

VOL

2

PLANT ECOLOGY AND TAXONOMY

BLOCK 3

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BLOCK 4

NOMENCLATURE AND SYSTEMS OF CLASSIFICATION **105**

One of the greatest assets of a sound classification is its predictive value. Mayr (1969)

PLANT ECOLOGY AND TAXONOMY

In this volume 2 you are going to study about plant taxonomy. Taxonomy is the most relevant field of enquiry for modern man. Plant taxonomy is a 2 credit course which comprises of Block 3 and Block 4. Both of these blocks consist of five units each. Plant taxonomy is a fundamental science - the science of classifying plants into groups and identifying them. The progress of civilization marked a relative increase in man's knowledge regarding plants - their identification, naming and classification on the basis of his needs.

During last three centuries, plant taxonomy has developed from a completely morphology oriented static and descriptive discipline to a most dynamic area of study. The first classification of plants was thus according to their usefulness or not. When man came to realize that most of the plants are of some or other use, he classified them into herbs, shrubs and trees. This was followed by various "Natural" systems of classification. Taxonomy is related to morphology, anatomy, embryology, cytology and chemistry. In this course we have tried to establish the relationship of taxonomy with all the above given branches.

Over the last few decades, the availability and usage of comparative and recombinant technology data from different species has made taxonomy more authentic and complete.

Objectives

After studying this block you will be able to:

- study the history of plant taxonomy, with special emphasis on plant taxonomy in ancient India; and discuss aims, objectives and importance of taxonomy;
- enlist some important national and international herbaria and botanical gardens; and know their roles and describe the various kinds of taxonomic documentations;
- describe the salient characteristics of the taxonomic groups : species, genus, family and order; and discuss the "species-concept";
- explain the concepts of binomial nomenclature; apply the principles of binomial nomenclature for naming plants; describe with suitable examples the rules for Nomenclature that governs: rank; typification; priority; valid publication; author citation and retention and rejection of scientific names.
- describe the historical background, outline, basis of classification, merits and demerits of the various systems of classification, especially the ones proposed by Linnaeus; Bentham and Hooker and Engler and Prantl; and
- appreciate modern aspects of taxonomy : numerical taxonomy and cladistics.

Block

3

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BLOCK 3 : PLANT TAXONOMY – TOOLS AND EVIDENCES

We all appreciate and like the environment around us which is filled with life including plants and animals. Plants particularly have played an important role in human's life by providing food, shelter, clothing and medicines.

Previously grouping of plants was done on practical findings and based largely on the economic uses of the plants. Plants were earlier classified as edible, poisonous and medicinal thus plant taxonomy originated. They were based mainly on morphology, smell, taste and nutritive value. From that period to present day the development of taxonomy has witnessed a series of changes.

Taxonomy is the method by which scientists, conservationists, and naturalists classify and organize the enormous diversity of living things on earth. Modern taxonomy came into existence in the mid-1700s when Swedish-born Carolus Linnaeus published his multi-volume ***Systema Naturae***, outlining his new and revolutionary method for classifying and, especially, naming living organisms. Before Linnaeus, all described species were given long, complex names and different names to single species. These names largely provided descriptive information and it was often difficult to use. The ancient concept about plants has undergone many changes, over time with the advancement of knowledge.

The taxonomy block starts with Unit 11. This is the first unit of plant taxonomy course which deals with the Philosophical giants like Theophrastus, Aristotle, Dioscorides and Pliny who are amongst the people who initiated a more systematic and scientific approach to taxonomical studies. It also describes principles, aims and objectives of taxonomy. It also describes four important steps used in taxonomy.

In Unit 12 you will study the ecological and phyto-sociological aspects of taxonomy, herbaria and botanic gardens. You will be given brief information about Royal Botanic Gardens, Kew (Richmond, Surrey, near London), Botanic Garden Sibpur, Howrah (India) and Botanical Survey of India (BSI).

Unit 13 deals with numerous kinds of resources from where the correct, authentic, complete, identification can be retrieved. These are called taxonomic documents. These include: general taxonomic indexes/indices; floras; monographs; manuals; revisions; periodicals; etc. In order to help a researcher to correctly, conveniently and quickly ascertain the name of an unknown, many of these resources are provided with 'keys'. We have also provided Internet address which provides a wealth of information on plants systematics for quick access.

Unit 14 deals with taxonomic information that can be collected from a few specific fields such as: palynology; cytology; phytochemistry and molecular biology. Molecular data obtained from the DNA of nuclear, mitochondrial and chloroplast origin provides important insight into phylogenetic systematics.

Unit 15 we have discussed about taxonomic hierarchy. Generally the taxa are arranged in an ascending order. The highest being the Kingdom and the lowest being the species. All of these categories, ranks taken together constitute taxonomic groups. This sequential placement of more than one taxa, one above the other or one inclusive of the other is known as Taxonomic Hierarchy. A special sub-section is devoted to the still evolving but a challenging issue in plant sciences (in fact in Biological Sciences) - the "Species concept."

Objectives

After studying this block you will be able to:

- Know the history of plant taxonomy, with special emphasis on plant taxonomy in ancient India; and discuss aims, objectives and importance of taxonomy;
- enlist some important national and international herbaria and botanical gardens; and specify the role of botanic gardens and Botanical Survey of India and
- describe the various kinds of taxonomic documentations; explain the concepts of single access and multi-access keys; their kinds and uses; and construct and use a key;
- specifically infer the taxonomic evidences from the fields of palynology, cytology, phytochemistry and molecular botany;
- provide a few examples where the taxonomic evidences have enhanced and strengthened the appreciation of classification and phylogeny of plants; and
- know the importance of the concept of taxonomical hierarchy.



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UNIT 11

INTRODUCTION TO PLANT TAXONOMY

Structure

11.1	Introduction	11.4	Aims and Objectives of Taxonomy
	Objectives		Characterisation
11.2	History of Plant Taxonomy		Identification
	The Ancient Greeks and Romans		Classification
	The Herbalists		Nomenclature
	The Transition Period	11.5	Summary
	The Post-Herbal Period	11.6	Terminal Questions
11.3	What is Plant Taxonomy?	11.7	Answers

11.1 INTRODUCTION

We all appreciate and like the environment around us which is filled with life including plants and animals. Plants particularly played an important role in human life by providing food, shelter, clothing and medicines.

The discovery of the use of plants for food and later as medicine began at a very early stage in the history of civilization. The early hunter-gatherer society eventually gave way to the classification of plants. Plants were classified as edible, poisonous and medicinal and in this manner plant taxonomy originated. The earlier groupings were done on practical findings and were based largely on the economic uses of the plants. They were based mainly on morphology and also on smell, taste and nutritive value. From that period to present day the development of taxonomy has witnessed a series of changes.

Taxonomy is the method by which scientists, conservationists, and naturalists classify and organize the enormous diversity of living things on earth. Modern taxonomy came into existence in the mid-1700s when Swedish-born Carolus Linnaeus published his multi-volume ***Systema Naturae***, outlining his new and revolutionary method for classifying and, especially, naming living organisms. Before Linnaeus, all described species were given long, complex names and

different names to single species. These names largely provided descriptive information and it was often difficult to use. The ancient concept about plants has undergone many changes, over time with the advancement of knowledge. Plants provide an orderly and widespread display of curiosities for their classification.

The history of plant taxonomy is fascinating, everlasting, self-correcting and an ever-evolving effort. The story of plant description dates back to the ancient Greek and Roman civilizations. Philosophical giants like Aristotle, Theophrastus, Dioscorides and Pliny are amongst the people who initiated a more systematic and scientific approach to taxonomical studies. Later, in the 15th and 16th century's naturalists such as Bock, Brunfels and Fuchs and many others helped in building a scientific repository of knowledge. The progress in taxonomy was gradual and assisted by all those interested in various aspects of economic importance of plants. Earlier attempts to classify plants especially to differentiate one from another were purely artificial and based alone on external features of the plants. But gradually, with the progress in understanding many aspects of botany, resulted in the further development of the science of taxonomy. In this unit you will get familiar with the history of taxonomy and will study about aims and objectives of plant taxonomy. The history of plant taxonomy can be traced back to *Rig Veda*. In this unit, there will be special emphasis on the development of plant taxonomy in ancient India.

Objectives

After studying this unit you should be able to:

- ❖ know the history of plant taxonomy, with special emphasis on plant taxonomy in ancient India;
- ❖ discuss aims, objectives and importance of taxonomy;
- ❖ define and differentiate between taxonomy and systematics; and
- ❖ describe various principles of taxonomy and systematics.

11.2 HISTORY OF PLANT TAXONOMY

The publication of Charles Darwin's epoch making work '**Origin of Species**' in 1859 can be considered as a very important landmark in understanding Biology. Therefore, the history of evolution of plant classification can broadly be divided into two distinct eras:

- pre-evolutionary (pre-Darwinian) and
- post-evolutionary (post-Darwinian) era.

The pre-evolutionary era can further be subdivided into four important periods for the sake of convenience and better understanding.

- i) The Ancient Greeks and Romans
- ii) The Herbalists

iii) The Transition Period and

iv) The Post-Herbal Period

In the present unit we will describe briefly about some ancient Greek and Roman naturalists and scholars who made important contributions to plant sciences in general and plant classification in particular in their own classical way. They made observations on plants and tried to classify them. The period of those classic ancient Greeks and Romans culminated into a period of descriptive botany when a series of important herbals were written by several celebrated physicians, naturalists and other scholars. It was a significant departure from the earlier works which were written for practical reasons only and had little academic importance.

11.2.1 The Ancient Greeks and Romans

Hippocrates, "The Father of Medicine" (**460-375 B.C.**) is reported to have been one of **Democritus's** disciples. He is regarded as the founder of the Hippocratic School of Medicine which started to study the causes of diseases. It also cast new light upon the use of herbs. A list of about 240 plants used in medicine may be found in the writings of the Hippocratic School, but they were mentioned primarily for their medicinal properties yet not described botanically. The Greek root diggers (*Rhizotomoi*) and drug merchants (*Pharmacopuloi*), who were engaged in the business of collecting and preparing drugs from plants, acquired knowledge which must have been advantageous, their knowledge of plants was, however, empirical and full of superstitions and would have contributed little to the science of botany.

Aristotle, the Stagirite : The remarkable work of Aristotle (**384-322 B.C.**) marks the peak of the Golden Age of Greece. The very existence of his works proves that he not only had great aptitude and brain of the highest order, but also that he used a large amount of research of his predecessors. His deep mathematical knowledge was nicely balanced by a very extensive connection with every branch of natural history.

Aristotle (born in **384 B.C.**) was the son of **Nicomachus**, physician to the royal family of Macedonia in Stagira. This was a small Greek colony on the Macedonian coast. He was sometimes called the Stagirite. His father, Nicomachus, was a member of the guild of the Asclepiads which had a group of physicians using herbs and other remedies known only to members of the guild. At seventeen, Aristotle went to Athens where he met and became a pupil of **Plato**. Aristotle, though essentially a biologist, was closely attached to his teacher and continued to be a member of his school until Plato's death in **347 B.C.**

Aristotle regarded the plant as an integrated entity. According to him leaves, shoots and roots were not mere appendages of the plant but were members of an organized thing. Each of them had its own uniqueness but they had dependencies, relationships, and harmonies which interacted to maintain the life of the whole plant.

Theophrastus of Eresus: The Father of Botany (372-287 B.C.);

Of all the men who ever lived, Theophrastus of Eresus, certainly was a very remarkable person. He was born about **372 B.C.** on the Isle of Lesbos (Modern Mytilene) in the Aegean Sea and is regarded as the “*Father of Botany*”. Botanical science in its broadest aspects received remarkable motivation in Greece under the leadership of **Theophrastus** and his disciples. Incredibly enough, only about one-twentieth of his voluminous writings were about botany. His most important work known as ‘**Historia Plantarum**’ (Fig. 11.1) is, the foundation of all we know about plants today. In this, Theophrastus classified and described about **480** kinds of plants. Besides classifying plants, he also provided accounts of woodland, marsh, lake, river and other plant associations. In this classic work he also indicated crucial differences between dicotyledons and monocotyledons. Theophrastus became a student of Plato at an early age. Plato died when Theophrastus was only 22. Thereafter he became a student and later a close friend and fellow teacher of Aristotle. When Aristotle died he bequeathed his manuscripts, books and botanical garden to Theophrastus who was then **48** years old.

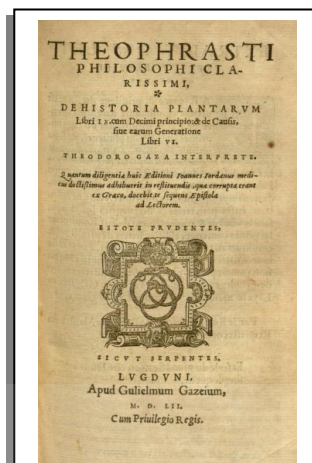


Fig. 11.1: Historia Plantarum.



Fig.11.2: De Materia Medica'.

Theophrastus's work clearly reflected the philosophy of Plato and Aristotle. He classified all plants on the basis of form or texture; as trees, shrubs, under-shrubs and herbs, and distinguished them as annual, biennial and perennial. He also differentiated between centripetal (indeterminate) and centrifugal (determinate) inflorescences, recognised differences in position of ovary, and in polypetalous and gamopetalous corollas. Theophrastus also recognised different types of insertion of floral parts, characteristic of hypogynous, perigynous and epigynous plants clearly.

Theophrastus' ‘**Historia Plantarum**’ survived the centuries from his death until the invention of printing in the mid 15th century. It was among the first books to be printed and, as it began to appear again and again in Greek, Latin, German and English, until by 1866 more than 20 editions had appeared in practically every European language.

Gaius Plinius Secundus was also known as **Pliny the Elder** (23-79 A.D.). He was a Roman naturalist and scholar, born in Como. Pliny listed nearly a thousand plants in his ‘**Historia Naturalis**’. This work in 37 volumes is a very elaborate encyclopedia of great value, since it contains a wealth of information not to be found elsewhere. Sixteen of these volumes dealt largely with plants, treated such topics as medicinal properties, classification, forestry, plant anatomy, and the practice of horticulture.

Pliny seemed to have a little interest in the classification of plants on the basis of their resemblances. He classified trees as forest trees, exotic trees, and fruit trees. He divided forest trees into glandiferous and pitch-bearing. The former included all the catkin bearing trees, and the latter were mostly the Conifers.

Pedanius Dioscorides, a Sicilian Greek, who lived in the first century A.D., was the most important botanist after Theophrastus. He was a military physician under Emperor Nero of Rome. His principal writings were on medical botany. During the middle Ages his work was far more popular than that of Theophrastus though he knew less about botany. For more than 1500

years he was the alpha and omega of European botany. His chief contribution, '**De Materia Medica**' (Fig. 11.2) was a description of about six hundred species mainly Mediterranean, used for medicinal purposes. Another manuscript, the '**Anicia Juliana Codex**' was prepared for the daughter of a Byzantine emperor about 512 A.D. from material originally compiled by Dioscorides. It contained coloured illustrations of plants and is still in existence.

The most significant aspect of this period of early Greek and Roman naturalists and scholars was that men began to think originally and fundamentally about the universe. Supernaturalism and mythology were abandoned in preference to logic. During this time the foundations for scientific study of nature were laid.

11.2.2 The Herbalists

During the middle Ages, following the decline of the Greek and Roman civilizations, little significant botanical progress was made. The early herbals (i.e., old books about plants), such as the **Codex** of Dioscorides, were copied and recopied for centuries only with few additions or improvements. In the first half of the sixteenth century, however, a botanical renaissance developed, and it was greatly stimulated by the still young art of printing.

The herbals of **Brunfels, Bock, Fuchs, Cordus** and others, sometimes referred to as the 'German Fathers of Botany', are representative of this period.

Between the years 1530 and 1536 **Otto Brunfelsius** (Brunfels) (1464-1534) published his '**Herbal**' which consisted of descriptions of a large number of plants, many illustrated by woodcuts. It was the beginning of modern taxonomy. This was soon followed by **Hieronymus Bock's 'Kreuterbuch'** (1539) and **Leonardus Fuch's 'De Historia Stripium'** (1542) and Fuchs was primarily a medical botanist. His idea of the flower in general is similar to that given by Theophrastus. He distinguished two kinds of flowers, the leafy and the capillary, but regarded both as being united in flowers like the rose. He arranged the plants in **De Historia Stripiurn** alphabetically by their Greek name, hence we find no attempt at classification made by him. In spite of these limitations, the Historia which he produced commands admiration.

William Turner (1515-1568), whose '**A New Herbal**' printed in English appeared in 1551 (first part), 1562 (second part) and 1568 (third part), is often called 'Father of English Botany'. He also arranged plants alphabetically since no thought was then given to plant relationships. Turner gave too many plants English names which they bear today. With an apparently inborn zeal for reformation he swept out many of the old superstitions about plants.

The Herbal of **Valerius Cordus** was published posthumously in 1561. It contained information about not only the medicinal plants found in Germany and Italy, but also many foreign woods, barks and fruits, acquired from other countries. His descriptions of plants were more accurate than any those of his contemporaries. He was the first to draw up botanical descriptions in a systematic form, including details about the type of plants, form of parts, colour, odour, taste etc.

The influence of gardening on the development of botany may be seen in the work of **John Gerard** (1545-1612). Gerard published an account in 1596 which contained over 1033 species of the plants growing in his garden. He published his greatest work '**The Herbal**' or '**Generall Historie of Plantes**' in 1597 illustrated with over 1800 wood-cuts of plants. The plants he described were arranged in three books: (a) the first included grasses, (b) second all herbs used for medicine and sweet smelling plants, and (c) the third one dealt with bushes, fruit-bearing plants, resins, and mushrooms. The result of this was a rough classification, based on superficial resemblances and upon the relationship of plant with man.

All of these works, in which the botanical descriptions were subordinated to the medicinal details of the plants, were overloaded with wide speculations regarding their supposed medicinal qualities. A large amount of this information would be dismissed today as pure fantasy. Gradually, however, a simple system of classification came into being, based partly upon morphology and partly upon the medicinal characteristics of plants.

A significant contribution to taxonomy was made at this time by **Caspar Bauhin**. Bauhin's '**Prodromus Theatri Botanici**' (1620) and '**Pinax Theatri Botanici**' (1623) are important references in which he listed all the species of plants. At the same time, we find one of the first attempts to utilize a '**binomial system of nomenclature**'. This has been recognized as the first attempt to differentiate the category of "genus" from the category of "species". (You shall study about binomial system of nomenclature in Unit 16) Bauhin also pointed out that several names referred to the same plant, thus introducing the concept of synonymy in nomenclature. The **Pinax Theatri Botanici** contained descriptions of 6000 species. He attempted a classification by natural affinities proceeding from the grasses through the lilies, dicot herbs, and shrubs and trees. However, he was singularly oblivious to the importance of flowers and fruits.

Handed down from the ancients, and elaborated on by the herbalists, was the '**Doctrine of Signatures**', which was based on the concept "that different plants/parts resembled portions of the human body", and therefore they must have been so created for the purpose of furnishing remedies for the ailments of those portions of the body. Many plants were given common names that referred to supposed remedial properties, and the origin of many scientific names that are still in use today may be traced to this doctrine. For example, the generic name **Hepatica**, the shape of the leaves in that genus being thought to resemble the shape of the liver, and the leaves, therefore, to be a remedy for diseases of that organ. Similarly, the almond (Hindi Badam) is shaped like the human eye and was believed to be good for improving the eyesight.

11.2.3 The Transition Period

The transition period from the Renaissance to the Modern period produced many notable workers and much literature. Extensive explorations during 1600's of New World led to the discovery of a number of new plants. European herbalists studied these plants and added them to the growing list of herbals. Fuchs in 1542 listed about 500 species; Bauhin in 1623 described 6000

species. John Ray (1703) described more than 18000 plants. It was followed by development of more specific systems of naming and arranging plants. With increase in number of plants known, there was a need to recognise and name genera.

Botanists gradually broke away from the traditional doctrines of the ancients and developed new systems of classification, a new terminology of description, and a system of nomenclature that was to become a permanent part of taxonomy. Since the concept of evolution, had not yet been developed, the arrangement of plant groups in various system of classification was still more artificial than phylogenetic. You will be given a detailed account of some important contributions made during this period in the units 16, 17 and 18.

11.2.4 The Post-Herbal Period

It is difficult to draw a sharp line of demarcation between the transition period, marked by various attempts of classification, all of which were more or less artificial (based on form relationships), and the Modern Period, which progressed steadily in the development of a system based on natural affinities.

Plant taxonomy in ancient India

In India, history of botanical science dates back to the Vedic period (approx 1500 B.C. to 500 B.C.). It started with the development of agriculture when humans undertook cultivation of various food crops. In the literature of that period, several technical terms are available which were used for the description of plants and plant parts. Details on classification, morphology and anatomy of important economic plants are also available. Plants were studied in relation to medicine, agriculture and horticulture. The early treatise on botany like '**Ayurveda**', '**Charka-Samhita**' and '**Sushruta-Samhita**' were, therefore primarily utilitarian. It is said that more than 2500 years ago Bhikshu Atreya, a well-known teacher at the University of Taxila asked one of his pupils Jivaka to collect, identify and describe the properties of all the plants growing within a distance of four 'Yojanas' of the University. Dignitaries like Dhanvantari, Nagarjun, Agnivesh Jatukarna, Bhela Harita etc., had an intimate knowledge of the characteristics of medicinal plants.

One of the earliest works dealing with plant life in a scientific manner is '**Vrikshayurveda**' compiled by **Parashara** (even before the beginning of the Christian era). This formed the basis of botanical teachings and medical studies in ancient India. The book deals with the categorisation, morphology and anatomy of plants, nature and properties of soil types, distribution and description of forests in the country. In this work, a system of classification based on comparative morphology of plants is also available.

This system of plant classification was considered much more advanced than any other system proposed anywhere in the world before eighteenth century. Many families ('ganas') were clearly distinguished as to be recognisable today. The present day family **Cruciferae** was called '**Swastikaganiyam**' because the arrangement of sepals and petals resembled a 'Swastika', and the flowers were further characterised by a superior ovary, four free sepals, four free petals, six stamens-two of which are shorter, and four longer, two carpels fused and formed a two-locular fruit. The present day **Cucurbitaceae** was

called '**Tripusaganiyam**' and was characterised by having flowers which were epigynous, sometimes bisexual with five sepals, five fused petals, three stamens and a unilocular ovary with three rows of ovules. This clearly shows that Parashara's work was not only utilitarian but a compilation of scientific studies too. It shows that here in India, classification of plants was attempted in that remote period on scientific lines.

SAQ 1

- a) State whether the following statements are **True** or **False** and indicate by putting **T** for true and **F** for False in the given brackets :
- i) The Herbalists belonged to post-Darwinian era. []
 - ii) Democritus is regarded as Father of Medicine. []
 - iii) Aristotle regarded roots and shoots of a plant as members of an organized entity. []
 - iv) Theophrastus recognised different types of insertions of floral parts. []
 - v) 'Historia Naturalis' was written by Pliny the Elder. []
- b) Fill in the blanks with appropriate word(s) :
- i) The Anicia Juliana Codex was originally compiled by
 - ii) Three- parts of 'New Herball' were written in English Language by..... .
 - iii) Parashara is famous for his scientific compilation called
 - iv) The 'Gana' "Swastikagniyam" of ancient India is recognised today as family
 - v) The influence of gardening on the development of botany may be seen in the works of
-

11.3 WHAT IS PLANT TAXONOMY?

Plant taxonomy is the science that finds, describes, identifies, classifies, and names plants. The term systematics is applied to the study or description of variations among organisms in order to formulate a classification system. Organisms thus arranged into groups enable a large population to be categorised and understood.

Plant taxonomy or systematics has undergone through four major approaches of study. These could be summarized as:

- 1) **Pioneer or Alpha:** This phase was early periods that involved explorations and discovery of new plants.
- 2) **Consolidation:** In this phase, the large amount of data collected was organised to understand classification.

- 3) **Synthesis:** During this phase, the consolidated data and adequate plant material collected was classified principally based on morphological characters. It attained its peak by late 1800's and to some extent still continues.
- 4) **Experimental:** Using different scientific tools and modern technology, the vast amount of collected data interpreted in evolutionary or phylogenetic terms is being currently analysed. This phase is still evolving.

11.4 AIMS AND OBJECTIVES OF TAXONOMY

Plants have a great significance and unmatched impact on our life. Most of our needs such as foodstuffs, medicinal products, and fodder resources are fulfilled by plants. Whether “plants are harmful or beneficial” is intimately associated with our daily life. Thus, it becomes necessary to have an orderly and scientific approach to study of the plants. There are millions of plants on this planet with differences or similarities but none of them are identical. Thus the individuals showing similarities are placed in smaller groups known as species and these species are placed in larger groups known as genera.

The basic knowledge of plants provides an idea about their morphological variations. Various usages of plants in everyday life necessitated formulation of standard terminology for description of various parts as an aid to identification and nomenclature. The systematic study of plants and animals has benefitted the people who are related to forestry, medicine, paper industry and food etc., as it helps them to procure proper material. This is also associated with the study of plant and animal diseases as they affect human economy.

In modern times there is an extensive development of hybrid plants since they are more useful for people as providing better fruit, seed and flower products, but without the knowledge of taxonomy man-induced **hybridisation** is not possible. The study of plants also helps in soil conservation as their special features are used to minimize the soil loss, and increase the soil fertility. Agriculture and horticulture, the interrelated branches of science, have a direct bearing on taxonomy. Fossil identification is possible only when adequate literature on the living plants is available. Identification of preserved specimens is sometimes difficult because of their fragmentary and ill-preserved nature. The information and knowledge of taxonomy helps in furtherance of establishing connecting links amongst various taxa.

