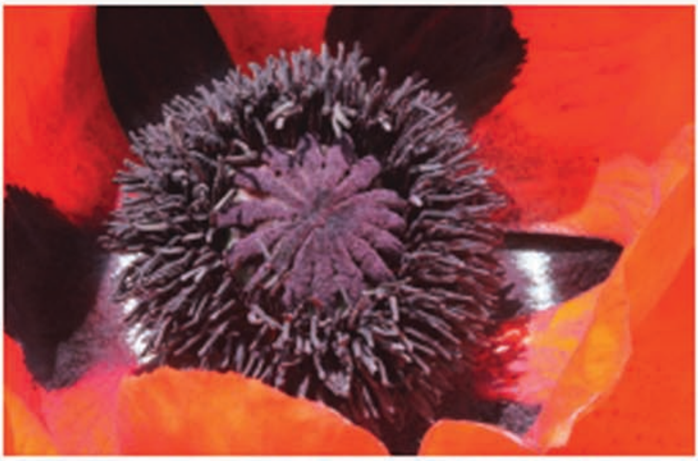

FOURTH EDITION

PLANT SYSTEMATICS

An Integrated Approach

GURCHARAN SINGH

CRC Press
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A SCIENCE PUBLISHERS BOOK

Fourth Edition

Plant Systematics
An Integrated Approach

Gurcharan Singh
Retired Associate Professor
University of Delhi, New Delhi, India

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Preface

The fourth edition of "Plant Systematics: An Integrated Approach" has been revised and reorganised thoroughly, and significantly updated to incorporate the developments of the last few years. The publication of current edition was forced mainly because of publication of revision of International Code of Nomenclature for Algae, Fungi and Plants (Shenzhen Code, 2018), new version of PhyloCode (Beta version of Phylocode 5, 2014), updated APweb version 14 (September, 2018 update), revised Angiosperm Phylogeny Group classification APG IV (2016), new Pteridophyte Phylogeny Group Classification PPG I (2016) and accumulation of large amount of information subsequent to the publication of third edition. There has been development of new tools of biotechnology, vigorous utilization of molecular data in understanding phylogeny, and redefining of affinities and arrangements of plant groups. Recent years have also seen disappearance of gaps between numerical and cladistical methodologies, and integration of former into latter for complete understanding of phylogenetic relationships. These trends have largely influenced the combination of numerical and cladistic methods under one chapter, and enlarged discussion on Molecular Systematics, discussing new concepts, tools and recent achievements and need to align these with morphological traits so that plants can be conveniently identified in the field. New chapters on Pteridophytes and Gymnosperms added in third edition have been retained and updated for complete understanding of systematics of vascular plants.

Actual photographs of plants and plant parts enable better understanding of taxonomic information. This practice (of using actual photographs) has been followed in several other recent publications too. The present edition incorporates numerous photographs of plants from diverse families of plants (color in the ebook, B&W in the print version). This has largely been possible with the assistance of my son Manpreet Singh who sponsored my recent visit to California and provided me the opportunity to visit and photograph temperate plants in and around California. The book, as such, contains images of both tropical plants, Himalayan plants, temperate American plants and plants from other parts of the world growing in the Botanical Gardens of University of California and San Francisco Botanical Garden, as also natural forest regions in California. In addition, 305 black & white illustrations help in a better understanding of the plants covered in the book.

The recent decades have seen major changes in schemes of classification of angiosperms. The traditional distinction between dicots and monocots seems to be disappearing, dicots are being split into the basal families and more advanced eudicots, and monocot families interpolated between these two groups of dicots. Whereas Angiosperm Phylogeny Group is attempting to establish monophyletic groups at the most up to the order level, grouped into informal groups, Thorne aims at blending these developments with the traditional Linnaean hierarchy. Both sets of classification have undergone major modifications in the recent years, such as the latest version of Thorne's classification (2007), Takhtajan's classification (revised in 2009), APG III (2009), APG IV (2016) and APweb Version 14 (2017). Attempts are also being made to provide unified Code of nomenclature for all living organisms.

The author has attempted to strike a balance between classical fundamental information and the recent developments in plant systematics. Special attention has been devoted to the information on botanical nomenclature, identification and phylogeny of angiosperms with numerous relevant examples and detailed explanation of important nomenclatural problems. An attempt has been made to present a continuity between orthodox and contemporary identification methods by working on a common example. The methods of identification using computers have been further explored to help better on-line identification. Outputs of computer programs especially used in molecular studies and construction of phylogenetic trees have been included based on actual or hypothetical data. This will acquaint readers with the handling of raw data and working of computer programs.

