contributions. Then the Bauhin brothers came to the field.The elder brother Jean (Johna) Bauhin (1541-1631) wrote a book entitled “Historia plantarum universalis” which was pub­lished after his death. Gaspard (Casper) Bauhin, the younger brother (1560-1624), published 3 botanical treatises the third one of which, viz., “Pinax theatri Botanic” became very popular. Both the Bauhins made use of the habit-character of plants in classifying them.

1. **Innovation of Navigation**

* Enabled sailors/investigators to go on long voyages.
* Exploration of several new areas of the world by crossing large water bodies and collection of new plants and animals.
* Increased man’s practical knowledge taxonomy.

1. ***Early taxonomists-*** *study of living things for basic knowledge*

Until end of 16th C, existing studies couldn’t replace the ideas of ancient Greek philosophers. Discovery of optic lenses & growth of science in 17th C. Emphasis was turned from medical aspects to taxonomic aspects; this means, scientists started to study living things for intrinsic purposes instead of only for food and medicinal uses.

**Andrea Caesalpino** (1519-1603) In - Italy

He classified the plants on the character of their habit, viz., trees, shrubs, and herbs but also took into account the characters of ovary, fruit, and seed. He wrote the book De Plantis (1583,) which contained 1500 spp,.the first of which contained his principles of classification. Some of the names given by him are still in use. e.g The names for plant families, Brassicaceae and Asteraceae, have been given by Caesalpino.

**Gaspard Bauhin**

He travelled extensively to collect plant specimens and formed a herbarium of 4000 specimens. He Published Pinax Theatri Botanici (1623) which contained a list of 6000 plants spp.He also introduced binomial nomenclature (writing species name in two words) for several species. He sought to clarify in a single publication the confusion regarding the multiplicity of names for all species known at that time. Although he did not describe genera, he recognized the differences between species and genera, and several species were included under the same generic names.

**Jean Bauhin** (1541-1613)-elder brother of C. Bauhin

Compiled a description of 5000 plant spp. with more >3500 figures. The work of J. Bauhin was published under the name Historia Plantarum Universalis in 1650-1651, several years after his death.It is tragic that the two brothers never collaborated and rather worked on identical lines independently.

**John Ray**, an English naturalist (1628-1705), set himself seriously to the study of plants and gave much thought in proposing a system of classification of plants. He wrote Methodus Plantarum Nova (1682)≈18 000 plant species He was the first to recognize 2 major taxa of flowering plants, viz., Dicotyledons and Monocoty­ledons. He also tried to group the plants into several families which he called “classes”.

He divided the plant kingdom first into 2 groups, viz., Herbae and Arbores. The Herbae were then divided into Imperfectae and Perfectae, the first of which included the Cryptogams and the second group, i.e., the Arbores included most of the flowering plants.The Perfectae were subdivided into Dicotyledonae and Monocotyledonae and under Dicotyledonae he placed 25 of his classes and 4 under Monocotyledonae. His system of classification came out in his “Historia plantarum” of which several editions were published and he revised and improved his system in the later editions. Ray aimed at publishing a complete system of nature, which included works on mammals, reptiles, birds, fishes and insects.

**Joseph Pitton de Tournefort (1656–1708)- Franch**  was a contemporary of John Ray and tried to work out a system of classification of flowering plants. He too divided the plant kingdom first into 2 groups as trees and herbs and used the character of inflorescence and flower for subdividing the latter group.

He was the first to give a clear concept of a genus although Gaspard Bauhin mentioned it in his works. Tournefort’s work proved very helpful in identifying the plants up to the species.

**B) Linnaean Era (1707-1778) -***Sexual sysytem*

**Carolus Linnaeus (1707-1778)**, a Swedish naturalist (also called Carl von Linne), who gave a new impetus to the study of plants. He was professor of medicine and botany in the Upsala University. He himself was an arduous collector of plants and made arrangement of collecting plant-specimens from different parts of the world by sending his students to countries far away and through missionary men and administrators.

The discovery of numerous plants from all over the world led him to think about bringing an order into the existing chaos and set himself in grouping and classifying all the plants known till his time. He proposed a system of classification which was published in his “Systema Naturae” (1735).

In this system he used the character of stamens, i.e., the number and nature of stamens, to distinguish the 20 classes in which he divided the plant kingdom. He also used the number and nature of carpels to distinguish the orders, i.e., subdivisions of his classes.In addition to presenting an excellent system of classification of plants **Linnaeus** published many botanical works of monographic and floristic nature and also books embodying his ideas of nomenclature of plants.

He developed a Hierarchy (a ranking system) for classifying organisms that is the basis for modern taxonomy.For this reason, he is considered to be “father” of modern taxonomy.Life forms must be distinguished by external criteria, e.g. skin, locomotion. Each life form should have roughly equal roles in the economy of nature. Within each life form criteria used for subgroups should be essential for ﬁnding or processing food, e.g. teeth for mammals, beak for birds. Linnaeus’ work resulted in classifications of plants based primarily on reproduction mechanisms and of animals based on feeding.Linnaeus used an organisms morphology (form and structure), to categorize it.

The “Species plantarum” the first edition of which came out in 1753 contained an enumeration of all plants known to him till that date, accompanied by brief description of each species with distribution and previous reference. In this work he consistently used binary nomenclature for every species with a generic name followed by a specific epithet.

The modern taxonomists have agreed to consider the year 1753 as the starting point of nomenclature of Phanerogams, Pteridophyta, and Sphagnum. In his “Philosophia Botanica” he laid down some principles which later formed the basis of the International Code of Botanical Nomenclature.

Owing to the efforts of Linnaeus the study of Botanical science entered the modern age and Linnaeus is rightly called the **“Father of Modern Botany”.**

* + His system is still being used today.
  + His system allowed organisms to be grouped with similar organisms.
  + He first divided all organisms into two Kingdoms, Plantae (Plants) and Animalia (animals).
  + This was the same as Aristotle’s main categories.

**C. Post-Linnaean Taxonomy**

**(ii) Second period:**

**Foundation Natural System of Classification**

* Different taxonomists criticized classification of Linnaeus= for being artificial, particularly French scientists.

1. **Georges de Buffon (1707–1788)** - strong critic to Linnaeus work

* Considered classification by Linnaeus as artificial order on the disorderly world.
* Buffon’s aim was to describe the world rather than to classify it.
* His theories touched with the development of species, infraspecific variety & acquired inherited characters in species
* **Opened pathway for an evolutionary theory.**

1. **Michel Adanson (1727–1806)**

* Familles des Plantes already in 1763.
* launched the idea that in classification one should :
* Use as many characters as possible
* Characters should be given equal weight/no priority and
* Classification depends on overall similarity
* Such classification is said to be called **Natural classification.**

1. **Antoine L. de Jussieu (1748–1836)**

* Estabilished family rank b/n genus andclass
* Acotyledons, Monocotyledons and Dicotyledons

1. **B.P. de Lamarck (1744–1829)**

* Theory of inheritance of acquired characters ="Lamarckism".
* Opened path for evolution theory (Charles Darwin & Wallace, 1858)

**e. Cuvier** (1768-1832). Through the late eighteenth and early nineteenth centuries Cuvier pioneered comparative anatomy, especially the internal resemblance of animals, as a means of classiﬁcation. Cuvier saw some characteristics as fundamentally more deﬁnitive than others, notably the nervous systems, though practicalities favored use of bones. Cuvier broke the vision of animal life as a ladder of progression, splitting animals into four lineages – vertebrates, molluscs, articulates (e.g. insects) and radiates – based on form and function. This split is still echoed in current classiﬁcation of animal lineages.

**ii. Formation of nomenclatural code (ICBN & ICZN)**

* First attempt to create botanical nomenclatural code = by de Candole in 1813.
* Published names should have priority starting Linnaeus
* On a congress in Paris, 100 botanists adopted the rules in a book by the son of Alphons de Candolle (1806–1873), **Lois de Nomenclature Adoptee** from 1867.
* On congress in Vienna (1905) starting date was set to 1753 (Species Plantrum)
* In 1907, Americans created their own code
* In 1935, both codes merged together by agreement & formed ICBN.
* Initiation of a zoological code started somewhat later. In 1842 a British ornithologist Hugh E. Strickland (1811–1853) elaborated the first nomenclatural laws for zoology, the "Strickland Code".
* He was assisted by a committee where Charles Darwin was a member, among others. The Strickland Code (which was first published in 1842) was accepted among British & American zoologists within three years.
* The code was accepted as International Code of Zoological Nomenclature firstly on an International Congress in Moscow in 1892. In 1905, a further modified international code was published in French, English and German languages.

**iii. Natural system developed to Numerical Taxonomy/ Phenetics- phenogram**

* Michel Adanson was published Familles des in 1763 and forwarded the idea that classification should depend on many characters with equal weight=overall similarity.
* With the development of computer softwares **(1960s)/cluster analysis by computer** software → numerical taxonomy/ phenetics became popular
* Principles of Numerical Taxonomy by Senath & Sokal (1963 & 1973) & it is the new method of organizing data of natural system & obtaining a classification.

1. **Phylogenetics/cladistics**

In this period the evo­lutionary classification was introduced by Charles Robert Darwin (1809-82) and varia­tion among the organisms is the main force in evolution which was discussed extensively. Darwin published his famous book “On the Origin of Species by Means of Natural Selection” in 1859. In his book the theory of evolution by natural selection was his own creation al­though based on the work of Lamarck, Cuvier (1768-1832) and Erasmus Darwin (1731-1802), the grandfather of Charles Darwin. This theory helped a lot to the systematic zoology. E. Darwin’s book Zoonomia (1794) presented the laws of organic life. He suggested the struggle for existence in Zoonomia which was elaborated by Charles Darwin.

**Ernst Haeckel** (1834–1919) and **August W. Eichler** (1839–18878) were two German biologists who started the construction of evolutionary trees. Haeckel established the term "phylogeny". However, the main part of the 20th century was dominated by extended phenetics (i.e., looking for overall similarities and differences to create classification). The German biologist Willi Hennig (1913–1976) founded the cladistic era in 1966, by stating that only similarities in derived characters (synapomorphies) should be used in classification of species, and that taxa should include all descendants from one single ancestor (the rule of monophyly).

**(iii) Third period:**

This period includes the development of modern taxonomy which started about 1930. The study of genetics and population biology was started with typical taxonomy.

This period is remarkable with the publication of New Systematics by J. S. Huxley in 1940, intraspecific variations were studied and the science of population genet­ics was started in 1908 by G. H. Hardy and W. Weinberg who independently discovered a principle concerned with the frequency of genes (allels) in a population in the light of evolutionary theory.

**Chapter two: Review questions**

**Answer the following questions properly**

1. What is folk taxonomy mean?
2. Compare taxonomic criteria used by taxonomist at beginning phase of with late approaches of taxonomy.
3. Discus strength and weakness of both Aristotelian and Evolutionary taxonomy.
4. Why Greek philosopher-scientist Theophrastus was considered to father of botany?
5. Explain Carolus Linnaeus was considered as “father” of modern taxonomy?
6. What were the two books written by Linnaeus?
7. What to mean monumental work in early taxonomy?
8. Tabulate names of books published by early taxonomist and put number of taxa identified and criteria used for each.
9. Who was named some plant families such as Brassicaceae and Asteraceae.
10. Who was the first to recognize 2 major taxa of flowering plants, viz., Dicotyledons and Monocotyledons?
11. Compare numeric and cladistics model of taxonomy.

# CHAPTER THREE

# 3. CLASSIFICATION SYSTEMS

**Unit Objectives**

**At the end of this unit the students will be able:-**

* Define classification
* Explain the need for classification
* Identify the main classification systems.
* Compare and contrast different classification systems in respect with strength and drawback.
* Appreciate the works of early taxonomist who involved in the grouping of vast array ofliving things.
* **Classification** is the arrangement of entities (in this case, taxa) into some type of order.Classification is concerned with identifying and defining groups or taxa sets of organisms possessing at least one characteristic in common and giving them names. A classification of the living world must be hierarchical, because the smaller groups are completely included in larger groups that do not overlap.
* Initially, in the renaissance, taxonomy was based on the notion of a descending classification system (the division of large classes into subclasses, as in the classification of inanimate objects). Later, taxonomy shifted to an ascending classification system whereby related taxa are grouped into taxa of a higher order.

A series of words used to name and arrange organisms according to some principle of relationship thought to exist among the organisms.The purpose of classification isto provide a system for cataloguing and expressing relationships between these entities.

Activity:

* What are different classification types? And what are strength and drawbacks of each classification ytpe?
* What are the criterias thatwere used by each classification types?
* Dfferentiate is the relationship beteween classification and Phylogeny?
* Explain phylocode?
* What is hypothesis behind phylogenetic tree?

## 3.1. Systems of Classification:

There are three different systems of classifications which have been proposed so far by different taxonomists.

**They are:** (i) Artificial

(ii) Natural

(iii) Phylogenetic

#### 1. Artificial System of Classification:

This type of classification is based upon characters of convenience without relation to phylogenetic significance; classification based upon characters erroneously presented to indicate phylogenetic relationship; also classification based on a single arbitrarily chosen criterion, instead of an evolution of the totality of characters known as artificial classification.This system of classification was adopted by Pliny in the first century A.D. for animals on the basis of habitats, e.g., land, air and water.

**Accordingly animals were classified into two categories on the basis of their flying ability:**

(i) Animals that can fly and

(ii) Animals that cannot fly.

In the first group unrelated animals like butterflies, birds and bats were placed together.

**The classification of plants on the basis of habit into:**

(i) Herbs,

(ii) Under shrubs,

(iii) Shrubs and

(iv) Trees is also an artificial one.

The criteria used in this classification, although very simple and easy to follow are arbitrary and do not reflect any natural relationship existing among the organisms. Moreover, it leads to heterogeneous assemblage of unrelated organisms under one heading and does not do justice to the totality of characteristics of an organism. The system adopted by Linnaeus was also artificial in which the plants were classified on the basis of number and arrangement of stamens and carpels. Closely related species of organisms are kept far apart in this system of classification.In the classification system proposed by Linnaeus, each level of the hierarchy corresponds to the name of a taxon. Naturalists around the world use the same system of general nomenclature the binominal system to designate and identify the species. This system consists of a genus name followed by a species name. The superior categories (genus, family, order, division, class, phylum, etc.) indicate the degrees of relationship between taxa Most formal taxonomic classifications are usually Linnean classifications formulated according to rules embodied in codes of nomenclature that have been adopted by international agreement.

**Strength and Weakness**

**Strength**: easy to use and classify organisms.

**Weakness:**

* Classify unrelated organisms together & separate more reacted ones
* Only superficial features don’t reflect natural relationships.
* Does not reflect the evolutionary r/ship

#### 2. Natural System of Classification and phenetics

The natural classification may be defined as **“classification based on characters which indicate natural relationships”.** The organisms of a natural systematic category agree with one another in so many characters because they are descendants of one common ancestor. The natural system of classification is based on similarity. Zoologists and botanists differ in their interpretation of the implication of this system of classification. According to zoologists, the natural system of classification includes the phylogenetic and evolutionary trends which are evident in the word **“natural”.** Botanists hold the opinion that the natural system does not necessarily include phylogenetic trends of plants. Here they proposed the **“phylogenetic system”** of classification separate from the **“natural system”** to include the evolutionary trends in plants. The **“natural system”** of classification of the plant kingdom was proposed by George Bentham (1800-1844) and Joseph Dalton Hooker (1817-1911).

In natural classification:

* Great numbers of characters with equal weight are used.
* Organisms classified based on overall similarity
* Highly predictive & organisms are classified objectively.
* Objective: one can predict natural group, regardless of whether or not & by whom they are classified

#### Numerical Taxonomy (phonetics)

Numerical taxonomy or taximetrics, nowadays frequently and perhaps more appropriately referred to as phenetics, refers to the application of various mathematical procedures to numerically encoded character state data for organisms under study. Thus, it is the analysis of various types of taxonomic data by mathematical or computerized methods and numerical evaluation of the similarities or affinities between taxonomic units, which are then arranged into taxa on the basis of their affinities. According to Heywood the numerical taxonomy may be defined as the numerical evaluation of the similarity between groups of organisms and the ordering of these groups into higher ranking taxa on the basis of these similarities. The period from 1957 to 1961 saw the development of first methods and of theory of numerical taxonomy. Plants as we all know are classified based on their characters. It was Michel Adanson, a French botanist, who for the first time put forward a plan for assigning numerical values to the similarity between organisms and proposed that equal weightage should be given to all the characters while classifying plants.He used as many characters as possible for the classification, and such classifications came to be known as Adansonian classifications. Numerical taxonomy was however largely developed and popularized by Sneath and Sokal. nThe application of Adansonian principles and use of modern methods and electronic data-processing techniques, have helped in the evolution of several new classifications of plants during the past few decades.

It evaluates resemblances and differences or primitiveness and advancement through statistical methods based on a large number of characters obtained from all disciplines of biology. This is followed by assigning them number and codes of computer like plus (+), minus (-), θ (data not available), followed by computer analysis. It establishes the numerical degree of relationship among individuals. The relationship or affin­ity values are then used to erect taxonomic categories. However, its effectiveness depends upon the judgment of the biosystematics in selecting characters and current knowledge about them.

#### Principles of ****Numerical Taxonomy****

**Numerical taxonomy involves two aspects:**

**(a) Construction of Taxonomic Groups:**

i. In numerical taxonomy, first, individuals are selected and their characters spotted out. There is no limitation to the number of characters to be considered. However, the larger the number of characters, better is the approach for generalization of the taxa.

ii. The resemblances among the individuals are then established on the basis of character analysis, which can often be worked out with the help of computers, the accuracy of which depends on the appropriateness in character. The best way to delimitate taxa is, to utilize maximum number of characters, with similar weightage given to all of them.

**(b) Discrimination of the Taxonomic Groups**

Taxonomic groups chosen for the study show overlapping of characters, discrimination should be used to select them. Discrimination analysis can be done by various techniques, specially devised for such purposes. Numerical taxonomy is thus, based on certain principles, also called neo Adansonian principles.

**Following seven principles of numerical taxonomy have been enumerated by Sneath and Sokal:**

1. The greater the content of information in the taxa, and more the characters taken into consideration, the better a given classification system will be.
2. Every character should be given equal weightage in creating new taxa.
3. The overall similarity between any two entities is a function of the individual similarities in each of the many characters, which are considered for comparison.
4. Correlations of characters differ in the groups of organisms under study. Thus distinct taxa can be recognized.
5. Phylogenetic conclusions can be drawn from the taxonomic structure of a group and from character correlations, assuming some evolutionary mechanisms and pathways.
6. The science of taxonomy is viewed and practiced as an empirical science.
7. Phenetic similarity is the base of classifications.

# Merits and Demerits of numeric taxonomy

#### Merits of ****Numerical Taxonomy****

According to Sokal and Sneath, numerical taxonomy has the following advantages over conventional taxonomy:

1. The data of conventional taxonomy is improved by numerical taxonomy as it utilizes better and more number of described characters. The data are collected from a variety of sources, such as morphology, chemistry, physiology, etc.
2. As numerical methods are more sensitive in delimiting taxa, the data obtained can be efficiently used in the construction of better keys and classification systems, creation of maps, descriptions, catalogues, etc. with the help of electronic data processing systems. Numerical taxonomy has in fact suggested several fundamental changes in the conventional classification systems.
3. The number of existing biological concepts has been reinterpreted in the light of numerical taxonomy.
4. Numerical taxonomy allows more taxonomic work to be done by less highly skilled workers.

#### Demerits of ****Numerical Taxonomy****

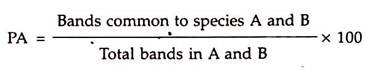
**Numerical taxonomy can however prove to be disadvantageous from the following points of view:**

1. The numerical methods are useful in phenetic classifications and not phylogenetic classifications.
2. The proponents of “**biological**” species concept may not accept the specific limits bound by these methods.
3. Character selection is the greatest disadvantage in this approach. If characters chosen for comparison are inadequate, the statistical methods may give less satisfactory solution.
4. According to Steam, different taxonometric procedures may yield different results. A major difficulty is to choose a procedure for the purpose and the number of characters needed in order to obtain satisfactory results by these mechanical aids. It is necessary to ascertain whether a large number of characters would really give satisfactory results than those using a smaller number.

#### Applications of ****Numerical Taxonomy****

**Numerical taxonomy has been successfully applied in the following studies:**

1. Study of similarities and differences in bacteria, other micro-organisms and several animal groups.
2. Delimitation of several angiospermic genera like Oryza, Sarcostemma Solarium, and other groups including Farinosae of Engler and a few others.
3. In the study of several other angiospermic genera including Apocynum, Chenopodium, Crotalaria, Cucurbita, Oenothera, Salix, Zinnia, wheat cultivars, Maize cultivars, etc.
4. Phytochemical data from seed protein and mitochondrial DNA RELP studies has been numerically analyzed by Mondal et al. to study the interspecific variations among eight species of cassia L .Based on the results of electrophoretic patterns, the degree of pairing affinity (PA) or similarity index was calculated by the following formula, according to the method of Sokal & sneth and Romero Lopes et al.:



Separate dendograms expressing the average linkage were computed using the cluster method UPGMA, which showed that the eight species could be placed into two categories or clusters (Fig. 1.1) with *C. alata*, *C siamea*, *C. fistula* and *C. reginera*, all being trees or large shrubs and characterized by the absence of foliar glands on petiole or rachis and presence of dense axillary terminal racemes greater than 30 cm long, being clustered into one group, whereas the other four species, i.e., *C. occidentalis*, *C. sophera*, *C. mimosoides* and *C. tora*, forming the other cluster, all being herbs or undershrub’s and characterized by the presence of short corymbose racemes less than 10 cm long and with foliar glands, either on petiole or rachis.

**Operational Taxonomic Units (OTU) & Characters**

* Selection of OTUs and characters
* It is an operational definition used to classify groups of closely related individuals.
* OTUs are the objects of taxonomy (eg. populations, species, genera, etc.)
* Similarity/ dissimilarity of OTUs is determined by using various statistical formulae (eg. Simple similarity coefficient = Ssm).
* Character state (attributes): alternate state of a character = feature varies from one organism to another

e.g. Character Character states/ attributes

* Hair colors of a Cow → Black and red hair colors
* No of leaves per node → Two, three and four leaves
* Important to select a unit character
* **Unit character**: a taxonomic character of two or more state; but not subdivided at character level

**3. Coding of characters**

* Most suitable if two-state characters are used.
* Can be coded as presence / absence of a character state: eg. Woody or herbaceous for plant habit, red or black for hair color, etc.
* may not be in two-states; may be qualitative multistate

(e.g. Petal may be white, red, blue, etc.) Or quantitative multistate (leaves 1, 2, 3 or 4 per node).