Taxonomic studies have major objectives of learning of the kinds of plants on earth, their names, distinctions, affinities, distribution, habit and habitat. In the beginning, the science of taxonomy was the study of small fragments of plants which were collected, labelled and put on record. The information, gathered from these studies is fundamental to the scientific knowledge of the inventory of the earth's plant resources.

A taxon (plural taxa) is a group (s) of organisms defined by a system of classification.

It is estimated that the inventory for North America is largely complete. However, in the tropics only about 5,00,000 species out of estimated 3 million have been described so far while out of estimated 1,500,000 species of

temperate regions of the earth only about 1 million have been described. According to an estimate, about 15000 flowering plants of South America are yet to be named.

Another objective of taxonomy is the assemblage of knowledge gained. This is usually in the form of treatises useful to fellow scientists and to civilization in general. But the knowledge thus gained is sterile unless it is transferred to others for study. Thus the floras are published to account for the plants of a given area. Manuals are prepared so that the plants of an area may be more readily identified and named; revisions and monographs are published so that one may, know the extent and delimitations of a particular group and its components. Distributional studies are published so that others may know of range extensions, corrections and interrelationships of the taxa within an area. All the products of taxonomic research add to the resources and are available to scientists. They are essential to any study of the natural resources of raw materials possibly suited to man's needs in a multiplicity of activities, for example, forest products, medicine, food, ornamentals, agriculture and industry.

An organised reconstruction of the plant kingdom as a whole can be made only after the inventory of its components has been assembled. After assemblage, charting of the degree and character of variation will demonstrate its diversity, and these data can be integrated with other facets of evolutionary knowledge to produce a more accurate phylogenetic scheme.

The principal objectives of plant taxonomy are:

- i) to provide a convenient method for identification and communication;
- ii) to produce a coherent and universal system of classification;
- iii) to provide a single Latin "scientific" name to every plant and groups of plants in the world, both living and fossil.
- iv) to maintain inventory of the world flora; and
- v) to demonstrate the evolutionary implications of plant diversity;

There are four important steps in taxonomy:

- 1. CHARACTERISATION**
- 2. IDENTIFICATION**
- 3. CLASSIFICATION**
- 4. NOMENCLATURE**

These are the primary activities of a taxonomist. Characterisation is the basic requirement for understanding the different parts of the organism. It is thus a description of the characters. By comparing the characters of two or more organisms, it becomes possible to differentiate them. This leads to identification. When two or more organisms have been differentiated (identified) by their characters, it becomes necessary to group them into categories. This is essentially what taxonomists do when they classify organisms. Once the identified organisms have been classified, it becomes

necessary to name them. Thus the process of taxonomy is a logical sequence of knowing (1) the characters of the organisms; (2) identifying them on the basis of an understanding of their characters; (3) classifying them into groups; and (4) providing them names.

You may perhaps want to know more about 'what does a taxonomist do? Let us briefly describe the work of a taxonomist.

- 1) **Observes** and studies the character(s) of organisms, populations and taxa for the discovery of spatial, temporal, abiotic, biotic relationship for better understanding of taxonomy of the group; and species relationships.
- 2) **Analyses** the character variations (within individuals, populations, taxon), and **chooses** parameters to evaluate the observations.
- 3) **Synthesises** the gathered information about the organism from many fields such as: morphology, anatomy, embryology, cytology, palynology, genetics, physiology, biochemistry, geography, ecology, paleobotany, molecular biology etc.
- 4) **Describes**, selects the characters and character states of circumscriptions of new taxa and changed circumscriptions of old taxa that have been remodelled, divided, united, transferred, changed in rank etc.
- 5) A taxonomist **Identifies** and **determines** the position and rank of new taxa and determines the correct position of old taxa that have been remodelled, divided, united, transferred, changed in rank etc. **Identifies** and distinguishes new taxa in a scientific manner.
- 6) **Provides** names for new taxa, and **determines** correct name for old; and determines, remodels, divides, unites, transfer's, and changes in the rank of the taxa.
- 7) **Coins** proper Latin or Greek root prefixes, suffixes to create a new name that are connotative, mnemonic, short, easy to pronounce.
- 8) **Communicates** effectively by classifying, identifying, objects, groups of objects, entities etc.
- 9) **Determines** relationships, selects organisms and characters to be studied. Calculates resemblances between organisms.
- 10) Functions as **historian** to develop perspective for better understanding of taxonomy by studying oldest to most recent documents etc.
- 11) **Generates** systems of information for taxonomic purposes to provide effective methods for collection, analysis, preservation of data; storage, retrieval, exchange of information etc.
- 12) **Theorises** concept-principle-process approaches to develop new concept and reinterpret and amplify the old ones.
- 13) **Conserves** our natural heritage and provides valuable information base for threatened and endangered species.

- 14) **Evaluates** research and concept-principle processes to findings to original purpose or hypothesis.
- 15) Practices as **systematist** to ascertain types, patterns, trends in variations, in population size, species, and higher taxa. Also, classifies, identifies, describes names, observes analyses, synthesises, evaluates, and determines the relationship, similarities, and differences from all fields of evidences.

SAQ 2

State whether the following statements are **True** or **False** and indicate by putting **T** for True and **F** for False in the given brackets.

- i) The basic knowledge of plants provides idea about their morphological variation. []
- ii) Man-induced hybridisation is possible without the knowledge of taxonomy. []
- iii) Study of plant taxonomy also helps in conservation of soil and to decrease soil fertility. []
- iv) Fragmentary and ill-preserved specimens sometimes help in establishing connecting links amongst various taxa. []
- v) One of the important objectives of plant taxonomy is to give accurate phylogenetic scheme. []
- vi) One of the most extensive works of plant taxonomists was to provide a single Latin scientific name to every plant. []

11.4.1 Characterisation

As mentioned above, characterisation is the first step in taxonomy. It is the primary source of data for understanding organisms. In simple terms, characterisation is the description of the organisms. It helps us to know the features (characters) of plants in plant taxonomy. All parts of the plant provide information and this leads us to know the characters in a scientific manner. When we study the appearance/form of the plant, we collect information of the morphological characters. On the other hand, if we analyse the structure of the different parts of the plant, we obtain knowledge about the anatomical characters. In this manner, the taxonomist can accumulate data from cytology and genetics, embryology and pollen morphology; chemical composition; ecology and environmental factors, etc. to provide a vast amount of data about the characters. Characterisation lays the foundation of the science of taxonomy. It provides the basic data for identification.

11.4.2 Identification

The data base provided by characterisation becomes the spring board for identification. This is due to the fact that comparison of two or more plants on the basis of their characters helps the taxonomist to decide whether the plants being compared have similar or different characters. When the characters are

similar, the plants are similar, but when the characters are different, the plants are dissimilar. This forms the basis of identification.

The process of identification is the determination of a 'taxon' "as being identical with or similar to another and already known element. In real terms, identification is a very important step in understanding the organism/plant being studied. It requires a very careful analysis of the characters of the organism. By proper comparison of the characters, it is possible to decide about the identification of the plant. It is like a judgment based on actual facts (about the characters). A taxonomist must express "an opinion with full confidence" when she/he identifies an organism. Usually the first, initial step towards correct identification of the given plant would be to determine the plant group to which it belongs. Taxonomists have prepared artificial keys for the identification of plants (refer Unit 13 for details). Proper identification leads to the next logical step in taxonomy.

11.4.3 Classification

Classification always follows identification. Thus when two or more groups of plants have been differentiated (identified) from their characters, it becomes necessary to recognize their relationships. This leads to placing the groups in defined categories. The end result of this leads to the synthesis of a system of classification.

First of all, you should know what is classification? Let us try to define it in simple terms. Classification is "organisation of knowledge". It is also a means of creating an organised sequence of information about organism/objects, etc. Classification is thus the placing of a plant or groups of plants in groups or categories according to a particular plan or sequence. This is generally in conformity with a nomenclatural system and taxonomic hierarchy (refer unit 15 for details). Table 11.1 provides an example.

Table 11.1: Taxonomical Hierarchy

Kingdom	:	Plantae
Division	:	Magnoliophyta
Class	:	Asteropsida
Order	:	Asterales
Family	:	Asteraceae
Genus	:	<i>Helianthus</i>
Species	:	<i>annuus</i>

Classification is the arrangement of organisms into groups having common characteristics. These groups are then arranged according to a system. For example similar species of flowering plants are placed into a genus (plural, genera); similar genera are grouped into families; families with common features are arranged into orders, orders into classes and classes into divisions. Classification results in the placing of organisms into a hierarchy of ranks or categories such as species, genera, and families and so on.

In practical terms classification deals more with the placing of a plant group with a selected scheme than the placing of an individual plant in one of several minor categories. Thus a system of classification is necessary to allow us to identify plants and to communicate scientifically with others. **Indeed, classification is both, an information storage and retrieval system without which scientific communication would be impossible.**

Classification thus enables us to summarise our knowledge about the organisms, and that is one of the most important functions of taxonomy. The saving of time and effort is thus one way in which we can define the utility and purpose of classification.

11.4.4 Nomenclature

Nomenclature is a very important constituent of plant taxonomy. It can be defined as the system of naming an object particularly that of biological origin. We are aware that man has been interested in plants since prehistoric times. The plants have been given names by tribes in their own languages. These are called common or vernacular names. Unfortunately, there is no uniformity in such names. Often the same plant is known by different common names in different places or even different plants belonging to different places are referred by similar names. Thus, the common names are many, different, indefinite and restricted to the people of one language or even one region of a country. You shall learn about this very important and interesting field of plant taxonomy, the nomenclature in Units 16 and 17. Figure 11.3 summarizes the principle aims of taxonomy which enable us to classify the diversity of organisms in different groups.

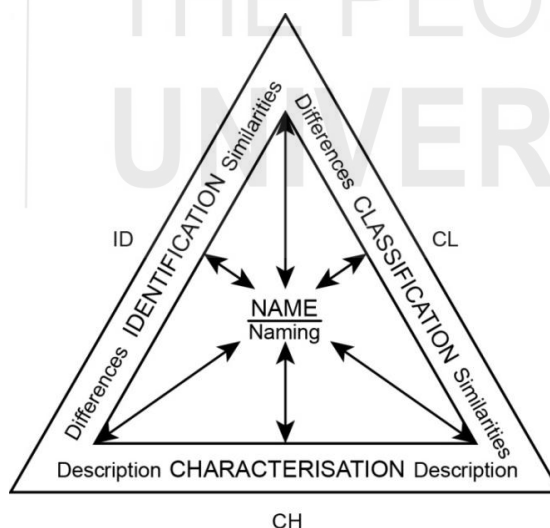


Fig.11.3: Illustrates the interrelationship between identification, characterisation, classification and nomenclature, basic procedures and systems.

For instance, a plant's name is the key that unlocks the door to its total biology. Ecologists, horticulturists, biochemists, agriculturists and others must have a reference system for the plants, they use in their research. However, the name of plant is not meant only for the scientist, it may be used by other people with varied interests and training, those who are interested in the natural history of plants. The scientific name of a plant communicates the species and genus, and from that the family may be easily determined.

SAQ 3

Fill in the blanks with appropriate words:

- i) The first step to know about the plant is
- ii) can be determined by the process of identification.
- iii) is also known as organisation of knowledge.
- iv) is known as naming of an object particularly of biological origin.

11.5 SUMMARY

In this Unit you have studied that:

- Plant taxonomy helps prepare an inventory of world's flora which is far from being complete, especially of the tropics.
- Understanding and knowledge of plant taxonomy is a prerequisite to prepare a coherent and universal system of classification of plants.
- Plant taxonomy is an important tool to study evolutionary implications of plant diversity.
- Principles and rules of plant taxonomy provide a single 'Latin' scientific name for every species of a plant, both extinct and extant.
- Study of plant taxonomy can be divided into pre- and post-evolutionary eras. The pre-evolutionary period is further divided into: Ancient Greek and Roman era; herbalist era; Transition period, and Post-herbal era.
- Plant taxonomy also flourished in ancient India. Aryurveda; Charak-Samhita and Shushruta-Samhita are some of the famous ancient Indian taxonomic literature.

11.6 TERMINAL QUESTIONS

1. List the main objectives of taxonomy.
2. Write a brief account of history of pre-evolutionary era of plant taxonomy.
3. Define the terms.
 - Plant taxonomy;
 - Classification;
 - Identification;
 - Nomenclature.
4. Discuss the role of a taxonomist in field of botany.

11.7 ANSWERS

Self-Assessment Questions

1. a) i) F; ii) F; iii) T; iv) T; v) T.
b) i) Dioscorides
ii) Turner/William Turner
iii) Vriksh ayurveda
iv) Cruciferae;
v) Gerard/John Gerard.
2. i) T; ii) F; iii) F; iv) T; v) T; vi) T
3. i) Characterization;
ii) Taxon;
iii) Classification;
iv) Nomenclature.

Terminal Questions

1. Refer to sections 11.1 and 11.3
2. Refer to section 11.2 and its sub-sections
3. Refer to section 11.4
4. Refer to section 11.4

Acknowledgements of Figures

Figure 11.1 : <https://archive.org/details/mobot31753000811833>

Figure 11.2 : https://en.wikipedia.org/wiki/De_materia_medica

UNIT 12

HERBARIA AND BOTANICAL GARDENS

Structure

12.1	Introduction	12.4	Botanical Gardens of World and India
	Objectives		Role of a Botanic Garden
12.2	Field Observations: Ecological - Phytosociological		Botanic Gardens and Conservation
12.3	Herbarium		Role of Botanical Survey of India
	Field Methodology	12.5	Summary
	Functions of Herbarium	12.6	Terminal Questions
	Collection of Plant Specimens	12.7	Answers
	Important Herbaria of World and India		

12.1 INTRODUCTION

Plant taxonomy is dependent on many sciences and in turn they are equally dependent on it. The activities of a plant taxonomist are basic to all other fields of plant sciences because the taxonomist provides an inventory of flora, ways for identification, names and a system of classification of plants. Plant taxonomy also depends on other disciplines like ecology, plant breeding, phyto-sociology, pharmacology and biochemistry. While dealing with taxonomic problems we have to understand the distribution of plants. The scores of thousands of plants known today as species have been established by the application of the existing and established principles of taxonomy.

You might know that the accumulated knowledge of Earth's flora is far from perfect and will become more perfect only by exploration of new areas, collection of its components, their study and classification. Once names and classification systems have been provided there must be methods for us to identify a taxon as being similar to another known entity. We will discuss keys to the identification of plants in Unit 13. In this unit you will study the ecological and phyto-sociological aspects of taxonomy, herbaria and botanic gardens. You will be given brief information about Royal Botanic Gardens, Kew

(Richmond, Surrey, near London), Botanic Garden Sibpur, Howrah (India) and Botanical Survey of India (BSI).

Objectives

After studying this unit you should be able to:

- ❖ the contributions of ecology to systematic understanding;
- ❖ preserve specimens for herbaria;
- ❖ enlist some important national and international herbaria and botanical gardens; and
- ❖ specify the role of botanical gardens and Botanical Survey of India.

12.2 FIELD OBSERVATIONS: ECOLOGICAL-PHYTOSOCIOLOGICAL

Field studies are desirable for an understanding of the relationship of any group of plants. If it is not possible to study the plants in the field you should grow these plants in one or more test gardens. Seeds and plants for this purpose could be obtained from indigenous sources. While making an ecological study in the field, record the season of flowering and of fruiting and collect material in all stages of development.

Make a precise note of:

- locations of collections,
- habitat types
- soil characteristics

Make a detailed study of characters and record the information. Some characters are often lost in the dried specimens. Therefore, features such as colouration of foliage and floral parts, smell, presence or absence of latex, corolla vernation, corolla colour and anther colour before and after dehiscence must be recorded in the field. Also, make a note of viscosity of parts especially nectariferous organs. Look for pollinating agencies and record the time of pollination. Texture of foliage and perianth parts is of great importance and also colour of freshly matured fruits. You should remember that root stock characters often provide immense information and should not be overlooked. While making a phyto-sociological study, determine the natural variation within and between populations.

Assign a different collection number to specimens from different colonies within the same general area. If the material is growing in abundance prepare four or five sets of duplicate collections and on completion of the study you can distribute it to important herbaria. You will learn more about herbaria in coming section. Mass collection will also provide a means of determining relationships with greater accuracy and whether a variation is one associated with or restricted to colonies, to habitats or to regions. From this information

you can determine that a population represents a sub species, variety or forma. Collect those parts that are significant for their characters and also random samples. Collect about 50 samples of a population after proper selection. This will constitute the material for study and permanent herbarium record; it shall then help the taxonomist in compiling information on frequency of variation, discontinuity of variation and correlation between variables.

12.3 HERBARIUM

First of all you must know the definition of herbarium **“The herbarium is a place where dried and mounted specimens are stored according to any recognized system of classification and are available for any reference”**. It can also be considered as “a warehouse of information about plant diversity”.

All research and educational institutions where science is taught have their own plant species specimens collected locally. They may also have thousands of specimens (gradually accumulated over time) which document the flora of one or more regions. These collections are preserved in specially designed cupboards for easy retrieval when needed.

The concept of Herbaria began early in the sixteenth century in Italy, when collections of dried plants were sewn on paper. Luca Ghini (1490 - 1556) invented the herbarium. This art was disseminated throughout Europe by his students. The specimens mounted on sheets of paper were often bound into volumes. This made it possible to move the herbarium specimens to different places. It also enabled the use of these specimens as reference material by physicians who prepared medicines from plants. Linnaeus popularized the current practice of mounting specimens on single sheets of paper and storing them in stacks. Herbaria are the permanent repositories of plant specimens and are sources of information about plants and vegetation (Fig.12.1).



Fig 12.1: Plant specimens arranged in a herbarium.

In the following subsections we will discuss the methodology you should adopt while going on a field trip for collection of plant.

12.3.1 Field Methodology

Before you plan for a field trip, decide the tools and equipment required. Certain equipments are necessary for plant collection. A collecting pick is

required for digging up roots and rhizomes. A strong knife is required for cutting branches and other plant parts. Pair of pruning shears is needed for cutting woody and hard material. A pair of forceps is needed for opening the flower bud to study the stamens and carpels. A vasculum is needed for accommodating collected specimens to be studied and pressed (Fig.12.2).

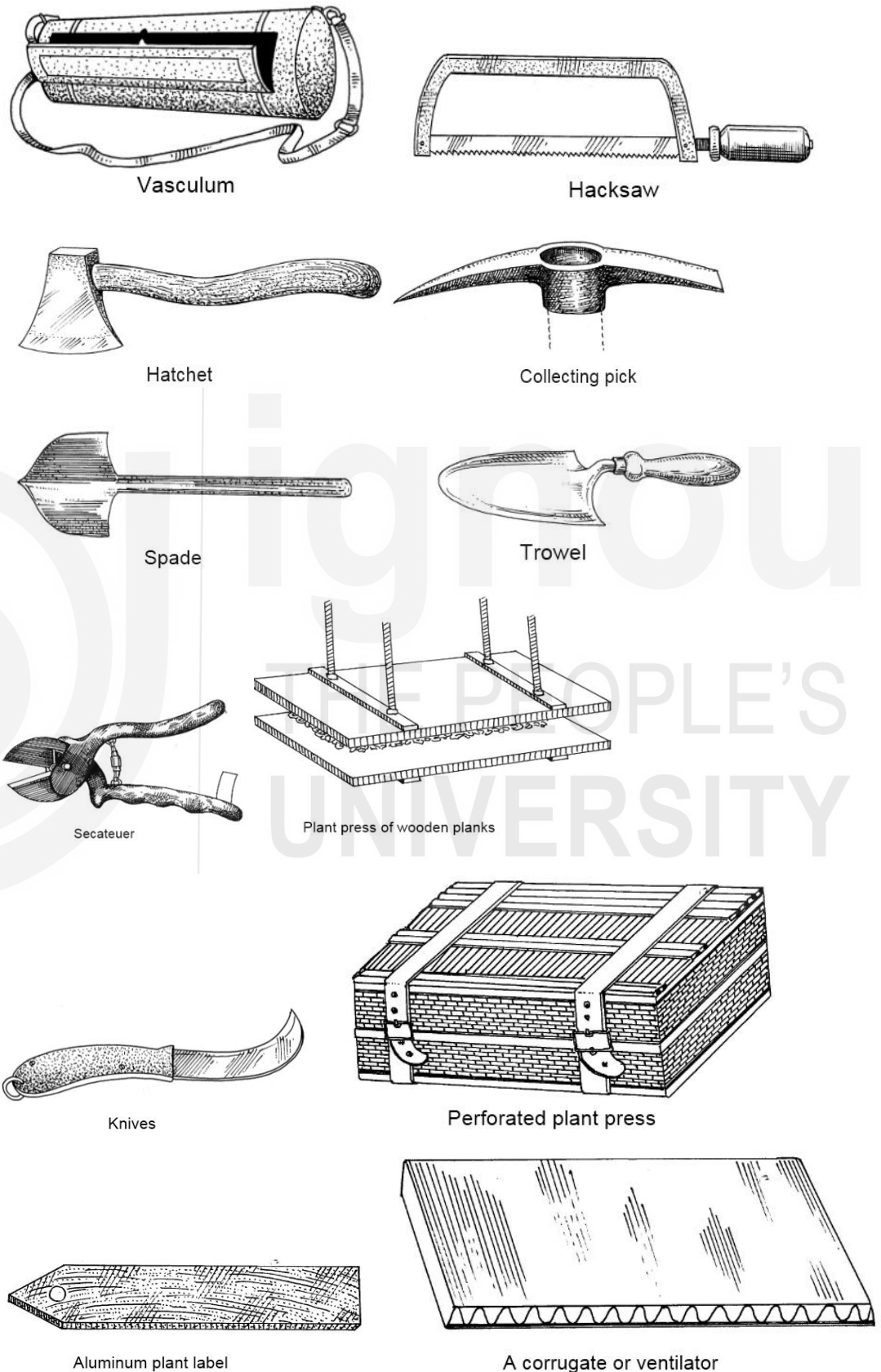


Fig. 12.2: Various equipments used in collection of plants.

- A plant press together with blotters or newsprint is needed for pressing and keeping the collected specimens (Fig.12.2). Also, you should carry with you a field book for noting down the details of collected specimens. Polythene bags in good number are also needed for keeping fresh plant specimens. After storing plants in these bags the mouth of bags should be tightly closed to avoid wilting. For collecting aquatic plants from ponds and lakes, carry bottles with a fixative. Also carry a long rope, for collecting cones, and fruits from trees. Fungal specimens need to be collected separately.
- Obtain necessary permission from the authorities concerned to visit a forest. Ask for forest guide or any other official assistance. Always keep a copy of all essential documents in your camp. Make proper arrangements for your stay, food, and clothing and wear field shoes.
- Best period of collection of plants in our country is from February to September. India is known for its rich flora and fauna. Therefore it is important to look at all possible places for plants. Thus explore for plants in rocky crevices, sand dunes, marshy regions, mountains, calcareous regions and even on dead and fallen trunks. Observe the nature of the plant, its association with other plants and the substrate. Collect complete and perfect material with flowers and fruits. While collecting medicinally valuable plants, collect sufficient quantities of root, shoot, seed and plant part/s which is/are of medicinal value. Later on you can sow these seeds in the garden and raise plants to add to your collection. If the size of the plant exceeds the size of mounting board or herbarium sheet bend it in N or U form, but do not break the stem.
- Phytoplankton should be collected by slowly towing a fine net (180 meshed unit). The small funnel container at the tip collects organisms. The organisms should be preserved in iodine (0.5 g), potassium iodide (0.1 g), glacial acetic acid (4.0 ml), formalin (24.0 ml), and water (400 ml). Sea weeds are collected in polythene bags, properly numbered and preserved in 2.5% formalin alcohol. Specimens of fungi are collected as a whole, fresh and healthy along with the substratum or host. While collecting lichens, note the name of the plant serving as substrate. Liverworts and mosses are preserved by drying while cacti and other succulents in liquid preservative. If you collect small fleshy fruits prick them at several places and dip in hot water until all juice is exuded out. Now, you can press these specimens. Aquatic plants are wrapped in damp newspaper and kept in a vasculum until they are pressed. You will also find some economically important algae, both marine and fresh water and diatoms. These are collected with a pipette consisting of a glass tube and a large suction bulb. Blue green algae is dried on paper, *Chara* species are spread on newspaper and then transferred to a herbarium sheet.
- If you collect tree ferns and other land plants, first keep them in polythene bags and then press these between the folds of newspaper. Keep cones, fruits and needles of gymnosperms in polythene bags.

12.3.2 Functions of Herbarium

- Plants specimens are permanently preserved in herbaria, and hence they are the major sources of information about plant diversity and vegetation.
- A representation of all species of a genus, or all the genera of a family may be gathered from the herbarium.
- Preserved plant specimens of herbaria are used in almost all types of taxonomic research programmes of fundamental as well as applied nature.
- The classification of the world's flora is based mainly on the herbarium specimens.
- A list of the endangered species of any region may be prepared after herbarium consultation.
- A list of the plant species with their medicinal as well as other ethnobotanical values may be prepared after herbarium consultation. A herbarium preserves national plant wealth including type material.
- Limited individual collections are identified only with the help of herbaria.
- Monographs of genera or families are prepared only after the study of herbarium specimens.
- A herbarium can give knowledge about the distribution and occurrence of plant species.
- Big herbaria organise training courses for young generation and thus provide job opportunities to young workers.
- Herbarium material is used in studying the palynology, anatomy and chemical aspects of desired plants.
- Herbaria provide loan of specimens for study at other institutions.
- Herbaria provide scientific information to the public regarding the plants.