Internet highways are revolutionizing the exchange of scientific information. Botanical organizations have plunged into this revolution in a big way. Instant information on major classification systems, databases, herbaria, gardens, indices and thousands of illustrations are available to users Worldwide at the touch of a button. Discussion on important aspects of this information highway and useful links have been provided in this book. My interaction with colleagues especially the members of the list 'Taxacom', 'efloraofindia' Facebook groups 'Plant Identification', 'California Native Plant Society' and 'Indian Flora' has been very helpful in resolving some doubts. I am greatful to all members whose information has been valuable on several occasions.

For providing me inspiration for this book, I am indebted to my students, who helped me to improve the material through frequent interactions. I am also indebted to my wife Mrs. K. G. Singh for constantly bearing with my overindulgence with this book and also providing ready help in computer-related activities during the processing of this work. I am also thankful to my son Manpreet Singh and daughter-in-law Komal for our visit to California, where many plants were photographed. My younger son Kanwarpreet Singh & daughter-in-law Harpreet provided help on various occasions. Manpreet and Kanwarpreet also provided important photographic tips.

I wish to record my thanks to all colleagues whose inputs have helped me to improve the information presented here. I also wish to extend my thanks to Dr. Jef Veldkamp for valuable information on nomenclature, Dr. Gertrud Dahlgren for photographs and literature, Dr. P. F. Stevens for literature on APG IV, APweb Version 14 (updated September 2018) and trees from his APweb, Dr. Robert Thorne for making available his 2007 classification, Dr. James Reveal for his help on nomenclatural problems, Dr. Patricia Holmgren for information about major world herbaria, Dr. D. L. Dilcher for photograph, Dr. Julie Barcelona and Harry Wiriadinata for photographs of *Rafflesia*, the authorities of New York Botanical Garden, Missouri Botanical Garden, USA, Royal Botanic Gardens Kew and University of California, Santa Cruz, for photographs used in the book. Special thanks to Philip Cantino of Ohio University for making available the Beta Version of PhyloCode 5. Thanks, are also due to all whose contributions are cited in this book.

New Delhi **Gurcharan Singh**
January 2019

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Chapter **1**

Plants, Taxonomy and Systematics

Taxonomy (or systematics) is basically concerned with the classification of organisms. Living organisms are placed in groups based on similarities and differences at the organismic, cellular, and molecular levels. Described species of organisms on earth were estimated between 1.4 million and 1.8 million (Stork, 1988; Barnes, 1989; Hammond, 1992). Wilson (1992) estimated that roughly 1.5 million species of described species comprised 73.1% Animals, 17.6% Plants, 4.9% Fungi, 4.1% protists and only 0.4% Bacteria. Hammond (1992) proposed a working estimate of 12.5 million species organisms on earth consisting of 9.6 m animals (1.2 m described), 300,000 plants (250,000 described), 990,000 Fungi (80,000 described), 400,000 protists (90,000 described) and nearly 400,000 bacteria (only 6000 described).

The United Nations Environment Programme's *Global Biodiversity Assessment* published by Convention on Biological Diversity (2001) estimates the number of described species of living organisms as approximately 1.75 million, slightly more than ten percent of estimated 14 million species. Whereas nearly 90 percent of estimated plant species have already been described (270,000 of 300,000), only 12.5 percent of animals (1.3 m of 10.6 m), 4.7 percent of Fungi (70,000 of 1.5 m), 13 percent of Protoctists (80,000 of 600,00) and only 0.4 percent of Bacteria (4,000 of 1 m) have been described so far. The list grows every year. Subsequent publication by Chapman (2009) puts figures of described plant species as 310,129 (of 390,800 estimated) that includes 268,600 described angiosperms (estimated 352,000). The more recent estimates, however, put figures of flowering plants only as around 400,000 (Edwards, 2010 on Physorg.com). Best estimate by Census of Marine life, published by Mora et al. (2011) in PLoS Biology puts total number of Eukaryotic species on earth as 8.7 million, with 6.5 million species on land and 2.2 million in oceans, as against the earlier rough estimates between 3 million and 100 million. These 8.7 m species comprised 7.77 m animals (954,434 described), 611,000 Fungi (43,271 described), 298,000 plants (215,644 described), 36,400 Protozoa or protists (8,118 described) and 10,358 bacteria (described, predicted 9680). Only 1.2 m species of 8.7 m estimated have been described and catalogued. Furthermore, the study says a staggering 86% of all species on land and 91% of those in the seas have yet to be discovered, described and catalogued.