* Multistate characters can be converted into two-state (e.g. flower white vs colored; leaves 4 vs leaves < 4).
* two-state (binary characters) are best coded as **0 or 1** for two alternate states
* matrix with t number of rows (OTUs) and n number of columns (characters) = with the dimension of the matrix (and the number of attributes) being t x n
* If character state is not available or irrelevant=NC (not comparable)= by passes during comparison

**Measuring Resemblance**

* To calculate similarity or dissimilarity:
* 1(presence of a character) & 0 (absence of a character); possible combinations are:

**A. Match (m) refers to:**

* Presence (1) x Presence (1) = a,

|  |  |  |  |
| --- | --- | --- | --- |
| OTU k → | | | |
| OTU j↓ |  | 1 | 0 |
| 1 | a | b |
| 0 | c | d |

* Absence (0) x Absence (0) = d;

**B. Mismatches (u) refer to:**

* Presence of (1) x Absence (0) = b, and
* Absence (0) x Presence (1) = c

Therefore:

* Match (m) = a + d
* Mismatch (u) = b +c; sample size n = a +b +c + d = number of combinations.
* **k and j are two OTUs under comparison**
* In phenetic analysis, about 100 or more characters should be used. But in the Table below, only 8 characters are used, as an example, to classify (compare) 14 OTUs (in this case 14 plant taxa). This table shows how to code character states.
* **Table below**: A Portion of the data matrix with hypothetical “t” (14) OTUs and “n” (8) characters to show character coding. Simple matching coefficient (Ssm) is represented as:

Ssm = Matches

Matches + Mismatches or

Ssm = m x 100

m +u

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Characters**  **(n) →**  **OTUs (t)↓** | **Habit:**  **0-Wood, 1-herbaceous** | **Fruit:**  **0-fillicle, 1-achene** | **Ovary:**  **0-superior, 1-inferior** | **Leaves:**  **0-simple, 1-compound** | **Habitat:**  **0-terrestrial, 1-aquatic** | **Pollen:**  **1-triporate,0-monosulcate** | **Ovule:**  **1-unitegmic, 0-bitegmic** | **Carpel:**  **0-free,1-united** |
| 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 |
| 2 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 |
| 3 | 0 | NC | 0 | 1 | 0 | 0 | 1 | 1 |
| 4 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 |
| 5 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 0 |
| 6 | 1 | 1 | 0 | 1 | 1 | NC | 0 | 1 |
| 7 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 |
| 8 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 |
| 9 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 |
| 10 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 |
| 11 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 0 |
| 12 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 |
| 13 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 |
| 14 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 |

* For example, from the table above:

Table below: Similarity matrix of the representative hypothetical taxa above.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| OTUs | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 1 | 100 |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 2 | 63 | 100 |  |  |  |  |  |  |  |  |  |  |  |  |
| 3 | 57 | 14 | 100 |  |  |  |  |  |  |  |  |  |  |  |
| 4 | 25 | 63 | 14 | 100 |  |  |  |  |  |  |  |  |  |  |
| 5 | 88 | 63 | 43 | 25 | 100 |  |  |  |  |  |  |  |  |  |
| 6 | 43 | 57 | 50 | 57 | 29 | 100 |  |  |  |  |  |  |  |  |
| 7 | 25 | 63 | 14 | 75 | 38 | 43 | 100 |  |  |  |  |  |  |  |
| 8 | 50 | 25 | 100 | 14 | 50 | 43 | 13 | 100 |  |  |  |  |  |  |
| 9 | 63 | 50 | 29 | 50 | 63 | 29 | 63 | 25 | 100 |  |  |  |  |  |
| 10 | 50 | 63 | 57 | 25 | 63 | 43 | 50 | 63 | 25 | 100 |  |  |  |  |
| 11 | 75 | 86 | 29 | 50 | 86 | 43 | 50 | 38 | 50 | 50 | 100 |  |  |  |
| 12 | 25 | 63 | 14 | 63 | 38 | 71 | 86 | 13 | 63 | 75 | 50 | 100 |  |  |
| 13 | 38 | 50 | 43 | 50 | 38 | 14 | 63 | 38 | 50 | 50 | 38 | 38 | 100 |  |
| 14 | 50 | 63 | 29 | 75 | 50 | 29 | 50 | 38 | 63 | 50 | 50 | 50 | 88 | 100 |

* Ssm for OTUs 1 and 2 = m x 100 = 5/8 x 100= 63%

m+u

* Ssm for 1 and 3 = 4/7x100= 57 (NC = not comparable).
* Ssm for 1 and 4 = 2/8 x100 = 25%
* Ssm for 1 and 5 = 7/8x100 = 88%
* Ssm for 1 and 6 = 3/7x100 = 43%, etc
* **Notice**: Dissimilarity coefficient (percentage) can be found by subtracting Ssm from 100.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| OTUs | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 1 | 0 |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 2 | 37 | 0 |  |  |  |  |  |  |  |  |  |  |  |  |
| 3 | 43 | 86 | 0 |  |  |  |  |  |  |  |  |  |  |  |
| 4 | 75 | 37 | 86 | 0 |  |  |  |  |  |  |  |  |  |  |
| 5 | 12 | 37 | 57 | 75 | 0 |  |  |  |  |  |  |  |  |  |
| 6 | 57 | 43 | 50 | 43 | 71 | 0 |  |  |  |  |  |  |  |  |
| 7 | 75 | 37 | 86 | 25 | 62 | 57 | 0 |  |  |  |  |  |  |  |
| 8 | 50 | 75 | 0 | 86 | 50 | 57 | 87 | 0 |  |  |  |  |  |  |
| 9 | 37 | 50 | 71 | 50 | 37 | 71 | 37 | 75 | 0 |  |  |  |  |  |
| 10 | 50 | 37 | 43 | 75 | 37 | 57 | 50 | 37 | 75 | 0 |  |  |  |  |
| 11 | 25 | 14 | 71 | 50 | 86 | 57 | 50 | 62 | 50 | 50 | 0 |  |  |  |
| 12 | 75 | 37 | 86 | 27 | 62 | 29 | 14 | 87 | 37 | 25 | 50 | 0 |  |  |
| 13 | 62 | 50 | 57 | 50 | 62 | 86 | 37 | 62 | 50 | 50 | 62 | 62 | 0 |  |
| 14 | 50 | 37 | 71 | 25 | 50 | 71 | 50 | 62 | 37 | 50 | 50 | 50 | 14 | 0 |

Table: Dissimilarity matrix of the representative hypothetical taxa above.

* The effective number of similarity/dissimilarity value (for t number of OTUs) = t**(t-1)/2.**
* If 14 OTUs are compared, the number of values calculated would be **= 14 x (14-1)/2 = 91**

**Cluster Analysis and Phenograms**

In this part, you will practice common numerical taxonomic method (cluster analysis) by using selected hypothetical organisms called Caminalcules (Figure below). In so doing, you will come to understand the important assumptions of this methodological approach, its strengths and its weaknesses.



* In the first step, let the paired similarities (simple matching coefficients) between all pair-wise combinations of the eight OTUs, using a scale of 1.0 (maximum similarity) to 0 (complete dissimilarity) are given. These similarity rankings are then cast into a similarity matrix. An example of such a matrix (for the eight OTUs in Figure above) is shown in Table-a below.

a) The given paired similarity matrix.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| OTUs | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1 | 1 |  |  |  |  |  |  |  |
| 2 | 0.2 | 1 |  |  |  |  |  |  |
| 3 | 0.2 | 0.1 | 1 |  |  |  |  |  |
| 4 | 0.7 | 0.3 | 0.4 | 1 |  |  |  |  |
| 5 | 0.5 | 0.2 | 0.8 | 0.3 | 1 |  |  |  |
| 6 | 0.8 | 0.2 | 0.4 | 0.7 | 0.4 | 1 |  |  |
| 7 | 0.1 | **0.9\*** | 0.2 | 0.3 | 0.2 | 0.3 | 1 |  |
| 8 | 0.5 | 0.3 | 0.6 | 0.4 | 0.6 | 0.4 | 0.4 | 1 |

* ***N.B:*** The rankings have been subjectively assigned, but can be calculated from given character states as we have already discussed.
* Our aim is to calculate over all similarities of all the 8 OTUs, using it as the base and draw a clustered graph/a branching diagram called a phenogram which shows the scaled similarity of all OTUs.
* ***Step 1:*** Find the pair of OTUs; having the highest similarity ranking.
* OTUs 2 & 7, Ssm = 0.9\* shown in bold with an asterisk\*) is the largest.
* ***Step 2*:** Combine OTUs 2 and 7, and treat them as a single composite unit from this point on.
* Construct a new matrix (this time it will be 7 x 7), as shown in Table-b.
* ***Step 3*:** Recalculate the similarity values for each OTU with the new composite 2/7 OTU.
* Compute average Ssm for each OTU with 2 &7. **For instance:**
* Ssm For 1 &2/7= Average of 1 with 2 & 1 & 1 with 7 =(0.2+0.2)/2 = 0.15
* Ssm for 4 &2/7= 0.3+0.3/2=0.3
* Ssm for 8 &2/7= 0.3+0.4/2 = 0.35; continue in this way until all OTUs will combine.

Table b: Reduced matrix with similarity values recomputed for all with composite OTU 2/7.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| OTUs | **2/7** | 1 | 3 | 4 | 5 | 6 | 8 |
| **2/7** | 1 |  |  |  |  |  |  |
| 1 | **0.15** | 1 |  |  |  |  |  |
| 3 | **0.15** | 0.2 | 1 |  |  |  |  |
| 4 | **0.3** | 0.7 | 0.4 | 1 |  |  |  |
| 5 | **0.2** | 0.5 | **0.8\*** | 0.3 | 1 |  |  |
| 6 | **0.25** | **0.8\*** | 0.4 | 0.7 | 0.4 | 1 |  |
| 8 | **0.35** | 0.5 | 0.6 | 0.4 | 0.6 | 0.4 | 1 |

***Step 4.*** In the new, reduced matrix with recomputed similarity values, find the next pair of OTUs with the highest similarity value. In this case, OTUs 1 & 6 and OTUs 3 & 5 have the highest similarity values (0.8). For simplicity, choose one pairing at random and recalculate the similarity indices, and then do the next pairing, as shown in Table c below.

Table c.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| OTUs | **1/6** | 2/7 | 3 | 4 | 5 | 8 |
| **1/6** | 100 |  |  |  |  |  |
| 2/7 | **0.18** | 100 |  |  |  |  |
| 3 | **0.3** | 0.15 | 100 |  |  |  |
| 4 | **0.7** | 0.3 | 0.4 | 100 |  |  |
| 5 | **0.45** | 0.2 | **0.8\*** | 0.3 | 100 |  |
| 8 | **0.45** | 0.35 | 0.6 | 0.4 | 0.6 | 100 |

***Step 5***: Continue to construct reduced matrices, each time recalculating the similarity indices between your new combined OTU with all remaining OTUs, as shown in Tables d-g below. The last step will result in a 2 x 2 matrix with a single, final similarity value. (In this example, composite OTU 4/1/6/8/3/5 has a 0.3 similarity with composite OTU 2/7).

Table d

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| OTUs | **3/5** | 1/6 | 2/7 | 4 | 8 |
| **3/5** | 100 |  |  |  |  |
| 1/6 | **0.38** | 100 |  |  |  |
| 2/7 | **0.35** | 0.18 | 100 |  |  |
| 4 | **0.35** | **0.7\*** | 0.3 | 100 |  |
| 8 | **0.6** | 0.45 | 0.35 | 0.4 | 100 |

Table e) Table f)

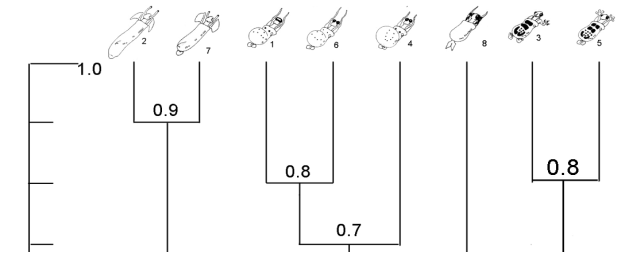
|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| OTUs | **4/1/6** | 3/5 | 2/7 | 8 |
| **4/1/6** | 100 |  |  |  |
| 3/5 | **0.37** | 100 |  |  |
| 2/7 | **0.24** | 0.35 | 100 |  |
| 8 | **0.43** | **0.6\*** | 0.35 | 100 |

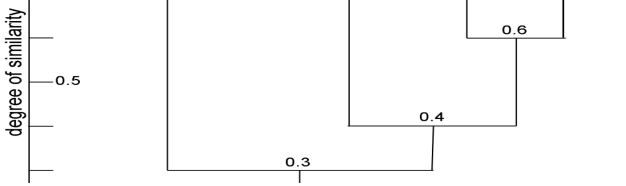
|  |  |  |  |
| --- | --- | --- | --- |
| OTUs | **8/3/5** | 4/1/6 | 2/7 |
| **8/3/5** | 100 |  |  |
| 4/1/6 | **0.4\*** | 100 |  |
| 2/7 | **0.35** | 0.24 | 100 |

Table g)

|  |  |  |
| --- | --- | --- |
| OTUs | **4/1/6/8/3/5** | 2/7 |
| **4/1/6/8/3/5** | 100 |  |
| 2/7 | **0.3\*** | 100 |

*N.B: i)* Your OTUs can now be clustered into a phenogram. The result of our sample cluster analysis is shown in Figure below. Note that the most similar OTUs from Table a (OTUs 2 and 7) have been paired at a branch point reflecting their similarity index (0.9). The next most similar OTU pairings (1/6 and 3/5) have been clustered at their respective levels (0.8) in the same fashion, and each successive reduced matrix yields the appropriate branch level, shown on the similarity scale at the left side of the diagram.





**Fig1:** Phenogram of the caminalcules clustered in the sample exercise

1. This phenogram is designed to not only indicate which of the Caminalcules are the most physically similar, but also to what degree they are phenotypically similar.

**Exercise1:** By using the hypothetical OTUs and characters in the following table, answer questions from i-iii. (OTUs represent four hypothetical taxa (e.g. species) for which their five characters are selected for this exercise. Presence of a character is represented by 1 while 0 represents the absence of a character).

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| OTUs  (Species) | Characters | | | | |
| 1 | 2 | 3 | 4 | 5 |
| A | 0 | 0 | 1 | 1 | 0 |
| B | 1 | 1 | 1 | 1 | 0 |
| C | 1 | 1 | 0 | 1 | 0 |
| D | 1 | 1 | 1 | 0 | 1 |

1. Calculate the simple similarity coefficient (Ssm) and construct a similarity table (a similarity matrix).
2. Which two different OTU’s are the most similar?
3. Which two different OTU’s are the most different?
4. Try to draw a phenogram for the given hypothetical OTUs.

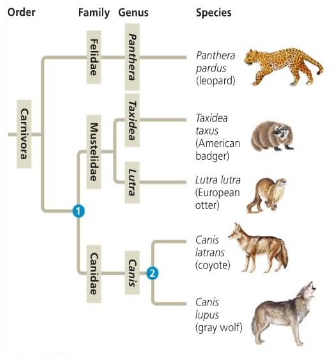
#### 3. Phylogenetic System of Classification (Clasdics)

Cladistics Taxonomy derived from (Gk. Clados which means sprout) and, it searches similarity due to common phylogeny or origin from a common ancestor. These are two types of characters, ancestral and derived. Ancestral characters are traits of basic body design which would be present in an entire group. Derived characters are those traits whose structures and functions differ from those of ancestral characters. They appear during evolution and cause the formation of new subgroups. One or more derived characters would be shared by an entire subgroup. In cladistics taxonomy (cladistics) each evolutionary step produces a branching. All the members of a branch would possess the derived character. It will be absent below the branch point. Arranging organisms on the basis of their shared similar or derived characters that differ from ancestral characters will produce a phylogenetic tree called cladogram.

This system is adopted by Adolph Engler (1844-1930) and Karl A.E. Prantl and John Hutchinson (1884-1974) in classifying the plants. The phylogenetic system is based on the evolutionary and genetic relationship of the organisms. It enables us to find out the ancestors or derivatives of any taxon. Our present-day knowledge is insufficient to construct a perfect phylogenetic classification and all the present phylogenetic systems are formed by the combination of natural and phylogenetic evidences. A classification that presents the genealogical relationships hypothesized to exist among a given array of organisms. Phylogenetic classifications have the property of being logically consistent with the hypothesized phylogeny of the organisms. Phylogenetic classiﬁcations are logically consistent with the phylogenetic tree advocated by the investigator. Thus, they are candidates for being natural classiﬁcations superior to alternatives that are not logically consistent with the phylogenetic tree hypothesis.

**Relationship between classification and Phylogeny**

The evolutionary history of a group of organisms can be represented in a branching diagram called a phylogenetic tree. The branching pattern in some cases matches the hierarchical classification of groups nested within more inclusive groups (Figure 2.1). in other situations, however, certain similarities among organisms may lead taxonomists to place a species within a group of organisms (for example, a genus or family) other than the group to which it is most closely related. If systematists conclude that such a mistake has occurred, the organism may be reclassified (that is, placed in a different genus or family) to accurately reflect its evolutionary history in addition, the categories in the Linnaean classification system may provide little information about phylogeny: We may distinguish 17 families of lizards, but that tells us nothing about their evolutionary relationships to one another.



**Figure 3.1:** the connection between classification and phylogeny. Hierarchical classification is reflected in the progressively liner branching of phylogenetic trees this tree traces possible evolutionary relationships between some of the taxa within order Carnivora and itself a branch of class Mammalia. The branch point (1) represents the most recent common ancestor of all members of the weasel (Mustelidae) and dog (Canidae) families. The branch point (2) represents the most recent common ancestor of coyotes and gray wolves.

In fact, such difficulties in aligning Linnaean classification with phylogeny have led some systematists to propose that classification be based entirely on evolutionary relationships. A recent example of this approach is the PhyloCode, which only names groups that include a common ancestor and all of its descendants. While PhyloCode would change the way taxa are defined and recognized, the taxonomic names of most species would remain the same. But species would no longer necessarily have "ranks" attached to them, such as family, order, or class. Also, some commonly recognized groups would become part of other groups previously of the same rank. For example, because birds evolved from a group of reptiles, Aves (the Linnaean class to which birds are assigned) would be considered a sub group of Reptilia (also a class in the Linnaean systern). Although PhyloCode is controversial and still being developed, many systematists are adopting the phylogenetic approach on which it is based. Whether groups are named according to PhyloCode or to Linnaean classification, a phylogenetic tree represents a hypothesis about evolutionary relationships. These relationships often are depicted as a series of dichotomies, or two-way branch points (Figure 3.2). Each branch point represents the divergence of two evolutionary lineages from a common ancestor. For example, in (Figure 3.2) branch point (1) represents the common ancestor of taxa A, B, and C. The position of branch point (4) to the right ofbranch point (1) indicates that taxa B and Cdiverged after their shared lineage split from that oftaxon A. Note thattree branches can be rotated around abranch point without changing their evolutionary relationships. In (Figure 3.2), taxa Band C are sister taxa, groups oforganisms that share an immediate common ancestor (branch point 4) and hence are each other's closest relatives. Note also that this tree, like most ofthe phylogenetic trees is rooted, which means that a branch point within the tree (typically, the one farthest to the left) represents the last common ancestor of all taxa in the tree. Finally, the lineage leading to taxa D-F includes a polytomy, a branch point from which more than two descendant groups emerge. A polytomy indicates that evolutionary relationships among the descendant taxa are not yet clear.

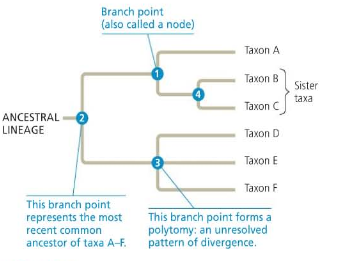


Figure 3.2 How to read a phylogenetic tree.

### 

**Figure 3.3.** Example of a Cladogram or Phylogenetic Tree for Taxa A–F

* Method that groups organisms that share derived characters = cladistics or phylogenetic systematics.
  + Constructing Cladogram
  + By considering symplesiomorphies & synapomorphies, and by identifying homologous & analogous characters
* a single branching pattern is selected from many possibilities.
* Number of possible branching cladograms increases with increase in number of taxa.
* eg. For 2 taxa, only 1 cladogram; for 3 taxa, 3 different cladograms; and for 4 taxa, 15 cladograms can be constructed, etc (Figure

### 

### Figure 3.4: Possible cladograms with the different numbers of ETUs.

* From these many cladograms the one that is based on the fewest assumption is selected = principle of parsimony
* i.e. the one exhibiting the fewest number of evolutionary steps (the simplest one is accepted. )=the best estimate of phylogeny.
* ***A cladogram*** - infer collective evolutionary changes occurred.

may be used.to - classify life in a way that directly reflects evolutionary history.

* N.B: Phylogenetic tree shows only decency of common descent.
* does not indicate s "primitive" or "derived” taxa.
* Look at to the following example.

### 

**Some Principles to Construct Evolutionary Trees**

*Rule 1*: The branches coming from every node can be rotated

### Do not imply any sort of order; indicate only recency of common descent

### 

*Rule 2*: Two lineages (clades) branching from a single ancestral node = *sister taxa.*

* specialization after a branch point is irrelevant to the systematist

*Rule 3*: There is no such thing as a “most highly evolved species”.

*Rule 4:* No extant taxon is ancestral to any other extant taxon.

When an ancestral lineage diverges to become two separate taxa, the ancestral lineage is considered extinct.

Eg. “Humans evolved from monkeys”.( incorrect)

Humans and monkeys share a common ancestor. (correct)

**Monophyletic, Paraphyletic and Polyphyletic Taxa**

* **A monophyletic taxon** -consists of a common ancestor and all descendants of that ancestor.

eg. Reptilia can be made monophyletic by including Aves (birds).

* **A paraphyletic group** -includes a common ancestor & some, but not all known descendants of that ancestor.

### 

Figure 3.6. Vertebrate taxa are grouped in Monophletic (a), Paraphyletic (b)

* **A polyphyletic taxon**- includes members that have descended from two or more different ancestors, but the common ancestor of those has not been included.

### 

* The polyphyletic tree/classification based on superficial similarity, such as “warm bloodedness” or “four-chambered heart”.
* These characters most likely evolved independently in mammals and in birds.

**Determining Primitive and Derived Characters**

The 1st step in cladistic analysisis determining *Plesiomorphic & Apomorphic* character states.*.*

Characters are identified into:

* primitive (plesiomorphic) and advanced/ derived (apomorphic)
* Shared primitive character synplesiomorphy & shared advanced character synapomorphy are considered
* Synapomorphy is more important than synplesiomorphy in cladistics.
* Having similar characteristics due to a common ancestor =homologous features or homology is more important in cladistics. This means organisms that have recently evolved common characters are considered as evolutionarily more related.
* Having similar characteristics due to convergent evolution= *analogous feature* or *homoplasy* is not show presence of recent common ancestor.

eg. Having streamlined body shapes (in aquatic animals) is analogous= due to living in similar environment or due to convergent evolution.

* Only shared derived homologous characters could possibly give us information about evolutionary r/ships or phylogeny ( Willi Hennig, 1966)
* The working units (taxa to be classified) in cladistics are called *Operational Evolutionary Units (OEUs)*
* Designation of relative ancestry to character states (morphocline)-determination of *polarity*

E.g. If a superior ovary is hypothesized as ancestral to inferior ovary, the polarized morphocline = superior ovary → inferior ovary.

For determination of polarity, outgroup comparison method is the primary one.

* If a taxon that is not a member of group of organisms being classified has a plesiomorphic character that is shared with some of the organisms in the group, the taxon will be *an outgroup* .
* The outside taxon = *outgroup* and the organisms being classified = *ingroup.*

### 

Figure 3.7. Branching of Ingroup and Outgroup from a common Ancestor

E.g. Let a character has states ‘a’ and ‘b’. There are only two possibilities:

1. ‘ b’ is *plesiomorphic* and ‘a’ is *apomorphic*, b →a (b has evolved to a), or
2. ‘a’ is *plesiomorphic* and ‘b’ is *apomorphic,* a →b (a has evolved to b).

* If state ‘a’ is also found in the outgroup, the 1st hypothesis will force you to make more assumptions than the 2nd (it is less parsimonious),

### 

In hypothesis 2, state a is the *plesiomorphic state* & both character states a & b each evolve only once.

* Thus, hypothesis 2 is more *parsimonious* and is a more defensible hypothesis.
* The state which is in the outgroup is primitive & the one found only in the ingroup is derived.
* Commonly, primitive states are designate by 0 (zero) and the derived states by 1 (one).

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| OEUs | Characters | | | | |
| 1 | 2 | 3 | 4 | 5 |
| Outgroup | a | A | A | a | A |
| A | a | A | B | a | b |
| B | b | A | A | b | A |
| C | a | A | A | b | B |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| OEUs | Characters | | | | |
| 1 | 2 | 3 | 4 | 5 |
| Outgroup | 0 | 0 | 0 | 0 | 0 |
| A | 0 | 0 | 1 | 0 | 1 |
| B | 1 | 0 | 0 | 1 | 0 |
| C | 0 | 0 | 0 | 1 | 1 |

Notice: In the tables above, the pleiomorphic (a) and apomorphic (b) character states  
constructing a Cladogram

* *By Hennig Argumentation* and *Wagner Method*.