Herbarium Ethics

Herbaria provide us with policy statements including such information as 1) filing arrangements, 2) re-shelving, 3) loan procedures, 4) annotation labels and 5) use of library collections. You should strictly adhere to the policy statements. If specimens are dry and fragile, mount them on paper that is flexible and keep these sheets flat. Lift these folders carefully one at a time and avoid placing of heavy objects like elbows, books, coffee cups etc. on specimens. Use long armed microscope while studying specimens and avoid bending the sheet. If specimens are damaged keep them aside and inform curator immediately. Do not dissect or remove flowers and fruits from the specimens, as they form the important organs of specimens using which specimens are easily identified.

12.3.3 Collection of Plant Specimens

Collection of plant specimens is essential for taxonomic research. This helps in documenting species and their variability. Plant material is carefully

selected, pressed and preserved. While collecting plant specimens, locations and habitat information is recorded, some features like flower colour and fragrance are noted because these are evident in living plants and are not easily observed in dried materials. For identification and research, an intact and complete plant is collected. Representative leaves and reproductive structures are essential. The flowers, fruits and seeds of flowering plants are especially important. By now you must have understood that herbaria are the repository of “original documents” that is specimens upon which all our knowledge of the taxonomy, evolution, and distribution of the flora rests.

Index Card Sketch

Flora of (place/area/town etc)..... No.
 Family.....
 Botanical name.....
 Local name.....
 Habit.....
 Flower colour.....
 Habitat Locality Altitude.....
 Ecological notes

 Date of collection.....
 Collector.....

Fig. 12.3: Index Card Sketch.

The collected specimens provide a standard reference material for verifying the identification of newly collected plants. This documents the presence of a species at a particular location and provides data on its geographic range and also points out the existence of classification problems. It also provides plant material and data for research. Vegetative and reproductive morphology, pollen samples, and leaf samples can be used for chemical analysis, and anatomical studies. Further, ecological, economical and ethnobotanical data can be obtained from the labels. Each label contains the information about local name, scientific name, locality, habitat, date of collection, name of collector and collection number. The labels (Fig. 12.3) are glued by one edge to the lower right corner of the herbarium sheet.

Borrowed Material

Relevant material can be obtained on loan for studying. Borrowed specimens benefit the lending institutions because borrowing institution has responsibility of annotating the specimens and revising identification. The loan specimens arriving from lending institutions are carefully checked for transit damage and the list is verified. The specimens are studied only on the institutional premises and housed in standard metal herbarium cases when not in use. For removing certain parts like pollen etc. prior permission is sought. The specimens are returned after proper annotation. The annotation label has the complete scientific name of the plant (genus, specific epithet and author), full name of the person making the annotation and the year of annotation. The original boxes and packing material is saved and used for return shipment giving details of packing.

Exchange of Material

The original specimens on whom the names of the species are based are very important and known as **type specimens**. These cannot be replaced and they serve as reference material for the identification of the species. These specimens should be stored in safe and standard cupboards separately from other general collection and handled with great care. If you receive a request from other coworkers, you can loan these specimens to qualified specialists with proper label. The specimens should be sent with safe and efficient means of transport. If you gift the type collection to other workers or to any museum, you still retain control and possession over this collection for your life time. You can also label type specimens as (1) “holotypes” (only specimen of an original collection OR the specimen designated as TYPE by the author of the name of the species); (2) “isotypes” (a duplicate of the holotype, i.e. another specimen from the same plant/group of plants collected with the holotype); (3) all other specimens mentioned in the original publication are collectively called “paratypes”. If the original holotype and its duplicates (isotypes) are lost or destroyed by fire or some other accident, you can collect a new specimen (later) from the same place as the original specimen/s and use it for nomenclatural purposes. On the other hand, if “paratypes” are available, they become very important for nomenclatural purposes. Because of their value type specimens (holotype/isotype/paratype) are given special care by curators of herbaria, and they do not permit them being sent out on loan to other botanists or institutions.

While examining the herbarium specimen every care is to be taken in shifting the herbarium sheet. It should be lifted with the hands so that it does not bend. Do not turn over the herbarium sheets like the pages of a book. It should be lifted with both the hands and kept over the other. If you do not handle these sheets properly there is every chance of damage to specimen.

The exchange of specimens among collectors is made on a one for one basis. It is an important means of augmenting a collection at minimal cost. The specimens for exchange are un-mounted and loose in the pressing paper and properly labelled. We should always exchange good quality material, because poor quality materials are not normally accepted by most curators as exchange materials.

Relationship with Co-workers

Herbaria provide visitors with policy statements and we have an obligation to adhere to the policy statements while visiting herbaria and in developing relation with co-workers. Visits to other herbaria are often profitable in terms of examining critical specimens and collections, searching the undetermined folders and exchanging ideas with other taxonomists. In order to make it possible for co-worker to render some help a note in advance should be sent. This will help the curator to prepare for the visit and to provide a place to work and a microscope. Since many herbaria are closed in the evenings and also on weekends, the privilege of visiting after normal hours may be offered but should not be requested.

SAQ 1

- List any 10 characteristics that may not be available in a dried specimen, but can be recorded easily during field studies.
- What is a herbarium?
- Draw a sketch of a representative index card to be used for a herbarium sheet.

12.3.4 Important Herbaria of World and India



Fig. 12.4: A herbarium sheet.

Important Herbaria

You have already learnt that the herbarium is a place where dried and mounted specimens are stored according to any recognized system of classification. Special attention is paid towards the protection of all specimens (including type specimens) from all sorts of insects, dust, moisture and other external injuries. Herbaria (Fig. 12.4) provide information about collected plants in various forms viz. recorded notes, photographs and hand drawn designs. Herbaria are associated with Botanic Gardens and other Institutions such as Universities.

For your information some important herbaria are mentioned below:

- 1) Herbarium of Royal Botanic Gardens, Kew, Richmond, Surrey, UK.
- 2) Herbarium of British Museum of Natural History, London, UK.
- 3) Herbarium of New York Botanical Garden, New York, U.S.A.
- 4) Herbarium of Missouri Botanical Garden, St. Louis, U.S.A
- 5) Herbarium of Museum National d' Histoire Naturelle, Paris, France,
- 6) Herbarium of Komarov Botanical Institute, St. Petersburg, Russia,

- 7) Central National Herbarium (Herbarium of Indian Botanic Garden, (earlier called Calcutta Herbarium), Howrah, India.
- 8) Herbarium of Forest Research Institute, Dehradun, India.
- 9) Southern Circle Herbarium of BSI, (earlier called the Madras Herbarium) Coimbatore, India.
- 10) Western Circle Herbarium, of BSI, Pune (Poona), India.
- 11) Eastern Circle Herbarium, of BSI, Shillong, (earlier called the Assam Herbarium) Meghalaya, India.
- 12) Herbarium of National Botanical Research Institute, Lucknow, India.
- 13) Herbarium of Indian Agricultural Research Institute, New Delhi, India.

Table12.1: Some large herbaria of the world.

Sl. No	Name of Herbaria	Abbreviated name	Approx. No. of specimens
1.	Herbarium of Royal Botanic Gardens, Kew, England	K	7 million
2.	British Museum of Natural History, London	BM	6 million
3.	Museum of Natural History, Paris	P	6 .8 million
4.	Azerbaijan National Academy of Science of Baku, Azerbaijan	BAK	6 million
5.	New York Botanic Garden Herbarium	NY	7.8 million
6.	US National Herbarium, Washington D.C.	US	4.5 million
7.	Herbarium of Missouri Botanical Garden St. Louis	MO	6.6 million
8.	Central National Herbarium, Kolkata (earlier known as the Calcutta Herbarium)	CAL	2 million
9.	Gray Herbarium of Harvard University, Cambridge	GH	2 million
10.	Royal Botanic Gardens, Edinburgh	E	3 million
11.	National Herbarium of Victoria, Melbourne, Australia	MEL	1.5 million
12.	Herbarium of the Forest Research Institute, Dehradun	DD	3.3 lakh
13.	Madras Herbarium, Coimbatore	MH	2.6 lakhs
14.	Herbarium of the National Botanical Research Institute, Lucknow	LWG	2.6 lakhs
15.	Herbarium of the BSI, Allahabad	BSA	69 thousand
16.	Herbarium of the BSI, Dehradun	BSD	86 thousand
17.	Herbarium of the BSI, Shillong	ASSAM	20 thousand
18.	Herbarium of the BSI, Pune	BSI	1.7 lakhs

12.4 BOTANICAL GARDENS OF WORLD AND INDIA

A botanical garden is essentially a collection of living plants maintained for both pure and functional studies. According to Jackson (1999), “A botanic garden is an institution holding a documented collection of living plants for the purpose of scientific research, conservation, display and education”. It is a place for *ex-situ* conservation, as well as a place where economically and endangered plants are displayed for purpose of research and education. Public parks and gardens are centres of aesthetic beauty and serve as places of recreation. The Botanic Garden is a living repository of plants arranged and maintained on scientific basis with accurate taxonomic identification of plants. A good botanic garden explains:

- importance of afforestation;
- evolution of cultivation of plants;
- horticultural practices for a layman; and
- distributes guides to go around the garden to look for plants of our liking and It also enables people to get interested in gardening.

You may look for a Jasmine suitable to grow in your house. A farmer may look for a bamboo suitable to cultivate in his land after judging the suitability of soil and available water source. A botanic garden generally has special enclosures for growing different kinds of plants. Thus, we come across green houses, glass houses, and other such special areas in the botanic garden.

Green House: It is a place to grow plants in desired environment. In temperate countries plenty of air and light is provided to the plants but in tropical countries it is meant for shade loving plants. The essential elements of a successful green house environment are heat, humidity, ventilation, light and managed in the method of arranging plants. The heating, humidifying, watering and introduction of nutrients are all done automatically. Green house soil is lighter and better aerated, richer in nutrient than garden soil and well made to compost, sand, vermiculite to avoid dehydration. In a tropical green house we can grow ornamental foliage plants, palms, ferns, orchids and shade loving plants. The glass roofing of the green house is substituted by split-bamboos, plaiting matting of coconut or date palm leaves supported by a strong frame. For permanent roofing creepers are grown while walls of the house are made with brick.

Apart from green and glass houses (Fig12.5), a botanical garden should possess phytotrons and conservatories. All of these should be architecturally attractive and well maintained so that rare and endangered plants as well as plants of ornamental, medicinal and horticultural importance are well maintained special attention should be given to cacti, succulents, orchids etc;.

The first garden for medicinal plants was established by an Italian professor of botany - Luca Ghini (A.D. 1290-1556). This was known as a “physic garden”. It was based on the idea (belief) that “all plants had been put on earth by God for man’s use”. The need to know the therapeutic use of plants was therefore

The earliest botanic garden was established in 1545-1550 with a collection of medicinal plants.

The word greenhouse was coined by John Evelyn in the 17th century.

A phytotron is an enclosed research greenhouse used for studying interactions between plants and the environment. It was a product of the disciplines of plant physiology and botany. Phytotrons unified and extended earlier piecemeal efforts to claim total control of the whole environment.

instrumental in the establishment of the physic gardens. Most of these early physic gardens became the fore-runners of the modern botanic gardens.

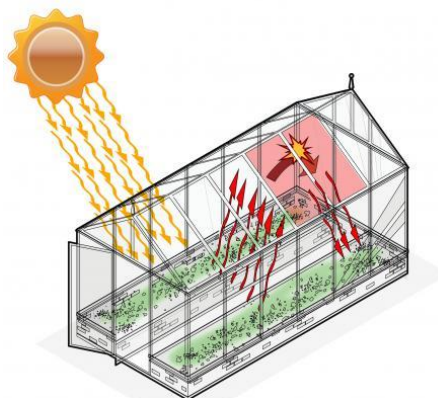


Fig. 12.5: Glass House.

'Charak Samhita' is recognized as the Materia Medica of ancient India (1000-800 B.C.). In India, botanic gardens also existed since pre-Vedic era as indicated by the cultivation of medicinal herbs in tapobans of ashrams. Further, during Mughal rule a large number of pleasure gardens were established in Delhi, Agra, Lucknow, Rajasthan, and Kashmir. Although not "true botanic gardens", they did influence the establishment of botanic gardens.

12.4.1 Role of a Botanic Garden

A botanic garden makes us to simply enjoy the beauty and variety of nature. The pleasure of admiring turns us into good naturalists. We can also appreciate the beauty of foliage and flowers. The role of botanic gardens is to:

- cultivate and maintain plants of interest on scientific basis;
- show vegetation of the world on geographical characteristics i.e. Himalayan flora, Alpine flora;
- maintain plants which are in danger of extinction and save species;
- plan germplasm collection;
- serve as research centres in various fields;
- facilitate taxonomic studies by preserved and live plants;
- promote educational programmes and research in experimental botany and ornamental horticulture; and
- exchange of material – live, dried and "Index semidum" i.e. list of seeds offered for exchange.

12.4.2 Botanic Gardens and Conservation

The UN Convention on Environment and Development held at Rio-de-Janerio in June 1992 led to the signing of the "Convention on Biodiversity" by 187 countries by April 2002. As many as 10 Articles of the CBD have emphasized the important role of botanic gardens. These are significant for developing "Global Strategies for Conservation". This adds to the major roles of botanic gardens listed above.

Some of the Important Botanic Gardens:

Royal Botanic Gardens, Kew (London)

Royal Botanic Gardens, Kew, (Fig. 12.6) is a monumental institute in the world. It has most modern and well equipped laboratories and collection of rare plants. This garden is situated on the bank of river Thames in London, UK. The garden extends over 200 acres of land which is beautifully planned. This is one of the chief attractions of the world and is regarded as very precious. Recently it has been felt that the garden is suffering due to pollution in England and also the soil is not suitable enough for the growth of several rare plants. The Government of Britain has paid immediate attention to the problem and about 400 acres of land near Kew with improved soil, topographic conditions and mild temperature has been sanctioned under the name "Kew Satellite through National Trust". This land is not exposed to severe winter due to long excessive low temperature and is away from London.



Fig. 12.6: Botanic Gardens, Kew, Richmond.

The foundation of this monumental garden dates back to 1759 when William Aiton took over as its superintendent. Before Aiton, W.B. Turrill worked as keeper of the herbarium and Library of the Royal Botanic Gardens. Sir William Chambers and Sir John Hill brought glory to the garden through the publications of the accounts of plants growing in the garden under the title "The Royal Botanic Garden Kew" and preparation of catalogues. One such catalogue "**Hortus Kewensis**" listed the plants grown during that period

Following Linnaeus' system of classification, Aiton published the second "**Hortus Kewensis**" listing more than 5,500 species. Sir Joseph Banks introduced plants from expeditions and spent his personal funds. This itself is enough proof of his keen interest, enthusiasm and devotion towards development of the garden and herbarium. In 1841, Sir William Jackson Hooker took over as the Director of Kew Gardens. He built palm house of exotic beauty and established a vast herbarium. His son J.D. Hooker (who also became the Director) added Rhododendrons (many species were collected from the Himalayas) which added excellence to Kew. He published

“Flora of British India” and was the editor of Botanical Magazine. Thisleton Dyre published the research journal called “Kew Bulletin” and the “**Index Kewensis**”. This became a very important source of reference for the botanical names of plants of the world. He also added Alpine house, Rose garden, Bamboo garden and a lily pond.

Herbarium of this botanic garden houses 6.5 million specimens (the largest herbarium of the world). The arboretum has more than 7000 species and varieties. There are about 13000, species and varieties growing in glass houses and 8,0000 herbaceous species are grown outdoor. The layout at Kew includes the collection of willows, oak, elm, cedar, lilies, pine, sweet chestnut, tulip, daffodils, hazel, sweet gum, poplar, filmy ferns, *Thuja*, cypress, Japanese cedar, roses, pears, prunus, Indian bean, Japanese cherries, horse chestnut, crab apples, acacia, lime, hibiscus, magnolias, and walnut. Special gardens at Kew comprise rhododendrons collection, bamboo garden, chalk garden, rock garden, shrub garden, heath garden and rosary. The splendid green houses in Kew include palm house, ferneries, water lily house, alpine house and temperature house. Some of the important publications of this garden are Flora of British India, Kew Bulletin and Index Kewensis.

Acharya Jagdish Chandra Bose Indian Botanic Garden, Sibpur (India)

Indian Botanic Garden, Sibpur, Howrah, (Bengal) is the largest and oldest in South East Asia. It was established in 1770 by Col. Robert Kyd as the “East India Company Garden”. Dr. William Roxburgh, (called the father of Indian Botany), took charge of the garden in 1793. It spreads over 109 hectares serving as repository of over 15,000 trees and shrubs representing 2,350 species in addition to thousands of herbaceous species. It is now maintained by the Botanical Survey of India, Ministry of Environment, Forestry and Fisheries, Govt. of India. It (IBG) is now called Acharya Jagdish Chandra Bose Indian Botanic Garden. Several economically important plants viz. *Cinchona*, jute, flax, hemp, Indian rubber, *Eucalyptus*, paper mulberry, cloves, cinnamon, pepper, tomato, tobacco, coffee are cultivated. Various subsidiary food species were introduced in 1787 when Bengal was worst hit by famine. Several trees in the garden were destroyed by the great cyclone in 1864 and 1867.

The great banyan tree about 250 years old with a circumference of 400 meters and more than 2900 aerial roots, is the greatest attraction of the garden (Fig. 12.7). It is about 100ft high and circumference of its canopy is about 440m and looking from long distance it looks like mountain or a small forest. The National Orchidarium contains 2000 orchids with everlasting beauty. Beside there is a Palm house (*Palmatum*) and *Bambusetum* etc.

The medicinal plants garden grows about 450 species used in Ayurveda, Unani, Homeopathy and modern Allopathy.

The garden, with its herbarium has played a significant role in floristics and botany of India since its establishment. It serves as a centre of plant taxonomic studies of India. These days research is carried out on Plant introduction, breeding and conservation. “Red Data Book” and “Flora India” in 24 volumes are the latest contribution of the publication division of the garden.

An old Banyan tree (*Ficus benghalensis*) that is more than 250 years old. What's more...the tree has over 2900 prop roots and covers an area of about 1.50 hectares. According to the archives, the Great Banyan Tree was born by a bird's dropping and it grew on a *Phoenix* Tree (date palm). The strong roots of the Banyan Tree strangled the date palm tree and the date palm tree was gradually killed.



Fig.12.7: Great banyan tree.

National Botanic Garden (NBG), Lucknow

National Botanic Research Institute (NBRI), Lucknow is spread over 75 acres of land on the south bank of the river Gomti. Once a flourishing royal garden of Nawab of Oudh, the garden is nicely decorated with a beautiful Rosarium (collection of varieties of roses), cactus house (Fig 12.8), palm avenue, different species of *Nymphaea* and aquatic garden of lotus. The woodland is an area with thickly planted trees. A large fruit orchard, a fern house and a palm house are unique to the garden.



Fig. 12.8: Cactus house at NBRI

A research laboratory is dedicated to the research on xerophytic plants, and a hydroponicum. A hydroponicum is a place where soil-less cultures of varieties of fruits, vegetables and ornamentals can be done. The garden also possesses largest collection of climbers. The herbarium at the garden possesses over a lakh of specimen representing flora of India and neighbouring countries.

12.4.3 Role of Botanical Survey of India

The Botanical Survey of India (BSI) was initially established in 1890 with the objective of exploring the plant resources of the country and for identifying the plant species with economic value. In 1954, the Government reorganised the BSI with the following objectives:

1. Undertaking intensive floristic surveys and collecting accurate and detailed information on the occurrence, distribution, ecology and economic utility, of plants in the country;
2. Collecting, identifying and distributing plant materials that may be of use to educational and research institutions; and

3. Acting as the custodian of authentic collection in well planned herbaria and documenting plant resources in form of local, district, state and national flora.

India is a country with very diverse geographical conditions. There are the Himalayan mountains; with the table land or plateaus and deep valleys. There are also Sub Himalayan tracts such as the Shiwaliks and the foothills of Assam. The Central Indian Highland (known as the Vindhya region) and Western and Eastern Ghats in Peninsular India are all elevated regions. In addition to these elevated areas, there are the alluvial plains of Northern India (the Indo-Gangetic region) and lower terrain of South India. As a result, the Indian region exhibits a variety of flora and forest types. This is unique to our country. Therefore, to explore the vegetative resources of the Indian Empire the BSI, established on 13th February, 1890 by British, was mandated to co-ordinate the botanical works in different parts of India.

For this purpose, the country was divided into four regions: Eastern, Northern, Western and Southern with centres at Kolkata, Saharanpur, Poona and Madras respectively. Calcutta unit was established as centre of BSI. Sir George King, the Superintendent of Sibpur Botanical Garden was the first Director of BSI. Some well known naturalists of 18th, 19th and early 20th century such as Thomas Henry Hamilton; William Roxburgh; Nathaniel Wallich; David Prain; J.F. Duthie; R. Strachey; J.E. Winterbottom; W. Moorcroft and J.F. Royle were important contributors to the activities of BSI. Dr. E.K. Janaki Ammal was appointed officer-on-special-Duty in 1952 at BSI. On March 29, 1954 Government of India reorganized the BSI with headquarters at Kolkata along with and four circles. These circles were:

1. BSI, Southern Circle at Coimbatore (10-10-1955)
2. BSI, Eastern Circle at Shillong (01-04-1956)
3. BSI, Western Circle at Pune (12-12-1955) and
4. BSI, Northern Circle at Dehradun (01-08-1956).

A research laboratory, Central Botanical Laboratory at Lucknow was established in December 1957 with the objective to study various aspects of plant biology - plant cytology, plant physiology, plant chemistry, seed biology, ecology with an interdisciplinary approach. Simultaneously around the same period Royal Botanical Garden at Kolkata was renamed as Indian Botanical Garden, Calcutta and the herbarium as Central National Herbarium, Kolkata.

In addition to four circles already established in 1954 seven more circles were established to explore plant resources of our country. These are:

1. Central Circle at Allahabad (1962)
2. Arid Circle at Jodhpur (1972)
3. Andaman and Nicobar Circle at Port Blair (1972)
4. Arunachal Pradesh Circle at Itanagar (1977)
5. Sikkim Himalayan Circle at Gangtok (1979)
6. Botanical Garden of India Republic at Noida (2002)
7. Deccan Circle at Hyderabad (2005).

The various activities and research findings of BSI are published in official organs in the form of annual reports, and records: (1) Records of the Botanical Survey of India and (2) Bulletin of Botanical Survey of India.

SAQ 2

- a) Describe the function of a green house.
- b) Choose the correct alternative among the provided in the parenthesis :
 - i) Palm houses, ferneries are characteristic of (Kew Garden / Western Circle Herbarium).
 - ii) Phytotrons are present in a (herbarium/botanical garden).
 - iii) Dried plant specimen could be exchanged from a (herbarium/botanical garden).
 - iv) Botanical Garden located at the banks of river Gomti is (National Botanical Garden/Central National Botanical Garden).
 - v) (BSI/IARI) acts as custodian of authorities' collection of plant material in India.
- c) Match the herbaria listed under column I with the locations mentioned in column II.

Column I

- i) Herbarium of Royal Botanic Gardens
- ii) Komarov Botanical Institute
- iii) Herbarium of National Botanical Research Institute
- iv) Central National Herbarium
- v) Herbarium of Indian Agricultural Research Institute

Column II

- a) St. Petersburg
- b) New Delhi
- c) Kolkata
- d) Lucknow
- e) Kew

12.5 SUMMARY

- Field studies are key to understanding of any ecological and phytosociological relationships of any group(s) of plants. Such studies can be made either in natural habitats or on plants reared and maintained in test gardens.
- During field studies precise recording of: location of collection; habitat types; soil characteristics; coloration of vegetative and floral parts; veneration of corolla; presence of laticiferous and nectariferous structures; pollinating agents; time of pollination etc is made.
- Herbarium is a place where dried and mounted specimens are stored according to any recognized system of classification. Herbaria are

available to taxonomists for any references. All educational and research institutes maintain their own herbaria. Earliest herbarium was established in early 16th Century in Italy.

- Careful collection, selection, processing, presentation, field notes, proper identification, storage etc constitute the herbarium ethics.
- A herbarium specimen may be exchanged, donated, borrowed from another herbarium. Strict structured protocol is maintained while exchange of such herbarium specimen.
- Herbarium of the Royal Botanic Gardens, Kew, U.K.; Herbarium of British Museum, London, U.K.; Central National Herbarium, Kolkata, India; Herbarium of National Botanical Research Institute, Lucknow, India are some of the important herbaria.
- A botanical garden should cultivate and maintain plants of special interest on a scientific basis. Such plants should be representative of various geographical regions of the country and the world. A botanical garden serves as reservoir of germplasm collection of rare and endangered plants.
- A botanical garden should serve as a research centre in various fields of biology. Such gardens should promote educational programmes not only for students but also for general public. It also offers life, plant material, seeds for exchange.

12.6 TERMINAL QUESTIONS

1. Write short notes on :
 - a) Royal Botanic Gardens, Kew
 - b) Functions of a herbarium
 - c) Herbarium ethics
2. “Ecological-phytosociological field observations are desirable for a plant taxonomist, in addition to studies based on herbarium sheets”. Explain
3. Name and comment on any **two** botanical gardens of India.
4. What is the significance of an “Index Card” pasted on a herbarium sheet?
5. Write a detailed note on history, objectives and organizational set-up of Botanical Survey of India.

12.7 ANSWERS

Self-Assessment Questions

1. a) Season of flowering; season of fruiting; soil characteristics; colouration of foliage, colouration of floral parts; odour of flower; presence or absence of latex; presence or absence of

nectariferous structures; corolla veneration; pollination agents;
texture of foliage; time of pollination; colour of freshly matured fruit;
root stock characteristics, etc. (any 10).