Pappas (2016), concluded that there may be 100 million to even 1 trillion species on this planet, based on scaling rules that linked the number of individual organisms to the number of total species. The list grows longer every year.

Christenhusz and Byng (2016) who have compiled a list of estimated number of genera and species in families recognized mainly in APG IV (2016) and other recent classifications estimate described and accepted number of plant species as ca 374,000, of which approximately 308,312 are vascular plants, with 295,383 flowering plants. Global numbers of smaller plant groups are as follows: algae ca 44,000, liverworts ca 9,000, hornworts ca 225, mosses 12,700, lycopods 1,290, ferns 10,560 and gymnosperms 1,079.

Most recent study by Brenden et al. (2017) estimates suggest that there are likely to be at least 1 to 6 billion species on Earth, and in contrast to previous estimates, rather than being dominated by insects, the new Pie of Life is dominated by bacteria (approximately 78%), protists 7.3%, plants 0.02%, Fungi 7.4%, and animals 7.3% (Figure 1.1). Classifying these organisms has been a major challenge, and the last few decades have seen a lot of realignments as additional ultrastructural and molecular information piles up. These realignments have primarily been the result of realization that the branches of the phylogenetic tree must be based on the concept of monophyly, and each taxonomic group, kingdoms included, should be monophyletic. Unfortunately, only a fraction of these estimates, just 1.5 million species have been described.

Before attempting to classify the various organisms, it is necessary to identify and name them. A group of individuals, unique in several respects, is given a unique binomial, and is recognized as a species. These species are grouped into taxonomic groups, which are successively assigned the ranks of genera, families, orders, and the process continues till all the species have been arranged (classified) under a single largest, most inclusive group. Classifying organisms and diverse forms of life is challenging task before the biologists.