*Hennig Argumentation method:*

* Considers the information provided by each character one at a time.

Easiest to understand with a small data set as shown in example below

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| OEUs | Characters | | | | |
| 1 | 2 | 3 | 4 | 5 |
| Outgroup | 0 | 0 | 0 | 0 | 0 |
| A | 1 | 0 | 0 | 0 | 1 |
| B | 1 | 1 | 0 | 1 | 0 |
| C | 1 | 0 | 1 | 1 | 0 |

1. Character 1 unites taxa A, B, and C because they share apomorphic state

### 

### b. For character 2, derived state is found only in taxon B. It is an *autapomorphy* for taxon B, and provides no more information.

### 

c. For character 3, the derived state is an *autapomorphy* for taxon C:



d. For character 4, the derived state is a *synapomorphy* that unites taxa B and C:



e. For character 5, the derived state is an *autapomorphy* for taxon A.

* The cladogram is finished: all characters have been considered and the relationships of the taxa are resolved

### 

**Challenges of Evolutionary Taxonomy**

* In essence, evolutionary taxonomists sometimes coupled Linnean rank (Order, Class, etc.) with some measure of how distinctive a group might appear. Perhaps the ultimate expression of this practice was Julian Huxley’s proposition that humans, as reasoning animals, should be accorded their own grade phylum (Psychozoa) and it was considered to be one challenge.
* The second challenge to evolutionary taxonomy came from the pheneticists in the mid - 1950s. The phylogeneticists entered the argument in earnest in the late 1960s, challenging both pheneticists and evolutionary taxonomistswith equal vigor.Evolutionary taxonomy, as a program of systematic inquiry, has also largely disappeared. However, its legacy lives on in numerous textbooks in the form of classiﬁcations that contain groups whose existence is based on criteria other than common ancestry, and in this respect, its legacy is negative.

### ****3.2. Development of Plant Classification****

# The early history of development of botanical science is nothing but a history of development of plant taxonomy. The herbalists and agriculturists of ancient times gat­hered some knowledge about plants which was passed on from generation to generation.

Table 3:1: Early contributors of Plant classification

|  |  |  |  |
| --- | --- | --- | --- |
| Taxonomist | Year or century | Book/Jorinal entitled | Major attributes for classifying plant |
| Theophrastus  **“Father of Botany”** | 372-287 BC | “Enquiry into Plants” | arrange the plants in several groups |
| Pliny |  | “Historia Naturalis” |  |
| Disocorides |  | “Materia Medica” | information about 600 medicinal plants |
| Albert Magnus | in the 13th century | “De Vegetabilis” | Based on difference in the stem structure of Dicotyledons and Monocotyledons divided in to two (Tunicate and Corticate). |
| Otto Brunfels | (1530-1536) | “Herbarium vivae Eiconis” |  |
| Jerome Bock, , pub­lished his which contained | (1498-1554) | “Nue Kreuterbuch” | German herbalist with accurate descriptions of about 600 species and 3 major groups; herbs, shrubs, and trees |
| Andrea Caesalpino also | (1519-1603) | “De plants” in 16 volumes | Classified the plants on the character of their habit, viz., trees, shrubs, and herbs but also took into account the characters of ovary, fruit, and seed. |
| Leonard Fuchs | (1501-1566), |  | were others who also advanced the cause of botanical science by their observations and contributions. |
| Valerius Cordus | (1515-1544), |
| Mattias de L’Obel | (1538-1616), |
| John Gerard | (1545- 1612), |
| Charles L’Ecluse | (1526-1909) |
| Jean (Johna) Bauhin | (1541-1631) | wrote a book entitled “Historia plantarum universalis” |  |
| Gaspard (Casper) | (1560-1624) | published 3 botanical treatises the third one of which, viz., “Pinax theatri Botanic | Had formulated the idea of a genus and in many cases gave binary nomenclature to his plants. |
| John Ray, an English naturalist | (1628-1705), | “Historia plantarum” | Recognize 2 major taxa of flowering plants, viz., Dicotyledons and Monocoty­ledons. and several families which he called “classes”. |
| Joseph Pitton de Tournefort |  |  | The character of inflorescence and flower for subdividing the lattergroup. |
| Antoine Laurent de | (1748-1836) | “Genera planetarium secundum ordines naturales deposita”- | Natural Systems classification |

### 

### Plant classification types

#### Linnaean System:

A Swedish naturalist (also called Carl von Linne), who gave a new impetus to the study of plants. He was professor of medicine and botany in the Upsala University. He himself was an arduous collector of plants and made arrangement of collecting plant-specimens from different parts of the world by sending his students to countries far away and through missionary men and administrators.

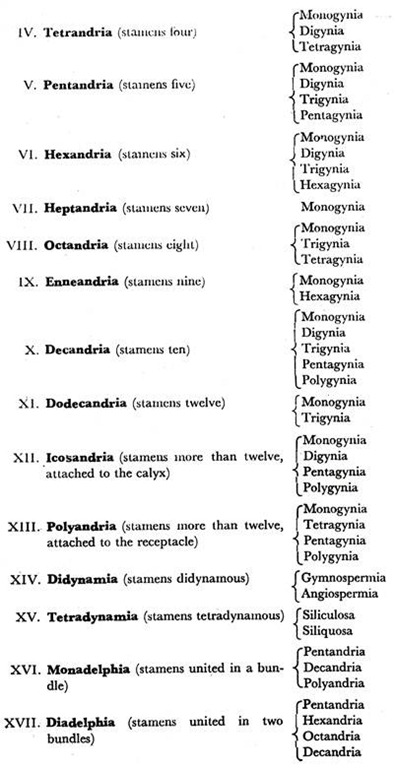
The discovery of numerous plants from all over the world led him to think about bringing an order into the existing chaos and set him self in grouping and classifying all the plants known till his time. He proposed a system of classification which was published in his “Systema Naturae” (1735) and later the “Species plantarum” the first edition of which came out in 1753.

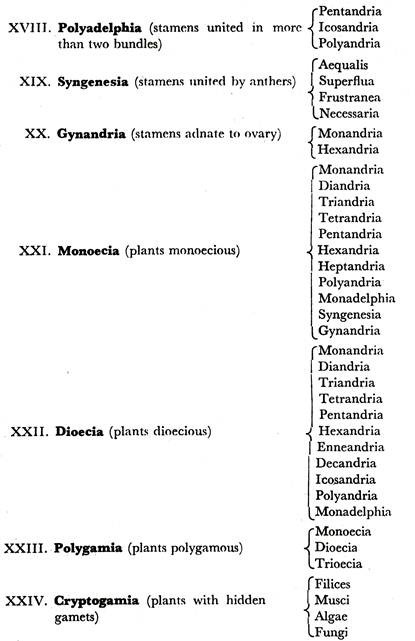
Linnaeus divided the plant kingdom into 24 classes depending on the number and nature of stamens. Each class was subdivided into orders according to the number and nature of stamens and carpels or on other characters of stamens.

In this system the names of the classes and orders indicate the nature of androecium and gynoecium and the name given to one order under a class was often given to another order under another class and similarly name of a class was often used to designate an order under another class which make it an artificial system where very distantly related plants by use of the morphological nature of stamens and carpels.In this work he consistently used binary nomenclature for every species with a generic name followed by a specific epithet.

The modern taxonomists have agreed to consider the year 1753 as the starting point of nomenclature of Phanerogams, Pteridophyta, and Sphagnum. In his “Philosophia Botanica” he laid down some principles which later formed the basis of the International Code of Botanical Nomenclature. Owing to the efforts of Linnaeus the study of Botanical science entered the modern age and Linnaeus is rightly called the “Father of Modern Botany”.

# http://cdn.biologydiscussion.com/wp-content/uploads/2016/07/clip_image004-297.jpg





#### Natural Systems

It was Augustin Pyrame de Candolle who classified plants in 11 classes and 161 natural orders. Dicotyledonae comprises all of the dicotyledonous natural orders and also the Coniferae in the rest of these 11 classes.

#### Phylogenetic System:

Since 19th c many phylogenetic taxonomist put tremendous efforts toward the classification of land plants based on phylogeny.According to many of the phylogetists land plants show phylogenetic relationship among them. Arthur Cronquist of New York Botanic Garden drew out a scheme to show the relation of the orders of Dicotyledonae and he classified the Dicots or the Magnoliatae into 6 subclasses, viz., Magnoliidae, Dilleniidae, Caryophyllidae, Hamamelidae, Rosidae and Asteridae.

Magnoliidae is the most primitive subclass from which Dilleniidae, Caryophyllidae, Hamamelidae and Rosidae have been derived while Asteridae originated from Rosidae. The relationship of these six subclasses has been shown graphically by him with the help of balloon like figures, the sizes of the balloons giving an idea of the number of orders and families in each subclass.

**This is reproduced below:**

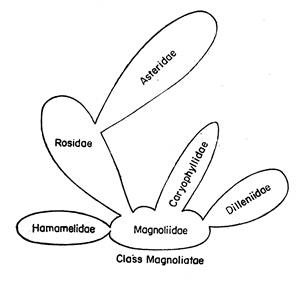


Figure: 3:8 Class magnoliatae

Derives the names of the subclasses from an order included under it and what forms the basal stock for the other orders in that subclass except in the Asteridae where Asterales is the highest order containing the more recent families among the dicots (or Magnoliatae). The most primitive order in that subclass is the Gentianales which, however, does not form the basal stock for other orders in Asteridae. Angiosperms were named in the two classes of as Magnoliopsida and Liliopsida. Liliopsida divides theinto 5 subclasses as indicated below figure.

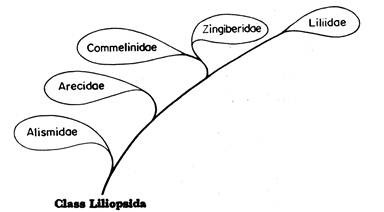


Figure: 3.8 Class Lilipsida

#### Zoological Classification

Zoological classification can be defined as the ordering of animals into groups or sets on the basis of their relationships.Biological clas­sification is the**“ordered grouping of organ­isms according to their similarities and consistencies with their inferred descent”.** This definition makes classification natural because it reflects the evolutionary pathway of the organisms.

**The purpose of classification:**

(i) Identification of the animals and to arrange the different types of animals into groups on the basis of relation­ships;

(ii) To express the degree of genetic rela­tionships or affinity between the dif­ferent types of animals.

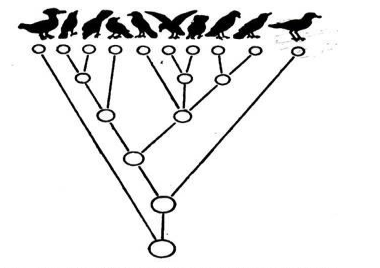


Figure: 3.9 Classification of ten different birds. Classification in one hand indicates interrelationship and at the same time their origin.

In zoological classification various taxonomic categories traditionally have been arranged in a branching hierarchical order that expresses the various levels of genetic kinship. The sequence from top to bottom indicates decreasing scope or inclusiveness of the various levels. For example:

Kingdom — Animalia

Phylum — Chordata

Class — Mammalia

Order — Carnivora

Family — Felidae

Genus — Puma

Species — Puma concolor

Our present classification scheme has been devised by using the genus and trivial name as a base and then grouping them in a hierarchical system. For example, dogs (Canis familiaris) are related in a single genus, and these in turn are related to foxes (Vulpes, Urocyon); and all of these are united in one family, Canidae. This group is somewhat more distantly related to the cats, bears, and other flesh-eaters; and all these forms are united in an order, the Carnivora. This order shares many features such as mammary glands and hair, with forms as diverse as bats and whales,and all are grouped in one class,the Mammalia (see **Appendix:I**).In turn,mammals have numerous characteristics such as an internal skeleton and a dorsal hollow nerve cord that are also present in fishes,amphibians, and reptiles; thus, all are grouped in one of the major subdivisions of the animal kingdom, the phylum Chordata. These seven categories are considered essential to defining the relationships of a given organism. Often, however, taxonomists find it necessary because of great variation and large numbers of species to recognize intermediate, or extra, levels between these seven categories of the taxonomic hierarchy by adding the prefixes “super-,” “infra-,” and “sub-” to the names of the seven major categories. The delineation of taxa higher than the species level is rather arbitrary: A taxonomist may divide a group of species into two genera if he or she is impressed by differences, or combine them into one genus if the similarities are emphasized. For example, some authorities have included the tiger and other large cats in the genus Felis with the small cats, whereas other authorities have segregated them as the separate genus Panthera.

**Microbial classification and Taxonomy**

Microbiologists are faced with the daunting task of understanding the diversity of life forms that cannot be seen with the naked eye but can live seemingly anywhere on Earth.However, the taxonomic assignment of microbes is not necessarily rooted in evolutionary relatedness. For instance, bacterial pathogens and microbes of industrial importance were historically given names that described the diseases they cause or the processes they perform (i.e., Vibrio cholerae, Clostridium tetani, and Lactococcus lactis). Although these labels are of practical use, they do little to guide the taxonomist concerned with the vast majority of microbes that are neither pathogenic nor of industrial consequence. Our recent understanding of the evolutionary relationships among microbes now serves as the theoretical underpinning for taxonomic classification. In practice, determination of the genus and species of a newly discovered procaryote is based on polyphasic taxonomy. This approach includes phenotypic, phylogenetic, and genotypic features.

**Chapter three: Review questions**

**Answer the following questions properly**

1. What does artificial classification mean?
2. What kind of naming was used in artificial classification?
3. What to mean composite OUT based on character state cluster analysisof taxa?
4. What are the strengths and its weaknesses of cluster analysis and phenograms?
5. Define the following taxonomic terms
6. Apomorhy
7. Autapomorphy
8. Synapmorphies
9. Pleisiomorphy
10. Cladogram
11. Synplesiomorphy
12. Homology
13. Analogous
14. A monophyletic taxon
15. A paraphyletic taxon
16. A polyphyletic taxon
17. Sister taxa
18. Ingroup
19. Out group
20. Explain parsimony hypothesis and its significance in phylogenetic classification

# 

# CHAPTER FOUR

# 4. TAXONOMIC STRUCTURE

**Unit Objectives**

**At the end of this unit the students will be able:-**

* Define Taxa
* Discus species concept
* Name different taxonomic ranks.
* Explain the need for taxonomic ranks

## 4.1. Taxonomic Hierarchy & Ranks of Taxa

Since the number of animal and plant species is very large, it is not possible to either know them individually by their names or to refer them in the literature. This necessitated arranging them into categories and taxa of different grades. Then arranging these categories and taxa in an ascending order so that a higher category includes one or more lower categories and higher taxa include one or more lower taxa.

Linnaeus was the first taxonomist to establish a definite hierarchy of taxonomic categories recognised within the animal kingdom. These are classes, order, genus, species and varieties. The varieties, used by Linnaeus as an optional category of various types of intraspecific variants, was eventually discarded or replaced by the species. These few categories sufficed to cope with small number of animals and plants known at that time.

However, as the number of known species increased and with it our knowledge of the degrees of relationship of these species, the need arose for a more precise indication of the taxonomic position of species and inserting additional ones among them.

Most are formed by combining the original category names with the prefixes super or sub. Thus, there are superorder, super-families and subfamilies, etc. The most frequently used additional new category name is perhaps the term tribe for a category between genus and family.

Vertebrate palaeontologists also used in routine the category cohort between order and class. Some authors used terms for additional subdivisions, such as cladus, legio, and sectio. Some used infraclass below the subclass and infra-order below the suborder.

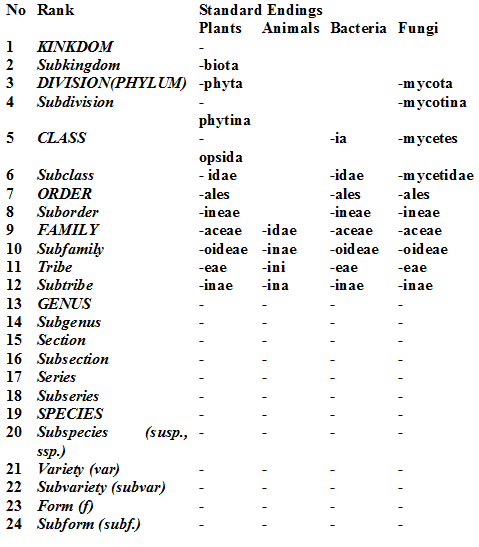
**Major Recognized Taxonomic Ranks in Biology**

* Theoretically, there is no limit to the number of levels contained in hierarchy.

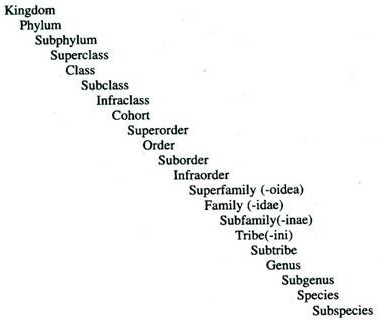
e.g. ICBN recognizes twelve main ranks in the hierarchy *(kingdom, division, order, family, tribe, genus, section, series, species, variety* and *form)*.

* Main taxonomic ranks and standard ending of for plants, animals, bacteria and fungi are shown in the Table below.

**Table 4.1** Main taxonomic ranks & standard ending of for plants, animals, bacteria.



**The generally accepted categories are the following:**



Indicated in the parenthesis are the standardised endings for the names of tribes, subfamilies, families and super-families. The systematic hierarchy or Linnaean hierarchy as it is commonly known, with its need for arbitrary ranking has often been attacked as an unscientific system of classification.

## 4.2. Concepts of the Kingdom

**Different Kingdom Systems**

* Number of kingdom has increased from 2 to 5 or 6/7.

**I. Two kingdom approach:**

The classification of living things into animals and plants is an ancient one. Aristotle (384 BC–322 BC) classified animal species in his work entitled History of Animals, and his pupil Theophrastus (371-287 BC) also wrote a parallel work on plants (the History of Plants).

Carolus Linnaeus distinguished two kingdoms of living things: Animalia for animals and Vegetabilia for plants (Linnaeus also treated minerals, placing them in a third kingdom, Mineralia). He also divided each kingdom into classes, later grouped into phyla for animals and divisions for plants.

According to the two kingdom approach, kingdom animalia included every living thing that moved, ate, and grew to a certain size and stopped growing. Kingdom plantea included every living thing that did not move or eat and that continued togrow throughout life.Later on, it became very difficult to group some living things into one or the other, so the number of kingdoms was increased**.**

* *kingdom animalia -living thing that moved, ate, and grew to a certain size*
* *Kingdom plantea - living thing that did not move or eat and that continued to grow*

**II. Three Kingdoms**

* A third kingdom, protista (unicellular) was proposed by Ernst Haeckel in 1866.
* Whether organisms are unicellular (Protista) or multicellular (Animals and Plants).
* **Three kingdom systems**: Kingdom Protista, Kingdom Plantae and Kingdom Animalia.

**III. Four kingdoms**

* The result of thee discovery of the electron microscope
* A four-kingdom was proposed by Copeland in 1938
* Prokaryotes (bacteria and blue green algae =kingdom Monnera) and eukaryotics (plantae, Animalia & Protista) were distinguished
* Initiated the rank above kingdom, a super-kingdom/ empire/ domain = Prokaryot vs Eukaryta

**IV. Five kingdoms**

* **Whittaker’s** ﬁve kingdoms by the mid-twentieth century advances in cell biology led to a revision of life into ﬁve main kingdoms deﬁned primarily by subcellular features, e.g. cell walls, links between cells, organelles and mechanisms of cell division. The ﬁve kingdom system. *Kingdom Monera (prokaryotic)* and Eukaryotics (*Kingdoms Protista*, *Plantae, Fungi* & *Animalia )*

**VI. Six Kingdoms**

* **16s rRNA**By 1990 analyses of DNA and RNA, particularly work on 16s rRNA, sequences suggested a fundamental revision of the ﬁve kingdoms. Shared and different 16s rRNA sequences suggested that life divided into two main branches, the Bacteria on one hand and a second branch itself split between the Archaea (previously thought of as close allies of the Bacteria) and the Eucarya (everything else).. Animals, plants and fungi are but three of the kingdoms within the Eucarya. Recent evidence suggests that the relationships between the three domains are muddied by transfer of genes between ancient lineages that eventually became isolated as distinct kingdoms. This ‘New Tree of Life’ suggests that the ancestors of all life on earth may be more a community of promiscuous microbes than a single lineage.
* Based on such RNA studies, Carl Woese divided prokaryotes (Kingdom Monera) = Eubacteria & Archaebacteria.
* Kingdom Bacteria, Archae, Protista, Plantae, Fungi & Animalia

|  |  |  |
| --- | --- | --- |
| Life | Domain Bacteria | Kingdom Bacteria |
| Domain Archaea | Kingdom Archaea |
| Domain Eukarya | Kingdom Protista |
| Kingdom Plantae |
| Kingdom Fungi |
| Kingdom Animalia |

## 4.3. The Concept of the Species

* How best to define "species" is one that has debated biologists/naturalists for centuries
* the debate itself is called the species problem
* Species can be delimited broadly & inclusively, or narrowly → created conflicts b/n groups of taxonomists (b/n “lumpers” & “splitters).
* No one definition of species has yet satisfied all naturalists/taxonomists.

**Different Species Concepts (** > 26 different concepts**)**

1. “**Biological” or reproductive isolation concept**:
   1. Taxa possessing reproductive isolation with respect to other species.
2. **Cladistic concept:** unbranched segments/ lineages in an organismal phylogeny.
3. **Darwin’s morphological concept**: “Varieties” between which there are no or few morphological intermediate.
4. **Recognition species:** a group of organisms that recognize each other for mating & fertilization
5. **Ecological concept**: “A lineage w/h occupies an adaptive zone different from that of any other lineage.
6. **Evolutionary concept:** a lineage evolving separately & “with its own unitary evolutionary role and tendencies.”
7. **Population concept:** Populations are the real units of evolution, not species.

**Organisms and Grouping of Organisms**

1. **Taxon***.*The general subjects of study are taxa (singular, taxon), which are defined or delimited groups of organisms. Ideally, taxa should have a property known as monophyly This is a grouping of organisms at the level associated with the application of proper scientiﬁc names, or a grouping of such organisms that could begiven such a name but is not named as a matter of convention.

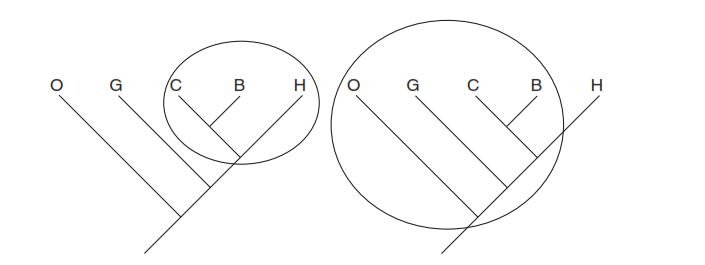
* The plural is **taxa**. Some taxa (the natural ones) are considered to have an objective realityin nature apart from our ability to ﬁnd and name them. Taxa in practice aregroups named by systematists. As such, they are hypotheses about taxa innature. As hypotheses, they may be accepted or rejected based on subsequentresearch, or even on logical grounds. For example, phylogenetic systematistsreject paraphyletic taxa on logical grounds because such taxa result in classiﬁcationsthat are inconsistent with an accepted phylogenetic tree (Wiley,

1981b). Higher taxa are taxa that include more than one species. Species taxa are the lowest formally recognized taxa usually considered in phylogenetic analysis.