- b) Refer Subsection 12.3
- c) Refer fig. 12.3 and Subsection 12.3.2
- 2. a) Refer section 12.4
- b) i) Kew Gardens
- ii) botanical gardens
- iii) herbarium
- iv) National Botanical Garden
- v) BSI
- 3. i) e; ii) a; iii) d; iv) c; v) b

Terminal Questions

- 1. Refer to
 - a) Subsection 12.4.2
 - b) Subsection 12.3.2
 - c) Subsection 12.3.2
- 2. Refer Subsection 12.2
- 3. Refer Subsection 12.4.2
- 4. Refer Fig. 12.3 and Subsection 12.3.2 (open-ended)
- 5. Refer Subsection 12.4.3

Acknowledgement of Figures

- Fig.12.1 : Herbaria (<http://www.iiim.res.in/herbarium/introduction.html>)
- Fig.12.4 : Herbarium sheet (<https://images.app.goo.gl/pmF2Pcan7KSb3dyX7>)
- Fig.12.5 : Green house (<https://garden.lovetoknow.com/wiki/4>)
- Fig.12.6 : Botanic Garden, Kew (London) <http://www.urban75.org/blog/a-photo-tour-of-kew-gardens-london-part-one/>
- Fig.12.7 : Great banyan tree (<http://indiasendangered.com/a-floral-paradise-kolkatas-indian-botanic-garden/>)
- Fig.12.8 : Cactus house at NBRI
(https://www.researchgate.net/publication/290433971_Exsitu_conservation_of_cacti_and_succulents_at_CSIR-NBRI_Botanic_Garden_Lucknow_India/figures?lo=1)

TAXONOMIC DOCUMENTATION

Structure

13.1	Introduction	Plant Systematics on Internet
	Objectives	13.3
13.2	Taxonomic Documentation	Keys
	General Taxonomic Indexes	Characteristics of a good Key
	Floras	Construction and use of a Key
	Monographs	Faults and Limitations of a Key
	Manuals	Types of Keys
	Revisions	13.4
	Periodicals	Summary
		13.5
		Terminal Questions
		13.6
		Answers

13.1 INTRODUCTION

Identification is integral to all taxonomic works. Most often the identification of any plant specimen is done by comparison with an authentic, i.e. a previously identified known plant specimen. Such a process of determination of correct name of a plant is called **species - determination**. To determine the correct identification of a species, the person should have knowledge of taxonomic methods, manuals and other resources. Expertise in identification of plants is an additional pre-requisite. To begin with it is assumed (that prior to the identification) that a classification exists and the plants have already been assigned names. Once named, these could be retrievable. An accurate identification of given plant is essential in the fields of : biogeography; biochemistry; ecology; genetics; physiology; agriculture; pharmacology apart from the classical disciplines of plant sciences.

There are numerous kinds of resources from where the correct, authentic, complete, identification can be retrieved. These are called taxonomic documents. These include: general taxonomic indexes/indices; floras; monographs; manuals; revisions; periodicals; etc. In order to help a researcher to correctly, conveniently and quickly ascertain the name of an unknown plants, many of these resources are provided with 'keys'.

This unit exposes you to the vast treasure of literature concerned with taxonomy to comprehend the future scope of its growth.

Objectives

After studying this unit you should be able to:

- ❖ know the need for species identification ;
- ❖ list and describe the various kinds of taxonomic documentations: general indexes/ indices; floras; monographs; manuals; revisions; periodicals etc;
- ❖ explain the salient characteristics of such documentations;
- ❖ name a few internationally acclaimed taxonomic documentations and list some Indian resources;
- ❖ explain the concepts of single access and multi-access keys; their kinds and uses; and
- ❖ construct and use a key.

13.2 TAXONOMIC DOCUMENTATION

There is an enormous amount of taxonomic literature where details regarding taxonomic aspect of plants (including identification, classification, and nomenclature) are given. Plants are studied in various parts of world and research work is published in different types of literature like floras, manuals, revisions and journals etc. we will describe these in the coming unit.

13.2.1 General Taxonomic Indexes

The indexes serve as an aid to locate quickly the source of original publication of a name. This helps us to learn if a particular name has been applied to a plant or to know to which order, family, subfamily or tribe a plant of a given name may belong. The important indexes to vascular plants are as follows:

- i) ***Index Kewensis Plantarum Phanerogamarum*** : 2 vols. (1893-1895) and 20 supplements, the last one published in 1996. Oxford. This work is a corner stone to the literature on the systematics of flowering plants. The compilation of original work was made possible by a gift of money by Charles Darwin. It was compiled at the Royal Botanic Gardens, Kew by B.D. Jackson and his clerical assistants under the direction of J.D. Hooker. *Index Kewensis* is the reference employed to determine the source of the original publications of a generic name or binomial of a seed plant. It does not account for the names of ferns or the names of any plants that are not seed plants. The original two volumes of the *Index Kewensis* listed 400,000 names of plant species published since 1753 to 1895. About 6,000 names were added every year and these accumulated names were published in the Supplements every 5 years. After the publication of Supplement 20, this *Index* has become available in electronic form called "*The International Plant Names Index – IPNI*"

- ii) **Gray Herbarium Card Index** is published from Harvard University, Cambridge, Massachusetts, USA. A Card Index has database accounting for all new names and new combinations applied in any category of the flowering plants and pteridophytes of the Western Hemisphere. It had covered 287225 cards for taxa published since 1873. Last update has covered publications till 1977. It is invaluable to the students of New World plants since it accounts for *Latin* names given to vascular plants since 1885.
- iii) **Genera Siphonogamarum** : (Berlin 1900-1907). The work edited by C.G. Dalla Torre and H. Harms, accounts for the names published for families and genera of spermatophytes in one volume. Orders and families are arranged essentially according to Engler & Prantl's System of Classification. In this, each family name is followed by the names of sub- families, tribes and genera. Finally, under each genus is indicated the number of species described in it. The names in each category are provided with the appropriate author citation, as well as the date of publication and synonyms.
- iv) **Index filicum. Hafniae** :(Copenhagen 1906). With supplements up to 1933. Similar to *Index Kewensis*, it provides references to the sources of original publication of generic and specific names applied to true ferns. It does not include 'fern-allies'. The original work and supplements were edited by Carl Christensen.
- v) **Index londinensis**: This provides illustrations of flowering plants, ferns and fern-allies .The 6-volume work provides an alphabetical index, by genus and species from 1753-1920. The supplement covers the period 1921-1935. The work was compiled at Royal Botanic Gardens, Kew by Otto Stapf, under the auspices of the Royal Horticultural Society of London.
- vi) **Index Nominum Genericorum** (ING), Botany: A compilation of generic names for organisms covered by the ICN: "International Code of Nomenclature for Algae, Fungi and Plants". Each entry is the result of painstaking bibliographic research and application of ICN for Algae, Fungi and Plants. Details of valid publication, precise date of publication, type specimen, basionym(s) of each organism is maintained as a card. Every card has name of genus, serial number; and the designation of person who prepared the card. The first issue published in 1955 had entries of 1000 cards. Now, index is being computerized and issued as volumes.

13.2.2 Floras

A flora is a work dedicated to the plants of a particular region and also usually restricted to a major segment of plant kingdom (as vascular plants, flowering plants etc.). There are numerous floras that account for all the vascular or seed plants. A flora provides an inventory of the plants occurring in a definite area. It is usually authenticated by citation of herbarium specimens, and their location. It is customary to arrange the plants in a known, recognized system of classification viz. Bentham and Hooker; Engler and Prantl; Hutchinson, etc.

It generally provides a key to the identification of plants recorded in the flora.

Field study is an important ingredient for preparation of an inventory. Some of the features that a taxonomist records during making an inventory are:

1. Texture of plant; habit; size; units; fragrance; pollinating agents; station/location; frequency etc;
2. Habitat type; other associated plants; soil type; soil pH; exposure to sun; direction of habitat; elevation etc;
3. Vernacular name(s); It is also recommended that the inventory should mention whether the recorded species/specimen is :
 - i) Indigenous : local;
 - ii) Naturalized : fully established; reproducing; migrating expanding in the new area;
 - iii) Introduced : brought deliberately by man without cultivation; or
 - iv) Adventive : enters area by any means but is unable to meet competition.

There is no single world flora that accounts for every species, even of the seed plants on the earth.

A few important floras are listed below:

World Floras

- 1) Baillon, H. **The Natural History of Plants**, 8 Vols. London .1871-1888.
- 2) Bentham, G.and Hooker, J.D. **Genera Plantarum**, 3 Vols. London. 1862- 1883.
- 3) Engler, A, and Prantl. K. **“Die Natürelischen Pflanzenfamilien”**, 23 vols. Leipzig 1887-1915.
- 4) Hutchinson, J., **“The Families of Flowering Plants”**, 2 vols. London. 1926, 1959, 1973.
- 5) Britton, N.L. *et al.* **North American Flora**, New York Botanical Gardens, 1905.
- 6) Bentham, G. **Handbook of the British Flora**; Ashford, Kent. 1930.
- 7) Komarov, V.L. *et al.* **Flora URSS (Flora Unionis Rerumpublicarum Sovieticarum Socialisticarum)**, 13 Vols. Moscow. 1934.
- 8) Bentham, G. **Flora Australiensis: A description of the plants of Australian territory**, 7 Vols. London. 1863-1878.
- 9) Brown, F.B.H. **Flora of Southeastern Polynesia**, Bishop Museum Bull. Hawaii 84, 89,130. Honolulu, Hawaii .1931-1935.
- 10) Tutin T.G. *et al.* **Flora Europea** , 5 vols. Cambridge University Press: Cambridge. 1966-1980.
- 11) Hutchinson, J. and Dalziel, J.M. **Flora of West Tropical Africa**, 2nd ed., 3 Vols. Her Majesty's Stationery Office London. 1954-1972.

Asian Floras: Some important Asian Floras are listed as under:

- 1) Babu, C.R. **Herbaceous Flora of Dehradun**, CSIR, New Delhi. 1977.
- 2) Bhandari, M.M. **Flora of Indian Desert**, Scientific Publishers Jodhpur. 1978.
- 3) Duthie, J.F. **Flora of Upper Gangetic Plain and of the adjacent Siwalik and sub Himalayan tracts**. Reprinted, Bishen Singh, Mahindra Pal Singh .Dehradun. 1971.
- 4) Hooker, J.D. **Flora of British India** 7 Vols. London 1876-1897 ,Reprinted, Bishen Singh, Mahendra Pal Singh, Dehradun, 1982-1990
- 5) Kachroo, P. **Flora of Ladakh**, Bishen Singh, Mahindra Pal Singh, Dehradun.1977.
- 6) Kirtikar, K. R. **Indian Medicinal plants**, Bishen Singh, Mahindra Pal Singh Dehradun. 1975.
- 7) Maheshwari, J.K. **The Flora of Delhi**, CSIR, New Delhi. 1963
- 8) Maheshwari, J. K. **Illustrations to the Flora of Delhi**,CSIR, New Delhi.1966
- 9) Nair, N.C. **Flora of Bashahr Himalayas**, International Bioscience Publication, Hisar 1977.
- 10) Royle.,J. Forbes. **Illustrations of the Botany and other branches of the natural history of the Himalayan mountains and the flora of Cashmere** , Today and Tomorrow's, New Delhi 1970 (reprint),
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- 17) Mukerji, A.K. **Flora of Pachmarhi and Bori Reserves** Botanical Survey of India. Kolkata. 1984.
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13.2.3 Monographs

A monograph is defined as “the complete account as can be made at a given time of any one family, tribe or genus, nothing being neglected of it”. It is worldwide in its scope and application. It reviews all taxonomic treatments that have been made in particular taxon. It synthesises all available cytological, genetical, morphological, anatomical, paleobotanical, and ecological studies of the taxon by its author, co-workers or others. Considering the large number of disciplines that are undertaken it needs several years of patient study for writing a single monograph. All elements of the treatise are accounted for by dichotomous keys, full synonyms, and complete descriptions, precise designations of types together with notes as to where the types are deposited, citations of specimens examined, distributional ranges, and notes on habitats and discussions of taxonomic and nomenclatorial considerations.

Example: Maheshwari P. and Konar R.N. 1971 ***Pinus***- Botanical Monograph-CSIR, New Delhi

13.2.4 Manuals

A manual is a book that contains information on the area of coverage and keys and descriptions to the families, genera and species. It includes the accepted scientific name, followed by the author of that name, and major synonyms. Information on infraspecific (below the rank of the species) taxa if any, is also provided along with ecological and distributional data and common names. Many manuals have been revised and reprinted numerous times. Such manuals become the standard reference for the flora of a particular area. Recent trends in taxonomy require much attention to detail and documentation of the taxa by means of herbarium specimens deposited in recognised herbaria. A modern floristic researcher diverts much attention to typification, nomenclature, distribution and ecology, in addition to the basic comparative morphology.

Examples :

Fernald, M.L. 1850 (8th Edition) **Gray's Manual of Botany**, American Biological Company, New York.

Fassett, N.C. 1940 **A Manual of Aquatic Plants** McGraw Hill, New York.

Bailey, L.H. 1949 **Manual of Cultivated Plants**. Macmillan, New York.

13.2.5 Revisions

A revision differs from a monograph being much less in degree of scope and completeness. It generally accounts for only a single genus or a section of a large genus. Revisions are generally restricted to a continent or smaller geographical area; these may/rarely contain reviews of previous publications and are most of the times based on herbarium sheets. Thus, a revision is a provisional document. The bibliographies by Pritzel, Jackson, Rehder and Merrill and Walker list several thousand monographs and revisions.

13.2.6 Periodicals

A periodical is a publication appearing at regular intervals. Each issue is called a number and collectively these numbers comprise a **Volume (Band/ Heft/ Fascicle** in German). Sponsors of periodicals often publish more than one serial. A Scientific Society may publish a monthly serial to provide a source of publication for a variety of relatively short papers contributed by its members, together with records of its own proceedings. Such a periodical is usually called **Journal/Annals**, or a **Bulletin or Proceedings**.

Botanists generally use the abbreviated form of the titles in citations and bibliographies and for this reason it is necessary to know the full title as catalogued. Libraries widely differ in the method of cataloguing titles of periodicals and too often fail to cross index titles under the various possible headings. In general if a periodical is published by a Government or Municipal institution, it is catalogued under the name of the sponsoring country or city; likewise, if by a Society, Academy or educational institution it is catalogued under the title of the organisation which is in turn placed under the name of the city where it has its seat.

Periodicals most frequently used in taxonomic studies of plants are as follows:

- 1) **Annals of Royal Botanic Gardens**, Kolkata
- 2) **Journal of Linnean Society**, Botany, London
- 3) **Records of Botanical Survey of India**, Kolkata
- 4) **Journal of Indian Botanical Society**, Meerut
- 5) **Tropical Ecology Bulletin**, Varanasi
- 6) **Bulletin of the Torrey Botanical Club**, Washington
- 7) **Kew Bulletin**, Kew, Richmond, London
- 8) **Blumea**, Netherlands
- 9) **Edinburgh Journal of Botany**, Edinburgh, UK
- 10) **Systematic Botany**, USA
- 11) **TAXON**, Berlin, Germany
- 12) **Bulletin of the Botanical Survey of India**, Kolkata

13.2.7 Plant Systematics on Internet

The internet now provides a wealth of information about plants. It provides quick access to floras, checklists, images of plants, detailed treatments to a group of plants, DNA sequences and other databases.

To get the same information or to reach the same website, there exist many starting points in addition to various paths to reach same destination.

A few of important websites are:

- www.ou.edu/cas/botany-micro/idb-alpha/botany.html Internet Directory for Botany or IDB
- www.tropios.org/Project/PCN (for chromosome numbers)
- www.mobot.org/mobot/research/apweb/top/glossary_h.html (for botanical glossary).
- www.ipni.org . (for database of the names and associated bibliographic details of all seed plants)
- <http://plants.jstor.org> JSTOR: Global Plants provides images of herbarium specimens (types) from numerous institutions.
- www.kew.org (Royal Botanic Gardens, kew, U.K.)
- www.ncbi.nlm.nih.gov/Genebank (the best source of DNA sequences).
- www.tolweb.org/tree (a website that focuses on phylogeny).
- www.treebase.org (data base of phylogenetic information, stored phylogenetic trees from previous published works).
- <https://datadryad.org/> (Dryad is a digital repository).

SAQ 1

- a) Fill in the blanks with appropriate word(s) :
- serves as an aid to locate the original publication.
 - An inventory of plants of a definite area is called.....
 - JSTOR provides images of herbarium specimen.
 - A collection of a numbers of a periodical is known as.....
 - Taxon, a bulletin published by International Association of Plant Taxonomy is an example of taxonomic literature called.....
- b) Choose the correct alternative from the two provided in parentheses :
- (Manual/Revision) is an example of provisional document.
 - A book that contains information on the area of coverage, keys, descriptions to families, genera, species, scientific names, author, synonyms etc. is called (Manual/Monograph).
 - Flora of Delhi is authored by (J.D. Hooker/J.K. Maheshwari).
 - Genera siphonogamarum is an example of (Flora/General Taxonomic Index).

13.3 KEYS

A key is an artificial device (tool) or an arrangement for the determination of names of the plants included in it. A botanical key can be defined as a device for easily identifying an unknown plant by a sequence of choices between two or more statements. A key, thus, represents one kind of taxonomic Literature. The first key was introduced in 1778 by French botanist Jean-Baptiste de Lamarck. For the identification of names of the plant, both fresh material as well as dried herbarium materials can be used. If the material to be studied is dry, then it can be softened by boiling with a detergent or a wetting agent, such as aerosol OT (Dioctyl sodium sulfosuccinate). In addition, the use of a 10x hand lens or a good dissection microscope, a pair of needles, sharp of pointed forceps, a single razor blade and millimeter scale is recommended. The critical observations that a person determining the specimen needs to record are: habit, phyllotaxy, shape, apex, margin, venation of a leaf, trichome characteristics, floral features, placentation, ovule number, fruit type, etc.

13.3.1 Characteristics of a Good Key

A good key is a “synopsis”, presenting graphically the technical characteristic which in general or in aggregate differentiates taxa. The most common form of keys present the user with a series of pairs of contrasting statements (couplets). The user is called upon to compare the plant under determination with the first of these pairs to decide which one of the two contrasting statements applies better to the plant. The key, then, further directs the user to appropriate following pair(s), until the given plant specimen is named.

Some characteristics of a key are:

- 1) A key should be reliable and constant.
- 2) It should be appropriate for the area from where the plant to be identified was collected. For example, plant collected from Delhi may or may not occur in South India. Therefore, using a Key for plants of South India may not help in identifying the plant of Delhi.
- 3) It can be used with ease and certainty of naming a plant.
- 4) It should employ macroscopic characters that are easily observable.
- 5) The statements should always be positive.
- 6) It is desirable that user is provided with a series of choices between two mutually exclusive and parallel statements, called **couplets**.
- 7) The initial word of a couplet should refer to a plant or plant part (Plant/Stem/Leaf/Flower/ ...).
- 8) The initial word of each lead (statement) of a couplet must be the same.
- 9) Two consecutive couplets should not begin with a same word. If one couplet uses one part of a plant/leaf/flower as the first word, then the next couplet should use a contrasting character for identification.
- 10) Both vegetative and reproductive characters are used in a couplet.

11) The initial word of a couplet should be a noun (referring to a plant/plant part). This means that in the key, the plant part should be mentioned first and its description must be mentioned afterwards. (e.g., **Leaves** entire/pinnate and not **Entire/Pinnate** leaves; **Flower** actinomorphic/zygomorphic

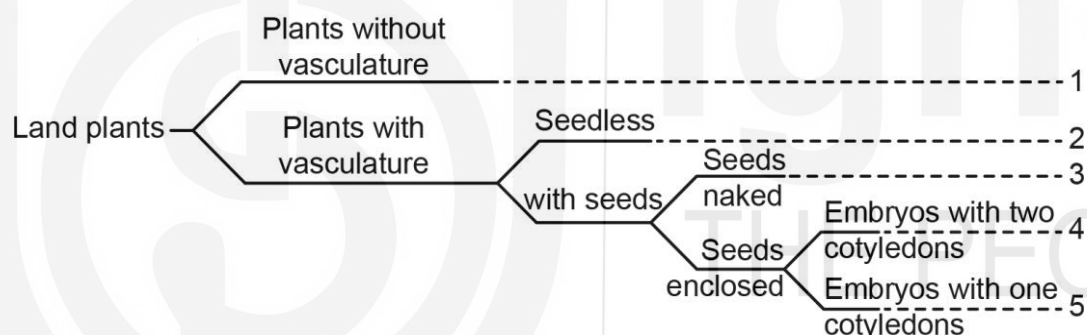
12) Three and more characters in a couplet should be avoided.

13.3.2 Construction and Use of a key

The taxonomic keys are made by using a number of contrasting characters to divide a larger group of plants into smaller and smaller groups. For example:

- 1) Plants with vasculature vs. Plants without vasculature;
- 2) Vascular Plants with seeds vs. Vascular Plants without seeds;
- 3) Plants with enclosed seeds vs. Plants with naked seeds;
- 4) Seeds with embryos with two cotyledons vs. Seeds with embryo with one cotyledon.

The above pairs of characters can also be presented as:



Some other character- pairs that are often used:

Herbaceous vs. Woody habit; Actinomorphic vs. Zygomorphic flowers;
 Perianth present vs. Perianth absent; Ovary superior vs. Ovary inferior; etc.
 Can you add more?

Also, it is very important to obtain as much information as possible about the characters of the taxa to be identified. Selection of a proper key is also necessary to arrive at quick, correct identification of an unknown taxon. It is also necessary to apprise oneself of various terms of glossary and abbreviations prior to reading of a key. It is possible that both the choices provided are probable, and then it is advisable to proceed both ways. Always confirm your choices by reading descriptions. To arrive at correct name it is advisable to verify the results, obtained through use of a key, by comparing the unknown specimen with an illustration or with a herbarium specimen.

The summarization of the steps which are prerequisite for the preparation of a key are:

- It should be dichotomous.
- First word of the couplet should be identical.

- Second part of the couplet should be contrasting.
- Avoid range of characters in a couplet.
- Statement of the couplet should be positive.
- Characters/features chosen should be easily observable.
- Leads of the consecutive couplets should not begin with same word(s).
- Couplet of a key may be numbered (1, 2, 3...) or lettered (A, B, C....).

13.3.3 Faults and Limitations of a Key

If a given key is not working, maybe it is faulty. (For example, as mentioned above, the key must be appropriate for the area to be useful). Sometimes the characters mentioned in a key are quite fictitious and are not really observable in the specimen. Sometimes, even if in the given pair it characters are contrasting they are not distinct. The choice of good characters can also be of no use if they are not properly presented (Leaves are large or small). Instead dimensions provided could be of help. The choice of an intermediate character in the plant to be named is unhelpful, say if the choice provided is: the number of flowers in the inflorescence is 2 to 10 or 10 or more. It would be difficult to choose the alternative when the plant in hand has 7-12 flowers in its inflorescence.

Keys could be difficult to use if the plant to be named is from extreme environmental conditions; new; a hybrid; or previously unreported. It is also possible that author has mentioned many species than actually are present in the given geographical area.

13.3.4 Types of Keys

By now you are aware that keys are determined as devices to help in identifying plants. Traditionally in floras, the keys are diagnostic. The **diagnostic characters** used are conspicuous and clear. Sometimes, such characters are referred to as **key characters**. Such characters are arranged in form of series of couplets. A key can be classified as **Single-access key** or **Multi-access key** (Polyclave). The single access key is further divided into two principle kinds: **Bracketed key** and **Indented key**. **Punch cards** may be used to operate a multi-access key.

Let us learn more about these different kinds of keys.

1) Indented keys

It is also known as **Yoked key**. In this type of key each couplet has its two leads indented by the same amount from the left hand edge of the page. The first couplet to be consulted is the one least indented and has its first lead at the head of the key. The next appropriate couplet that is to be consulted has its first lead placed immediately below the chosen lead of the previous couplet and so on.

An indented key is sometimes provided with accessory numbers to help the user, especially if the key is too long. Such numbers help the user to easily pick up corresponding couplets.

2) Bracketed key

In a bracketed key, each couplet has its two leads immediately adjacent, one below the other under the same number on the left hand side of the page. The first couplet to be read stands the top of the key under the number 1 on the left hand side of the page.

Opposite the leads on the right-hand side of the page subsequent number (2, 3) are used as reference numbers further down the key. In a bracketed key it is by use of the numbers that the determiner is directed to the next appropriate couplet to consult.

Example 1

Let us now, construct both indented and bracketed, keys for the major group of seed plants viz: gymnosperms vs angiosperms; dicotyledons vs monocotyledons; gamopetalae vs. polypetalae.

(A) Indented Key

1. Plants with seeds, ovules enclosed **Angiosperms**
 2. Flowers tetra-/pentamerous.....
 3. Calyx and corolla both present
 4. Petals free..... **Polypetalae**
 4. Petals fused **Gamopetalae**
 3. Calyx or corolla present or both absent.... **Monochlamydeae**
 2. Flowers trimerous, embryo with one cotyledon... **Monocotyledonae**
1. Plants with seeds, ovules naked **Gymnosperms.**

(B) Bracketed Key

1. Plants with seeds; ovules enclosed within ovary.....2
1. Plants with seeds; ovules naked **Gymnosperms**
2. Flowers mostly tetra or pentamerous; 3
 - embryos with 2-cotyledons
2. Flowers mostly trimerous;
 - embryos with one cotyledon..... **Monocotyledonae**
3. Petals and sepals, both present..... 4
3. Petals or sepals or rarely none present..... **Monochlamydeae.**
4. Petals free..... **Polypetalae**
4. Petals fused..... **Gamopetalae**

Example 2

Let us now attempt to prepare both indented and bracketed keys for some families of Monochlamydeae : Urticaceae; Euphorbiaceae; Polygonaceae; Nyctaginaceae; Amaranthaceae and Chenopodiaceae.

(A) Indented Key

1. Flowers unisexual
 2. Inflorescence cymose or racemose.....**Urticaceae**
 2. Inflorescence cyathium.....**Euphorbiaceae**
1. Flowers bisexual
 3. Leaves stipulate.....**Polygonaceae**
 3. Leaves ex-stipulate
 4. Leaves opposite.....**Nyctaginaceae**
 4. Leaves alternate
 5. Flowers with dry,.....**Amaranthaceae**
scariose, bracts as perianth.
 5. Flowers with **Chenopodiaceae**
sepalloid perianth

(B) Bracketed Key

1. Flowers unisexual.....2
1. Flowers bisexual.....3
2. Inflorescence cymose or racemose.....**Urticaceae**
2. Inflorescence cyathium.....**Euphorbiaceae**
3. Leaves stipulate.....**Polygonaceae**
3. Leaves ex-stipulate.....4
4. Leaves opposite.....**Nyctaginaceae**
4. Leaves alternate.....5
5. Flowers with dry, scarious bracts/perianth..... **Amaranthaceae**
5. Flowers with sepalloid/green perianth.....**Chenopodiaceae.**

Advantages vs Disadvantages

In indented keys similar elements are placed in such a manner that they can be visualized as groups very easily. Such easy visualization is not possible in bracketed keys. However, in an indented key which are quite extended (large), there is sloping or shortening of lines to the right hand side of the page with a resultant loss of economy of the page. In contrast, in a bracketed key majority of the lines are of equal length thereby utilizing the page space very efficiently.

Letters vs. Numbers

In extended and lengthy keys, not enough letters in alphabet are available to accommodate the necessary couplets. The author then uses alternate series of alphabets AA, BB....etc. Moreover, the presence of often multiple couplets each designated by same characters or letter leads to confusion, especially while referring back to a lead.

In contrast, in a numbered key, each couplet is numbered consequently and no two couplets of a given key receive the same number. It also helps to provide a direct reference to each couplet. In indented key, many a times, one section contains a fewer number of taxa than the other.

3) Multi-access key or Polyclaves

The dichotomous keys mentioned earlier are based on the principle of one-entry point (single-access) or sequential access. In order to improve the efficacy with which the determination of the name of taxon, **multi-access** or multi-entry, order-free keys have been introduced. These are also referred to as **polyclaves**. Such keys are user-oriented and can be commenced at any position. Unlike the dichotomous keys where the author provides the characters, in multi-access keys, the user selects the character(s) and not the author. Also, unlike the rigid, given order of the choice of character(s) to be used in a single access key, the user, in a multi-access key, can choose not only any character(s) but also in any sequence. It can proceed even if the information about a few character(s) is insufficient or unavailable.

Multi-access keys are usually produced in the form of punched cards.

Punch Cards

A.T.J. Biachi (1931) and S.H. Clarke (1938) were first to use punch cards. Clarke prepared such multi-entry perforated keys for the identification of hard woods. There exist two kinds of perforated or punch keys:

1) Edge-punched Key

In this kind of punch key, a given card represents a taxon (Fig.13.1). Each card has a number of characters (attributes). Each attribute is represented by a hole at the margin of the card.

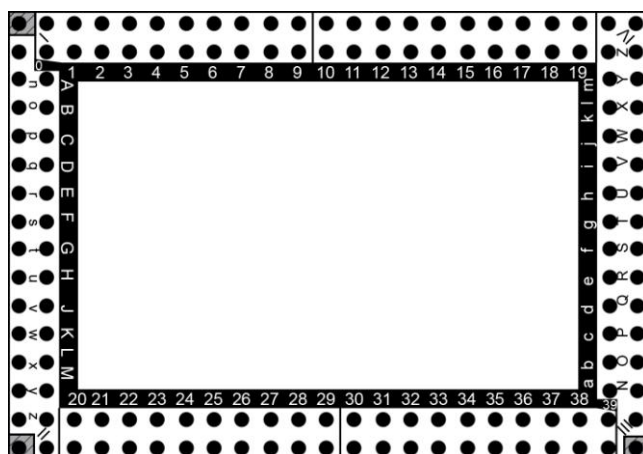


Fig. 13.1: An edge punch card (a hypotheticalal sample).

If a given taxon possesses that character the given hole is notched. The cards of different taxa are then stacked. The taxon cards are sorted by use of a large needle. The user runs the needle through the character hole of card (say, leaves opposite). From all the stacked cards, once the needle is pierced through the 'leaves opposite' holes, only the cards notched for the character 'leaves opposite' shall fall down. Interestingly, the choice and the order of selection of characters are solely decided by the user. The fallen cards are stacked again, and another character is chosen where the needle is to be pierced. The process continues till only one card remains and that represents the unknown taxon.

2) Body-punched Key

In this kind of key, the holes are punched in rows on the main body of the card. Unlike the edge-punched key where each card represents a taxon, in body punch key, each card represents a character-state (attribute). Numbers are printed on the card to point out the standard position of each taxon. If the taxon possesses that particular attribute (mentioned on the card), its position is punched out. The cards are stacked and held against the light. When only one hole shows through the light, that taxon (hole) represents the identity of unknown plant.

In both the above two-kinds of cards, keys are operated by user in step-by-step elimination process. However, any character and in any order may be used. Such keys can be used as partial keys.

A multi-access key contains much more information than a traditional dichotomous key. It contains data necessary to construct many different dichotomous keys thus the term- **Polyclave**.

With the help of computer software, it is possible to convert multi-access key to a computer interactive format. Computer assisted identification programs such as DELTA (Descriptive Language of Taxonomy) or Lucid system are important tools for future means of plant identification.

Modern technology has provided a digital platform for identification. Databases of plants from different parts of the world are now available to help in identification. For example, "Flowers of India" www.flowersofindia.in and the <eflora of india>. Recently, these have introduced a QR code on the page of different species. This can be used for obtaining details about the plant. Similarly, the Centre for Ecological Studies, Indian Institute of Science, Bengaluru, launched an "online database of Plants of Peninsular India" on March 02, 2019 - <http://flora-peninsula-indica.ces.iisc.ac.in>.

A very recent feature of digital technology is the use of QR codes (fixed on the plant itself) for information about plants. These can be scanned with a mobile phone to know several details about the plant. For example, in the Lodi Gardens (New Delhi), the "New Delhi Municipal Council - NDMC" has provided QR codes to the different trees growing in the Gardens. When these are scanned, details of the tree can be read. Thus, besides the botanical name and the common name, there is information about the native home (country of origin) of the species along with pictures, the height and canopy size of the tree, the age and lifespan of the specimen, its Flowering period, flower colour, Fruiting period, and (medicinal) uses.

SAQ 2

- a) Define key.
 - b) Enumerate any ten characteristics of a key.
 - c) Choose the correct alternative from the two provided in the brackets :
 - i) Multientry keys are also referred to as (polyclave/bracketed) keys.
 - ii) A yorked key is an example of (multiaccess/indented) key.
 - iii) Punch cards are used in (Multiaccess/bracketed) key.
 - iv) An edge-punch card represents a (taxon/character state).
 - d) Differentiate between multiaccess and single access keys.
-

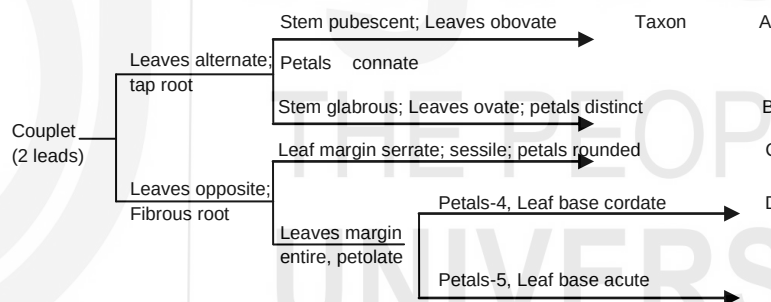
13.4 SUMMARY

- Identification is integral to a taxonomic work. Process of identification of any plant specimen is called species determination. General taxonomic Indexes, Floras, Monographs, Manuals, Revisions, Periodicals etc constitute important documents to determine correct name of a plant specimen. These are also called taxonomic documents.
- General Taxonomic Indexes help locate the source of original publication of a name. Index Kewensis, Plantarum Phanerogamarum and Gray Herbarium Card Index are among the most authentic taxonomic indices.
- A flora provides an inventory of plants of a definite area and often restricted to the vascular plants. It includes plants that are indigenous; naturalised; introduced or adventive.
- A monograph is a complete account at any given time of any one family, tribe or genus.
- A manual is a book that contains information on the area of coverage, keys and description. It contains information about families, genera, and species along with citation, authorship; synonyms etc.
- A revision accounts for only a section of a genus or elements as restricted to a continent, or smaller geographical area.
- A publication appearing at regular intervals is called a periodical. Each issue is called a number. A collection of numbers is called a volume.
- Internet provides a wealth of information on plants systematics for quick access.
- A key is an artificial device or an arrangement for determination of names of the plants included in it. A key is described as taxonomic literature. It may be single access or multi-access type.

- Single-access key uses a single set of characters in pre-described format at any given time in a step by step manner until the identification is made. It may be indented or bracketed type.
- A multi-access key involves a number of attributes and in any order as desired by a user. It involves use of punch cards: Edge-punched cards or Body-punched cards. Collective use of attributes is referred to as polyclave.
- A key is often constructed and used following a standard protocol.

13.4 TERMINAL QUESTIONS

1. Differentiate between :
 - a) Flora and Monograph
 - b) Manual and Revision
2. What is the importance of a General Taxonomic Index?
3. Write a note on faults and limitations of a key.
4. Mention advantages of multi-access key over a single access key.
5. Observe the following dichotomy of characters and prepare (a) a bracketed key and (b) an indented key.



13.5 ANSWERS

Self-Assessment Questions

1. a) i) Index;
 ii) floras;
 iii) zoomable;
 iv) volume;
 v) periodical
 b) i) Revision;
 ii) Monograph;
 iii) J.K. Maheshwari;
 iv) General taxonomic index

2. a) Refer to Section 13.3 (Introduction)
- b) Refer to Subsection 13.3.1
- c) i) polyclave
- ii) indented
- iii) multi-access
- iv) taxon

3. Refer section 13.3.4

Terminal Questions

1. a) Refer to Subsections 13.2.2 and 13.2.3
- b) Refer to Subsections 13.2.4 and 13.2.5
2. Refer to Subsection 13.2.1
3. Refer to Subsection 13.3.3
4. Refer to Subsection 13.3.4
5. **a) Bracketed Key**

1. Leaves alternate; tap root.....2
1. Leaves opposite; fibrous root.....3
2. Stem pubescent; leaf base obovate; petals connate.....A
2. Stem glabrous; leaf base ovate; petals rounded B
3. Leaf margin serrate; leaves sessile; petals rounded.....C
3. Leaves entire; leaf petiolate.....4
4. Leaf base cordate; petals - 4 D
4. Leaf base acute; petals - 5.....E

b) Indented Key

1. Leaves alternate; taproot
 2. Stem pubescent; leaves obovate; petals connate.....A
 2. Stem glabrous; leaves ovate; petals distinct.....B
1. Leaves opposite; fibrous root; petals 4 or 5
 3. Leaves serrate; leaves sessile, petals 4.....C
 3. Leaves petiolate; Leaves entire;
 4. Leaf base cordate; petals - 4.....D
 4. Leaf base acute; petals 5 E

TAXONOMIC EVIDENCES |

Structure

14.1	Introduction	14.5	Evidence from Phytochemistry
	Objectives		Directly Visible Chemical Characters
14.2	Alpha Taxonomy and Omega Taxonomy		Primary Metabolites
14.3	Taxonomic Evidences from Palynology		Secondary Metabolites
14.4	Taxonomic Evidences from Cytology		Semantides
	Chromosome Numbers	14.6	Evidence from Molecular Data
	Chromosome Structure	14.7	Summary
	Chromosome Behaviour	14.8	Terminal Questions
		14.9	Answers

14.1 INTRODUCTION

In Taxonomy, evidence is the information used in context for a purpose such as identification or classification. The foundation of plant taxonomy was laid on a number of characters (attributes) of plants and plant groups studied from time to time. Such taxonomic information can be realised in many ways to prove a hypothesis, solve a problem, characterize a taxon, classify a group of plants or derive evolutionary relationship among plants. The gross morphology provides the foundation of plants taxonomy and it is supplemented by the information from various other fields of botany.

In this Unit you will study about taxonomic information that can be collected from a few specific fields such as: palynology; cytology; phytochemistry and molecular biology.

Objectives

After studying this unit you should be able to:

- ❖ know the history of plant taxonomy, with special emphasis on plant taxonomy in ancient India;
- ❖ comprehend the concept of plant taxonomic evidences;
- ❖ classify the taxonomic evidences as physical, chemical and biological;
- ❖ specifically infer the taxonomic evidences from the fields of palynology, cytology, phytochemistry and molecular botany;

14.2 ALPHA TAXONOMY AND OMEGA TAXONOMY

The scope and methods of taxonomy have evolved with times. However, the principal core of the discipline has remained the same: concepts, classification of plant and plant groups; and nomenclature. To achieve these objectives the approaches adopted are broadly classified into two kinds: **alpha taxonomy** and **Omega taxonomy** (Turrill 1935).

On the other hand, taxonomists such as Valentine and Love (1958) and Davis and Heywood (1963) have suggested that the developments in taxonomy occurred in 4 phases. These are **(i) the pioneer or exploratory phase, (ii) the systematic or consolidation phase, (iii) the experimental or biosystematic phase, and (iv) the encyclopedic or holotaxonomic phase.** According to this classification of the developments in taxonomy, the first 2 phases are more or less equivalent to alpha taxonomy while phases (iii) and (iv) are similar to omega taxonomy.

Alpha Taxonomy

At the level of alpha taxonomy, the organisms are characterized, identified, classified and named. The pioneer or exploratory phase of taxonomy is basically analytical. It involves collection of plants for analysis of their characters. Therefore, in this sense, it is a pioneering effort for understanding the plants. At the same time it is also considered as an exploration of nature. Hence this is regarded as the **pioneer or exploratory phase** in taxonomy. This relates to the basic or preliminary classification based almost entirely on external morphology. This can be considered as the empirical approach in taxonomy where the classification is synthesised from the observed facts. The vast amount of data collected by taxonomists must be evaluated and consolidated. This leads to the development of systems of classification. Thus, the pioneer or exploratory phase progresses to a **systematic or consolidation phase**. Alpha taxonomy has also been called **Classical** or **Orthodox** or **Formal taxonomy**. This has been practised since ancient times and different aspects of this approach are in use even today.

Omega Taxonomy

After synthesising a basic classification, the taxonomist can attempt to improve upon it. Therefore, the observed facts are interpreted in **Omega taxonomy** to provide an interpretive classification. Evolutionary and phylogenetic approaches are applied to understand taxonomic and evolutionary

relationships of plants at all levels. This can be achieved by experimentation or use of a larger number of features such as cytology and genetics for evaluating taxonomic relationships. Thus developments in taxonomy involving detailed cytological and genetical studies became important. This has been referred to as the **experimental or biosystematic** phase. It was then realized that knowing all aspects of the biology and chemistry of plants would provide a much better understanding of relationships. Thus collecting and collating information from as many sources as available led to the recognition of the **encyclopedic or holotaxonomic** phase in taxonomy. Omega taxonomy has also been called **Beta taxonomy** or **Neotaxonomy** or **Modern taxonomy**.

Taxonomic evidences are the characters (attributes) gathered from a variety of disciplines. Most of these characters are used in describing patterns of variations at or below the species level. The source(s) of such characters could be from morphology, anatomy, embryology, palynology, cytology, biochemistry, sementides, molecular biology, etc.

In this Unit we will describe about the following of taxonomic evidences:

Palynology;

Cytology;

Phytochemistry; and

Molecular biology.

SAQ 1

- a) Differentiate between alpha- and omega- taxonomy.
 - b) Identify the following statements as true or false by putting letter **T** for true or **F** for false in the brackets provided at the end of the statements.
 - i) Omega taxonomy is also called formal taxonomy. []
 - ii) Turrill proposed the term alpha taxonomy. []
 - iii) The observed facts are interpreted in alpha taxonomy. []
 - iv) Any evidence is an information used in context for a purpose. []
-

14.3 TAXONOMIC EVIDENCES FROM PALYNOLOGY

Palynological Evidence

Palynology is the study of pollen and spores. The taxonomic characters of pollen grains include wall structure, polarity, symmetry, shape and grain size. In angiosperms pollen grains are of two kinds viz. monocolpate and tricolpate (Fig: 14.1). Monocolpate pollen grains are boat shaped, have one long germinal furrow and one germinal aperture. This is characteristic of primitive dicotyledons, such as Piperaceae and Chloranthaceae, majority of monocotyledons, cycads and seed ferns. According to some palynologists the

first flowering plants had monocolpate pollen grains. Tricolpate grains are globose, symmetrical, have three germinal apertures and are characteristic of advanced dicotyledons.

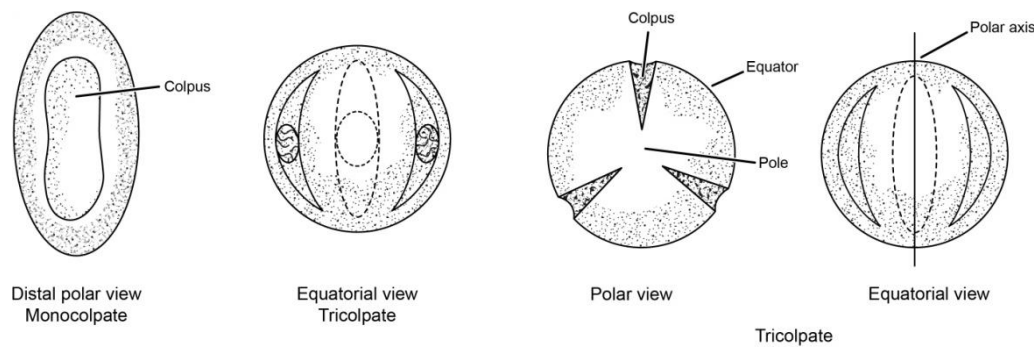


Fig: 14.1: Monocolpate and tricolpate pollen grain.

Some of the characters of the pollen grains that constitute taxonomic evidence are: unit; polarity; shape, symmetry; nuclear state; wall architecture; exine stratification; exine structure and sculpture (Fig: 14.2). It also includes shape, structure, position, number and types of apertures.

Let us now learn some examples.

The pollen grains of Magnoliidae are binucleate whereas those of Caryophyllidae are trinucleate. In Ericaceae the pollen grains occur as tetrads while pollinium (pl. pollinia) are characteristics of Asclepiadaceae, Apocyanaceae) and Orchidaceae.

Within the family Betulaceae the exine of pollen grain in section is knob-like in *Betula*; club-shaped in *Corylus*; unexpanded in *Carpinus*, arch-like in *Alnus*. Within the family Epacridaceae the pollen grains of the genus *Brachyloma* are solitary while those of the genus *Epacris* are in tetrads.

Pollen apertures can be distinct in different species of the same genus. It is pilate in *Bauhinia acuminata*, striate in *B. krugii* and echinulate in *B. malabarica*.

The pollen grain size could also be used to identify the species of a genus. For example, the pollen grain size in *Malva rotundifolia* is 74-84 μm while it is in range of 105-126 μm in *M. sylvestris*.

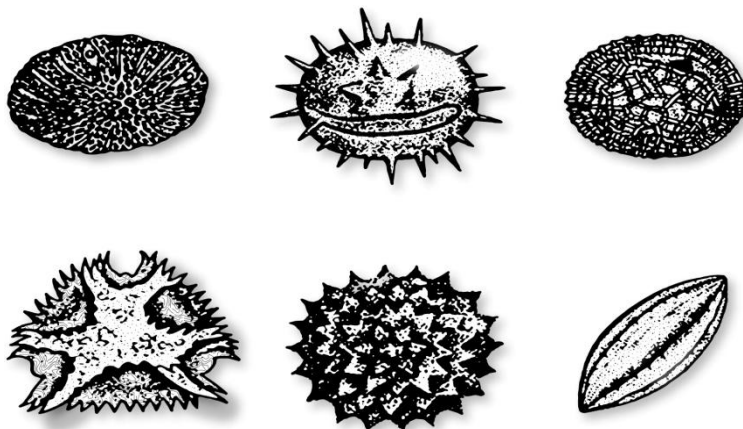


Fig. 14.2: Pollen grain showing various sculpturing.

An interesting example of palynological evidence in taxonomy is of the genus, *Trisyngyne*. This plant has separate male and female plants (dioecious). On the basis of morphological evidences, the genus was placed in the family Euphorbiaceae. However, when female plant was discovered it was transferred to the family Fagaceae. Later, when the pollen grains of male specimen was examined, they were found to be exactly similar to the member of Fagaceae. So, now *Trisyngyne* is regarded as a member of the family, Fagaceae. (Some taxonomists suggest the name *Nothofagus* for this genus, and classify it in the Family Nothofagaceae).

14.4 TAXONOMIC EVIDENCES FROM CYTOLOGY

Cytology is the study of the morphology and physiology of cells. The information about the chromosome number, shape and pairing at meiosis is used for classification purpose. Cytotaxonomy refers to the use of chromosome number, morphology, ploidy level, ploidy type and chromosome aberrations as data for classification. Cytogenetics includes those studies dealing with observations of chromosome pairing or behaviour at meiosis.

In the following sub-sections you will study about importance of chromosome number, structure and behavior at meiosis as taxonomic evidence.

14.4.1 Chromosome Numbers

We are generally aware that the number of chromosomes in each cell of all individuals of a single species is constant. It is also established that the more closely related species are likely to have similar chromosome numbers while the more distantly related ones shall have different numbers. Due to this relative conservativeness, chromosome number becomes an important and frequently used taxonomic character. In addition, there is a very wide range of chromosome numbers in the angiosperms from as low as $2n=4$ (in *Haplopappus gracilis*) (Asteraceae) to as high as $2n=530$ (in *Poa litorosa*) (Poaceae). A large number of angiosperms have been analysed for their chromosome numbers, providing useful taxonomic information (see Table 14.1).

Table 14.1 : Basic chromosome numbers of a few plants.

<i>Haplopappus gracilis</i>	$n = 2$
<i>Zea</i> and <i>Sorghum</i> (all species)	$n = 10$
<i>Pinus</i> (all species)	$n = 12$
<i>Quercus</i> (all species)	$n = 12$
<i>Kalanchoe</i> sp.	$n = 125$
<i>Poa litorosa</i>	$n = 132$
<i>Morus nigra</i>	$n = 154$

Table 14.2 : Chromosome Series - a few examples.

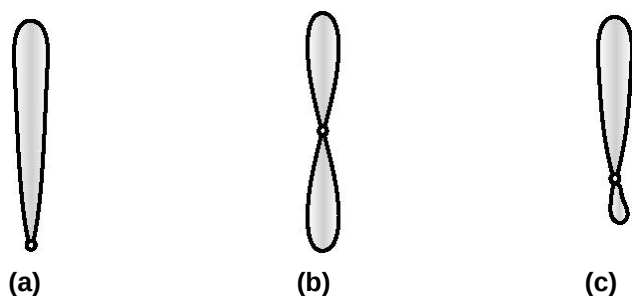
<i>Brassica</i>	$n = 6, 7, 8, 9, 10$
<i>Aster</i>	$n = 9, 18, 27$
<i>Taraxacum</i>	$n = 8, 12, 14, 20, 24$
<i>Vicia</i>	$n = 5, 6, 7, 12, 14$
<i>Festuca</i>	$2n = 14, 28, 42, 56, 70$

Many interesting ideas have developed from knowledge of chromosome numbers. For example, in the genus *Festuca*, different species have different chromosome numbers forming a mathematical series (See Table 14.2). The chromosome numbers are $2n = 14, 28, 42, 56, 70$ etc. From this information, a generalisation can be made, that different species may have some common basis. If we assume that these chromosome numbers are based on a common denominator called x (and $x = 7$), then we can consider the different species to have multiples of this number. This denominator or base number ($x = 7$) can be considered as the basic set of genetic information carried by a plant, and due to the multiplication of this basic genetic set, the evolution of different species has occurred. Such a series is said to be polyploid in which the basic number (x) is equivalent to the haploid number of chromosomes in a diploid species (i.e. $x = n = 7$). The other species would then be tetraploid ($4x = 2n$), hexaploid ($6x = 2n$), octaploid ($8x = 2n$), decaploid ($10x = 2n$), respectively.

$2n$ is equal to the diploid or somatic chromosome number: while n is the haploid or the gametic number

14.4.2 Chromosome Structure

Cytologists have studied chromosome morphology and have pointed out that the most interesting feature about the chromosome structure is the position of the centromere. The centromere or constriction in the length of the chromosome provides information about the relationship of the 2 arms of the chromosomes. Thus, depending on the position of the centromere, chromosomes are described as metacentric, acrocentric, and telocentric (Fig. 14.3). Metacentric chromosomes are considered to be more advanced than the acrocentric chromosomes.