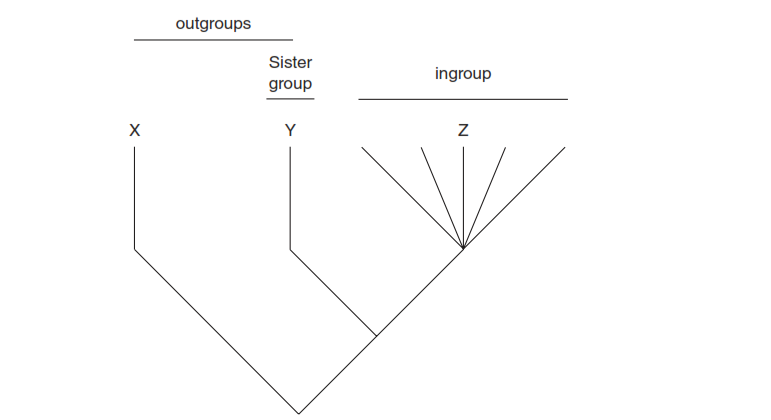
**2 Monophyletic Group***.*  A monophyletic group is a taxon comprised of two or more species that includes the ancestral species and all and only the descendants of that ancestral species (Fig 1.2a). *Monophyleticgroup* is usually considered synonymous with the term **clade,**and the two terms are frequently used interchangeably. As used here, species are not monophyletic groups

Because they are self – referential entities of process while monophyletic groups are neither self referential nor units of process, except the process of descent. Instead, they are entities of history. Monophyletic groups in nature are real, but again monophyletic groups named by systematists are hypotheses, and these hypotheses stand or fall on the empirical evidence.

**3. Para - and Polyphyletic Groups***.*  Paraphyletic groups are incomplete groups in which one or more of the descendants of the common ancestor are not included in the group (Fig. 1.2 b). Invertebrata is an example, as are Reptilia (birds and mammals excluded) and Pongidae ( *Homo* and allied fossil genera excluded). Polyphyletic groups are comprised of descendants of an ancestor not included in the group at all. Homothermia (birds + mammals) would be an example as



**Figure 1.2.**Concepts of monophyly and paraphyly.(a) A monophyletic Hominidae thatincludes humans (H), chimpanzees (C), and bonobos (B). (b) A paraphyletic Pongidae that includes orangutans (O), gorillas (G), chimpanzees, and bonobos but excludes humans.



**Figure 1.3.** Some terms for groups used in a phylogenetic analysis. Relationships of out-groups

to the in-group are shown as “ known ” as a matter of prior knowledge, backed up with empirical data.

the ancestor of birds and mammals would presumably be included in Reptilia.Para - and polyphyletic groups are not real in nature. From the phylogeneticperspective, paraphyletic and polyphyletic groups named by systematists are illogical, either through ignorance (group named in the absence of a phylogeny) or practice (as in evolutionary taxonomic practice for naming paraphyletic

groups).

**Sister Group***.*  In nature, a sister group is a single species or a monophyleticgroup that is the closest genealogical relative of another single species or monophyletic group of species (Fig. 1.3). True sister groups share a unique common ancestral species — an ancestral species not shared by any other species or monophyletic group. In phylogenetic analysis, a sister group is the

hypothesized closest *known* relative of a group the investigator is analyzing, given current knowledge. Hypotheses of sister group relationship are fundamental to phylogenetic practice.

In analyses, the sister group is the most inﬂuential outgroup for determining the relative merit of presumed homologies to indicate genealogical relationships within the group studied.

**5 Outgroup**. An outgroup is a species or higher taxon used in phylogenetic analysis to evaluate which presumed homologs indicate genealogical relationships within the group studied and which are simply primitive characters (Fig. 1.3). The outgroup is used to root the tree and determine character polarity. The sister group is a special – case outgroup. Critical analysis requires the investigator to consult both the sister group and at least one additional outgroup to

make the determination about homologs

6. I**ngroup***.*The ingroup is the group that is being analyzed by the investigator. It is shown in Fig. 1.3 as a polytomy because relationships within the group

There is a tree of life that links all living organisms in a genealogical nexus,and it is possible to reconstruct relationships among the species that populate the tree.

2. Relationships among organisms do not have to be invented and treated as some form of scenario; they only have to be discovered. Our hypotheses reﬂect our best efforts to discover these relationships.

3. All characters are potentially useful in discovering these relationships, but only some characters are useful at any particular and restricted level of analysis.

4. Phylogenetic classiﬁcations are logically consistent with the phylogenetic tree advocated by the investigator. Thus, they are candidates for being natural classiﬁcations superior to alternatives that are not logically consistent with the phylogenetic tree hypothesis.

1. The relationships between hypothesis, evidence, and summary must be transparentin the sense that one can examine the evidence used in arriving at each piece of the puzzle.

* Phenetics occupies the opposite end of the spectrum from phylogenetics. Early pheneticists were hopeful that if they could arrive at a measure of overall similarity between species this would be useful in showing the evolutionary relationships of those species, or perhaps higher taxa (Sokal and Sneath, 1963 ). When this proved not to be the case, they largely abandoned the search for evolutionary relationships in favor of a system of grouping taxa by overall similarity.
* Evolutionary taxonomy occupied an intermediate position. Post - Hennigian evolutionary taxonomists largely adopted the methods of phylogenetic analysis advocated by Hennig (e.g., Mayr and Ashlock, 1991 ). However, they continued to assert that classiﬁcations could andshould express a balance between overall similarity and genealogical relationships. While this sounds reasonable, we shall see that the methods of striking this balance were often arbitrary and result in illogical classiﬁcations if they contain non monophyletic groups.
* Evolutionary taxonomy is the oldest of the three approaches we have discussed thus far. It is reﬂected in the work of some systematists to integrate classiﬁcation and taxonomy into the Neo - Darwinian Synthesis that began in the 1920s, resultingin classic works by Ernst Mayr, George Gaylord Simpson, and Julian Huxley.

### Taxon and Category:

**Taxon (Plural: Taxa.):**

The taxa are the groups of animals generally groups of species. The words insects, fishes, birds, mammals in animals; algae, fungi, ferns, mosses, grasses, etc., in plants are the groups of organisms. These are the concrete objects of classification. Any such group of such population is called taxon.

But in ordinary usage only the so called basic categories (genus, family, order, class, phylum, kingdom), are treated as such groups. The super taxa at all levels are treated as groups of the basic taxa (a superclass as a group of classes) and the sub taxa at all levels as a subdivision of the basic taxa (a suborder as a section of the order).

**According to Simpson “A taxon is a group of real organisms recognised as a formal unit at any level of a hierarchic classification.”**

**According to Mayr, “A taxon is a taxonomic group of any rank that is sufficiently distinct to be worthy of being assigned to a definite category.”**

**Category:**

The group of animals are taxa. Each taxon is placed at some level in hierarchy. A category designates rank or level in a hierarchic classification. It is a class, the members of which are all the taxa assigned a given rank. A category can be higher or lower than some other one, so we may speak of a higher category.

The categories have names, but these are terms and not names in biological nomenclature. They are kingdom, phylum, class and so on. It is an error to state **“this animal belongs to category Mammalia”**, Mammalia is the name of taxon not of category.

### Taxonomic Categories:

#### Species:

Species is the most important category in the taxonomic hierarchy. It is the basic unit in taxonomy and also in evolution. Its definition has long been one of the major problems of taxonomy. Several definitions and aspects are discussed about the definition of species.

According to Blackweldler, the species can be defined as follows:

1. One of the groups, the one placed in the category called the species level (a species group).
2. The category or level at which the species groups are placed (the species level).

Two main definitions are given for species.

These are as follows:

**Biological species:**

Biological species are usually defined as groups of actually or potentially interbreeding natural populations, which are reproductively isolated from other such groups. This gives theoretical groups which can seldom be distinguished in practice.

Simpson has pointed out that all the definitions of animal species give us biological species. He, therefore, prefers the name genetical species for this and cites also bio-species. (It should be noted that populations do not interbreed, only individual animals and plants interbreed).

**Genetical species:**

Genetical species are groups of interbreeding populations which are reproductively isolated from each other. They are, thus, the same as biological species. For example, in Homo sapiens, the sapiens is a species of Homo.

#### Genus:

The taxa placed in the genus category are the genera. These are groups of species brought together by the taxonomists as evidenced by the fact that generic name is a part of each name of each of the included species.

The genus is involved from naming of the first species of whose name it forms the first part. Again it is possible to say that a genus is any group of species included under the one generic name by any taxonomist. This is completely subjective, but it is approximately the working definition which is the basis of most taxonomic work.

The genus cannot properly be described as the next higher level above the species, because it is common and always possible to. use subgenera between the genus and species, and to use also sections or other informal categories.

A pragmatic definition of the genus states, **“A genus is a taxonomic category containing a single species or a monophyletic group of species, which is separated from other taxa of the same rank (other genera) by a decided gap.”**The genus Felis includes the golden cat (Felis temincki) the fishing cat (Felis viverrina) and the leopard cat (Felis bengalensis).

#### Family:

This is a taxonomic category containing one or more related genera and which is separated from other related families by important and characteristic differences. The family Felidae which includes the lion, the leopard, the tiger and all types of cats belonging to different genera. This family is distinctly separate from the family Canidae which includes dogs and foxes.

#### Order:

The order is the basic category of what has been called the order group which includes also super-orders, the suborders, the infra-orders and taxa at any other levels interpolated between superfamily and infraclass. In many phyla, orders are very well known groups, but in some phyla they are less well known than the classes, whereas classes do have a fairly evident uniformity throughout the animal kingdom.

The orders of vertebrates, for example, are scarcely comparable to families in insects and levels vary in other groups. For example, the order Carnivora includes families Felidae and Canidae.

#### Class:

The class is the basic category of what has been called the class group which included also super classes and infraclasses, as well as any others interpolated among these. In the animal kingdom as a whole, the classes are undoubtedly the best known taxa, even the phyla being subject to more differences of the opinion.

A class is generally a subdivision of a phylum. For example, the order Carnivora includes the lion, the cat, etc., are included in the class Mammalia.

#### Phylum:

The taxa placed in the phylum category are the phyla, subdivisions of the kingdom. They may be assembled into super-phyla or subdivided into subphyla. The phylum Porifera includes three classes such as Calcarea, Hexactinellida and Demospongia.

#### Kingdom:

This is the highest taxonomic category. All animals are included in the animal kingdom and all plants are included in the plant kingdom.

### Species as a Category:

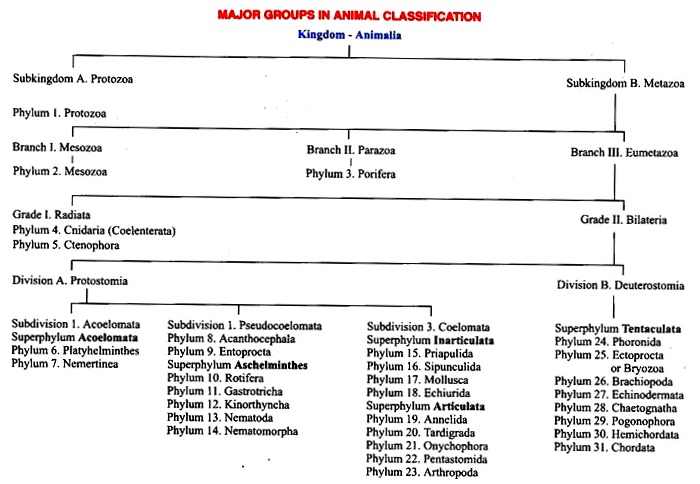
The importance of the term species in all fields of biology is so immense that it deserves special consideration. It has already been stated that individual organisms which have many features in common and are able to breed only amongst themselves are encompassed by the term species.

The definition of species is not restricted only to the taxonomists. Nowadays the other fields of biology also consider the species to a great extent. Cytologists, geneticists, ecologists, biochemists and others have also defined the species.

**The definitions given by different workers are as follows:**

**Allopatric species:**

The species inhabiting different geographical areas.



**Sympatric species:**

The species normally occupying the same geographical areas.

**Morphospecies:**

**“These are ones established by the morphological similarity regardless of other considerations” (Simpson).**

**Bio-species and genetical species:**

A group of inter-breeding populations which are reproductively isolated from other such group.

**Sibling species:**

It is a term applied to pairs or groups of very similar and closely related species. When applied to closely related species (in phylogenetic sense) this expression refers to hypothetical species, these cannot be dealt with in taxonomy but can be useful in speculations on evolution.

**Taxonomic species:**

A species which has been provided a specific name under the International Rules of Nomenclature.

**Evolutionary species:**

These are lineages (ancestral descendent sequences of populations) evolving separately from each other and with their own unitary evolutionary roles and tendencies.

**Polytypic species:**

Polytypic species are those which consist of two or more subspecies.

**Monotypic species:**

Monotypic species consist of a single subspecies.

## 4.4. Taxonomic Characters

Self test

* Define taxonomic characters
* Mention taxonomic characters
* Explain types of variation and tell how they contribute for used for inferring taxonomic charcters.

Taxonomic characters are Features used as evidence for classification/ taxa discovery.

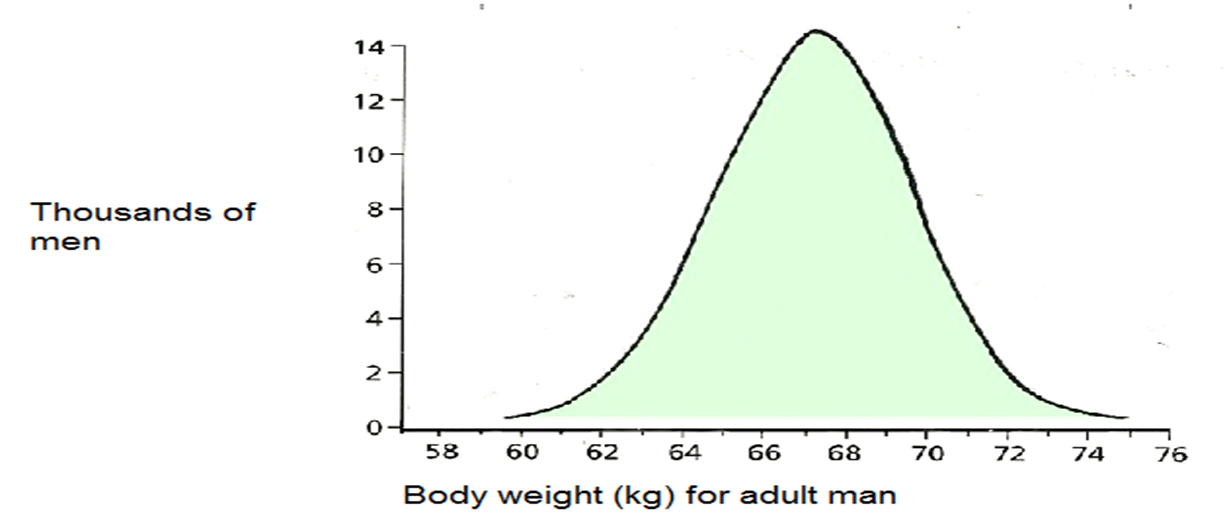
Continuous and discontinuous characters/ variations

* Characters show slight or significant differences among individuals or taxa=   variations

1. **Discontinuous Variation:** two or more distinct phenotypes are observed.
   1. e.g. Blood group: O, A, AB and B ; ability to roll tongue: either tongue roller or not
2. **Continuous variation:** phenotypes with a wide range of quantitative or qualitative values exist.

e.g. Body weight, height, hand span & shoe size in human& milk yield in cows

* Continuous variation is more common than discontinuous ones



**Fig 9:** Body weight of adult men (examples of continuous variation)

* Discontinuous characters are commonly used in classification as they are easier to analyze.
* **Diagnostic characters**: identify a taxon from other related taxa.
* Diagnostic characters aredistinct and sometimes unique to a particular taxon.

### 4.4.1. Sources of Taxonomic Characters

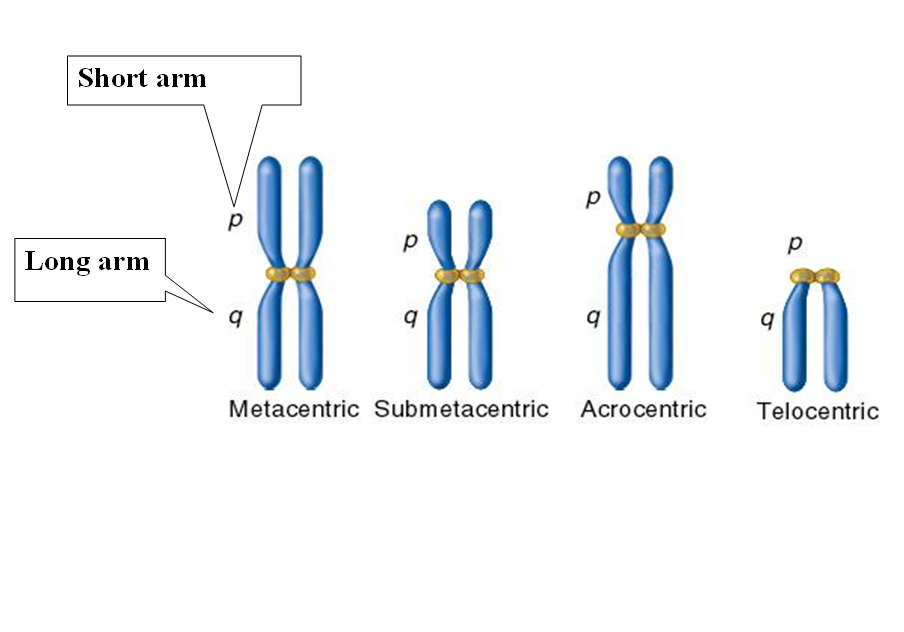
* Includes morphological & anatomical structures, molecular structures (genetic materials and proteins), embryology, palynology, and behavioral features.
* **Morphological characters**
* Morphological character refers to characters of external form or appearance of an organism.
* e.g. Vegetative characters (roots, stems, and leaves) & reproductive structures (flowers, fruits, & seeds) in plants
* Skull bones, limb bones, scales, hair & feathers can be used for the same purpose in animals
* Can be from living specimens and fossils
* Extensively used for centuries & for practical identification; e.g. In practical identification keys
* **Anatomical characters**
* Anatomical characters refers to the characters of internal structures of an organism

eg. Xylem & phloem,nodal anatomy, leaf anatomy, & floral anatomy, etc. in plants, and the bone structure, and the structures of different organs and tissues of animals.

* Homologous structure is more important than analogous ones in classification, particularly in cladistics.
* **Comparative Embryology**
* Study of embryological development of an organism.
* Homologous structures sometimes can be evident only in embryological stage, not exist in adults.

eg. Post-anal tail & paired pharyngeal pouches on sides of throats in all embryos of vertebrates.

* Develop to gills (fish), cavity of middle ear & auditory tube, tonsils, thymus and parathyroid glands (man)
* Embryologists of late 19th C proposed extreme view = "*ontogeny recapitulates phylogeny*" = *theory of recapitulation*.
* Ontogeny is a replay of phylogeny, but it is overstatement (exaggeration).
* not supported by scientific evidence
* In plants, embryology = study of development of sporangia, gametophytes & embryos.
* Differ from Bryophytes to seed plants.
* **Palynology**
* the study of pollen & spores
* Taxonomic characters: pollen nucleus number, storage product, polarity, aperture (pore), symmetry, pollen size, shape and pollen sculpturing (lobes).
* **Behavioral or Ecological Features**
* conform the biological peculiarities of particular taxa.
* genetically fixed without ontogenetic learning, such as call patterns of insects, bats and frogs.
* **Genetic (Chromosomal and Molecular) Evidence**
* **Evidences from Chromosomes**
* \*\*Chromosome number= chromosome number is generally constant within a species
* May vary for varieties, subspecies, etc
* **Chromosome Structure**
* Chromosome size, location of the centromere and banding patterns varies and may used in classification.



* **Molecular systematics:** using data on the molecular constitution of biological organisms: DNA, RNA, or both (and sometimes proteins), in order to resolve questions in systematics.
* Sequences of nucleotides in DNA and RNA, and the sequences of amino acids in polypeptides (proteins) are good sources of molecular data for classification.

**Alternate methods, such as numerical scheme have been proposed but have not found favour among taxonomists, primarily for following two reasons:**

(i) Assigning definite numerical values to taxa demands a far greater knowledge of the relationships of taxa than can be inferred from available evidences.

(ii) An assignment of such values would freeze the system into a family which would preclude any further improvement.

It is the very subjectivity of the Linnaean hierarchy which gives it the flexibility required by the incompleteness of our knowledge of relationships. It permits the proposal of alternate models of relationships and gives different authors an opportunity to test which particular balance between splitting and lumping permits the presentation of maximum amount of information.

**Chapter four: Review questions**

**Answer the following questions properly**

1. Who the first taxonomist was to design two kingdom classifications?
2. Differentiate continuous and discontinuous variation with specific examples.
3. Explain different sources of taxonomic characters.
4. What traits were used to classify plants in artificial classification?
5. Explain how evolutionary classification combines artificial and natural characters of plants.
6. Among the three plant classification system which one do you think is more reliable? Why?
7. In taxonomic rank particularly in biological species concept, it is in agreement that they are genetically compatible to produce viable offspring, but in case they may not be in such normal condition. Justify the case and what rank can they be so called?
8. Explain "lumpers," and "splitters," view of taxonomy in plant classification.
9. It is true that plant genera are descended from common monophyletic stock, but there are also, unusual cases some paraphyletic taxa are grouped in one genus, explain the reason.
10. Assign all taxonomic ranks for the following plant species.
11. *Zea mays*
12. *Coffeaarabica*
13. *Eragrottistef*
14. *Enseteventricosum*
15. *Cordiaaficana*
16. Differentiate between taxa and category.
17. Mention purpose of zoological classification.
18. What methods are used by zoological taxonomist in animal classification?

# CHAPTER FIVE

# 5. BIOLOGICAL NOMENCLATURE

Objectives of the chapter

At the end this chapter the students will able to:

* Define Biological nomenclature
* Discus the significance of nomenclature
* Explain causes that lead to name change
* Differentiate between binomial and trinomial naming
* Tell common rules in Iinternational Code of Botanical Nomenclature and International Code Zoological Nomenclature
* Explain the way to use taxonomic key

## 5.1. Definition of nomenclature

Giving name to organisms or taxa is as old as human language. As folk taxonomy grew to the science of taxonomy, different taxonomic names were given to a taxon (resulted in confusion). Then, came the time when codes (rules) of naming of organisms (biological nomenclature) areneeded.

Nomenclature is defined as the system of naming of plants, animals and other objects or groups of plants, animals and other objects. Scientific names are the language of taxonomists. When a taxonomist identifies and describes the natural group of animals, he gives appropriate scientific names to the groups.

Common names do not serve the purpose because a particular animal is known by different names in different parts of the world. For example, the bird that we know as gauraiya in India and Pakistan is known by different names in other countries, house sparrow in England; Pardal in Spain; Musch in Holland; Suzune in Japan and so on.

**Importance of using scientific names**

These formal names are known as scientificnames, which by convention are translated into the Latin language. The fundamental principle of nomenclature is that all taxa may bear onlyone scientificname. Although they may seem difficult to learn at first, scientific names are muchpreferable to common (vernacular) names. Common names do not serve the purpose because a particular animal is known by different names in different parts of the world.

Table 5:1 Common names for birda house sparrow

|  |  |  |
| --- | --- | --- |
| Scientific name | Common name (vernacular) | Countries |
| *Passer domosticus* | Bird known as Gauraiya | India and Pakistan |
| house sparrow | England |
| Pardal | Spain |
| Musch | Holland |
| Suzune | Japan |

Moreover the common name may be used for different kinds of animals. For example, the name kenchua is used both for the earthworm and Ascaris. In addition to these using scientific names important for various reasons and some of the discussed below

1. Only scientific names are universal, used the same world-wide; common names may vary from region to region, even within a country or within regions of a country. For example, species of the genus *Ipomoea* are known commonly as Morning glory in the United States, but as Woodbine in England, differences in language will, of course, further increase the number of different common names. To ensure that one scientific name stands for one particular kind of animal everywhere and is the only name for that organism, the taxonomist must see the following:

1. The name chosen for an animal has not been already given to some other animal or plant.
2. The animals and plants have been described in such detail that another taxonomist can determine from the description exactly the kind of animal to which the name has been given.
3. The animal or plant has been duly placed in the system of classification establishing its relationships.
4. Common names are not consistent. One taxon may bear more than one common name, these often varying in different regions. For example, *Adenostoma fasciculatum* of the Rosaceae is known by at least two common names, Chamise and Grease wood. Alternatively, a single common name may refer to more than one taxon. For example Hemlock may refer to two quite different plants, either a species of;-*Tsuga*, a coniferous tree of the Pinaceae, or *Conium maculatum*, an herb of the Apiaceae (the extract of which Socrates drank in execution).
5. Common names tell nothing about rank and often nothing about classification, whereas scientific names automatically indicate rank and yield at least some information about their classification. For example, sea-blite tells nothing about rank; it could be variety, species, genus, or family. However, one immediately knows that *Suaeda californica* is at the rank of species and is a close relative to other species of *Suaeda*.
6. Many, if not most, organisms have no common name in any language; thus, scientific names alone must be used to refer to them. This is especially true for plants that are non showy, occur in remote areas, or belong to groups whose members are difficult to distinguish from one another. There is a tendency in some works to arbitrarily convert all scientific species names into common names by translating from the Latin, even when these common names are not used by the native people. For example, *Carex aurea* might be designated golden care x or golden sedge, even if these names are not in common useage. It is the author s opinion that this is less than ideal policy and that it is preferable simply to utilize scientific names and refer to common names only if they are, in fact, commonly used.