**Fig.14.3: Chromosome structure- a) acrocentric, b) metacentric, c) telocentric.**

The appearance of the basic chromosome set in a dividing cell is known as the karyotype of the cell. This can be analysed to provide information not only of the chromosome number, but also about the chromosome size, chromosome volume, and type of chromosomes in the cell. This information is used by taxonomists for identifying plants and understanding relationships. The karyotype can be represented diagrammatically as an **idiogram** or

karyogram, and these diagrams can be compared for taxonomic purposes. Another interesting observation is that the absolute size of the chromosomes of a karyotype is fairly constant since it is controlled by the genotype. Taxonomists have found that monocots generally have larger chromosomes than dicots, and that smaller chromosomes are found in hardwood plants in comparison to their herbaceous relatives.

Let us now describe some examples where chromosome structures have been successfully used as taxonomic evidence. *Paeonia* was earlier placed in the family Ranunculaceae. However, on the basis of embryological and other evidences it is suggested that it be placed in an independent family, Paeoniaceae. Cytologically, it is found that *Paeonia* possesses large chromosomes as opposed to smaller chromosomes that are characteristic of members of the family Ranunculaceae.

Plants of *Polygonum* growing in three different habitats exhibited morphological differences and were hence considered belonging to different species. Interestingly, it was found that all of them were not only interfertile but had similar chromosome morphology. Hence, they are now clubbed together as *Polygonum amphibium*.

Chromosome karyotype studies have suggested placing the genus *Butomus* in a separate family Butomaceae while retaining *Limnocharis*, *Hydrocharis* and *Tenagocharis* in the family Alismataceae. Closer affinities of the families Cyperaceae and Juncaceae have been established due to the presence of holocentric chromosomes in their members.

Karyotype studies have confirmed the separation of the family Agavaceae from Amaryllidaceae. Presence of 5 large and 25 small chromosomes in their cells have helped transfer of *Yucca* from the family Liliaceae to the family Agavaceae.

14.4.3 Chromosome Behaviour

When we study meiosis, we not only observe the regularity of pairing which is important for the fertility of the plants, we are also able to make a chromosome to chromosome comparison. This provides valuable information about the role of chromosomes in heredity. Taxonomists use this information to understand relationships amongst different species of plants. We can also determine the nature of the genome to find out if it is homozygous or heterozygous. Genome analysis in plant taxonomy has been particularly useful in understanding polyploidy and for establishing the parentage of polyploids. A very significant study in this regard is the case of the common hexaploid bread-wheat, *Triticum aestivum*. The genome of this economically important plant has been designated as AABBDD with $2n=42$ chromosomes. Detailed genome analyses have established that 3 diploid species have contributed to the evolution of this hexaploid wheat. The A genome is from a wild grass *Aegilops speltoides* ($2n=14$), and the D genome has been contributed by *Aegilops squarrosa* ($2n=14$). Many geneticists have suggested different grasses as the source of the B genome.

Finally, we must remember that as with any other character, the value of cytotaxonomic data depends upon the group or category under investigation. A combination of cytological information with data from other disciplines will provide a more useful tool to the taxonomist.

SAQ 2

- a) Fill in the blank spaces with appropriate word(s):
- i) Monocolpate pollen grains are shaped.
 - ii) Union of 3 or more chromosome complements of the same species result in
 - iii) The basic number of chromosome (x) is equivalent to the number of chromosomes in a diploid plant.
 - iv) The karyotype can be represented diagrammatically as an
 - v) Diploid chromosome number in *Haplopappus gracilis* is
- b) Write a note on “pollen grains as taxonomic evidence”.

14.5 EVIDENCE FROM PHYTOCHEMISTRY

Chemotaxonomy is a science which uses chemical information as a character for taxonomic purposes. Before we analyse the basis of this modern trend in plant taxonomy, let us for a moment think about the different kinds of plants in our daily lives. When we drink tea or coffee, we appreciate the flavour or aroma and differentiate the two by this character. Similarly, when we eat fruits such as the mango, the banana or an apple, we find that they taste differently. These differences are due to the chemical constituents of these foods and this forms the basis of chemotaxonomy where the chemical features or chemical constituents serve as the evidence for taxonomy. The potential importance of chemical evidence in plant taxonomy has been suggested by both botanists and chemists and this has become an important recent trend especially because newer techniques for quick analysis of plant material have been developed. Chemotaxonomists suggest that chemical characters have a particularly high taxonomic value because they are i) stable, ii) unambiguous, and iii) not easily (if at all) changeable. Further, chemical characters will show chemical relationships amongst plants in the same way as morphological characters show morphological relationships.

Although chemotaxonomy is considered to be a relatively recent development in modern taxonomy, its origin can be traced to very early classical taxonomy. You will recall that the spice plants were identified on the basis of their aromatic properties, or the medicinal plants by their curative value. These aromatic properties or the curative value was largely based on the chemical constituents of the plants and taxonomists have classified them since ancient times using these chemical features along with morphological characters. However, it is only in recent years that chemotaxonomy as an important field of study has been established.

A review of the large amount of literature published in this field reveals that chemical data may be obtained from any part of the plant. Secondly, depending on the purpose of the investigation, the chemical information may be used for description or identification of plants, or for establishing relationships. This evidence assumes greater significance when it is used to sort out differences in taxonomic relationships when 2 or more possibilities are suggested on the basis of morphological characters.

Although theoretically, all chemical constituents of a plant are potentially valuable to a taxonomist, in practice some kinds of molecules are more useful than others. Thus we can use directly visible chemical constituents such as crystals, raphides, or starch grains occurring in different plants as chemical characters.

Alternatively, we can chemically analyse plant material for different chemical constituents and use this information for taxonomic purposes. Most chemotaxonomists recognise three broad categories of chemical compounds, primary metabolites, secondary metabolites, and semantides, as important taxonomically.

14.5.1 Directly Visible Chemical Characters

Very few chemical substances in plants can be observed directly, but the few substances such as starch grains which are present in most green plants as food reserves have been used for chemotaxonomic purposes (fig. 14.4). The types of starch grains present in different plants are very specific and this information can be used without any ambiguity. Reichert (1913) examined the starch grains in 350 species of plants and established their differentiation and specificity of occurrence in relation to genera and species, thus providing chemotaxonomic information. Tateoka (1962) reviewed the starch grain form in the grass family (Poaceae) and used this as additional information to classify the family into tribes. For example, in the Tribe Hordeae, the typical members such as *Hordeum* have compound starch grains, while other genera like *Lolium*, *Nardus*, and *Papapholis* have simple starch grains.

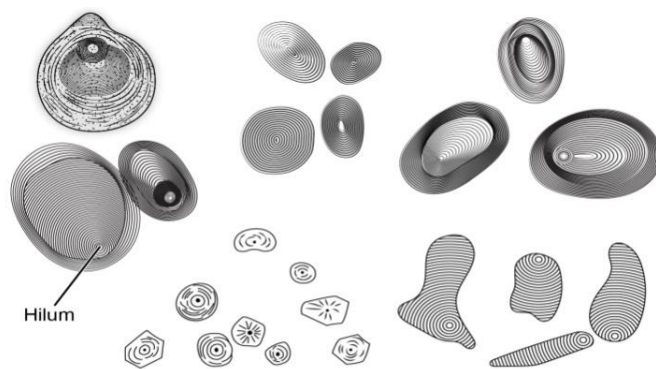


Fig. 14.4: Morphology of starch grains in some plants.

Raphides are the crystals of calcium oxalate which are present in large cells in different plant tissues and can be observed directly. They are long needle shaped crystals, pointed at both ends and usually occur in bundles, thus being easily identified. They occur very commonly in some aquatic plants such as *Pistia* and *Eichhornia* and found in the members of Araceae.

The presence or absence of raphides is a key character, in natural classification of family Rubiaceae, along with some other ones. All those Rubiaceae members that possess raphides are placed in the tribe Rubioideae.

Another example where raphides are important taxonomically is the sub-division of the Order Scitamineae. The raphides are present in the families Heliconiaceae, Musaceae, Sterlitzziaceae and Lowiaceae. Further, classification within these families is based on other taxonomic features. On the other hand, within order Scitamineae, in the families Costaceae, Marantaceae, Zingiberaceae, and Cannaceae the raphides are absent.

Another kind of crystal, made-up of calcium oxalate are called druses and provide good taxonomic evidence. A druse is an aggregate or conglomerate of a large number of crystals. They are characteristic of the families Caricaceae, Apocyanaceae, etc.

Cystoliths are the crystals made up of calcium carbonate and are usually very common in leaves of various species of *Ficus*. Presence of crystals of gypsum (a soft mineral) made of Calcium sulphate ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) is characteristic of family Tamaricaceae (Fig 14.5).

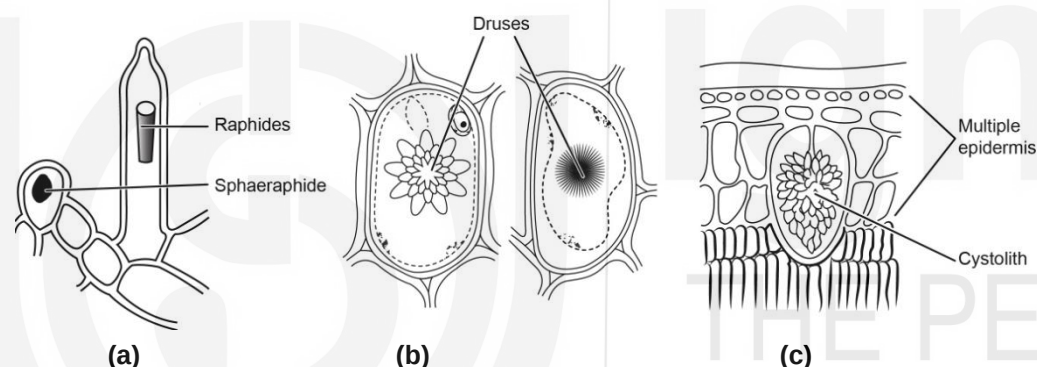


Fig. 14.5: Crystals of various types: a) Raphide; b) Druses; c) Cystolith.

14.5.2 Primary Metabolites

As the name indicates, primary metabolites are molecules involved in vital metabolic pathways. They are of universal occurrence and not very significant in chemotaxonomy. However, these molecules become useful as chemotaxonomic features when the quantity of such molecules varies considerably between taxa. For example, the sugar 'sedoheptulose' is stored in large quantities as a reserve food in the genus *Sedum*. Thus members of this genus can be easily identified by the presence of this primary metabolite. Interestingly, sedoheptulose biphosphate is a part of the photosynthetic carbon cycle and in a majority of the plants sedoheptulose does not accumulate at all. In the same way, the 22 amino acids are of universal occurrence. They serve as the building blocks of proteins. They can provide useful macromolecular data for chemotaxonomy. The amino acid sequence of different proteins can be investigated and the degree of similarity is presumably proportional to the degree of genetic relationship. However, only a few out of about 3 lakh species of angiosperms have been analysed for amino acid sequences. For example, the amino acid data on wheat and barley confirms the relationship of these genera as suggested by classical taxonomists.

14.5.3 Secondary Metabolites

Secondary metabolites or secondary plant products are those macromolecules that lack nitrogen and are of restricted occurrence and therefore, of greater taxonomic importance than primary metabolites. This group includes different kinds of compounds such as flavonoids, terpenes, iridoids, alkaloids, anthocyanins, glucosinolates, cyanogenic glycosides, polyacetelenes etc. They are usually not involved in vital functions and are largely storage products or pigments.

FLAVONOIDS

Amongst the secondary metabolites, flavonoids, which are the commonest phenolic compounds of leaves, have been very useful for chemotaxonomic purposes. Both monocots and dicots have been extensively surveyed for these compounds which show structural variability and chemical stability besides widespread distribution. They can be rapidly and easily identified and provide important chemical characters for taxonomic purposes. For example, 80 species of plants from the family Ulmaceae were investigated for their flavonoid chemistry by Giannasi (1978). Majority of the species contain flavonols, but a few species have glyco-flavonols and these two types of flavonoid compounds are never present together in any species. Interestingly, enough, in most classical systems of classification, the family Ulmaceae is divided into two subfamilies called Ulmoideae and Celtoideae which are also distinguishable by the flavonoid chemistry. Therefore, morphological criteria combined with flavonoid dichotomy can be used to divide the family Ulmaceae into two distinct families: family Ulmaceae is characterised by the presence of flavonols, and family Celtaceae is characterised by the presence of glucoflavonols.

Several other studies have used flavonoid chemistry for taxonomic purposes in families such as Arilidaceae, Cornaceae, Labiatae (Lamiaceae), Leguminosae (Fabaceae), Orchidaceae, Rutaceae, Lemnaceae and others.

Although useful in assessing relationship among closely related species (infraspecific variations), flavonoids are occasionally useful in assessing phylogenetic relationship at higher levels.

TERPENES

A second group of secondary metabolites commonly examined by chemotaxonomists are the terpenes. Volatile terpenes are major components of essential (ethereal) oils which are characteristics of the order Magnoliales, Austrobaileales, Piperales and Laurales. They are also reported in families Myrtaceae, Rutaceae, Apiaceae, Lamiaceae, Asteraceae. Chemically speaking, these compounds can be classified on the basis of their molecular structure into monoterpenes, diterpenes, triterpenes, sesquiterpenes, etc., and each group can be used for taxonomic purposes. For example, in the genus *Salvia*, 19 species could be distinctly identified and classified on the basis of their monoterpenes. The terpene composition was as useful as the morphological characteristics in the analysis of introgression and hybridisation within the genus. Similarly, triterpenes and sesquiterpenes have been particularly important and useful in the classification of the families Cucurbitaceae and Compositae (Asteraceae) respectively.

Kinds of Terpenes

C₅ = Isoprenes

C₁₀ = Monoterpenes

C₁₅ = Sesquiterpenes

C₂₀ = Diterpenes

C₃₀ = Triterpenes

C₄₀ = Tetraterpenes

C_n = Polyterpenes

IRIDOIDS

Iridoids are 9-10 carbon monoterpene derivatives. They are commonly found in plants grouped as *Asterids*.

ALKALOIDS

Alkaloids are structurally diverse chemicals that are derived from amino acids or from mevalonic acid. Cocaine, morphine, codeine, atropine, colchicines, quinine are some important alkaloid plant products. The plant groups, where they are biosynthesized represent a vast diversity, hence of little systematic interest.

BETALAINS AND ANTHOCYANINS

Betalains are nitrogenous red and yellow pigments are restricted to the Order Caryophyllales except the families Caryophyllaceae and Molluginaceae.

Anthocyanins, in contrast, are red, yellow, blue or purple pigments of most other plants.

Betalains and anthocyanins are mutually exclusive; as they have never been found together in the same species.

GLUCOSINOLATES

The glucosinolates are also known as mustard oil glucosides. They are hydrolysed by the enzymes known as myrosinases to yield pungent mustard oil. They are characteristic of Brassicaceae, Resedaceae and Tovariaceae.

CYANOGENIC GLYCOSIDES

The cyanogenic glycosides are defensive compounds that are hydrolysed by various enzymes to release hydrogen cyanide. The process cyanogenesis, is widespread in angiosperms. Leucine derived cyanogenic glycosides is common in the families Rosaceae, Fabaceae, Sapindaceae. In the Orders Magnoliales and Laurales, these compounds are derived from the amino acid, tyrosine.

POLYACETYLENES

Polyacetylenes are a large group of non-nitrogenous secondary metabolites. They are formed by linking of acetate units via fatty acids. Taxonomically, they are important because of their presence in related groups of Asteroid families: Asteraceae; Apiaceae; Campanulaceae; Caprifoliaceae etc.

14.5.4 SEMANTIDES

The information carrying molecules in plants are called semantides, and they have been recognised to be of 3 kinds; deoxyribonucleic acid or DNA (primary semantide), ribonucleic acid or RNA (secondary semantide) and proteins (tertiary semantide) following the sequential transfer of the genetic code. Of these, the proteins are the most favoured molecules for chemotaxonomic purposes. Plant proteins can be studied by different methods; by electrophoresis or by serological methods, and both processes have been used for obtaining information about the protein chemistry of different plants.

In the common breadwheat, *Triticum aestivum*, the storage proteins were analysed by electrophoresis. For comparative purposes, the storage proteins of the tetraploid wheat, *Triticum dicoccum* and the diploid grass *Aegilops squarrosa* were also analysed electrophoretically. This study confirmed the conclusion that the hexaploid wheat did contain a sum of the proteins possessed by the diploid species which have contributed to the evolution of the hexaploid wheat. This study supports the observations based on morphology and cytological evidence.

Serological analysis of proteins is based on the immunological reaction shown by mammals when a foreign protein is introduced into the system. In other words, this is based on the antibody-antigen reaction wherein the antibodies being specific to an antigen bringing about coagulation. This information can then be analysed to understand the relationships of the different plants on the basis of the serological evaluation of the plant proteins. Serology has proved a useful taxonomic tool at different levels of classification. J. G. Hawkes (1960) and his co-workers studied several tuber-producing species of *Solanum* to understand the evolution of the cultivated potato *Solanum tuberosum* and determine the species of *Solanum* which could be established as the ancestors of the common cultivated potato. Similarly, in the family Ranunculaceae, serological studies supported cytological data for the classification of the family into tribes and genera. Fairbrothers (1959) and his co-workers have studied several plant groups serologically particularly the members of grass family. A general conclusion from such studies is that the different amount of serological activity in members of different plant families may be interpreted as a reflection of the evolutionary differences in the primary structure of the proteins due to which serological differences can be recognised between members of different families.

14.6 EVIDENCE FROM MOLECULAR DATA

In the preceding section you learnt that the nucleic acids and proteins constitute semantides. However, only nucleic acids (DNA and RNA) contribute towards significant analysis of phylogenetic relationships among plants. Traditionally the taxonomists use tools of use taxonomy to construct phylogeny of plants or plant groups. However, it has now been realized that the molecular data based on variations in DNA and RNA of different plants provide more reliable inputs. Such an assumption is based on the hypothesis that the phylogenetically closer species should possess similar genetic material and distant species should exhibit variations in their genetic constitution. In recent times, DNA fingerprinting has become a very useful source of information in taxonomy. It allows comparison of different species of a genus enabling understanding of phylogenetic relationship.

From where do the scientists obtain genetic material for studies?

Our understanding of cell biology reveals that such molecular data lie within the cell organelles, nucleus, mitochondria and chloroplast of a cell. All of them possess DNA and are referred to as: **nuclear-DNA** (Nucleus); **mt DNA** (mitochondrion), and **cp DNA** (in chloroplast) respectively. A nuclear DNA of a cell generally consists of a million to many billions kilo base pairs (kbp) and is

biparental in origin (a combination of male and female genome). Though stable, it evolves rapidly and is more difficult to analyse. However, it is a source of data that could throw light on final evolutionary processes.

Both mitochondrial and chloroplast DNA are uniparental in origin.

Based on the observations that **mt DNA** (made up of 200-2500 kbp) undergo a lot of rearrangement as well as occurrence of many forms of it within a mitochondrion, it is regarded relatively as of little significance in the phylogenetic systematics.

The most suitable genetic material as taxonomic evidence of green plants is **cpDNA**. In higher plants the size of a cpDNA in a chloroplast is only 120-140 kbp. Thus, it is smallest among all the three sources of genetic material within a cell. The advantages of cpDNA in taxonomic studies could be summarised as:

- relatively smaller size;
- large number of chloroplasts per cell;
- relatively stable not only in an organism but also in a species;
- easy to isolate and analyse;
- not much altered by evolutionary processes; and
- all cpDNA molecules carry basically same set of genes, however, arrangement varies in different species.

Molecular data is being used to construct phylogenetic trees of green plants, at almost all ranks. It principally helps in establishing affinities and relationships within and outside the ranks. For example : monophyly of families Apiaceae, Caprifoliaceae, Plantaginaceae, Scrophulariaceae, Apocyanaceae, Saxifragaceae etc is well supported by molecular data analysis. It supports the union of families Apocyanaceae and Asclepiadaceae; Braliaceae and Apiaceae; Brassicaceae and Capparaceae.

However, the importance of evidences from other, rather classical taxonomy, should not be brushed aside. All sources of evidences should be incorporated and analysed to arrive at a phylogenetic understanding of living organisms.

SAQ 3

- a) Choose the correct alternative from the two provided in the parantheses.
- Hordeum vulgare* possesses (simple/compound) starch grains.
 - Chemically raphides are (Calcium sulphate/Calcium oxalate).
 - Betalains are (nitrogenous/non-nitrogenous) pigments.
 - C₁₀ - terpenes are called (diterpenes/monoterpenes).
 - cpDNA is (not/very) much altered by evolutionary processes.

- b) What are semantides? How do they differ from secondary metabolites.
- c) Match the chemical items in column I with the choices provided in column II.

Column I	Column II
i) Volatile terpenes	a) Anthocyanins
ii) Purple pigments	b) Alkaloids
iii) Cyanogenic glycosides	c) Ethereal oils
iv) Colchicine	d) Chloroplast
v) Rubisco	e) Rosaceae

14.7 SUMMARY

- The scope and methods of plant taxonomy have evolved through times. Broadly, they are classified as: **Alpha** and **Omega** taxonomy.
- Alpha taxonomy is analytical and empirical. At this level an organisms is identified, characterised and named on the basis of morphology. It is also referred to as: classical, orthodox or formal taxonomy.
- Omega taxonomy provides interpretive classification. It helps understand evolutionary and phylogenetical relationships among organisms. It is also referred to as: beta-, neo-, and modern taxonomy.
- The characters/character-states/attributes provide useful inputs to identify, classify a plant. All of them together are called taxonomic evidences. Such evidences could be physical, chemical or biological.
- Taxonomic evidences from morphology, anatomy, embryology, palynology, cytology etc. constitute physical taxonomic evidences. Primary and secondary metabolites constitute chemical taxonomic evidences. Information-carrying biomacromolecules such as nucleic acids and proteins are called biological taxonomic evidences. They are also called semantides.
- Molecular data obtained from the DNA of nuclear, mitochondrial and chloroplast origin provides important insight into phylogenetic systematics.
- Study of structure, polarity, symmetry, shape and size of pollen grains is called palynology. Palynological evidences from both extant as well as extinct plants are very important physical taxonomic evidences.
- Chromosome morphology, karyotype studies (idiograms), position of centromere in a chromosome and behavior of chromosomes at meiosis, all together are also very informative taxonomic evidences.
- Directly visible chemicals, within a cell, in the form of starch grains and crystals, are also helpful in identification, and determination of

relationships in plants. Chemicals such as flavonoids, iridoids, alkaloids, betalains, anthocyanins, glucosinates, polyacetylenes, cyanogenic glycosides, terpenes etc. are termed secondary metabolic taxonomic evidences.

- For proper characterisation, identification, classification of plants, taxonomic evidences from a variety of sources should be gathered prior to any definite interpretations regarding phylogenetic relationships amongst various plants or plant groups.

14.8 TERMINAL QUESTIONS

1. Differentiate between the following pairs. Provide one example of each.
 - a) Semantide and Secondary Metabolites.
 - b) Alkaloids and Flavonoids.
 - c) Autopolyploidy and Allopolyploidy.
2. Mention briefly the importance of molecular data in modern plant systematics.
3. List the characteristics of the pollen grains that are useful as taxonomic evidences.
4. Write a note: "Cytology as taxonomic evidence".
5. Discuss the significance of secondary metabolites in taxonomy.

14.9 ANSWERS

Self-Assessment Questions

1.
 - a) Refer section 14.2
 - b) i) F; ii) T; iii) F; iv) T
2.
 - a)
 - i) boat
 - ii) autopolyploidy
 - iii) haploid
 - iv) ideogram
 - v) 4
 - b) Refer Subsection 14.3
3.
 - a)
 - i) compound
 - ii) Ca-oxalate
 - iii) nitrogenous
 - iv) monoterpenes
 - v) not

b) Refer Subsection 14.5.4 and 14.5.3

c) i) c.; ii) a.; iii) e.; iv) b.; v) d

Terminal Questions

1. a) Refer to Sections : 14.5.4 and 14.5.3

b) Refer to Section: 14.6

c) Refer to Section: 14.4.1

2. Refer to section : 14.6

3. Refer to section : 14.3

4. Refer to section 14.4

5. Refer to section 14.5.3



UNIT 15

TAXONOMIC HIERARCHY

Structure

15.1	Introduction	15.6	Species Concept
	Objectives		Nominalistic Concept
15.2	Concept of Taxa		Morphological Concept
15.3	Ranks		Typological Concept
15.4	Categories and Hierarchy		Biological Concept
15.5	Taxonomic Groups		Evolutionary Concept
	Species		Phylogenetic Concept
	Genus		Ecological Concept
	Family	15.7	Summary
	Order	15.8	Terminal Questions
		15.9	Answers

15.1 INTRODUCTION

Plant taxonomy basically comprises of four components: description; identification; nomenclature, and classification. These components taken together help biologists to communicate among themselves about each and every aspect of any of the plant without any confusion or chaos. Of course, there exist some minor as well as some major disagreements in their identification, nomenclature and classification. However, all such disagreements can be resolved by following the guidelines provided by International Code of Botanical Nomenclature of Algae, Fungi and Plants (For details of this Code, refer to Unit 17). The process of agreements, disagreements and resolutions of the same is dynamic.

To begin with, each and every plant/organism has to be provided a scientific name which is a binomial comprising of a generic name and a specific epithet. Such species are then grouped together into a higher taxon/group/category called, the Genus. The genera are then grouped into a still higher unit/taxon, called the Family and so on. In this manner, it is possible to reach the highest

level in a System of Classification. This ultimate unit/taxon is the Plant Kingdom, or even a Domain. This sequential placement of more than one taxa one above the other or one inclusive of the other is known as **Taxonomic Hierarchy**. Generally the taxa are arranged in an ascending order. The highest being the Kingdom and the lowest being the Species. All of these categories, ranks taken together constitute taxonomic groups.

In this Unit, you shall learn the concept of hierarchy, taxonomic groups and taxa. A special sub-section is devoted to the still evolving but a challenging issue in plant sciences (in fact in Biological Sciences) - the “Species concept”.

Objectives

After studying this unit you should be able to:

- ❖ know the importance of the concept of taxonomical hierarchy;
- ❖ define and explain the terms : taxon, category and rank;
- ❖ describe the salient characteristics of the taxonomic groups : species, genus, family and order; and
- ❖ discuss the “Species-concept”.

15.2 Concept of Taxa

Extensive taxonomic literature is available which broadly describes various aspects of plant identification, classification and nomenclature. Studies on plants are been carried out throughout the world and results are published in floras, amended additions and research journals. We will describe these later in this Unit.

A. Meyer (1926) introduced the term **taxon**. Later H.J. Lam (1948) was first to proposed the term taxon at Utrecht Symposium on Nomenclature. The first International Botanical Congress held at Stockholm (1950) finally adopted the term “taxon” (*pl.*- taxa).

What is Taxon?

Taxon is regarded as an adequate, appropriate and specific term to designate an “entity” or a “taxonomic group”. The word ‘entity’ is not preferred because it cannot designate a biological category or a taxonomic group above the level of an individual. Similarly, an individual cannot be termed a taxonomic group. The term taxon has the advantage as:

- It possesses a single meaning that is devoid of any vagueness or ambiguity;
- It is descriptive; and
- It is used to indicate any of the taxonomic groups of any rank.

These ranks could be : Division (Phylum); Class; Order; Family; Genus or even a Species. For example, Division Magnoliophyta is an example of taxon. So are the Order Rosales, Family Asteraceae, Genus *Mangifera* or a species *Allium cepa*. Can you add more?

There exists plasticity in the nomenclature, inclusiveness and the rank of any taxon. Ranks of a taxon can be changed, pushed up or down the hierarchy. Such variations, however, are more pronounced at higher level of hierarchy than the lower level. Let us discuss an example.

Traditionally living beings were classified into two kingdoms **Plantae** and **Animalia** (Both are examples of taxa). H.E. Copeland (1938, 1947) proposed a Four Kingdom Classification. This classification suggested that all the prokaryotes be assigned to the kingdom **Monera**. Organisms with little or no tissue differentiation were assigned to a kingdom **Protista**. Kingdom **Metaphyta** included plants and all animals and were a part of kingdom **Metazoa**. You are quite familiar with the Five-kingdom classification of R.H. Whittaker (1969). These kingdoms are: **Monera, Protista, Fungi, Plantae** and **Animalia**. L. Margulis (1971, 1975) made minor modifications to the five-kingdom classification. H.P. Traub (1975) created two super-kingdoms: **Cellulaire** and **Eucaryote**. Interestingly, kingdoms **Plantae** or **Animalia** were thus put in lower hierarchy of sub-kingdoms under the kingdom **Eucaryote**. P. Edwards (1976) proposed a seven-kingdom classification while raising the status of **Procaryota** and **Eucaryota** to the level of Super Kingdom.

From the above examples, it can be assumed that a species *Pisum sativum* L. can be a part of a taxonomic hierarchy at the highest taxon Kingdom Plantae, taxon Kingdom Metaphyta, still higher taxon Super-Kingdom Eucaryota or even a lower taxon Sub-Kingdom Plantae depending on the system of classification. Interesting, in all of such variations, the taxon, *P. sativum* retains the lowest ranked species taxon rank in the taxonomic hierarchy.

A common principle of systematics mandates that taxa should be monophyletic. If an assemblage of plants is polyphyletic then they are divided into two or several monophyletic groups.

A **monophyletic taxon** is the **one that is derived from one ancestral population system**. On the contrary, a polyphyletic taxon is derived from two or more ancestral population systems/taxa.

In phylogenetic studies the term 'taxon' represents a **clade**. And, a clade is "a monophyletic ancestor - descendant lineage".

15.3 Ranks

A Rank is defined as a "level in the hierarchy or the location of a category in the taxonomic hierarchy." Kingdom, Division (Phylum), Class, Order, Family, Genus and species are the most prominent examples of taxonomic ranks. Any given organism may belong to more than one rank, the lowest of which is the rank of species. For example, according to the classification of plants by Engler and Prantl, the genus *Aster* belongs the followings ranks :

Class	:	Dicotylendons
Order	:	Campanulatae
Family	:	Asteraceae

However, according to the classification system proposed by Bentham and Hooker, the same genus *Aster* is placed in the ranks:

Class	:	Dicotylendons
Order	:	Asterales
Family	:	Compositae

It is apparent that while the designation of ranks (Class, Order, Family) are the same, the names of the ranks may differ with different systems of classification. It could be Order Companulatae (Engler and Prantl) but Order Asterales (Bentham and Hooker). In most classical classifications ranks are based on subjective dissimilarities. They do not reflect gradual natural variations. This accounts for variations in the number of taxa at a given rank in different systems of classification (Table 15.1).

In addition, each of these major ranks (Kingdom, Division, Class, Order and Family) can be sub-divided into two or more ranks. These additional ranks are prefixed with word *sub*. For example: Sub-Kingdom; Sub-Division; Sub-Class; Sub-Order and Sub-Family. Similarly, the rank of genus can further be divided with into: sub-genus; section; sub-section; series and sub-series. The rank of species may be further sub-divided into: sub-species; variety; sub-variety; forma; sub-forma and cultivar.

Table 15.1 : Variations in number of taxa in a given rank in different systems of classification.

Classification proposed by	Number of taxa	
	Orders	Families*
Engler and Prantl	44	258
Hutchinson	76	264
Bessey	22	255

* The number of families in different systems of classification is more or less similar but there is a vast difference in the number of orders (Table.15.2).

Table 15.2 : Different ranks, suffix and examples.

Rank	Categories	Ending	Example (taxa)
	Division	- phyta; -Mycota*	Pterophyta; Eumycota*
	Sub-Divison	- phytina; -mycotina	Pterophytina; Eumycotina*
	Class	- opsida; -mycetes*; phyceae**	Pteropsida; Basidiomycetes*; Chlorophyceae**
	Sub class	- opsidae; -mycitidae*; - phycidae**	Pteropsidae; Basidiomycidae*; Cyanophycidae**

Order	- ales;	Asterales; Rosales
Sub order	- ineae	Asterineae; Rosineae
Family	- aceae	Asteraceae; Rosaceae,
Subfamily	- oideae	Asteroideae; Rosoideae
tribe	- eae	Astereae; Roseae
sub-tribe	- inae	Asterinae; Rosinae

* = for fungi

** = for algae

The process of ranking of particular organism is a dynamic process. With availability of new evidences, newer interpretations; newer data, taxon ranking in the hierarchy can be remodelled.

SAQ 1

a) Mark the following statements as true or false. Write **T** for true and **F** for false statements :

- i) A taxon represents a clade.
- ii) A taxon is a group of organisms typically treated at a given rank.
- iii) The process of ranking is dynamic
- iv) A rank cannot be sub-divided.
- v) Species represents the highest rank in taxonomic hierarchy.

b) Define the following terms.

- i) Monophyletic
- ii) Taxon
- iii) Rank
- iv) Additional Rank

c) Fill in the blanks :

- i) The term taxon possesses a single meaning devoid of and
- ii) Asteraceae is an example of rank,
- iii) proposed the term taxon.
- iv) A..... represents a monophyletic ancestor descendent lineage.

15.4 Categories and Hierarchy

Categorisation is a system in which members of an organization or society are ranked according to relative status or authority. It may be an arrangement or classification of things according to relative importance or inclusiveness.

Hierarchy Gr.
“*hierarkhia*”
(‘*hierarkhe*’s = sacred ruler” “**Hierarkhia**”
hieros (sacred) +
archein (rule) – the
sacred ruler.

Hierarchy represents a pyramid-like ranking of individuals, items, etc., where every level (except the top and the bottom) have one higher and one lower rank, e.g., in armed forces; bureaucracy; corporate ladder; positions in the universities, etc. The traditional hierarchy in nature is from atoms to biomes (Fig. 15.1 a). Fig. 15.1 b represents a hierarchy of biological organization. Similarly, a **taxonomic hierarchy** is an “*orderly array composed of a series of inclusive levels called categories*”. These categories represent the rank to which taxa are assigned. These taxa are (in ascending order): Species; Genus; Family; Order; Class; Division; Kingdom; and/or even a Domain.

This hierarchy principally helps us to avoid chaos. There are thousands of organisms which have to be classified. There exist several systems of classification to organise these organisms. Categorisation helps in providing homogeneity to the various systems of classification. It makes comparisons smooth and scientific. It is to be understood that irrespective of system of a classification, the categorisation is identical in all of them. The principle of ranking is similar.

With a system of classification of organisms, hierarchy refers to an ascending series of levels or ranks wherein above placed rank (category) in the hierarchy is inclusive of all the ranks beneath it (Fig.15.1c).

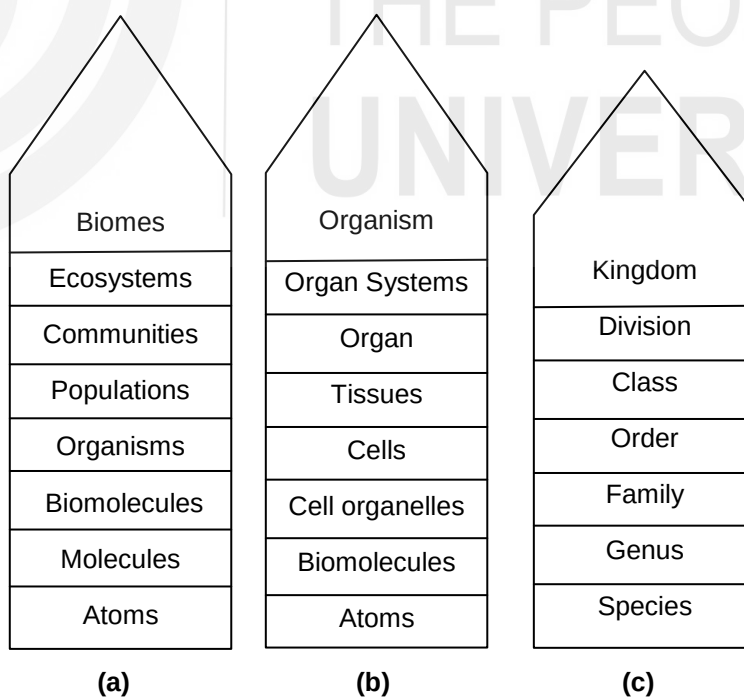


Fig. 15.1: Hierarchy : (a) Natural; (b) Biological; (c) Taxonomical

↑ = smaller to larger category
lower higher

↓ = Inclusive of all the categories beneath it.

You will not be wrong to conclude that, “higher the category in a hierarchy, more inclusive it is”. The fig. 15.1 illustrates a set of conventional taxonomic categories. These categories are abstract concepts to which groups of plants are assigned. These categories, in turn, provide a structure to a taxonomic hierarchy. The primary goal for such an exercise is to provide unified, comparable, inputs to the systems of classification.

Salient features of structure of Taxonomical Hierarchy

- A taxonomical hierarchy consists of a number of categories.
- A category is an abstract concept.
- A group of plants are assigned to such categories for the purpose of classification.
- The categories are employed in a conventional order which must be strictly adhered to.
- The level at which a category stands in the hierarchy is known as rank.
- The group of plants themselves are known as taxa (*singular* : taxon).
- The taxa of lower rank are always “sub-ordinate to” and “included in” those ranks which are higher to it.

To understand the above structure of taxonomical hierarchy let us look at the Table 15.3 and take an example of tree *Vernonia* : (1) All the tree *Vernonias* together form one taxon, *Vernonia arborea*. These are a group of plants assigned to the taxonomic category- the species; (2) This category, the species stands lowest in the taxonomic hierarchy; (3) There exist 1000 or so other kinds of *Vernonia*. Each of these is likewise assigned to the taxonomic category of species; (4) Grouped together, all such 1000 or so species of *Vernonia* form a larger taxon known as the genus *Vernonia*. This is assigned to the next higher taxonomic category called – the genus; (5) Thus, category of genus is at higher rank than a rank of species in the taxonomic hierarchy ; (6) There are other genera such as *Dahlia*, *Helianthus*, *Launaea*, *Tagetes*, *Cichorium*, *Senecio* and some 950 of them are all grouped together into a still larger taxon at higher rank, called the family – Asteraceae/ Compositae; (7) This family in turn along with 5 more families are grouped together into a still larger taxa at higher rank - called the order, Campanulales; (8) Such an ascending grouping of taxa at subsequent higher ranks ultimately are assigned to the largest category Plantae, the Plant kingdom. The rank, kingdom thus forms the highest category in the taxonomic hierarchy. This successive classification into larger and larger groups is the basic feature of taxonomic hierarchy (Table.15.3).

Table 15.3 : Taxonomic hierarchy and Categories of Tree *Vernonia*, *Vernonia arborea*.

Taxonomic Category	Classification of <i>Vernonia arborea</i>
Kingdom	Plantae
Division	Embryophyta Siphonogamia

Sub-division	Angiospermae
Class	Dicotyledons
Order	Campanulales
Family	Asteraceae /Compositae
Genus	<i>Vernonia</i>
Species	<i>Vernonia arborea</i>
*based on (Engler and Prantl's system of classification)	

This use of the hierarchy as exemplified here by the example of Tree *Vernonia* also applies to all other plants.

You may raise a question, how do we identify, delimit or set-aside a taxon? It is primarily expressed by way of description of its characteristics (basically morphological plus inputs from various fields of biology) including the range of variations. It may include sub-ordinate taxa. Such a description which identifies, separates, sets aside, delimit a taxon from any other taxon is called it **circumscription**.

Properties of Hierarchical System

A species is made up of a number of individuals (all the individuals of *V. arborea* make the species *Vernonia arborea*). A unit higher rank in the taxonomical hierarchy, the genus may consist of one or more number of species. All of them in turn are made up of all the individuals of that species. Thus, the genus ***Vernonia*** includes all the individuals of all the 1000 species of genus ***Vernonia***. Here, it is evident that a genus will eventually include a greater number of individual plants than any one of its species may contain individually. In other words, the genus (here *Vernonia*) as a whole shows much greater range of variations than any one of the species within the genus. Can you visualize and estimate the number of individuals, the category at the rank of Plant Kingdom - Plantae, may possess? And the variations it may exhibit?

The above discussion can be summarized as under:

- i) Lower the rank of a taxon in the taxonomic hierarchy, the fewer are its members and more they have common with one another, and the converse is also true;
- ii) Higher the rank of a taxon in the taxonomic hierarchy, the more numerous are its members and less they have in common.

The concept of taxonomic hierarchy can also be explained by any of the following approaches:

(A) Box-in-Box Concept

It is also called **nested-box system**. The figure 15.2 illustrates the box-in-box concept of hypothetical family A and its genera. All the five genera in total possess a total of 15 species. The 15 species are grouped into 10 genera, 6 families, 4 orders, 2 classes, 3 subclasses and 1 division.

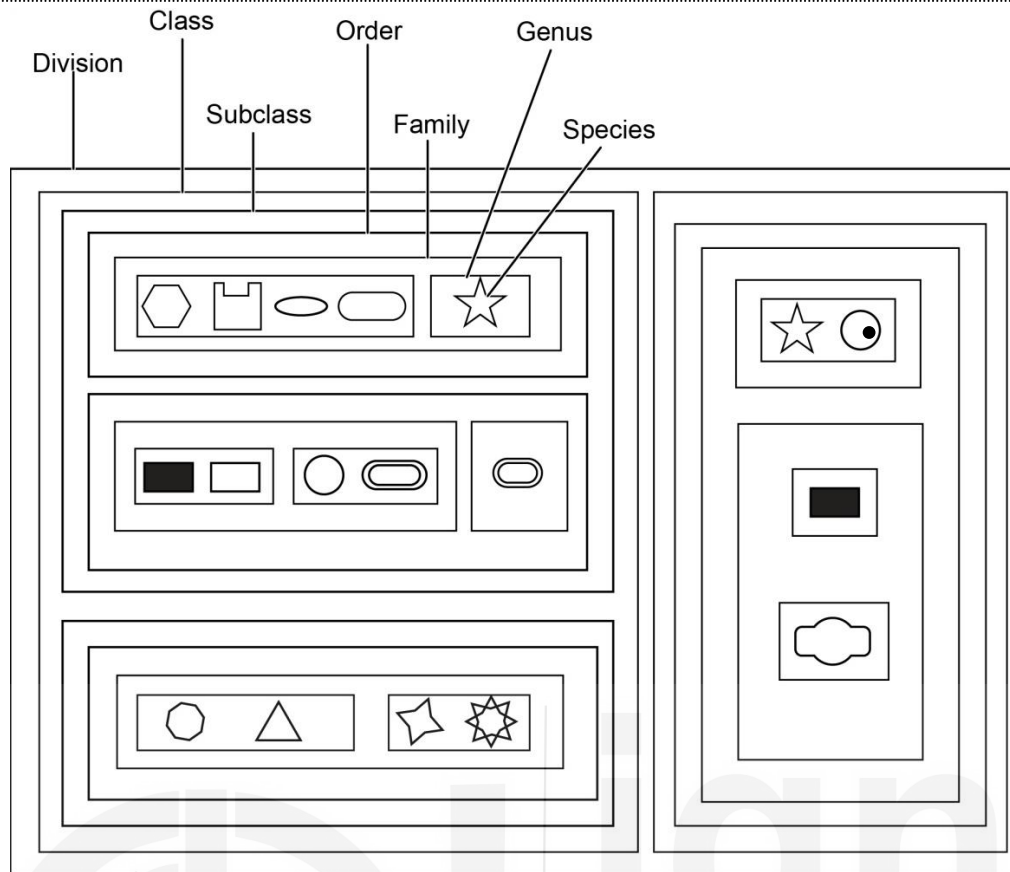


Fig. 15.2: Box –in-box method for assembling taxonomic groups according to hierarchial system.

The figure 15.3 also illustrates a box-in-box concept to explain the categorization and taxonomic hierarchy with *Vernonia arborea* as an example. *V. arborea* and all individuals form the lowest rank-species.

Along with 1000 more species the higher rank of genus, *Vernonia* is formed. It is included along with 950 more genera in next higher box rank of family Asteraceae /Compositae. Along with 5 more families still higher rank of order Campanulales, the next larger box is formed. Ultimately, largest, highest, all inclusive box of kingdom-Plantae is formed.

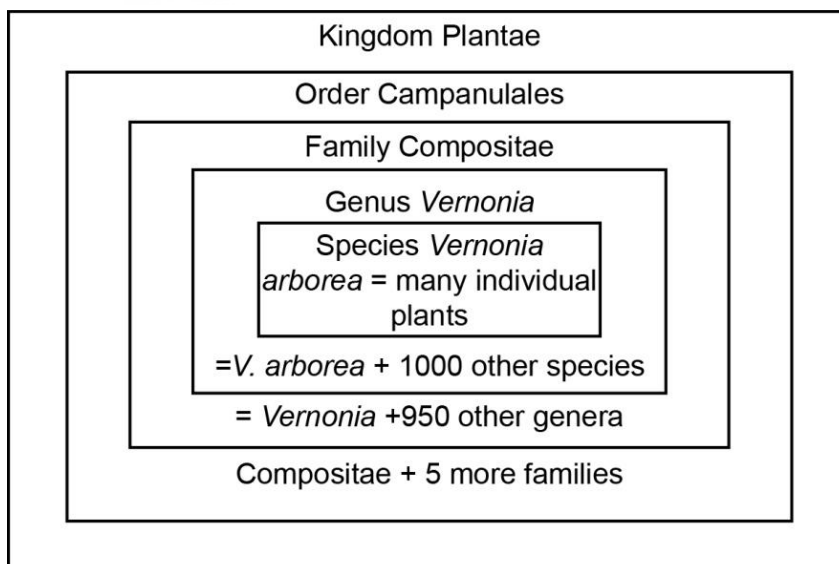


Fig. 15.3: Box-in-box representation of taxonomic categories in *Vernonia arborea*.

(B) Dendrogram Concept

Categorisation and hierarchy and relationship among ranks can also be represented by the dendrogram (Fig 15.4). Here, at each and every step of categorization lower taxa/ranks are placed in the form of a branching pattern.

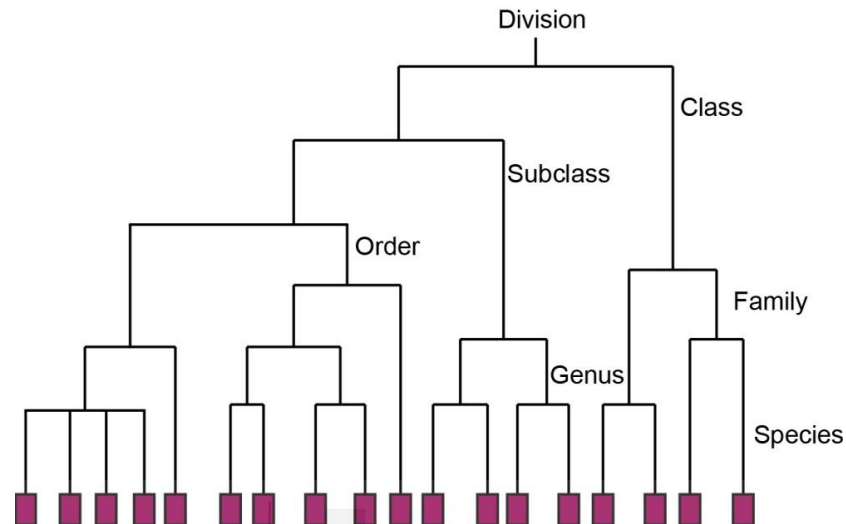


Fig. 15.4: Depiction of hierarchical system by the dendrogram method (based on hypothetical results).

This is a categorisation of an illustrative example of a species upto the kingdom level based on the classification of Bentham and Hooker (You may choose any other classification other than of Bentham and Hooker (You may choose any other example or prepare a dendrogram of your choice).

(C) Filing – Cabinet Concept

The category and hierarchy concept can also be clarified by the example of a filing- cabinet (Fig. 15.5). This cabinet consists of a series of vertical boxes, A, B, C. The level (upper, middle, lower) of each box represents the taxonomic 'rank' in the taxonomical hierarchy. The empty box at any level represents the taxonomic 'category' and the 'contents' of the box represents the taxonomic group or taxon". Some boxes may have one or more taxa.

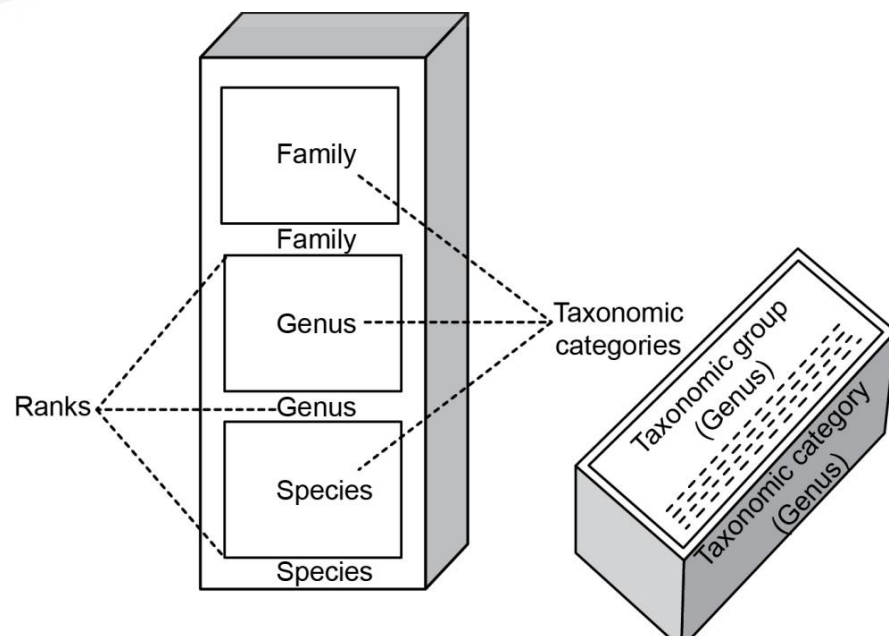


Fig. 15.5: Categorisation of various taxa by Filing Cabinet method.

The hierarchical categories and ranks are thus the general terms embracing all taxa at certain levels. They represent certain concepts. These categories **do not actually 'exist'** in nature. Only the taxonomic groups or 'taxa' exist in the nature. These taxa are assemblages of individual organisms defined on the basis of certain morphological or phylogenetical relationships. Ranks and Categories are defined only by their relative positions in the hierarchy, and **not** in terms of organisms. What exist in nature are individuals - representative, the conceptual taxon "species".

15.5 TAXONOMIC GROUPS

In the preceding section, you have studied that taxonomic hierarchy is an orderly arrangement to which taxa are assigned. Although these taxa could be species, genus, family, order, class or divisions, it is only the family, the genus and the species that are mostly discussed in taxonomic literature. On the other hand, taxa such as order, class or divisions are regularly discussed to express or reflect evolutionary (phylogenetic) relationships. For example, in the phylogenetic classification of plants proposed by Engler and Prantl, the Plant Kingdom is divided into 13 divisions, wherein division 12 (*Embryophyta Asiphonogamia*) and division 13 (*Embryophyta Siphonogamia*) are considered more advanced than the earlier 11 divisions because they possess 'embryos'. Even, within these divisions 12 and 13, the division *Embryophyta Siphonogamia* is considered more advanced. Also, within this division the sub-division Gymnospermae is more primitive to other sub-division Angiospermae. Similar examples can be provided to reflect phylogenetic relationships among such highly placed taxonomic groups: class and orders and, to a lesser extent to the taxon, family. However, the lowly placed groups, genus and species; do not reflect such sharp, emphatic evolutionary categorization. Therefore, in this section, we will restrict to the taxonomic groups: species, genus, family and order.