**Binomial Nomenclature:**

The history of binomial system of nomenclature is very long. Two centuries before Christ, Cato used two names for plants in his De Re Rustica. But he had no knowledge that genera were usually composed of several species. Later, two ideas developed with the evolution of the idea of nomenclature.

One was to translate the descriptive Greek nouns used for genera into Latin. As a result of this translation into Latin, the generic name consists of two words.

These were called binary generic names. The other tendency was to use descriptive phrases for specific names. These tendencies in conjunction gave rise to a polynomial system of nomenclature. According to this system the name of a plant was composed of several words in a series which bore a brief description of the plant.

For example, Bentham used the name Caryophyllum saxatilis, Folis gramineus umbellatis corymbis to represent the Caryophyllum which grew on rocks, with grass-like leaves and flowers in umbellate corymbs. This was the system of cumbersome.

In the middle of the sixteenth century, a number of binary generic names were changed by Brunfels to single ones. Dodonaeus and Gaspard Bauhin later followed in general the binomial system but it is usually credited to Linnaeus who used it more than hundred years later in his Species Plantarum. According to this binomial nomenclature, long names were cut short so that they could be used with greater convenience.

This system postulates that every individual of plant and animal kingdom consists of only two words in Latin; the first word designating the genus and the second, the additional epithet, that signifies the particular species with that genus. It is also known as two naming system or binary system. For example, the genus of modern horse is Equus.

Among its species are Equus caballus and Equus asinus. The word caballus and asinus standing above have no meaning in taxonomy; they are not names of species or anything else. Only when they are part of a binomial combination, they are meaningful taxonomically and then it is the combination that is the name of the species.

Often, specific names of animals and plants are given in honor of some persons. If the person honored is a man the specific name ends in **“i”**. For example, the earthworm, Lumbricus friendi is named after Rev. H. Friend. If the person honored is a woman, the specific name ends **“ae”**. Sometimes, the specific name indicates a locality (e.g., indica for Indian) or colour (e.g., niger for black).

In scientific literature, it is a general practice to write a specific name followed by the name of the person who first described the species and the year when he did so. For example, the scientific name of man is written as Homo sapiens Linnaeus 1758. If the species, after its publication, is transferred to any other genus or the generic name is changed the first author’s name is written in brackets (parenthesis).

For example, Panthera leo (Linnaeus) means that species leo was originally assigned by Linnaeus to some other genus (Felis).

#### Trinomial Nomenclature:

This system of nomenclature is employed to name the subspecies. In classification the subspecies is a category below the species. The subspecies name is also a Latin or Latinised word and follows the name of the species to which it belongs. For example, the specific name of the house crow, which occurs throughout India, Pakistan, Myanmar and Sri Lanka is Corvus splendens.

The house crows of India and Pakistan, Myanmar and Sri Lanka differ with each other in minute morphological features and are, thus, separated as distinct subspecies. The Indian and Pakistani house crow has been assigned the sub-specific name Corvus splendens splendens, the Myanmarian house crow, Corvus splendens insolens and the Sri Lankan house crow, Corvus splendens protegatus.

**The full scientific name of subspecies is, therefore, a trinomial name consisting of three names:** the names of genus, the species and subspecies itself.

## 5.2. Rules of Nomenclature:

In 1898, the International Congress of Zoology organised an International Commission on Zoological Nomenclature to formulate a set of rules, which would be binding for all taxonomical publications. The aim of International Code of Nomenclature is to make the stability in naming the taxa, avoiding the use of names which may cause error, ambiguity or confusion.

The standardization and legislation of nomenclatural practices are usually made at International Botanical and Zoological Congresses. This is done in order to put the nomenclature of the past in order and to provide guidelines for that of the future.

A few commonly followed rules and recommendations which may be considered as the essentials of a code of nomenclature are given below:

1. The system of nomenclature adopted is the binomial system to indicate the specific name and trinomial for sub-specific name.
2. The name of the genus is a single word in a nominative singular and must begin with a capital letter. The name of the species may be a single or compound word and must begin with a small letter.
3. The name of the author, who first publishes the name when describing it, should follow the species name and should rarely be abbreviated and is printed in roman type.
4. The scientific names of animals and plants must be different.
5. The names must be in Latin or Latinized form and are usually printed in italic type.
6. Within the animal and plant kingdom, no two genera can have the same name, and within a genus, no two species can have the same name.
7. The generic or specific name first published is the only one recognised. All duplicate names are synonyms.
8. When the name of the genus is not the one under which a species is placed by the original author, or if the generic name is changed the original author’s name is written in parenthesis.
9. The formation of family and subfamily names follows rules which are different in the Zoological and Botanical Codes.
10. A name must retain its original spelling, obvious errors and misprints may be corrected; diacritic marks are dropped.
11. A name may be based on any part of an animal or a plant, or on any stage of an organism’s life history.

### Recommendations:

**To make new names the following suggestions are followed:**

1. A name should be in Latin or easily converted into Latin form.

2. A name should not contain less than three and more than twelve letters.

3. A name should be easy to pronounce.

4. The name given should preferably describe some characteristics of the organism.

5. A name should not be derived from two languages.

6. A name should not be frivolous.

### Familiarity with Taxa:

According to Darwin (1850), **“All organic beings are found to resemble each other in descending degree, so that they can be classed in groups under groups”.** All major groups of animals can individually be subdivided into smaller and smaller subgroups.

Within the vertebrates we can distinguish subgroups such as birds and mammals; within the mammals, carnivores and rodents; within the carnivores, those that are dog-like, those that are cat-like and so forth. If one wants to construct a classification of these species, this classification is not arbitrary.

The task of classification then is the delimitation of these groups and their arrangement in an orderly sequence, i.e., hierarchy.

## 5.3. The Codes of Nomenclature

* **Biological Nomenclature:** system of principles, procedures and terms related to naming organisms
* **Nomenclatural codes**/**codes of nomenclature**: various rulebooks that govern biological nomenclature
* Criteria /internationally accepted codes for formally naming:

1. **Land plants, algae and fungi**=based on the rules and recommendations of ICBN:
2. **cultivated plants =** International Code of Nomenclature for Cultivated Plants(ICNCP);
3. **animals =** is International Code of Zoological Nomenclature or ICZN;
4. **prokaryotes or bacteria =** International Code of Nomenclature of Bacteria or ICNB; and a draft code for naming **Viruses.**

* All codes are independent and continuously modified from time to time.

### 5.3.1. Botanical Codes and Its Operative Principles

The criteria for formally naming land plants, algae, and fungi are based on the rules and recommendations of the **International Code of Botanical Nomenclature** or **ICBN**

Botanical names serve as symbols of a group of natural entities for the purpose of communication and data reference.Of interest is the fact that the ICBN deals with the names of extant or extinct (fossil) organisms traditionally treated as plants, i.e., encompassed by the field of botany. These include not only the land plants, but also the blue-green algae (Cyanobacteria); fungi, including chytrids, oomycetes, and slime moulds; photosynthetic protists and taxonomically related non-photosynthetic groups, many of these groups are not closely related phylogenetically. Yet, the ICBN still deals with these taxa.Separate nomenclatural codes exist for traditional zoology (International Code of Zoological Nomenclature) and for prokaryotes (International Code of Nomenclature of Bacteria).

One difficulty with this is that photosynthetic bacteria arenamed both under the ICBN and under the Bacteria Code. Similarly, some of the so-called protists (itself a paraphyletic assemblage) are named both under the ICBN and the Zoological Code. Thus, some organisms have two names, from two different nomenclatural codes. A future universal code, covering all forms of life, has been discussed recently and may be of advantage.

The International Code of Botanical Nomenclature governs the rules both for the specific names assigned to taxa and for the name endings that denote taxon rank.

* ICBN is organized into a number of rules (mandatory &written as articles), notes, recommendations and explanatory examples and footnotes.
* ICBN can only be changed by **International Botanical Congress (IBC),** with the International Association for Plant Taxonomy providing the supporting infrastructure
* first set of international rules governing the naming of plants was created at the second International Botanical Congress in Vienna in 1905=**Vienna Rules**
* IBC have produced revised versions of the Rules of Botanical Nomenclature which later on called the **ICBN.**

Table: Subsequently revised versions of Botanical Nomenclatural Rules or Code

|  |  |  |  |
| --- | --- | --- | --- |
| **Year of adoption** | **Informal name** | **Year of adoption** | **Informal name** |
| 1905 | Vienna Rules | 1981 | Sydney Code |
| 1935 | Cambridge Rules | 1987 | Berlin Code |
| 1952 | Stockholm Code | 1993 | Tokyo Code |
| 1969 | Seattle Code | 2005 | Vienna Code |
| 1975 | Leningrad Code | 2011 | Melbourne Code |

**The ICBN is utilized in two basic activities:**

1. Naming new taxa, which were previously unnamed and often not described; and
2. Determining the correct name for previously named taxa, which may have been divided, united, transferred, or changed in rank.

**Legitimate names** are those that are in accordance with the rules of the International Code of Botanical Nomenclature. Any name that violates one or more rules of the ICBN is known as an **illegitimate name**. A **valid name** is one that is **validly published**. The rules of the ICBN can be somewhat complex, often necessitating careful scrutiny (and a lawyerlike mentality).Points of controversy and periodic changes to the International Code of Botanical Nomenclature are voted upon during meetings of the International Botanical Congress, which assembles about every 6 years in some city around the world. As of this writing, the last International Botanical Congress was held in St. Louis, Missouri, in 1999. The following summary is based on the ICBN resulting from that Congress (Greuter *et al.* 2000).

#### 5.3.1.1 Principles of Nomenclature

The **Principles** of the International Code of Botanical Nomenclature are stated verbatim below from the 2000 St. Louis Code. Each of these will be covered in detail.

1. Botanical nomenclature is independent of zoological and bacteriological nomenclature. The Code applies equally to names of taxonomic groups treated as plants whether or not these groups were originally so treated.
2. The application of names of taxonomic groups is determined by means of nomenclatural types.
3. The nomenclature of a taxonomic group is based upon priority of publication.
4. Each taxonomic group with a particular circumscription, position, and rank can bear only one correct name, the earliest that is in accordance with the Rules, except in specified cases.
5. Scientific names of taxonomic groups are treated as Latin regardless of their derivation.
6. The Rules of nomenclature are retroactive unless expressly limited.

The details of the International Code of Botanical Nomenclature are organized into a number of **Rules** (which are mandatory and written out as Articles), **Notes** (which are binding and clarifying), **Recommendations** (which are not binding but suggested), and explanatory **Examples** and **Footnotes**.Currently, the entire International Code of BotanicalNomenclature is available on a Web site (Greuter *et al.* 2000).

**A. Scientific Names**

The fundamental principle of nomenclature is the fourth principle of the ICBN, stating that every taxon, whether species, genus, family, etc., can bear only one correct name (see below for precise definition of correct name). This is only common sense. Confusion would reign if taxonomic entities could bear more than one name or if one name could refer to more than one entity. The names assigned by the rules of the ICBN are known as **scientific names**. Scientific names are, by convention, in the Latin language. Scientific names of species are **binomials**, i.e., composed of two names. The binomial convention was first consistently used by Carolus Linnaeus. Prior to the use of binomials, the designation of species was inconsistent and may have utilized several words.

As an example of a binomial, the species commonly known as sweetgum has the scientific name

*Liquidambarstyraciflua*.

The first name of the binomial, *Liquidambar*in this case, is the **genus name** and is always capitalized. The genus name may be abbreviated by its first letter, but only after it is spelled out in its entirety (and would not be confused with another genus name); thus, the above may be abbreviated as:

*L. styraciflua*.

The second name of the binomial, *styraciflua* in this example is the **specific epithet**. The specific epithet may be capitalized if it is a commemorative (named after a person or place), but this is optional; the trend today is to never capitalize the specific epithet. Binomial species names are always either italicized or underlined. Taxa above the rank of genus are notunderlined or italicized.

A species name is always the entire binomial.

* It is incorrect to say that the species name for sweetgum is *styraciflua*, as this is the specific epithet; the species name is *Liquidambar styraciflua*.

In contrast to scientific names, many taxa also bear **common names** (also called vernacular names), which are generally used by people within a limited geographic region.Common names are not formally published and are governed by no rules.

**Importance of using scientific names**

1. Because only scientific names are universal, used the same world-wide; common names may vary from region to region, even within a country or within regions of a country.

For example, species of the genus *Ipomoea* are known commonly as

* Morning glory in the United States, but as
* Woodbine in England,differences in language will, of course, further increase the number of different common names.

1. Common names are not consistent. One taxon may bear more than one common name, these often varying in different regions. For example, *Adenostoma fasciculatum* of the Rosaceae is known by at least two common names,

* Chamise and
* Grease wood.

Alternatively, a single common name may refer to more than one taxon.

For example Hemlock may refer to two quite different plants, either a species of;-

* *Tsuga*, a coniferous tree of the Pinaceae, or
* *Conium maculatum*, an herb of the Apiaceae (the extract of which Socrates drank in execution).

1. Common namestell nothing about rank and often nothing about classification, whereas scientific names automatically indicate rank and yield at least some information about their classification.For example, sea-blite tells nothing about rank; it could be variety, species, genus, or family. However, one immediately knows that *Suaeda californica* is at the rank of species and is a close relative to other species of *Suaeda*.
2. Many, if not most, organisms have no common name in any language; thus, scientific names alone must be used to refer to them. This is especially true for plants that are non showy, occur in remote areas, or belong to groups whose members are difficult to distinguish from one another. There is a tendency in some works to arbitrarily convert all scientific species names into common names by translating from the Latin, even when these common names are not used by the native people. For example, *Carex aurea* mightbe designated golden care x or golden sedge, even if these names are not in common useage. It is the author s opinion that this is less than ideal policy and that it is preferable simply to utilize scientific names and refer to common names only if they are, in fact, commonly used.

**Ranks**

Taxa are classified hierarchically by **rank**, in which a higher rank is inclusive of all lower ranks. [Note that there are principal ranks, secondary ranks, and additional ranks (if needed) that may be used by adding the prefix sub. Each scientific name of a particular rank must end in a certain suffix according to the rules and recommendations of theICBN.

For example, Asteridae is a taxon at the rank of subclass, Asterales is at the rank of order, and Asteraceae is at the rank of family, etc. Note that taxa above the rank of genus are *not* underlined or italicized.One exception to these rank endings of taxa is the acceptance of eight alternative family names, none of which end in -aceae.

These are Compositae (= Asteraceae),

Cruciferae (= Brassicaceae),

Gramineae (= Poaceae),

Guttiferae (= Clusiaceae/Hypericaceae),

Labiatae (= Lamiaceae),

Leguminosae (= Fabaceae),

Palmae (= Arecaceae), and

Umbelliferae (= Apiaceae).

In addition, within the Fabaceae (= Leguminosae), the subfamily name Papilionoideae is an acceptable alternative to the Faboideae. The trend today is to consistently apply the type principle by using the standardized family names that end in -aceae and to use subfamily names that are based on these (e.g., to use Faboideae over Papilionoideae ). However, plant taxonomists should know these alternative names, as they are often used in older, as well as some current, floras and other taxonomic works.

**Table:** Taxonomic ranks recognized by the ICBN.

|  |  |  |  |
| --- | --- | --- | --- |
| **No** | **Rank** | **Standard endings and examples** | |
| **Plants** | **Examples** |
| 1 | **Kingdom** | - | **Plantae** |
| 2 | **Division(Phylum)** | -phyta | Magnoliophyta |
| 3 | Subdivision | -phytina | Magnoliophytina |
| 4 | **Class** | - opsida | **Asteropsida** |
| 5 | Subclass | - idea | Asteridae |
| 6 | **Order** | -ales | **Asterales** |
| 7 | Suborder | -ineae | Asterineae |
| 8 | **Family** | -aceae | **Asteraceae** |
| 9 | Subfamily | -oideae | Asteroideae |
| 10 | Tribe | -eae | Heliantheae |
| 11 | Subtribe | -inae | Helianthinae |
| 12 | **Genus** | - | ***Helianthus*** |
| 13 | Subgenus | - | *Helianthus* |
| 14 | Section | - | *Helianthus* |
| 15 | Series | - | *Helianthus* |
| 16 | **Species** | - | ***Helianthus annuus*** |
| 17 | Subspecies (susp., ssp.) | - | *Helianthus annuus*ssp. *annuus* |
| 18 | Variety(var) | - | *Helianthus annuus*var. *annuus* |
| 19 | Form (f) | - | *Helianthus annuus*f. *annuus* |

**Position** is the placement of a taxon as a member of anothertaxon of the next higher rank. For example, the position of the genus *Aster* is as a member of the family Asteraceae. Taxa may be the same in rank but differ in position. *Rosa* and *Aster*are both at the rank of genus but differ in position, the former in the Rosaceae, the latter in the Asteraceae.The prefix *sub-* can be used formally in a rank name in more categories are needed, such as*subgenus* or *subspecies*. In a less formal sense, the prefix *sub*- or *infra-* can be used to denote taxa below one of the major ranks. For example, *subfamilial* or *infrafamilial*taxa are those *below* family, including subfamily, tribe, subtribe, genus, subgenus, section, species, subspecies, variety, etc.

A subspecies or variety name is a **trinomial** (three names), e.g., *Toxicodendron radicans* ssp. *diversilobum* or *Brickelliaarguta* var. *odontolepis*. In these examples, the **sub specific epithet** is *diversilobum*; the **varietal epithet** is *odontolepis*. Note that, technically, the rank of subspecies is above that of variety. In practice, subspecies and variety are sometimes used interchangeably. However, it is possible, but very rare, to have a subspecies that is divided into varieties itself (these constituting quadrinomials!).

**Authorship of scientific name**

All scientific names at and below the rank of family have an **author**, the name of the person who first validly published the name, for example, the full name (including authorship) of the family Rosaceae is Rosaceae Jussieu because de Jussieu first formally named the family. In other examples, the full name of the tribe Conostylideae is Conostylideae Lindley; that of the genus Mohavea is MohaveaA. Gray; that of the species *Mohavea confertiflora* is *Mohaveaconfertiflora* (Bentham) Heller; and that of the subspecies *Monardella linoides* ssp. *viminea* is *Monardella linoides* A. Gray ssp. *viminea* (Greene) Abrams. Author names are often abbreviated, such as Haemodoraceae R. Br. (for Robert Brown) or *Liquidambar styraciflua*L. (L. being the standardized abbreviation for Linnaeus). (See Name Changes for an explanation of author names appearing in parentheses.)Although authorship is part of a scientific name and should be cited in all scientific publications, in practice the author is not typically memorized or recited as part of a scientific name. The authors of higher taxa are sometimes omitted in print even in scientific publications, except in detailed monographic treatments in which the nomenclatural history of thetaxaunder study is described. In manyfloras and journal publications, only species and infraspecific taxa (subspecies or varieties) are listed with full authorship, and these generally only once, when the name is first cited.

**Principles of Scientific names**

1. **Learning scientific names**

As argued earlier, it is important to learn the scientific names of plants, correctly spelled. The serious plant taxonomist will learn many hundreds of scientific names in his/her lifetime, still just a tiny fraction of the more than 250,000 described plant species. Beginners may at first have difficulty learning scientific names. Some suggestions for mastering them are as follows.

First, learn to divide into syllables and accent scientific names (see **BOTANICAL NAMES**). It is often easier to recite and spell a scientific name if it is consciously broken down into syllables, each of which is separately pronounced. Second, use mnemonic devices. Select one distinctive feature about the plant. Then find a common word that *sounds* somewhat similar to the scientific

name. Link the distinctive plant feature with the similar sounding word in an active, vivid mental image, the weirder and more active the better. Thus, when you see the plant, you associate it with the mental image, which sounds like (and reminds you of) the scientific name. For example, visualizing liquid amber flowing from the distinctive, ball-shaped fruits of sweetgum may help you remember the genus name, *Liquidambar*. Third, learn the etymology (meaning) of scientific names.

Scientific names often are descriptive about the morphology of the plant. Once you know, for example, that the Latin word *alba* means white or that *leptophylla* means narro wleaved, you can better associate the name with the organism. Other scientific names may be named after a person or place of significance; learning the history of these commemorative names may be helpful in memorizing them. Finally, there is no substitute for continual practice and review. Use a combination of both oral and (for correct spelling) written recitation, with the plant, plant specimen, photograph, or mental image in view.

**B. Nomenclatural Types**

The second principle of the ICBN states that scientific names must be associated with some physical entity, known as a **nomenclatural type** or simply **type**. A nomenclatural type is almost always a specimen, e.g., a standard herbarium sheet specimen, but it may also be an illustration. The type serves the purpose of acting as a reference for the name, upon which the name is based. If there is ever any doubt as to whether a name is correct or not, the type may be studied.There are different types of types.

* A **holotype** is the one specimen or illustration upon which a name is based, originally used or designated at the time of publication. It serves as the definitive reference source for any questions of identity or nomenclature. It is recommended that a holotype be deposited in an internationally recognized herbarium and cited as one of the criteria for the valid publication of a name (see later discussion).
* Holotypes constitutethe most valuable of specimens and are kept under safe keeping in one (usually a major) herbarium.
* **Isotype** is a duplicate specimen of the holotype, collected at the same time by the same person from the same population. The ICBN recommends that isotypes be designated in the valid publication of a new name. Isotypes are valuable in that they are reliable duplicates of the same taxon and may be distributed to numerous other herbaria to make it easier for taxonomists of various regions to obtain a specimen of the new taxon.
* A **lectotype** is a specimen that is selected from the original material to serve as the type when no holotype was designatedat the time of publication, if the holotype is missing, or if the original type consisted of more than one specimen or taxon.
* A **neotype** is a specimen derived from a nonoriginal collection that is selected to serve as the type as long as all of the material on which the name was originally based is missing.

**Other types of types include**

1. **Syntype**, which is any specimen that was cited in the original work when a holotype was not designated; alternatively, a syntype can be one of two or more specimens that were all designated as types;
2. **Paratype**, a specimen cited but that is not a holotype, isotype, or syntype.
3. **Epitype**, a specimen (or illustration) that is selected to serve as the type if the holotype, lectotype, or neotype is ambiguous with respect to the identification and diagnosis of the taxon.

Normally, we think of types as referring to a species orinfraspecific taxon. However, type specimens may serve as references for higher taxonomic ranks as well. For example, the type specimen for a genus name is the same as the one for the species within the genus that was published first. The type specimen for a family name is the same as the one for the genus within the family that was published first.

**C. Priority of Publication (3rd principle of the ICBN)**

The third principle of the ICBN is priority of publication, which generally states that of two or more competing possibilities for a name, the one published firstis the correct one, with some exceptions. Priority of publication only applies to taxa at the rank of family and below and does not applyoutsidea particular rank (with a transfer in rank; see laterdiscussion).Forexample, of two competing names (both legitimate and validly published) Mimulus (published in 1753) and *Diplacus* (published in 1838) the genus *Mimulus* has priority and is the correct name when the two genera are combined into one. The principle of priority for vascular plants starts 1 May 1753 with the publication of *SpeciesPlantarum* by Linnaeus; names published prior to that are not considered for priority.

**D. Conservation of Names**

One adverse effect of the principle of priority is that scientific names that are well known and frequently used may be replaced by some other name if the latter was discovered to have been published earlier. This lends a degree of instability to nomenclature. However, in such a case, a petition may be presented (in the botanical journal Taxon) and voted upon at the International Botanical Congress to conserve one name over another that actually has priority. Such a procedure is outlined as three Amendments to the ICBN: Nomina familiarum conservanda, Nomina generica conservanda etrejicienda, and Nomina species conservanda. The rationale for the conservation of names is to provide greater stability in nomenclature by permitting names that are well known and widely used to persist, even upon the discovery of an earlier, but more obscure, name.

**E. Name Changes**

Occasionally, the name of a taxon will change. Name changes can occur for only two reasons: (1) because of the recognition that one name is contrary to the rules (i.e., is illegitimate), and, thus, another name must take its place; or (2) because additional taxonomic study or research (for example, a cladistics analysis) has resulted in a change of the definition and delimitation of a taxon; this process is known as a **taxonomicrevision**.There are four basic types of nomenclatural activities that can result in a name change.

* First, a single taxon may be **divided** into two or more taxa, often called se gregate taxa because they are segregated from one another relative to the original classification. This is done generally via the recognition of features that clearly distinguish two or more groups from one another. For example, the genus *Langloisia* hasbeen split into two genera, *Langloisia* and *Loeseliastrum*, based on a number of morphological, anatomical, and palynological (pollen) features that distinguish them. Ideally, the segregate groups should be monophyletic, as based upon a rigorous cladistic analysis. Other examples of taxa being divided are:

1. The genus *Carduus* of the family Asteraceae is often split into two genera: *Carduus*, having barbellate pappus bristles, and *Cirsium*, having plumose pappus bristles
2. The genus *Rhus* of the Anacardiaceae has been split into several segregate genera, such as *Malosma*, *Rhus*, and *Toxicodendron*, the last including poison-oak and poison-ivy
3. The classical family Liliaceae has been split into numerous families, such as the Alliaceae, Hyacinthaceae, Liliaceae s.s., and Melanthiaceae

The large genus *Haplopappus* of the Asteraceae has been split into several genera, including *Anisocoma*, *Ericameria*, *Hazardia*, *Haplopappus*, and *Isocoma* Note that when a larger taxon is divided into two or more smaller taxa of the same rank, the terms **sensu lato** (abbreviated **s.l.**) and **sensu stricto** (abbreviated **s.str.** or **s.s.**) may be used to distinguish the more inclusive and less inclusive treatments, respectively. For example, *Haplopappus* s.l. contains many more species than *Haplopappus*s.s., the latter of which is what remains after *Haplopappus* s.l. is split into many segregate genera.

* A second, major name change occurs when two or more separate taxa are **united** into one. One reason for uniting taxa is the recognition that features previously used to distinguish them are, upon more detailed study, unsupportive of their being different; i.e., there is no clear character state discontinuity. Anotherreason to unite taxa may be based on cladistics studies, in which of two or more separate taxa, one (or more) is demonstrated to be paraphyletic; thus, one way to eliminate a paraphyletic taxon is to unite it with other taxa such that the new inclusive group is now monophyletic (see Chapter 1). In cases of taxa being united, the final name used is that which was publishedearliest, according to the principle of priority.
* Examples of taxa being united are:

1. The species *Bebbia juncea* and *Bebbia aspera*, which were considered indistinct and were united into one species, *B. juncea*
2. The genera *Diplacus* and *Mimulus*, which were united into one genus, *Mimulus*
3. The families Apocynaceae and Asclepiadaceeae, which have been united into one family, the Apocynaceae (which could be designated Apocynaceae s.l. to distinguish it from the earlier circumscribed less inclusive family)

Third, a taxon may be **transferred in position**, i.e., from one taxon to another of the *same rank*. Examples of this are:

1. The species *Rhus laurina* was transferred in position asa member of the genus *Malosma*, the new species name being *Malosma laurina*
2. The species *Sedum variegata* was transferred to the genus *Dudleya*, the new species name being *Dudleyavariegata*

Note that a transfer in position may be an automatic result of uniting or dividing taxa of higher rank. For example, if the *genera Diplacus* and *Mimulus* are united into the genus *Mimulus*, then the *species* of *Diplacus* must be transferred in position.

Fourth, a taxon may be **changed in rank**. Examples include:

1. The species *Eruca sativa* was changed to the rank ofsubspecies (of the species *E. vesicaria*), the new combination being *Erucavesicaria*ssp. *Sativa*
2. The variety *Viguiera deltoidea* var. *parishii* was changed to the rank of species, the new name being *Viguieraparishii* (with *V*. *deltoidea* persisting as a separate species equivalent in circumscription to the earlier *V*. *deltoidea*var. *deltoidea*).

Note in the two rank change examples just given that the original names for the epithets are retained. The retention of a name that is changed in rank is recommended (but not required) by the ICBN, but only if an earlier name for the same taxon had not already been published at that rank (and also, only if the *same* name had not already been used for another taxon; see **homonym**).

The principle of priority does not apply outside the rank of a taxon, however; this means that if a name is changed in rank, the date of publication of the original name (before being changed in rank) cannot be considered in evaluating priority of publication with respect to the change.In some cases a taxonomic study results in the **remodeling** of a taxon, i.e., a change in diagnostic characteristics, those that distiguish the taxon from other taxa. In these cases, a name change is not warranted and the rules of the ICBN need not apply.A **basionym** is the name-bringing or epithet-bringing synonym, i.e., the original (b ut now rejected) name, part of which has been used in a new combination. As seen earlier, if a species or infraspecific name is transferred in position or rank, the specific or infraspecific epithet of the (nowrejected) basionym may be retained (unless violating another rule of the code, such as priority of publication, e.g., if the taxon had already been named, or if the name had already been used for another taxon at that rank). The name of the author(s) who originally named the basionym is also retained and placed in parentheses ahead of the author who made the change. Thus, botanical names may have two sets of authors: the author(s) set in parentheses who originally named the basionym, and the author(s) who made the name change.

From some of the examples cited previously:

1. When *Sedum variegata*Wats. was transferred to the genus *Dudleya* by Moran, the new species name became *Dudleya variegata* (Wats.) Moran. The original epithet, *variegata*, is retained, and the author associated with that epithet, Watson in this case, is also retained, but is placed in parentheses preceding the new author. Thebasionym in this case is *Sedum variegate* Wats., the original name.
2. When *Dilatris caroliniana* Lam. was transferred to the genus *Lachnanthes* by Dandy, the new species name became *Lachnanthes caroliniana* (Lam.) Dandy. The basionym in this case is *Dilatris caroliniana* Lam.
3. When *Fumaria bulbosa* L. var. *solida* L. was elevated to the rank of species by Miller, the new name became *Fumaria solida* (L.) Miller. The basionym in this case is *Fumaria bulbosa* L. var. *solida* L. Subsequent to this change, *Fumaria solida* (L.) Miller was transferred in position by Clairv to the genus *Corydalis*, the new name becoming *C. solida* (L.) Clairv [*not C. solida* (Mill.)Clairv]. Note that it is the author of the varietal name of the basionym, *Fumaria bulbosa* L. var. *solida* L., that is retained in parentheses.

An **autonym** is an automatically created name for infrafamilial, infrageneric, and infraspecific

taxa. Autonyms are used whenever a family is divided into subfamilies,tribes, or subtribes; a genus is divided into subgenera or sections; or a species is divided into subspecies or varieties. Of the two or more subtaxa formed, the autonym is assigned based on priority, i.e., to the group containing the taxon that was published first. Autonyms have no authors; only the higher taxa upon which they are based and the other subtaxa have formal authorship. For example, Isely split *Lotusstipularis* (Benth.) E. Greene into two varieties: *L.stipularis* (Benth.) E. Greene var. *ottleyi* Isely and *L. stipularis* (Benth.) E. Greene var. *stipularis*; note that the latter variety, containing the autonym, lacks authorship because its type is the same as that for the originally described species.

For infrafamilial taxa, the autonym has the same root name as the family but a different ending that corresponds to the infrafamilial rank. For example, the family Euphorbiaceae is usually divided into subfamilies, one of which, the Euphorbioideae, is the autonym; this subfamily, of course,contains the genus *Euphorbia*, the type for the family.For infrageneric taxa, the autonym is identical to the genus name and should be preceded by the name of the rank to avoid confusion. For example, *Ceanothus* (a genus) consists of two subgenera, subgenus *Ceanothus* and subgenus *Cerastes*; subgenus *Ceanothus* is the one that includes the type for the genus itself. For infraspecific taxa, autonyms are identical to the specific epithet. For example, *Eriogonumfasciculatum* is divided into several varieties, one of which, *Eriogonum fasciculatum* var. *fasciculatum*, includes the autonym (and is based on the original type specimen for the species).

**Valid Publication**

According to the ICBN, in order for a scientific name to be formally recognized, it must be **validly published**. There are four general criteria for valid publication of a name.

* First, the name must be effectively published, which means that it must be published in a journal commonly available to botanists (not, say, in the local newspaper or National Enquirer magazine).
* Second, the name must be published in the correct form, i.e., properly Latinized, with the rank indicated (e.g., as sp. no v. or gen. no v. ; see **Abbreviations).** Such a legitimate name in correct form is known as an admissible name.
* Third, the name must be published with a Latin description or diagnosis or with a reference to such. The Latin description may be brief, e.g., listing how the new taxon is different from a similar, related taxon. (In addition, a more detailed description in some vernacular language, or a reference to a previous description, is usually included but not required.)
* Fourth, for taxa of the rank of genus and below, a nomenclatural type must be indicated; the location of this type is also indicated (using the acronyms of Index Herbariorum; see Holmgren *et al*. 1990; Chapter 18). An example of a valid

publication, illustrating these criteria, is seen in Figure 16.2.The full citation of a scientific name includes not only the authorship, but also the place and date of publication. For example, the full citation for the species cited in Figure 16.2 is *Perityle vigilans* Spellenb. & A. Powell, Syst. Bot.

15: 252. 1990. Full citations are listed in the citations of the International Plant Names Index (see References for Further Study).

**SYNONYMS**

A **synonym** is a rejected name, *by a particular author or authors*. Synonyms are rejected for either of two reasons:

1. Because they are illegitimate, i.e., contrary to the rules of the ICBN; or
2. Because of taxonomic judgment, i.e., a particular author rejects the classification represented by the synonym. Synonyms may be based on the same or on adifferent type specimen from the correct name.

A **correct name** is a legitimate (and therefore validly published) name that is accepted *by a particular author orauthors*. Recall that the fundamental principle of the ICBN states that each taxon can have only *one* correct name. Thus, if there are two or more competing names for the same taxon, e.g., *Malosma laurina* (Nutt.) Abrams and *Rhus laurina*Nutt.,only one of them can be correct. However, *which* name is correct may depend on the author(s) of a given reference book or journal.

For example, according to one author, *Rhuslaurina* Nutt.is the correct name and *Malosmalaurina* (Nutt.) Abrams is the synonym. According to other authors, *Malosma laurina*(Nutt.) Abrams is the correct name and *Rhus laurina* Nutt. is the synonym.Synonyms are typically indicated in brackets following the correct name, such as *Malosma laurina* (Nutt.) Abrams [*Rhus laurina* Nutt.] or *Machaeranthera juncea* (Greene) Hartman [*Haplopappus juncea* Greene]. Alternatively, if a synonym (according to one author) is cited or referenced, the correct name is often indicated preceded by an = sign. For example, in *Cyrtanthera* Nees = *Justicia*, the correct

name is *Justicia* and the synonym is *Cyrtanthera*.

A **homonym** is one of two (or more) *identical* names(not including authorship) that are based on different typespecimens. The later homonym, based on publication date, isillegitimate (unless it is conserved; see earlier discussion).For example, *Tapeinanthus* Herb.(1837), of the Amaryllidaceae,and *Tapeinanthus* Boiss.ex Benth. (1848), of the Lamiaceae,are homonyms. The later homonym in the Lamiaceae is illegitimate [and was renamed *Thuspeinanta* T. Durand (1888)].

A **tautonym** is a binomial in which the genus name and specific epithet are identical in spelling. Tautonyms are not permitted in botanical nomenclature. For example, the name *Helianthus helianthus* is a tautonym and illegitimate, whereas *Helianthus helianthoides* is not a tautonym and would be permitted. (Note that zoological nomenclature does permit tautonyms, as in *Gorilla gorilla*.)

**ABBREVIATIONS**

Certain abbreviations are used in scientific names. For example, the word **ex** means validly published by. For example, *Microseris elegans* Greene ex A. Gray means that Asa Gray validly published the name *Microseris elegans* that was originally proposed (but not validly published by) Greene.The **e x** plus the author(s) *preceding* it may be omitted, as in*Microseris elegans* A. Gray.The word **in** means in the publication of, referring to a name published within a larger work authored by the person(s) following the **in**. For example, *Arabis sparsiflora* Nutt. In T. & G. means that Nuttall validly published the name *Arabissparsiflora* in another work authored by Torrey & Gray. The **in** plus the author(s) *following* it may be omitted for brevity, as in *Arabis sparsiflora* Nutt. (The use of **in** is not recommended by the ICBN.). An × indicates a hybrid. For example, *Salvia* × *palmeri* (A. Gray) E. Greene is a named (validly published) taxon representing a hybrid between two species: *S. apiana* Jepson and *S. clevelandii* (A. Gray) E. Greene. Alternatively, this hybrid could be represented as *S. apiana* Jepson × *S. clevelandii* (A. Gray) E. Greene. Hybrids may also be indicated by placing the prefix *notho*- prior to the rank name, as in *Polypodiumvulgare* nothosubsp. *mantoniae* (Rothm.) Schidlay (indicatingthat the named subspecies is of hybrid origin).

The abbreviation **sp. nov.**following a binomial (e.g.,*Eryngium pendletonensis*, sp. nov. ) refers to the Latin*species nova* and means that the species is new to science.Similarly, **gen. nov.** (*genus novum*) cites a new genus name.The abbreviation **comb.nov.**following a binomial refersto the Latin *combinatio nova* and means that the taxonhas recently been transferred to a new position or rank. An example is *Porella acutifolia* (Lehm. & Lindenb.)Trevis.var. *ligulifolia* (Steph.) M. L. So, comb. nov. Two abbreviations af, f.and cf. are used to describeplant specimens whose identity is uncertain. The distinction between the two abbreviations is unclear, as different taxonomists have used them with slightly different meanings.

The abbreviation **aff.**preceding a taxon name literally means related to (Latin *affinis*, related, connected), as in *Calyptridium* aff. *monandrum* or af f. *Calyptridium monandrum*. This abbreviation implies some type of close relationship, presumably an evolutionary relationship, but also that the specimen differs from the cited taxon in some way, e.g., beyond the described range of variation for one or more characters; the cited specimen might, in fact, be indicative of a new taxon.

The abbreviation **cf.** (Latin *confer*, compare) preceding a taxon name, as in *Calyptridium* cf.*monandrum* or cf. *Calyptridium monandrum*, indicates that the identify of a specimen is more questionable or uncertain (perhaps because references or comparative specimens are not available), and should be compared with specimens of the taxon indicated (i.e., the name followingcf. ) for moredetailed study.

As mentioned earlier, **s.l.** (*sensu lato*) means in the broad sense, referring to a broad, inclusive taxon circumscription, and **s.str.**or**s.s.** (*sensu stricto*) means in the strict sense, referring to a narrow, exclusive taxon circumscription. Other, minor abbreviations or specialized words include:

1. **auct. non** (*auctorum non*) refers to a misapplication of a name, such that the type specimen of the name does notfall within the circumscription of the taxon being referredto by that name
2. **emend.** (*emendatio*) means a correction or amendment
3. **et** is Latin for and
4. **nom. cons.** (*nomen conservandum*) means a conserved name
5. **nom. nov.** (*nomen novum*) means a new name
6. **nom. nud.** (*nomen nudum*) means published without a description or diagnosis, making the name invalid
7. **non** is Latin for not
8. **orth. cons.** (*orthographia conservanda*) means a con-served spelling.
9. **stat. nov.** (*status novus*) means a change in rank,e.g., elevating a varietal name to specific status
10. **typ. cons.** (*typus conservandus*) means a conserved type specimen
11. **typ. des.** (*typus designatus*) means the designation of a type specimen
12. **vide** (*video*) means to cite a reference
13. **!** (symbol for *vidi*, I have seen it ) means a confirmation of a name

**Independence of Botanical Nomenclature**

The International Code of Botanical Nomenclature is independent of the International Code of

Zoological Nomenclature. Thus, there may be some names of plants, algae, or fungi that are identical to those of some animals (and Protista). For example, the genus *Morus* refers both to a flowering plant, the mulberry, and to a bird, the gannett; *Ficus* is the genus name of the figs and of a group of gastropods. A separate code is also used for the Prokaryotes (including the bacteria) and viruses.

**Retroactivity of the ICBN**

The Rules of the International Code of Botanical Nomenclature are retroactive, except in specified cases.

**Treatment of botanical names in Latin Language**

* The fourth principle of the ICBN is that botanical names are treated as Latin, a language chosen because of its classical history (in the past being the language of scholars)
* No matter what the language of the person who published a name, the name itself must consist of direct Latin words or be Latinized

**Gender**

* All Latin words have a gender: masculine, feminine, or neuter.
* Gender determination is usually needed for names at the rank of genus or below.
* The standardized gender endings are:

**Masculine Feminine Neuter**

-us -a -um

-er -ra -rum

-is -is -e

-r -ris -re

* The first row of endings (-*us*, -*a*, and -*um*) are those most commonly used.
* e.g. The gender of the genus *Amaranthus*is masculine, *Crassula*is feminine, and *Polygonum* is neuter.
* Specific or infraspecific epithets are usually adjectives, the endings of which must agree in gender with that of the genus name, as in *Amaranthusalbus*, *Crassulaconnata*, and *Eriogonumfasciculatum*ssp*. polifolium*.
* Note that a **name change** (divided, united, transferred in position, or changed in rank) can necessitate **a change in thegender ending of a specific epithet.**

e.g. For species *Haplopappussquarrosus*, the ending (-*us*) is masculine. When this species is transferred to the genus *Hazardia*, the new name becomes *Hazardiasquarrosa*. Although the root of the specific epithet does not change, its ending may, in order to agree in gender with the new genus name.

**Number**

* Names of genera, infrageneric names (such as subgenera or sections), and species or infraspecific combinations are all treated as singular in Latin.
* All taxon names above the rank of genus are treated as Latin plural nouns.

**Commemoratives**

* Commemorative names are those named after a person or place.
* Specific or infraspecific commemorative names are usually treated as the genitive case (denoting possession) and must have genitive endings.
* For male commemoratives, the ending is (1) -*ii*, if the name ends in a consonant, as in *Isoetesorcuttii*(unless the terminal consonant is -*r* or -*y*, in which case a single -*i* is used, as in *Erigeron breweri*; (2) -*i*, if the name ends in a vowel other than *a*, as in *Arctostaphylospringlei*.
* For male commemorative names that end in -*a* and for all female commemorative names (regardless of ending) an -*e* is added, as in *Baccharisvanessae*or *Carexbarbarae*.

### 5.3.2. Zoological Nomenclature

In this article we will discuss about zoological nomenclature.

#### a. Need for Zoological Nomenclature:

Names are given to all animals. The name of a particular animal differs in different languages. Even within the same country one animal is known in different names in differ­ent regions. To avoid this intricacy of names, it was proposed to give them a scientific name.

The term nomenclature comes from the two Latin words [L. nomen = name and clatura = calling (from ‘calare’ = to call)] and means literally to call by name. Animals are iden­tified by names, and scientific names for the animals are necessary for the immediate access of a particular taxon.

Zoological nomenclature is as botanical nomenclature serves to minize confusion among world community due to enormous quantity invertebrate and vertebrate fauna. Zoloogical nomenclature follows the following some reccommondations.

### 5.3.3. International Code of Zoological Nomenclature

The below mentioned article provides an overview on International Code of Zoological Nomenclature:-

1. Brief History of International Code of Zoological Nomenclature

2. Parts of International Code of Zoological Nomenclature

3. Rules

### **5.3.3.1. Brief history of international code of zoological nomenclature**:

The need for a code to give a scientific name to every species was first realized by British Association for the Advancement of Science in 1842, when a set of rules were framed by it. This was also felt by American Association for the Advancement of Science in 1877. Then similar learned bodies in different countries like France, Germany and Soviet Union devel­oped codes for their respective countries. In 1889, at the International Congress of Zoology in Paris, discussions were made to find out some common code of nomenclature. First version of the code .was adopted in the 5thInternational Congress of Zoology in Berlin in 1901. In the 15th session held in London in 1958, the codes were rewritten and published on 6th November, 1961 and the updated version of the code (1961) was made available in 1964 (2nd edition).

This code is concerned only up to naming of superfamily and did not satisfy the zoologists. The latest edition (4th edition) of the code was published in 1999 and its effective use has started from 2000.

The International Zoological Congress elects a judicial body, called International Commis­sion of Zoological Nomenclature which interprets or recommends the provisions of the code for classification or nomenclatural problems of the animals.

Again the International Code of Zoological Nomenclature (ICZN) formed by the International Commission of Zoological Nomenclature to see the rules and principles of nomenclature and the application of these rules for both living and fossil animals.

### **5.3.3.2. 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 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.

### **5.3.3.3. 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.

**Among these rules, 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 kind of gastropod shell) is Ficus. The scientific name of fig tree is *Ficus carica* or *F. indica*, 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, is trinomial. Such a system of naming by three Latin or Latinised words is known as trinomial nomenclature. Sometimes it becomes imperative to recognize subspecies within a species and is given a third specific name.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.
3. 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.:

Table 5:1 species name with adjective form in nominative singular agreeing in gender with genus name which is in noun form.

|  |  |  |
| --- | --- | --- |
| **Ending in species name** | **Ending in genus name** | **Full name of the species** |
| Musculine eding(\_i) | (\_i/-us/-es) | Common mongoose(*Herpestes edwardsi*)  River lawing (*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 elephantium*)  Common crane (*Grus gyrus*)  Lesser lack-backed gull (*Larus fuscus*) |

The specific name (species part) indicates distinctness while generic part shows relationship.

1. 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 geographical place, the endings of the species are ‘ensis’, ‘iensis’,:see table 5.2 below.

Table 5.2 Naming of species after Pesron and place

|  |  |  |  |
| --- | --- | --- | --- |
| **Name after Pesron and place** | **Species name** | **Person name** | **Common name** |
| Species name after Persons name | *Sepia prashadi* | Prasad + i | Hooded cuttle fish |
| *Rhacophorus jerdonii* | Jerdon + ii | Tree frog |
| *Todarodes filippovae* | Filippov + ae | Antarctic flaying squid |
| Species name after place name | *Varanus bengalensis* | Bengal + ensis | Common Indian monitor |
| *Isistius brasiliensis* | Brasil + iensis | Cookiecutter shark |
| *Chaetodon madagascariensis* | Madagascar + iensis | Buttefly fish |

1. 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 = recessChina-rose (a kind of coloured rose)Hibiscus rosa-sinensis. L. rosa = rose
2. 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.:

Table 5:2 The naming of sub gunus and subspecies

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Name** | **Genus** | **Subgenus** | **Species** | **Subspecies** |
| Fan shell (Bivalvia) | Atrina | (servatrina) | Pectinata | pectinata |
| Dussumieri’s half-beak (Osteichthyes) | Hemirhampus | (Reporthampus) | dussumieri |  |

7. 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 or Felis leo L., 1758.

8. 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., mulleri becomes muelleri.

9. 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,

For Example:-

Lion(Felis leo Linnaeus, 1758) or Lion(Panthera leo Linnaeus, 1758)

Jungle cat(Felis chaus)

11. The names are not acceptable before the publication of Linnaean treatise, Systema Naturae (10th edition) which was published on 1st 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) [in printed form]

Indian leopard—*Panthera pardus* fusca [in handwritten or typed forms]

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 suprageneric taxa from superfamily to tribe, e.g.