15.5.1 Species

The most basal taxon, species, (pl. species) in taxonomic terms is described as a group of individual plants that are fundamentally alike. Ideally, a species should be separated from the other otherwise closely related species through conspicuous morphological features. However, in actual practice such demarcation may not always be simple and precise. Even within a population of a species, not all the individuals are exactly alike. There exists a few to several minute morphological variations. If we were to take such minor variations seriously, then there is likelihood of a no limit to the number of species.

This basic unit of taxonomy, the species, unlike the other taxa, can be described and recognized without relating to the taxa. In fact, every herbarium sheet or a living plant can be dealt with, without any difficulty for the identification of the species (plant). Also, no genus can be recognized or described without a reference to the included species. Thus, a species directly relates to the given plant. For example, the mere mention of the genus *Allium* does not provide any clue to the identification or reference to any plant. But, by merely mentioning of the species *Allium cepa* or *A. sativum*, we can immediately relate the species to the plants of onion or garlic respectively.

Theoretically, however, a question is raised – What is an ideal species? The answer(s) could be:

- i) the one which can be distinguished on the basis of morphology without any discontinuity of variation;
- ii) it should not exhibit any discontinuity of variation (i.e. it should not have any intra specific taxa);
- iii) it must also be genetically isolated from others, it should be least out breeding, but sexually reproductive; and
- iv) Its characters should not vary with environment. However, no such “ideal” species exists in nature.

Intraspecific Taxa: A number of variations within a population of a species may warrant categorisation of a species into a number of intraspecific taxa. Some of such common taxa are:

1) Sub species

They are species of small magnitude. They are also referred to as ‘baby species’. They are distinguished by less obvious, less significant morphological variations than the obvious features of the said species of the same genus.

A sub-species, however, could possess major morphological variations and have specific geographical distribution of their own (i.e., they occupy distinct geographical areas from other sub-species of the same parent species). An ecotype is also regarded as a sub-species. Crowson (1970) describes intraspecific taxa as “*phenotypically distinguishable, genetically determined variant*”. Huxley (1939) refers to them as *clines*. A cline may be defined as “*a gradual and progressive change in the characters of a species when it is traced along an extensive tract of natural distribution*”.

A few examples of sub-species are:

Portulaca pilosa spp. *pilosa*

Urena lobata spp. *lobata*

Pisum sativum spp. *sativum*

Grevillea victoriae spp. *nivalis*

G. victoriae spp. *brindabella*

G. victoriae spp. *victoriae*

Grevillea pyramidalis spp. *leucadendron*

2) Varieties

A variety (Latin: *Varietas*) is a term used indiscriminately especially by horticulturists for any variant of a species. The common botanical considerations for designation of the term variety are:

- i) A morphological variant of the species without regard to distribution, e.g., a dwarf (var. *nana*);
- ii) a morphological variant of the species having its own geographical distribution e.g., a coastal area (var. *maritima*);
- iii) a morphological variant of a species sharing an area in common with one or more other varieties of the same species, e.g., *Vitex negundo* var. *heterophylla*; *Fagus sylvatica* var. *heterophylla*; and
- iv) A variant represented only by a colour or habit *Urena lobata* spp. *sinuate* var. *glauca*.

3) **Forma**

Forma is the smallest category used in the taxonomic literature. The designation, forma is given to for *trivial* variation(s) among the individuals of a population. For example: colour of corolla or a fruit; habit responses. Some examples are:

Cedrus atlantica f. *glauca*

Fagus sylvatica var. *heterophylla* f. *laciniata*

It is possible that a 'sub-species' designated by a taxonomist is called a 'variety' by another or even a 'forma' by the third taxonomist.

4) **Lesser Groups**

These categories of a species are below the level of forma. They could be:

- i) **Race:** The term is used *in lieu* of or as a substitute to the term 'forma'.
- ii) **Clone:** A term mostly used in horticulture for the individuals propagated asexually or apomictically.

Forsberg (1942) suggested that during an evolutionary process, a sub-species is an "incipient" species in a series of stages of speciation.

15.5.2 Genus

The term genus (pl. genera) is also a concept. It is described, rather visualised, as a group whose species have characteristics in common with each other than with the species of another genera within the same family. It is also regarded as an aggregate of closely related species. A genus also represents a sum of all the characteristics of its closely related species. Rollins (1953) defines the genus – "**as a group of closely related species with emphasis on its 'naturalness of the group as shown by its homogeneity and distinctiveness'**".

Davies and Heywood (1963) put forth three primary parameters that should determine the status of a genus: (i) naturalness; (ii) delimitation from closely related genera, and (iii) practicability of keeping them distinct or including them in other genera.

Genus is also regarded as to represent different species in a phylogenetic manner by placing the closely related species together. For example; peach (*Prunus persica*); plum (*P. domestica*); apricot (*P. armeniaca*); sour cherry (*P. cerasus*); sweet cherry (*P. avium*) and almond (*P. amygdalus*) all are species with their own characteristics, yet all of them possess enough characters in common to be species of a common genus, *Prunus*. All of them have simple, unlobed, lanceolate leaves often with nectarines; several stamens; fleshy fruit with a single, relatively large hard-coated seed (stony fruit).

There is no size requirement in number of species a genus should possess. *Amborella* has only one species, *A. trichopoda*; *Leitneria* has also one species, *L. floridana*. Such genera are called monotypic. Some other representative ranges are: *Nymphaea* (more than 40); *Magnolia* (over 200); *Vernonia* (about 1000); *Senecio* (2-3000); *Aster* (in excess of 20,000) and so on.

Since, the number of species to a genus is no criteria; a genus must be delimited following a world-wide study of their species. Once distinct, even deciduous *Azalea* and evergreen *Rhododendron* of N. America, are, for example, now categorized as one genus *Rhododendron*.

Sometimes, the characteristics of a genus are so pronounced that they are popular by their colloquial names, for example: Oaks for *Quercus* spp.; buttercup for *Ranunculus* spp.; sunflower for *Helianthus* spp.; pine for *Pinus* spp. and so on.

15.5.3 Family

The category family is also grouped and classified on the same principles as that for a genus. However, category family is more inclusive than the category genus. Both vegetative and reproductive features are taken into account for the delimitation of families. However, the reproductive characteristics being more conservative are more reliable than the vegetative features. Such reproductive features can be inclusive of variable characters such as: Ovary position; kinds of pistils; number of carpels; placentation; types of fruits; free or fused accessory parts of a flower; symmetry of a flower; kinds of inflorescence etc. In addition, habit of the plant; leaf morphology, phyllotaxy, venation, etc., can also be criteria for the delimitation of a family.

Some very distinct morphological characteristics of some families are:

- Distinct insect trapping mechanisms : Droseraceae; Nepenthaceae, Lentibulariaceae
- Floral Characters (Inflorescence) : Asteraceae; Umbelliferae, Cruciferae
- Fruits : Fabaceae; Poaceae

Such families are termed homogenous. Members of families such as Ranunculaceae, Rosaceae, Berberidaceae possess a range of characters. Such families are categorized as heterogenous.

Ideally, a family should be monophyletic, irrespective of the number of genera included in it. Similar to a genus, all families also do not include a fixed number of genera within it. Families like Amborellaceae, Leiteneriaceae are monogeneric and monotypic (Only one genus and one species to a family), while more than 900 genera and thousands of species comprises of Asteraceae (earlier-Compositae). Some other variations are: Magnoliaceae (12 genera); Ranunculaceae (approx. 50 genera); Malvaceae (about 75 genera); Lamiaceae (More than 150 genera); Brassicaceae (about 375 genera) and so on.... Historically, Pierre Magnol (1689) introduced the idea of term families into systematics. He suggested that groups of organisms are related either by birth (**cognationem**) or by marriage (**affiviatum**).

15.5.4 Order

One or more families comprise a category order, a taxonomic group higher in rank than a family. However, it is more difficult to define and delimit an order than a family. It is believed that more divergence occurred in orders, early in evolutionary history of flowering plants hence, a poor fossil record. Like categories higher to it, orders are based and delimited on the basis of aggregate of characters. There are greater numbers of variations in the characteristics of families that make an order than the variations in the genera that make a family. The size of an order is the number of families to an order is also variable.

SAQ 2

- a) Write a note on the following taxonomic groups.
 - i) order
 - ii) genus
 - iii) species
- b) Fill in the blanks using appropriate word(s):
 - i) Higher the category in a hierarchy the more.....they are.
 - ii) is the most basal taxon.
 - iii) The term race is used *in-lieu* of the term.....
 - iv) Individuals produced by apomixes are termed as
- c) Rearrange the following in descending order of hierarchy :
 - i) Forma; kingdom; genus; order; sub-species; class.
 - ii) Family; variety; sub-species; genus; order; forma; species.

15.6 Species Concept

“Nature produces individuals and nothing more” (Bessey, 1908)

BIOTYPE is a group of organisms having an identical genetic constitution.

SPECIATION-

Formation of new and distinct species in the course of evolution

What is a species? How does one define a species? Do species really exist? Many such questions are raised but no definite answer exists. Camp and Gilly (1943) aptly reflected that *“the term species as a kind or as unit has become so firmly entrenched in the mind of man, of his awareness, so necessary to his basic philosophy that remains only for the systematists to interpret...”*

There exist a number a number of schools of thoughts that define, interpret, and conceptualize the term species. Since there is no unanimity in defining a species, let us discuss some prominent, albeit very divergent, views about species in this section. The botanists, however, realize that ‘species’ exists and is a concept.

Reitzo (1930) defined species – “as the smallest natural population permanently separated from each other by a distinct continuity in the series of biotypes”. It implies that a species is a group of organisms having an identical genetic constitution. It also reflects the importance of morphological continuity transmitted through generations.

Lamprecht (1949), a cytogeneticist traced the development of changes in the species concept. He recognized five distinct periods of taxonomic research :

- i) The period of description without taxonomic systems;
- ii) The period of development of artificial and natural systems of classification;
- iii) The period of evolutionary studies;
- iv) The period beginning with the detection of speciation by the addition of genome; and
- v) The period beginning with the detection of genetic basis of species – barrier.

It is apparent that most classical (*alpha*) taxonomists belonged to first 3 periods, while biosystematists (*Omega*)/taxonomists belonged to last 2 periods. The views expressed by omega taxonomists can be synthesized as follows :

- i) All populations tend to vary and no **two** individuals or **two** populations are exactly the same;
- ii) Some of these variations are adaptive and are of survival value;
- iii) Forces of nature result in the extinction of some individuals while others survive in the same forces;
- iv) Some of the variations displayed by individuals within a population may be hereditary, if the successive generations are to be modified from ancestral conditions; and
- v) The environment of the individuals must not be static to avoid course of evolution by the forces of natural selection.

Thus, the resultant individuals (“Species”) are different taxa. Biologically, such taxa are derived by means of selective and genetic mechanisms. The ‘species’

are evolving all the times, the process is dynamic. And, may be the plant we pick for study at any given time represent on individual in course of such dynamicity.

From the above explanation(s) it is apparent that chances for the creation of 'new' individuals within the population exist. Can we call them species? Does every researcher, explorer, student possess sufficient expertise to designate or suggest such 'new' species with authenticity? Do we then 'visualise' any given plant as 'new' species? This scenario would definitely be chaotic. And, therefore, for taxonomic expediency or purposes there has to be a way out. Apart from theoretical consideration(s) some practical way out becomes apparent and necessary. The experience of a vast number of taxonomists, mostly classical taxonomists, has been to delimit a species on the basis of circumscription. This in turn, helps in effective systems of classifications and comparisons. In addition to achieve universal acceptance and for sound references, such a species is provided a binomial nomenclature.

Let us now briefly describe some of the prominent concepts regarding species. These are:

Nominalistic concept; **Morphological** concept; **Typological** concept; **Biological** concept; **Evolutionary** concept; **Phylogenetic** (cladistic); **Ecological** concept.

15.6.1 Nominalistic Concept

According to this concept species is nothing but a brain child of man. It is objectively unread. It is non-existent. What we observe are individuals that led to each other on account of similarities of characters, hence termed 'species'. Nominalistic concept envisages term species as a devise to refer collectively a large population of individuals. Mayr (1957) and Simpson (1961) are of the view that objective delimitation of the species is necessary. According to Haldane (1956), the species does not exist as a taxon but as a unit of convenience.

15.6.2 Morphological Concept

Historically the description, nomenclature and classification of a species have been based largely up on morphological details of herbarium specimens. To a lesser extent living material is collected from wild or cultivated source. Such details are also supplemented by geographical and ecological information. Of course, in such detailing of information, the subjectivity of the concerned taxonomist cannot be ruled out. It may result in disagreement among taxonomists and agreement to larger extent exists except for certain "critical groups".

15.6.3 Typological Concept

Whenever and wherever floras have been studied over years, a 'type' specimen (refer Unit 12) exists to provide diagnosis to differentiate a 'new' taxon to be designated a species. Only if the diagnosis does not match with the "type", the 'new' is regarded as a new species. Hence, a "species" is regarded as an aggregate of individuals that have in common the essential properties of the 'type' of specimen and that 'agrees' with diagnosis.

There are many practical advantages of this concept based on type, These are :

- i) It provides data/information of any plant;
- ii) It is easy to communicate/disseminate such data;
- iii) It helps compare experimental findings from other fields of study;
- iv) It helps maintain the information in literature;
- v) It helps to create a data-base;
- vi) It helps museum taxonomists to recognize species on the basis of discontinuities and patterns of correlated variations in morphology; and
- vii) Species thus delimited provides unified, convenient information as classificatory unit for a trained biologist.

15.6.4 Biological Concept

Reproductive behavior of an organism is also an aid to the development of species concept. However, a taxonomist does not have enough direct evidence to designate a given species on the basis of reproductive behaviour. Nonetheless, it is a very influential concept across many fields of biology. A number of biologists including a zoologist **Dobzhansky** (1937) defines the biological species as” that stage of evolutionary progress in which the once actually or potentially interbreeding array of forms become segregated into two or more separate arrays which are physiologically incapable of interbreeding”.

This concept of species is a dynamic process and not a static one (as morphological or typological). Another Zoologist **Mayr** (1942, 1963) suggested the following definition of a biological species.....” groups of actually or potentially interbreeding natural populations which are reproductively isolated from other such populations”. Mayer (1969) modified the concept as...” a species is reproductive community of populations (reproductively isolated from others) that occupies a specific niche in the nature”.

Biological concept of species finds favour with a number of leading biologists such as Dobzhansky, Huxley, Mayr, Simpson, Stebbins, Clause, Heslop-Harrison among others.

15.6.5 Evolutionary Concept

Evolutionary concept of species is based on modern and fossil lineages. Simpson (1961) defines on evolutionary species as “an evolutionary species is a lineage (and ancestor descendent sequence of population) evolving separately from others and with its own unitary evolutionary role and tendencies”. According to Grant (1971) populations are dynamic and it includes both sexual and asexual groups of a population. Both such populations do possess their own ecological niches too.

15.6.6 Phylogenetic Concept

In the post- Darwinian era strengthened by molecular data analysis **Cracraft** (1983) suggests that a species be defined as “the smallest diagnosable cluster of individual organisms within them there is a parental pattern of ancestry and descent”. Thus, the cladistic species concept defines the species as.... “the group of organisms between two speciation events” **OR** “.... between one speciation event and one extinction event”, **OR** ...” the one that are descendent from a speciation event”. Since, this phylogenetic approach, principally based on molecular data, fossil record and such parameters, is regarded more as a theoretical concept (refer unit 18).

15.6.7 Ecological Concept

Valen (1976) defines the species through ecological considerations. This concept envisages that “a lineage (or a closely related set of lineages) which occupies an adaptive zone minimally different from any other lineage in its range and which evolves from all lineages outside its range”.

In essence, according to this concept every species has an ecological niche and habitat. It is in this habitat the species is able to survive and contribute to the relevant ecosystem (i.e. ecological niche).

Brower and Zar (1977) put forward “*Voltera Principle*” It suggests that any two species having exactly the same ecological niche cannot survive in the same ecosystem. If they do, then they could only be **one** not **two** species.

For a classical taxonomist, however, the fundamental approaches of taxonomic studies and the morphological typological species concepts are most practical (unless otherwise specifically mentioned within blocks 4 and 5, in this course of study, the same approach is being followed). The modern cladistic approach is briefly dealt separately in the Unit 20 of block.

15.7 SUMMARY

What we have studied in this unit can be summarized as follows:

- Taxon represents as an adequate, appropriate and specific term to designate an entity or a taxonomic group.
- A taxon should be monophyletic. A monophyletic taxon represents a clade – “an ancestor – descendent lineage”.
- Rank is a level in the hierarchy or location of a category in the taxonomic hierarchy. Division, class, order, family, genus, species are all examples of ranks. Any given organism can belong to a number of ranks.
- Major ranks can be sub-divided into minor ranks. For example: class into sub-class; Family into sub-family and so on.
- An orderly array composed of a series of inclusive levels comprises of categories. Categories are the ranks to which taxa are assigned. Species, genus, family or all are the examples of categories.

- Higher category is inclusive of all lower categories beneath it. For example: Category family comprises of all the genera belonging to that given family and so on.
- Species, genus, family, order, class, division constitute various taxonomic groups. Species is the most basal taxonomic group. However, even lowly placed species too can be inclusive of sub-species, variety, form, race or clone.
- Species concept could be interpreted in terms of: morphology, biology, typology, evolution, phylogeny, ecology etc.

15.8 TERMINAL QUESTIONS

1. Define the term species and briefly discuss the species concept.
2. Differentiate between :
 - i) Category and Rank
 - ii) Rank and Sub-Rank
 - iii) Categories and Hierarchy
3. “Categorization and ranking are dynamic processes”. Briefly discuss the statement.
4. Provide brief comments on the taxonomic groups : family, genus, and order.
5. Write salient features of structure of taxonomic hierarchy.
6. Prepare a box-in-box hierarchical presentation for the species *Vernonia arborea*

15.9 ANSWERS

Self-Assessment Questions

1. a) i) T; ii) T; iii) T; iv) F; v) F
 b) i) Refer to Section 15.2
 ii) Refer to Section 15.2
 iii) Refer to Section 15.3
 iv) Refer to Section 15.3
 c) i) Vagueness; ambiguity
 ii) Family
 iii) H J. Cam
 iv) Clade

2. a) i) Refer to Section 15.5.4
ii) Refer to Section 15.5.2
iii) Refer to Section 15.5.1
- b) i) inclusive
ii) species
iii) forma
iv) clines
- c) i) Kingdom → class → order → genus → sub-species → forma
ii) order → family → genus → species → sub-species → variety → forma

Terminal Questions

1. Refer to Section 15.6
Hint : Morphological concept,
Biological concept,
Typological concept,
Ecological concept,
Phylogenetic concept,
Evolutionary concept.
2. i) Refer to Section 15. 3 and 15. 4
ii) Refer to Section 15.3 and 15.2
iii) Refer to Section 15.4
3. Open-ended
4. Refer to Section 15.5
5. Refer to Section 15.4
6. Refer to Section 15.4 A box in box concept

GLOSSARY

- Alkaloid** : Structurally diverse, physiologically active secondary metabolites; derived from amino acids or from mevalonic acid. Their nitrogen atoms are mostly basic.
- Allopolypoidy** : Presence of two or more genomes from different species in a cell.

Aneuploidy	:	Having a chromosome number that is not an even multiple of the base number.
Anthocyanins	:	Violet, blue, red and yellow flavonoid pigments not containing nitrogen.
Aperture of Pollen	:	Thin, variously shaped region of the pollen wall through which pollen tube emerges during germination.
Autopolyploidy	:	Presence in a cell of three or more chromosome sets from the same species.
Betalains	:	Nitrogenous red and yellow pigments; restricted to caryophyllales.
Biotype	:	A group of organisms having an identical genetic constitution.
Botanical Garden	:	An establishment where plants are grown for scientific study and display to the public.
Bracketed Key	:	A key in which two leads of a couplet are placed on adjacent lines so that the leads of a couplet are not separated by intervening lines.
Calcium oxalate	:	Oxalic acid associated with calcium, often occurring in plant tissues as raphides, druses etc.
Category	:	The rank to which a taxon is assigned.
Centromere	:	Small, constricted region of chromosome having attachment sites for spindle fibres during nuclear divisions.
Circumscription	:	Definition of a taxon, that is a group of organisms, based on certain distinct identifiable characteristics.
Classification	:	Assigning a plant group in groups or categories according to a particular plant or sequence in conformity with a nomenclature system and taxonomic hierarchy.
Clone	:	The individuals that are propagated asexually (by apomixis).
Colpate	:	A pollen grain with long and grooved aperture(s), the colpus (i).
Colporate	:	Pollen grain in which the apertures are composed of furrows (colpi), each with an internal pore.
Conservatory	:	A room with glass roof and walls used as Sun Lounge or for growing delicate plants (to keep or preserve them in frost-free environment).
Cyanogenic glycosides	:	Defensive compounds that are hydrolyzed to release hydrogen cyanide.

Ecotype	:	The sub-species that occupy specific geographical areas distinct from other sub-species of a given species.
Flavonoids	:	Phenolic compounds that usually occur in a ring system derived through cyclization of an intermediate from a cinnamic acid derivative and three malonyl CoA molecules.
Flora	:	Documentation of plant life occurring in a particular region: generally of native plant life.
Flora	:	An account of plants occurring in a particular area, including keys, descriptions and illustrations.
Forma	:	The smallest category in taxonomic literature.
Glass House	:	Synonym : Conservatory.
Glycosides	:	Organic compounds that yield a sugar when hydrolysed.
Green House	:	A structure, where the walls and the roof is made up of transparent material, in which plants requiring regular climatic condition are grown (Also called hot house).
Herbal	:	Relating to or made from herbs, especially those products that are used in cooking or medicine,
Herbarium	:	A collection of preserved plant specimen, placed according to an accepted system of plant classification, along with associated data used for scientific study.
Identification	:	Determination of 'taxon' as being identical whether similar to another and already known element.
Indented Key	:	A key in which each pair of contrasting choices (leads) that are equally indented and followed by the appropriate couplets, and thus the two leads are often widely separated in the key.
Irioides	:	Nine or ten-carbon derivatives of a simple terpene unit.
Isoprenoid alkaloids	:	A group of alkaloids that contain isoprene units.
Karyotype	:	Preparation of metaphase chromosomes shorted by length, centromere location, and other features.
Key	:	An artificial device (tool) or an arrangement for the determination of names of the plants included in it. It is a kind of taxonomic literature.

Manual	:	A book that contains information on the area of coverage and keys and descriptions to the taxa, including accepted scientific names with citations; synonyms etc.
Monocolpate	:	Pollen grain with a single, long, grooved aperture.
Monograph	:	A comprehensive systemic study of a particular taxon; includes keys, descriptions and illustrations.
Monophyletic taxon	:	The taxon that is derived from one ancestral population system.
Monosulcate	:	Pollen grain with a single, long and grooved aperture located at the pole.
Naturalist	:	An expert in study of natural history.
Nomenclature	:	A system of naming of an object particularly of biological origin.
Palynology	:	Study of the form and structure of pollen and spores.
Periodical	:	A publication appearing at a regular interval, each issue is called a number which collectively constitute a volume.
Phytotron	:	An enclosed research greenhouse used for studying interactions between plants and environment.
Pollen	:	Microspore containing a male gametophyte.
Pollinium (pl. pollinia)	:	Mass of pollen grains transported as a unit, characteristic of many Orchidaceae, Apocyanaceae.
Polyacetylenes	:	Non-nitrogenous compounds formed from the linking of acetate units via fatty acids.
Polyclave	:	A multi-access key constructed through use of punch cards.
Polycolpate	:	Pollen grain with several long, grooved apertures.
Polycolporate	:	Pollen grain with several long, grooved apertures, each with a central pore.
Polyphyletic taxon	:	A Taxon that is derived from two-or-more ancestral population systems/taxa.
Polyploidy	:	With three or more complete sets of chromosomes in a cell.
Polyporate	:	Pollen grain with many pore-like apertures.
Punch Card	:	A card represents a taxon and with characters represented by holes around the margin of the card. If a taxon possesses a character the hole around that character is notched.

Race	:	A term used <i>in-lieu</i> of or as substitute for the term 'forma'.
Rank	:	A position in the hierarchy; or – a level in the hierarchy or the location of a category in the taxonomic hierarchy.
Revision	:	It accounts only for a section of a genus or for elements as restricted to a condition or smaller geographical area.
Steroids	:	Hydrophobic molecules based on four connected carbon rings; often physiologically active.
Systematics	:	A branch of science that formulates a classification system following study of the variations among organisms.
Tannin	:	Yellow, astringent, bitter phenolic compounds.
Taxon	:	A taxonomic group of any rank, such as species, family, or class.
Taxonomy	:	Branch of science that finds, describes, identifies, classifies and names an organism.
Terpenoids	:	Structurally diverse compounds formed by the union of five-carbon isopentenoid pyrophosphate units formed in the mevalonic acid pathway.
Tricolpate	:	Pollen grain with three, long, grooved apertures.
Tricolporate	:	Pollen grain with three long grooved apertures, each with a central pore.
Triporate	:	Pollen grain with three equatorial, pore like apertures.