Table 5:3 Name change fromsuperfamily to subtribe

|  |  |  |
| --- | --- | --- |
| Taxon level | Ending of the name | Examples |
| Superfamily | \_\_\_\_oidea(for vertebrates) or | Homoinoidea |
|  | \_\_\_\_acea(for invertebrates) | Genus Homo(Latin) = man  Genitive Hominis |
| Family | \_\_\_\_idae | Hominidae [Homin + idae] |
| Subfamily | \_\_\_\_inae | Homininae [Homin + inae] |
| Tribe | \_\_\_\_ini |  |
| Subtribe | \_\_\_\_ina |  |

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

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

18. Nomenclature of 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 (Mayr and Ashlock, 1991).

21. As per the zoological code’s provision (Art. 18), 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 seniormost (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, Forster s 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

24. Principle of priority:

Of all the rules of zoological nomenclature, it is the most controversial part to choose the correct name when two or more names of a single taxon are discovered. Arbitrari­ness in nomenclature prevails since the period from 1780-1850. The taxonomists of different countries especially in Europe were unable to consult the names of different taxa during the period of French revolution and Napoleonic wars.

A large number of synonyms appeared on these days. The continuous change of names of different taxa could be prevented when priority was adopted as a basic principle of nomenclature.

#### Reasons for the Changes of Name:

**1. Changes dictated by scientific progress:**

1. Change of the generic part of binomial (binominal).
2. Change of specific name.
3. Synonymizing of currently accepted species names.
4. Analysis of species complex.

**2. Changes dictated by rules of nomenclature:**

1. Discovery of an earlier (senior) synonym.
2. Discovery of an earlier (senior) homonym.
3. Discovery of an earlier genotype fixation.
4. Discovery of inapplicable type-specimen.

#### Law of Priority:

The Law of Priority includes that any name given to a species or genus for the first time (from 1st January 1758 till this day) will be accepted provided**:**

1. The specific name is accompanied by an indication or in description figures.
2. The author has followed the system of Linnean binominal nomenclature.
3. The author has published his contention in a scientific book or journal which has been properly printed and widely circulated.
4. In case of a name proposed as a substitute for a name which is invalid by reason of being a homonym, with a reference to the name which is thereby replaced.
5. In case of the generic or sub-generic name, it should accompany the genotype or sub-generic type fixation.

The Law of Priority in zoological nomenclature is a basic law of International Code and promotes stability. A zoological name and name of a taxon become valid if they belong to the category of senior synonym and senior homonym.

The Law of Priority in zoo­logical nomenclature applies only from subspecies to family category but not to the higher categories. Priority of the zoological name and taxon are considered from the date of publication. Priority means the oldest date, month and year of the publication.

### 5.3.4. Some Similarities and Difference of ICBN and ICZN

#### 5.3.4.1. Shared features of the two codes

* + The purpose of both codes is to ensure a unique and stable scientific name for every taxon.
* Both provide rules for publication, validation, documentation and typification of names.
* Allow assignment and changes in names without interfering with scientific freedom.
* Commissions provide an administrative system to oversee and interpret rules, but not based on “case law”.

5.3.4.2. Some notable differences between the two codes**:**

* **Botanical and zoological codes are independent**: names are not required to be unique, e.g. *Pieris*-butterfly; *Pieris*–heath (a plant genus).
* **Supra-generic name endings and italicization**: similar levels in the hierarchies have different endings, or the same endings may refer to different levels. ICZN italics applied to genus and species ranks only,but the ICBN encourageitalicizationfor all ranks but not mandatory.
* **Ranks covered by ICBN and ICZN:** taxa regulated byICBN and ICZN show some differences as shown in table below.

**Zoological Code Botanical Code**

(Kingdom) Kingdom

(Phylum) Division or Phylum

(Class) Class

(Order) Order

Family Family

Tribe Tribe

Genus Genus

- Section  
- Series

Species Species

- Variety  
- Form

[plus sub-categories of all [plus subcategories of all]

and super-categories above Genus]

NB: Zoological taxa in brackets “( )” are not regulated by the zoological code.

* **Infraspecific connecting terms**: such terms are not used by ICZN. In the ICBN, infraspecific connecting terms are used as indicated in the examples below.

e.g. *Saxifragaaizoon*var.*aizoon*subvar. *brevifolia*f.*multicaulis*subf. *surculosa* Engl. and Irmsch.

* **Different terminologies used in the codes include the followings:**

**Zoological Code Botanical Code**

Junior homonym Later homonym

Objective synonym Nomenclatural synonym

Subjective synonym Taxonomic synonym

Available Validly published

Valid name Correct name

Specific name Specific epithet

Binomen, name of a species Specific name

* **Priority/Availability/Validity**: mostly, these concepts were needed in post-Linnaeus to deal with the chaos created due to subsequentnaming.
* **Priority**: first published name is the correct one to use in both codes (with some differences).
* **Availability:** a properly published name is “available” in zoological name (known as “validly published” in ICBN)
* **Validity**: the correct name to use (known as “correct name” in ICBN)
* **Recombining author**: in ICBN, the concept of priority includes a particular binomial combination. For instance, when Cucamis*chrysocomus*Shumacher, (1827) moved to a different genus, it becomes *Rhaphiodiocystischrysocoma*(Shumacher) C. Jeffrey (1962). But in ICZN, species authorship is unchanged. eg. *Bothynoproctusportai*Straneo, 1941 and after moving to a different genus, it became Neotalis*portai* (Straneo, 1941).
* **Tautonyms**: In ICBN, tautonyms are prohibited. In ICZN, tautonyms are allowed. eg.  *Bison bison* is an available name.
* **Recent vs date for priority**: In ICBN, names based on a recent type specimen have priority over names based on a fossil type, while in the ICZN the first valid publication in all cases is used.

### 5.3.5. International Code of Nomenclature of Bacteria

The International Code of Nomenclature of Bacteria (ICNB) governs the scientific names for Bacteria, including Archaea bacteria. It denotes the rules for naming taxa of bacteria, according to their relative rank. As such it is one of the Nomenclature Codes of biology. Originally the International Code of Botanical Nomenclature dealt with bacteria, and this kept references to bacteria until these were replaced in 1975. An early Code for the nomenclature of Bacteria was approved at the 4th International Congress for Microbiology in 156 1947. These rules are maintained by the International Committee on Systematics of Prokaryotes.

### 5.3.6. International Code of Nomenclature for Cultivated Plants

The need for a comprehensive set of practical, easily understood and internationally acceptable regulations on the naming of cultivated plants has long been evident. The International Code of Nomenclature for Cultivated Plants (ICNCP) regulates the names of cultigens (plants whose origin or selection is primarily due to intentional human activity). These are, for the most part, plants with names in the classification categories cultivar and groups. Since cultivated plants are artificial populations maintained & propagated by man, the botanical hierarchy of infraspecific categories is hardly applicable to cultivated plants.

It is largely replaced by a system based on the taxonomic category cultivar. Cultivar is any assemblage of cultivated plants which is clearly distinguished by any characters and which retains its distinguishing characters when reproduced sexually or asexual. It is internationally recognized term for category of distinct cultivated sorts, which are usually called varieties. Cultivar names are preceded by the abbreviation **Cv**. or placed in single quotation marks and not Latinized names

### 5.3.7. International Organizations & Unions for the Stabilization of Changes

At various times, taxonomists are concerned with the classification of organisms and come together at international meetings to discuss the overabundance of problems associated with nomenclature. As a result of such meetings, a set of International Commissions or Committees have been created to lay down sets of rules and recommendations covering the application of nomenclatural procedures to their particular groups of organisms. For example:

* For ICBN: International Botanical Congress;
* For ICZN: International Congress for Zoological Nomenclature.
* For Cultivated plants: The International Commission for the Nomenclature of Cultivated Plants.
* For Fungi: The International Commission for the Taxonomy of Fungi (ICTF).

However, the codes for above groups of organisms may be modified by a decision of the above bodies.

**Phylocode**

A relatively recent development in classiﬁcation is the proposal for an alternative formal system of nomenclature. Despite of lagging its acceptance the aim of the PhyloCode is the same as that of phylogenetic taxonomy in general (including phylogenetic taxonomy using Linnean nomenclature): to produce classiﬁcations that are logically consistent and fully informative concerning relationships among organisms. Unlike the three major codes, the PhyloCode is not sanctioned by the International Union of Biological Sciences, and its rules of nomenclature will not carry the force of international “sanction” until such time as it is so sanctioned. This, of course, may be a matter of time or politics depending on the reception the PhyloCode receives when its governing body implements its rules.

The PhyloCode is designed to ensure the stability of names by deﬁning the names of taxa through the use of speciﬁers. Speciﬁers are existing taxa or character homologies referenced to deﬁne the name relative to taxa included within the clade. There are three ways of deﬁning the name relative to speciﬁers.

1. The ﬁrst is an inclusion statement: “ Xinae is the name that refers to the clade stemming from the common ancestor of (the taxa named) Xus and Yus , ” where Xus and Yus are included taxa.
2. The second is an inclusion/exclusion statement: “X inae is the name of the clade that consists of all species that share a common ancestor with the taxon named Yus but not with that named Zus. ”
3. The third is a synapomorphy statement: “X inae is the name of the clade stemming from the ﬁrst species to have the character ‘ hole on top of the head’ that is homologous with the hole on top of the head found in the taxon named Yus”. At least two speciﬁed things must be referenced in each case, either a combination of names of taxa or a combination of characters and taxa. There are alternative ways of specifying that are suitable depending on the intention of the author. Speciﬁcally, some forms of the deﬁnition are more suited for “crown clade” deﬁnitions (those designed to circumscribe only extant clades) as compared to “total clade” deﬁnitions where the taxon is circumscribed to include a number of more basal fossil species or clades. The PhyloCode differs in some important aspects, PhyloCode names differ from Linnean names in a number of other respects. Available names are placed in an approved database of clade names maintained by the PhyloCode commission. Xinae will forever mean “the name of the clade stemming from the common ancestor of Xus and Yus.” If one wishes to extend the name, Xinae to include more basal taxa, then one would form a panclade name, Pan- X inae, and deﬁne it appropriately.

The PhyloCode also differs from Linnean codes in its treatment of ranks. Ranks might be used (they are completely optional), but name endings do not change with a change in rank. For example, if we ﬁnd that Agamidae is a clade that includes Chamaeleonidae, then Chamaeleonidae would be included within Agamidae without changing the sufﬁx of the root name. This treatment of names is one of the sticking points for those who use Linnean nomenclature. In particular, name endings mean something in Linnean nomenclature at certain levels of the hierarchy, where they serve as exclusion devices (a member of Agamidae cannot also be a member of Chamaeleonidae if both are monophyletic).

However, name endings are meaningless in PhyloCode nomenclature at all levels of the hierarchy. It should be noted that name changes in, for example, the Zoological Code, are only affected if the name is referred to a clade of the rank family or below, no name changes are governed for the names of taxa ranked higher than the family group. This does not mean that name endings will not change, but the changes are not governed by the code. The PhyloCode also differs from the Linnean Codes in its view of the meaning of the taxon names. The Linnean Codes do not sense to give biological meaning to the names of taxa.

**PhyloCode Controversies**

A vigorous debate has ensued over the PhyloCode since it was ﬁrst proposed by de Queiroz and Gauthier (1992). Part of this debate has resulted from a seeming misunderstanding, on the part of PhyloCode proponents, about the Linnaean Codes. A number of such misunderstandings are signiﬁcant. Early advocates of what became the PhyloCode claimed that a new code was needed because Linnaean classiﬁcations are essentialitic, classiﬁcation has not caught up with the Darwinian revolution, and Linnaean taxonomic practices have inhibited the modernization of classiﬁcation.

Further demonstration that Linnaeus was not following Aristotle is the fact that he used genus and species as ﬁxed hierarchical terms; their use in Aristotelian logic is relative (e.g., bird is a genus containing the species swan; bird is a species contained in the genus animal; Winsor, 2 006). This “nonessentialistic” concept of the Linnean system, such expression as that famous one of Linnaeus, and which we meet with in a more or less concealed form, the characters do not make the genus, but that the genus gives the characters, seem to imply that something more is included in our classiﬁcation, than mere resemblance.

# 

**Chapter Five: Review question**

**Answer the following questions properly**

1. Define nomenclature
2. Explain binomial nomenclature
3. What is the needs for scientific names and what is the difference between scientific names and common name
4. List five different animal species and show their common names and scientific names in table.
5. What to mean trinomial name and when we use it? Give at list five plant names with trinomial nomenclature?
6. List common rules of nomenclature.
7. Explain the following words and phrases commonly used in principle of nomenclature.
8. Priority
9. Independence
10. Stability
11. Conservation of names
12. New names
13. Names are Latin or Latinized
14. Homonymy
15. Synonyms
16. Explain different international codes of nomenclature for bacteria, viruses, Plants and animals.
17. Explain different nomenclatural types in ICBN.
18. Explain reasons that names can be changed in botanic nomenclature.
19. Name different nomenclature editions in ICZN.
20. Explain reasons that names can be changed in ICZN.
21. Discus Some similarities and difference of ICBN and ICZN

# CHAPTER SEVEN

# 7. TAXONOMIC TECHNIQUES

**Dear learners at the end of this unit you should achieve the following objectives**

* Define harbarium
* Mention the attributes that should collected togather with plant data
* Forward the need for establishment of herbaria
* Explain basic steps in preparing herbarium
* Tell standar d plant press sizes.

## 7.1. Botanical Techniques (Field and Herbarium Techniques)

**Herbaria and Data Information Systems**

Herbaria are repositories of preserved plant collections, these usually in the form of pressed and dried plant specimens mounted on a sheet of paper. The purpose of herbaria is both to physically contain the plant collections and to act as centers for research. The plant collections themselves function as vouchers for identification and as sources of material for systematic work. Herbaria also may house numerous geographic and taxonomic references, particularly floras or manuals that may aid in plant identification. In addition to housing plant collections, many herbaria today have initiated computerized data information systems to record and access the collection information of the plant specimens, as well as to access information from other collections worldwide (see **Data Information Systems**).Information about herbaria is contained in *IndexHerbariorum* (Holmgren et al. 1990; see also listing of on-line computer access in References for Further Study), which lists the names, addresses, curators, and number and types of specimens. Each herbarium listed in *Index Herbariorum* is assigned an acronym. It is this acronym that is cited in publications in order to specify where voucher specimens are deposited. Herbaria are typically associated with universities or colleges, botanic gardens, museums, or other research institutions.

**Field collecting**

Locating specific plants may be by chance or can involve prior checking of specific collection records (e.g., herbarium sheet label information) or pertinent maps to locate the likely location of a plant in a specialized habitat. The collector should obtain prior permission or the proper permit for collecting on a tract of land. Once a plant of interest is located in the field, the conscientious botanist must evaluate whether or not the species should be collected. The first guideline is to become aware of and be able to recognize any possible sensitive species, i.e., those that are rare, threatened, or endangered. These are typically protected by law and may not be collected legally without special permits. Second, regardless of the legal status of a plant species, any collecting should not endanger the local population. A good rule of thumb is the so-called 1 to 20 rule: for every one plant sample you collect, there should be at least 20 more present in the surrounding population. (For herbs, the 1 to 20 rule applies to individual plants; for shrubs and trees, it applies to shoots removed).

In collecting an herb, at least one whole plant must be completely dug up to show roots and rootstocks. (The exception might be a plant that is extremely rare or endangered.) This is often necessary to determine whether the plant is an annual, biennial, or perennial and to determine the type of root (e.g., fibrous or tap) or underground stem (e.g., corm, bulb, or rhizome). With shrubs, trees, or vines, only one or more branches need be clipped off, using hand clippers to minimize damage to the plant. An attempt should be made to collect plants at flowering and fruiting stage and to collect enough individual specimens (population size permitting) to represent the range of individual variation.

**Preparation of plant specimens**

The standard method of preserving plants for future study and reference is by the preparation of a specimen that is deposited in a herbarium. A herbarium specimen consists of a pressed and dried plant sample that is permanently glued and strapped to a sheet of paper (of standard weight and type, measuring 11.5" × 16.5" in most U.S. herbaria) along with a documentation label. Herbarium specimens or sheets will last for hundreds of years if properly maintained. They are still the most efficient and economical means of preserving a sample of plant diversity.

To prepare a herbarium specimen, material from the field plant press or bag is transferred to a standard plant press to be pressed flat and air dried. A plant press consists of several 12" × 18" pieces of standard cardboard that are placed between two outer 12" × 18" frames or 1/4" plywood pieces all secured by two straps. Optionally, two 12" × 18" felts may be placed between adjacent cardboards to help absorb moisture, but good results can be obtained without felt. Plants are pressed by placing the specimen inside a single page of folded paper (again, used newspaper, preferably close to the size of herbarium paper, about 11.5" × 16.5"), which is then placed between two adjacent cardboards (or felts and cardboards) in the plant press.

The plants to be pressed should be positioned on the newspaper in a way that best represents the plant in the wild and maximizes information content, according to the following guidelines. Open the single sheet of newspaper and carefully place plant organs in a position that allows full view of morphology. Press herbs to show roots and underground stems, which should first be rinsed to remove dirt. Place whole, small herbs on the newspaper with several plants on a single sheet, enough to fill up the space. Taller herbs may be bent into a V , N, or M shape in order to fit the entire plant on one sheet.

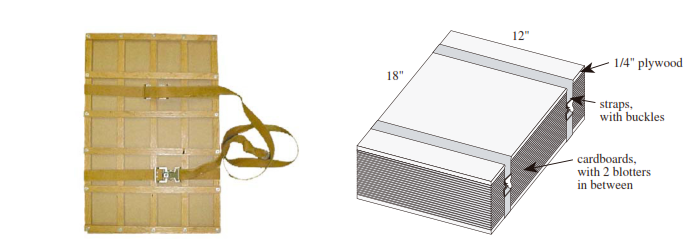
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Figure 7.1 a standard herbarium plant press.

If necessary, cut a tall herb into two or more pieces, preparing a separate newspaper for each. Slice large rhizomes, corms, or bulbs longitudinally and place one cut side face down and the other face up to show internal structure. For larger or highly branched specimens, clip back the shoots or leaves (leaving the shoot or leaf base) in order to minimize overlapping of parts. Orient at least one leaf up and one leaf down, so that both leaf surfaces will be in full view upon drying. To dry succulent plants properly, cut their leaves or stems longitudinally and, if large, scoop out the fleshy tissue, placing the cut side face down. Cacti and other succulents may be soaked in 95% alcohol for one to two days before drying.

Arrange flowers or flower parts carefully; section larger flowers to allow viewing of internal organs. Place extra flowers or inflorescences to one side in order to provide extra material for morphological study. Fruits may be sectioned to illustrate internal wall layers or placentation and to facilitate drying. Use wax paper on both sides of fleshy, aquatic, or delicate plant samples in order to prevent adhering to the newspaper. Place folded sections of newspaper on top of leaves or flowers in order to press them flat when the adjacent stems are thick. For all pressed plants, keep the space at the lower right corner (about 3" × 5" area) free, as this is where the herbarium label will be glued on the herbarium specimen. After final positioning of the plant sample, carefully fold the newspaper over the plant and place between two cardboards in the press. After all plants have been placed in the plant press, the straps are tightened and the press is positioned on its long edge (with buckles on the opposite side) inside a plant drier. The plant drier consists of a ventilated box or cabinet having at its base heating elements or light bulbs plus a fan to provide air circulation. Because modern techniques permit removal and amplification of DNA from herbarium material, it is important that plant specimens be dried at not too high a temperature, to prevent DNA degradation. Heated and circulated air rises through the cardboards and newspapers, drying most plants in 2 or 3 days. After this time, the plant specimens should be removed and checked individually; if any specimen feels cool to the touch, water is still evaporating from its tissues, necessitating a longer drying time.

**Documentation of plant collections**

It is critical that certain data be recorded at the time of collecting a plant. Such data will be typed onto a herbarium label and may be entered into computerized database systems. The following is an explanation of the data categories to be recorded at the time of collecting.

**Field Site Data**

It is important that considering the following points in the field.

* List a locality number to cross-reference to other collections.
* Date of collection: List day month ( spell out to avoid confusion) year Time (optional): Country/state/province/county/city:
* List as needed specific locality information
* List complete locality data for possible relocation of habitat in the future, including measured or estimated distance on roads or trails.
* Latitude and longitude:
* Important to list for biogeographic data systems
* Use GPS device or put dot on topographic map to reference plant collection numbers. Source/accuracy of latitude or longitude
* List how latitude or longitude is determined, e.g., by USGS 7.5 quad or GPS device.
* List (in seconds) accuracy of determination Township and range: May be listed instead of lat./long., but less preferable.
* Elevation (feet or meter): List in units appropriate for source of determination.
* Landmark information: Describe nearest major landmark (preferably one listed on standard topographic map) and list distance and direction from landmark.

****

Figure 7.2 Examples of plants collected and pressed. A. Herb, stem bent twice to t on newspaper. B. Herb, in which whole plant is collected, including rootstock. C. Small shrub, whole plant collected, including roots. D. Tree, in which a branch (in fruit, in this example) is collected. E. Vine, in flower; rootstock not collected.

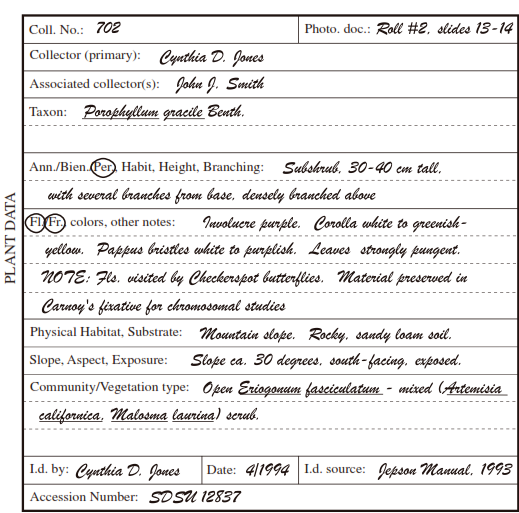


Figure 7.3 Plant collecting documentation sheet.

**Plant Data**

**Collection number**: A unique number associated with the primary collector. Standard format is for a given person to begin with 1 for the first plant collected, 2 for the second, etc. Another format is to transform the date into a collection number, e.g., 10VI94A, in which the month is in Roman numerals, A represents the first plant collected that day, B the second plant, etc. Note: Duplicate specimens of a taxon collected at the same site and time receive the same collection number. If one plant specimen is divided into two (or more) parts, the labels for the pressed sheets are listed as 1 of 2, 2 of 2, etc.

**Photograph documentation**: For keeping track of photos or other images.

**Collector (primary):** The one person associated with a plant collection.

**Associated collector(s):** Other people present or aiding in collecting. These names are not directly associated with the collection number.

**Annual, biennial, or perennial**.,**habit, height, branching:** Circle or list duration (annual, biennial, or perennial), habit (herb, shrub, subshrub, vine, or tree), height from ground level (in metric, not essential if entire plant is collected), and any distinguishing features of the branching pattern that are not apparent from the specimen itself.

**Flower colors, other notes:** Circle or list phenology, whether plants are in flower and/or fruit. Precisely describe the colors of unusual vegetative parts and of all flower parts (e.g., of calyx, corolla, anthers). Describe features that are obscure or might be lost from specimen upon drying. Other field notes may include references to additional research studies or additional field observations, such as observed visitors/pollinators.

**Population size and distribution**: A few notes about the size and distribution of the population are useful, such as very rare, population very large ( >1000 individuals per hectare), or plants locally common.

**Physical habitat or substrate:** Physical habitat refers to abiotic features, such as dry creek bed, granite outcrop, or flood plain. For substrate, list color and basic soil type (e.g., clay, clay-loam, loam, sandy-loam, sand, gravel, boulder, or rock). More detailed information can include soil series and/or rock type.

**Slope or aspect or exposure:** List angle of slope, from none (flat) to 90° (cliff face). Aspect is general compass direction toward which slope is facing. Exposure is either exposed, partly shaded, or shaded.

**Community or vegetation type:** Both immediate and surrounding plant communities or vegetation types may be listed for a single plant collection. Community or vegetation type may be general (e.g., chaparral or woodland) or precise.

**I.D. by date or source:** List the person who identified the taxon, even if it is the same as the primary collector. Also list the date, usually just the month and year, and the source or reference of determining the taxon identity. The source will generally be a flora of the region, but could include monographic treatments or expert determination.

**Accession number:** After the plant collection is processed into a herbarium sheet and deposited in a herbarium, list the herbarium acronym and accession number for a complete record of the collection. Accession numbers are usually cited in publications to document a collection.

**Liquid-preserved collections:** It is often valuable to preserve samples of a plant collection in a liquid preservative. Liquid preservation maintains the shape, size, and internal structure of plant tissues. This is particularly valuable to do for delicate floral parts, whose form is easily distorted or even destroyed from standard herbarium specimen drying techniques. Liquid preservation is also essential for anatomical, developmental, or ultra-structural studies, in which the internal structure of cells and tissues must be maintained.

The most commonly used, general liquid preservative (known as a fixative ) is F AA, one recipe being 10 parts 70% ethanol : 1 part commercial (37%) formalin : 1 part glacial acetic acid (all by volume). (Note: FAA is toxic; avoid getting on skin or breathing the fumes!) Plant samples are simply placed into a glass or plastic vial or jar filled with FAA. Although FAA penetrates most plant tissues rapidly, some plant samples should be cut open to allow the fixative to fully infiltrate into the tissues. At least some closed flower buds or ovaries, leaves, and stems should generally be sectioned with a razor blade prior to fixation.

For cytological studies, e.g., chromosome counts, flower buds or root tips may be fixed in Carnoy’s fixative (3 parts 100% ethanol: 1 part glacial acetic acid). For detailed ultra-structural studies, e.g., using electron microscopy, other fixatives may be needed, such as glutaraldehyde or osmium tetroxide. These compounds are dangerously toxic and should only be handled in a laboratory hood. Because they penetrate less rapidly than FAA, the material must be cut into much smaller pieces, generally 1 mm or less. Plant material may be fixed in 70 or 100% ethanol and used for general morphological studies and sometimes DNA analysis. This is not commonly done for the latter, as material dried in silica gel is better preserved.

Any liquid preserved material should have a corresponding herbarium voucher specimen to serve as a reference for identification. The vial or jar should be labeled both on the outside and on a strip of paper (using a pencil) placed into the fixative. Label information should include the species name and collector and collection number; other data are optional and can be obtained from the field collection notebook or voucher.

**Living collections:** A very valuable type of plant collection is a live specimen removed from the wild. This may be a whole plant, a vegetative propagule, or a seed. Living plant collections are typically grown in a greenhouse or botanic garden, where they can be accessible to a researcher. Growing them and keeping them alive requires some horticultural experience and may involve trial and error under different regimes of potting or soil mixture, moisture, and photoperiod. As with liquid-preserved collections, they should be properly labeled with permanent metal or plastic tags, with collection information corresponding to a voucher specimen deposited in a herbarium.

A living plant collection has the great advantage of permitting long-term observations, e.g., through an entire reproductive stage, or experimental manipulations, such as breeding studies. It also permits removing fresh samples of material for study over an extended period of time (rather than from a single field expedition). However, one precaution about studying live plant collections is that their morphology may be altered in cultivation from that in the wild. In addition, pollinators normally present in the wild will not normally be present in an artificial environment, perhaps preventing normal seed set.

**Collections for molecular studies:** A standard method for collecting material for studies of DNA is to cut pieces of leaves or other plant tissue and immerse these in a container (vial or plastic bag) of silica gel. A paper label, indicating the taxon and the name and number of the collector (corresponding to a herbarium voucher collection), is placed in the container. The silica gel rapidly dehydrates the material, preserving the DNA for future extraction, purification, and amplification. Extracted plant material is usually frozen at −80 0C to prevent degradation of the DNA. Plant material to be used for DNA analysis may also be fixed in 70 or 100% ethanol, but this may not preserve the DNA as well. For allozyme analysis, fresh material must be used, as enzymes degrade very rapidly. Extra plant material is placed in a plastic bag (again with a slip of paper or label indicating the voucher information) and kept in a cooler until it is transported to the lab

**Herbarium specimens**

Aherbarium specimenconsists of a pressed and dried plant sample that is permanently glued and strapped to a sheet of paper along with a documentation label. The herbarium paper is high quality, heavyweight, and acid-free to inhibit yellowing. In most American herbaria, standard herbarium paper measures 11.5" wide × 16.5" tall; in other countries the dimensions may be slightly different. Herbarium specimen can last for hundreds of years if properly maintained.

They are still the most efficient and economical means of preserving a record of plant diversity.

**Herbarium labels**

A**herbarium label** is affixed to each specimen, usually at the lower right hand corner. Herbarium labels are typically computer generated using a laser or ink jet printer. Label sizes vary, but are generally about 4 - 5" (10 - 12 cm) wide and 2- 3" (5 - 7 cm) tall, using high-quality thick-weight (20- or 24-lb), acid-free bond paper. Virtually all of the information recorded at the time of collecting should be placed on the herbarium label. A convenient formatting is to list (following the taxon name) all characteristics about the plant itself in the first paragraph, including duration, habit, height, branching pattern and phenology, colors, and other features.

The second paragraph contains information about the habitat and locality of the plant, including physical habitat, slopeor aspector exposure, community or vegetation type, specific locality information, landmark information, latitude and longitude, source or accuracy of latitude and longitude long., and elevation.

A third paragraph may include other field notes and photographor image documentation. At the bottom of the label, the collector, collection number, and date of collection are listed. The last item on the herbarium label may list by whom and when the identity was determined (even if by the same person who collected the material) and what the source of that identification was. Information on taxon determination is important to include on the label, as it cannot be assumed that the person who collected a plant identified it. In addition, the source or means of identification (whether a flora, monograph, or expert determination) may constitute valuable information in verification of identities.If the plant specimen is so large that it must be divided between two or more herbarium sheets, a separate label must be prepared for each of these parts. All labels referring to the same plant have the same collection number (but different accession numbers; see later discussion). The two herbarium sheets may differentiated by the designation, e.g., 1 of 2, 2 of 2.

**Mounting Herbarium Specimens**

Plant specimens are affixed to herbarium paper with glue and/or straps. The glue used may be standard white glue or a solution of methyl cellulose, available from chemical supply and some herbarium supply companies. White glue is best diluted slightly, ca. 9 parts glue to 1 part tap water, stirred well. Methyl cellulose is prepared by adding about 70 grams of methyl cellulose powder to a liter of warm tap water and stirring briskly until well mixed; more water or powder may be added to achieve a thick, viscous solution.

The advantage of methyl cellulose is that, with minimal moistening, it willsoften or dissolve, allowing for relatively easy removal ofdried plant material from the herbarium specimen (see later discussion). Glues containing organic solvents are not recommended, as they are toxic and require special ventilation.The following is one useful method to glue a dried plant specimen and label to a sheet of herbarium paper. Have the following supplies on hand: herbarium paper, cardboard (12" × 18"), a flat sheet (ca. 12" × 18"), paintbrush (2 4” wide), glue, two pairs of forceps, spatula, and weights (standardbathroom tiles, measuring 4", 6", and 8" square work well). First, place a sheet of herbarium paper on top of a cardboard. Position the herbarium label (without gluing yet) on the lower right corner of the herbarium paper, leaving ca. 1/8 1/4" space between the label and the margins of the paper.

Place the pressed plant specimen (also without gluing yet) on the paper in order to test the final positioning. Make sure the specimen does not overlap the label or go beyond the edges of the herbarium paper; if overlap occurs, the plant must be cut. Also, try to leave some room above and to the left of the label for placing an accession number or barcode and possible annotation labels (see later discussion). Extra pieces of the plant specimen (e.g., individual flowers, fruits, or inflorescence) may be placed on the sheet as well. Smaller pieces are best placed in a separate small envelope that may be glued to the final specimen, such that it may be opened to remove the material for study. (Envelopes may be constructed by cutting heavyweight, 100% bond typing/printing paper (e.g., 8.5" × 11") into two pieces; each 8.5" × 5.5" piece is then folded to make a 4.25" ×5.5" rectangle, which is then folded to overlap ca. 1/4" along the three cut margins.)Next, using a paintbrush, coat a large (at least 12" × 18") sheet (e.g., of glass, Plexiglas, or a cookie sheet) thoroughly with a layer of glue. Transfer the plant specimen from the paper to the glue-covered sheet, gently press down, carefully remove (using forceps for delicate material to prevent damage), and place back onto the herbarium paper, positioning the plant as originally placed. You may use a scalpel or squirt jar to transfer glue directly to plant surfaces that require greater adhesion. Continue this until all plant components are glued to the sheet. Finally, in a smaller region of the sheet, paint a very thin layer of glue (preferably white glue, diluted as specified above) on the sheet, place and press down the herbarium label onto this region, and transfer back to the herbarium specimen with forceps, being careful to correctly position it about 1/4" from the edges. Flatten and smooth the herbarium label by placing a used paper towel or sheet of paper (to absorb excess glue) over the label and pressing down firmly.

Finally, place weights (e.g. different-sized ceramic tiles or lead weights) overboth herbarium label and various locations of the plant material. Leave the specimen overnight to dry thoroughly. Specimens, with underlying cardboard, may be stacked if needed to conserve space.After the glue has dried, remove the weights and check thespecimen. Reapply glue to individual spots as needed. Place narrow (ca. 1/8" wide) strips of strapping tape (available from herbarium supply companies) over stout stems to better secure them to the sheet.Some herbaria use little to no glue, relying on heavy use of strips of strapping tape to secure the specimen. Although this may not secure some plant specimens as well, it has that advantage of making removal of plant material from a mounted specimen (e.g., for detailed study) much easier.

## 7.2. Zoological Techniques (Field Techniques and Museum Techniques)

# CHAPTER EIGHT

# 8. THE APPLICATIONS OF TAXONOMIC RESULTS

**Unit objective**

Derar Learnres! At the end of this unit will will be expected to achieve the following objectives.

* Explain how to apply taxonomic results
* Discus applications of **numerical Taxonomy**
* Exxplain the use of molecular clock.

## 8.1. Dependence of Taxonomy on Other Fields

**Actvity**

* What are some applications of taxonomic results?
* Why do biologists care about studying phylogenies?
* Taxonomy depends on other field of biological sciences & other disciples of natural sciences for its data. Thus, it is probably unique in being a science without any data of its own.
* In turn, it is expected to serves workers who are dealing with living things by providing the correct identification of their organisms’ of study, along with the relationships of the study organisms with other living things.
* It supports various scientific disciplines including conservation science, evolutionary biology, bio-discovery, ecology, biogeography, medicine, etc.
* In selection of high yield/disease resistant crops, biological control of pests, in conservation of endangered, rare and vulnerable plants or animals, in drug discovery,in invasive species and pest management, etc, taxonomy plays a major role.
* **N.B:** Taxonomy is basic to other life sciences and at the same time,it is dependent on them. It has to depend for its improvement, and indeed for its existence, extremely on information from other fields such as Morphology, Anatomy, Embryology, Cytology, Biochemistry, Physiology, Genetics/ Molecular Biology, Ecology, Biogeography, etc. Generally, taxonomy has no data of its own.

## 8.2 Applications of ****Numerical Taxonomy****

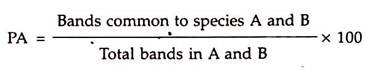
Numerical taxonomy has been successfully applied in the following studies:

(i) Study of similarities and differences in bacteria, other micro-organisms and several animal groups.

(ii) Delimitation of several angiospermic genera like Oryza, Sarcostemma Solarium, and other groups including Farinosae of Engler and a few others.

(iii) In the study of several other angiospermic genera including Apocynum, Chenopodium, Crotalaria, Cucurbita, Oenothera, Salix, Zinnia, wheat cultivars, Maize cultivars, etc.

(iv) Phytochemical data from seed protein and mitochondrial DNA RELP studies has been numerically analyzed by Mondal et al. to study the interspecific variations among eight species of cassia L .Based on the results of electrophoretic patterns, the degree of pairing affinity (PA) or similarity index was calculated by the following formula, according to the method of Sokal & sneth and Romero Lopes et al.:



Separate dendograms expressing the average linkage were computed using the cluster method UPGMA, which showed that the eight species could be placed into two categories or clusters (Fig. 7.1) with *C. alata*, *C siamea*, *C. fistula* and *C. reginera*, all being trees or large shrubs and characterized by the absence of foliar glands on petiole or rachis and presence of dense axillary terminal racemes greater than 30 cm long, being clustered into one group, whereas the other four species, i.e., *C. occidentalis*, *C. sophera*, *C. mimosoides* and *C. tora*, forming the other cluster, all being herbs or undershrub’s and characterized by the presence of short corymbose racemes less than 10 cm long and with foliar glands, either on petiole or rachis.

**Molecular Clocks**

We stated earlier that researchers have estimated that the common ancestor ofHawaiian silverswords lived about5 million years ago. How did they make this estimate? They relied on the concept ofa moleculardock, a yardstick for measuring the absolute time ofevolutionarychange based on the observation that some genes and other regions of genomes appear to evolve at constant rates. The assumption underlying the molecular clock is that the number ofnucleotide substitutionsin orthologousgenes is proportional to thetimethat has elapsed since the species branched from their common ancestor (divergence time). In the case of paralogous genes, the number ofsubstitutions is proportional to the time since the genes became duplicated. We can calibrate themolecularclock ofagene thathasa reliable average rate ofevolution by graphing the number ofgenetic differences-for example, nucleotide, codon, or amino acid differences-against the dates of evolutionary branch points that are known from the fossil record. Such graphs can then be used to estimate the dates ofevolutionary episodes that cannot be discerned from the fossil record, such as the origin ofthesilverswords discussed earlier. Ofcourse, no gene marks time with complete precision. In fact, some portions of the genome appear to have evolved in irregular fits and starts that are not at all clocklike. And even those genes thatseem to have reliable molecular clocks are ac· curate only in the statistical sense ofshowing a fairly smooth average rate of change. Over time, there may still be chance deviations above and below that average rate. Furthermore, the same gene may evolve atdifferent rates in different groups oforganisms, making it necessary to calibrate and use molecular clocks with care. Finally, even among genes that are clocklike, the rate of the dock may vary greatly from one gene to another; some genes evolve a million times faster than others.

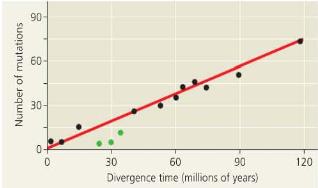


Figure 7.2A molecular clock for mammals. The number of accumulated mutations in seven proteins increased over time in a consistent manner for most mammal species. The three green data points represent primate species. whose proteins appear to have evolved more slowly than those of other mammals. The divergence time for each data point was based on fossil evidence.

**Applying a Molecular Clock: The Origin of HIV**

Researchers at Los Alamos National Laboratory in New Mexico used a molecular clock to date the origin of HIV infection in humans. Phylogenetic analysis shows that HIV, the virus that causes AIDS, is descended from viruses that infect chimpanzees and other primates. (The viruses do not cause any AJDS-likediseases in nonhuman hosts.) When did HIV jump to humans? There is no simple answer, because the virus has spread to humans more than once. The multiple origins of HIV are reflected in the variety ofstrains (genetic types) ofthe virus. HIV's genetic material is made of RNA, and like other RNA viruses, it evolves quickly. The most widespread strain in humans is HIV-l M. To pinpoint the earliest HIV-l M infection, the researchers compared samples of the virus from various times during the epidemic, including one sample from 1959. A comparison of gene sequences showed that the virus has evolved in a clocklike fashion since 1959 (Figure 26.20). By extrapolating from their molecular clock, the researchers concluded that the HIV-l M strain first spread to humans during the 193Os.

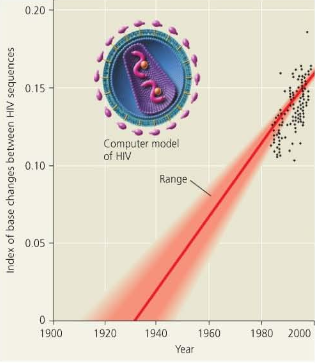


Figure 8.3 Dating the origin of HIV·' M with a molecular clock. The numerous data points in the upper right-hand corner of this graph are based on DNA sequences for a specific HIV gene in blood samples collected from patients at different known times. If we project the relatively constant rate at which changes occurred In this gene in the 1980s and 1990s back In time. we intersed the x-axis of the graph in the 1930s,

Chapter seven review questions

* Explain applilication of taxonomic results in other fields
* Discuss the interrelationships of taxonomy and an others biological fields
* Discus applications of **numerical Taxonomy**
* Exxplain the use of molecular clock.

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**Appendix I**: Mammalian taxonomy is based on Wilson and Reeder (1993)

Class Mammalia (Synapsida)

Order Monotremata—3 species

Family Tachyglossidae—echidnas, spiny anteaters

Family Ornithorhynchidae—duck-billed platypus

Order Didelphimorphia—63 species

Family Didelphidae—American opossums

Order Paucituberculata—5 species

Family Caenolestidae—“shrew” opossums

Order Microbiotheria—1 species

Family Microbiotheriidae—monitos del Monte

Order Dasyuromorphia—63 species

Family Thylacinidae—thylacines and Tasmanian wolves

Family Myrmecobiidae—numbats and banded anteaters

Family Dasyuridae—marsupial “mice” and “cats,” and Tasmanian devils

Order Peramelemorphia—21 species

Family Peramelidae—bandicoots

Family Peroryctidae—bandicoots

Order Notoryctemorphia—2 species

Family Notoryctidae—marsupial “moles”

Order Diprotodontia—117 species

Family Phascolarctidae—koalas

Family Vombatidae—wombats

Family Phalangeridae—possums and cuscuses

Family Potoroidae—rat kangaroos

Family Macropodidae—wallabies and kangaroos

Family Burramyidae—pygmy possums

Family Pseudocheiridae—ring-tailed possums

Family Petauridae—gliding and striped possums

Family Tarsipedidae—honey possums

Family Acrobatidae—pygmy flying possum

Order Xenarthra—29 species

Family Bradypodidae—three-toed tree sloths

Family Megalonychidae—West Indian and two-toed tree sloths

Family Dasypodidae—armadillos Family Myrmecophagidae—anteaters

Order Insectivora—428 species

Family Solenodontidae—solenodons

Family Nesophontidae—West Indian shrews (extinct)

Family Tenrecidae—tenrecs and Madagascar hedgehogs

Family Chrysochloridae—golden moles

Family Erinaceidae—gymnures and hedgehogs

Family Soricidae—shrews Family Talpidae—moles

Order Scandentia—19 species

Family Tupaiidae—tree shrews

Order Dermoptera—2 species

Family Cynocephalidae—flying lemurs and colugos

Order Chiroptera—925 species

Family Pteropodidae—Old World fruit bats

Family Rhinopomatidae—mouse-tailed bats and long-tailed bats

Family Craseonycteridae—bumble-bee bats

Family Emballonuridae—sac-winged bats, sheath-tailed bats, and ghost bats

Family Nycteridae—slit-faced bats and hollow-faced bats

Family Megadermatidae—false vampire bats

Family Rhinolophidae—horseshoe bats

Family Noctilionidae—bulldog bats and fisherman bats

Family Mormoopidae—spectacled bats

Family Phyllostomidae—American leaf-nosed bats

Family Natalidae—funnel-eared bats

Family Furipteridae—smoky, thumbless bats

Family Thyropteridae—disc-winged bats and New World sucker-footed bats

Family Myzopodidae—Old World sucker-footed bats

Family Vespertilionidae—vespertilionid bats and mouse-eared bats

Family Mystacinidae—New Zealand short-tailed bats

Family Molossidae—free-tailed bats and mastiff bats

Order Primates—233 species

Family Cheirogaleidae—dwarf lemurs and mouse lemurs

Family Lemuridae—lemurs

Family Megaladapidae—sportive lemurs and weasel lemurs

Family Indridae—avahi, sifakas, and indris

Family Daubentoniidae—aye-ayes

Family Loridae—loris and pottos

Family Galagonidae—galagos

Family Tarsiidae—tarsiers

Family Callitrichidae—marmosets and tamarins

Family Cebidae—New World monkeys

Family Cercopithecidae—Old World monkeys

Family Hylobatidae—gibbons and lesser apes

Family Hominidae—bipedal primates and humans

Order Carnivora—271 species

Family Canidae—dogs, wolves, coyotes, jackals, and foxes

Family Felidae—cats

Family Herpestidae—mongooses

Family Hyaenidae—aardwolves and hyenas

Family Mustelidae—weasels, badgers, and otters

Family Mephitidae—skunks and stink-badgers

Family Odobenidae—walruses

Family Otariidae—eared seals, fur seals, and sea lions

Family Phocidae—true, earless, or hair seals

Family Procyonidae—raccoons, ringtails, coatis, and kinkajous

Family Ursidae—bears and pandas

Family Viverridae—civets, genets, linsangs, and fossas

Order Cetacea—78 species

Family Balaenidae—right whales

Family Balaenopteridae—rorquals

Family Eschrictiidae—gray whales

Family Neobalaenidae—pygmy right whales

Family Delphinidae—dolphins and porpoises

Family Monodontidae—belugas and narwhals

Family Phocoenidae—porpoises

Family Physeteridae—sperm whales

Family Platanistidae—freshwater dolphins

Family Ziphiidae—beaked whales

Order Sirenia—5 species

Family Dugongidae—dugongs and sea cows

Family Trichechidae—manatees

Order Proboscidea—2 species

Family Elephantidae—elephants

Order Perissodactyla—18 species

Family Equidae—horses, zebras, and asses

Family Tapiridae—tapirs

Family Rhinocerotidae—rhinoceroses

Order Hyracoidea—6 species

Family Procaviidae—hyraxes and dassies

Order Tubulidentata—1 species

Family Orycteropodidae—aardvarks and ant bears

Order Artiodactyla—220 species

Family Suidae—pigs and hogs

Family Tayassuidae—peccaries

Family Hippopotamidae—hippopotamuses

Family Camelidae—camels, guanacos, llamas, alpacas, and vicuñas

Family Tragulidae—chevrotains and mouse deer

Family Giraffidae—okapis and giraffes

Family Moschidae—musk deer

Family Cervidae—deer

Family Antilocapridae—pronghorns

Family Bovidae—antelopes, cattle, bison, buffalo, goats, and sheep

Order Pholidota—7 species

Family Manidae—pangolins and scaly anteaters

Order Rodentia—2,021 species Suborder Sciurognathi

Family Aplodontidae—sewellels and mountain beavers

Family Sciuridae—squirrels, chipmunks, marmots, and prairie dogs

Family Castoridae—beavers Family Geomyidae—pocket gophers

Family Heteromyidae—pocket mice, and kangaroo rats and mice

Family Dipodidae—jerboas, birch mice, and jumping mice

Family Muridae—rats, mice, hamsters, voles, lemmings, and gerbils

Family Anomaluridae—scaly-tailed squirrels

Family Pedetidae—springhares and springhaas

Family Ctenodactylidae—gundis

Family Myoxidae—dormice Suborder Hystricognathi

Family Bathyergidae—African mole rats and blesmois

Family Hystricidae—Old World porcupines

Family Petromuridae—dassie rats

Family Thryonomyidae—cane rats

Family Erethizontidae—New World porcupines

Family Chinchillidae—viscachas and chinchillas

Family Dinomyidae—pacaranas

Family Caviidae—cavies and Patagonian “hares”

Family Hydrochaeridae—capybaras

Family Dasyproctidae—agoutis

Family Agoutidae—pacas

Family Ctenomyidae—tuco-tucos

Family Octodontidae—octodonts

Family Abrocomidae—chinchilla rats and chinchillones

Family Echimyidae—spiny rats Family Capromyidae—hutias

Family Myocastoridae—nutrias and coypus

Order Lagomorpha—80 species

Family Ochotonidae—pikas, mouse hares, and conies

Family Leporidae—hares and rabbits

Order Macroscelidea—15 species

Family Macroscelididae—elephant shrews