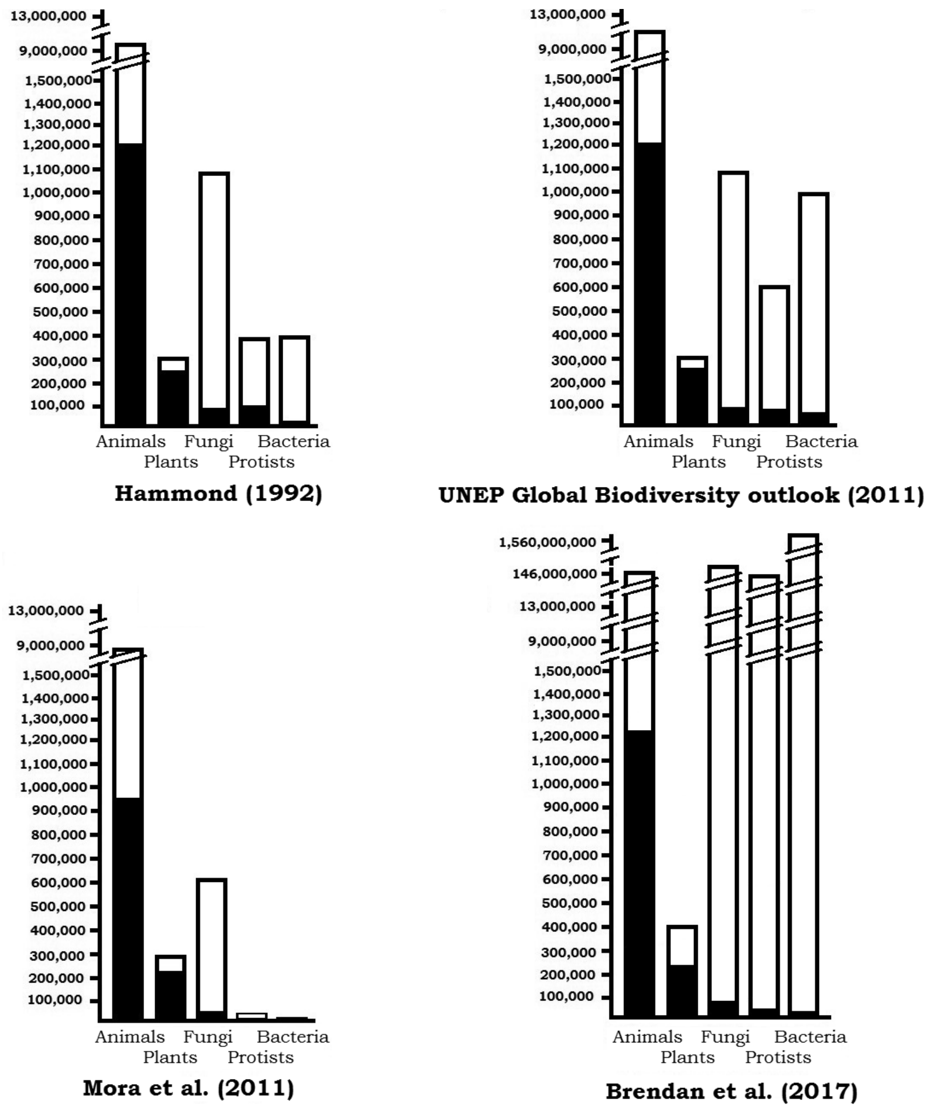

Figure 1.1: Estimated number of species on earth and the described number of species (solid lower portion of bar) in major groups of organisms. The estimates in recent years have shifted from Animals to Bacteria, Fungi and Protists as dominant groups.

PLANTS AND KINGDOMS OF LIFE

Plants are man's prime companions in this universe, being the source of food and energy, shelter and clothing, drugs and beverages, oxygen and aesthetic environment, and as such they have been the dominant component of his taxonomic activity through the ages. Before attempting to explore the diversity of plant life it is essential to understand as to what our understanding of the term **Plant** is, and the position of plants in the web of life. Traditionally the plants are delimited as organisms possessing cell wall, capable of photosynthesis, producing spores and having sedentary life. A lot of rethinking has resulted in several different interpretations of the term plant.

Two Kingdom System

The living organisms were originally grouped into **two kingdoms**. Aristotle divided all living things between plants, which generally do not move or have sensory organs, and animals. Linnaeus in his *Systema naturae* published in 1735 placed them under **Animalia** (Animals) and **Vegetabilia** (Plants) as two distinct kingdoms (Linnaeus placed minerals in the third kingdom Mineralia). Linnaeus divided each kingdom into classes, later grouped into phyla for animals and divisions for plants. When single-celled organisms were first discovered, they were split between the two kingdoms: mobile forms in the animal phylum Protozoa, and colored algae and bacteria in the plant division Thallophyta or Protophyta. As a result, Ernst Haeckel (1866) suggested creating a third kingdom **Protista** for them, although this was not very popular until relatively recently (sometimes also known as **Protoctista**). Haeckel recognized **three kingdoms**: **Protista**, **Plantae** and **Animalia**.

Two Empires Three Kingdoms

The subsequent discovery that bacteria are radically different from other organisms in lacking a nucleus, led Chatton (1937) to propose a division of life into **two empires**: organisms with a nucleus in **Eukaryota** and organisms without in **Prokaryota**. **Prokaryotes** do not have a nucleus, mitochondria or any other membrane bound organelles. In other words, neither their DNA nor any other of their metabolic functions are collected together in a discrete membrane enclosed area. Instead everything is openly accessible within the cell, though some bacteria have internal membranes as sites of metabolic activity these membranes do not enclose a separate area of the cytoplasm. **Eukaryotes** have a separate membrane bound nucleus, numerous mitochondria and other organelles such as the Golgi Body within each of their cells. These areas are separated off from the main mass of the cell's cytoplasm by their own membrane in order to allow them to be more specialized. The nucleus contains all the Eukaryote cell DNA, which gets organized into distinct chromosomes during the process of mitosis and meiosis. The energy is generated in mitochondria. The exception to this rule are red blood cells which have no nucleus and do not live very long. Haeckel (1966) proposed a three kingdom classification recognizing Protista, Plantae and Animalis, the additional kingdom Protista including all single-celled organisms that are intermediate between animals and plants. Herbert Copeland (1938), who gave the prokaryotes a separate kingdom, originally called Mycota but later referred to as **Monera** or **Bacteria**. Copeland later on (1956) proposed a **four-kingdom system** placing all eukaryotes other than animals and plants in the kingdom **Protoctista,** thus recognizing four kingdoms **Monera**, **Protoctista**, **Plantae** and **Animalia**. The importance of grouping these kingdoms in two empires, as suggested earlier by Chatton was popularized by Stanier and van Niel (1962), and soon became widely accepted.

Five Kingdom System

American biologist Robert H. Whittaker (1969) proposed the removal of fungi into a separate kingdom thus establishing a **five kingdom system** recognizing **Monera**, **Protista**, **Fungi**, **Plantae** and **Animalia** as distinct kingdoms. The fungi like plants have a distinct cell wall but like animals lack autotrophic mode of nutrition. They, however, unlike animals draw nutrition from decomposition of organic matter, have cell wall reinforced with chitin, cell membranes containing ergosterol instead of cholesterol and have a unique biosynthetic pathway for lysine. The classification was followed widely in textbooks.

Six or Seven Kingdoms?

Subsequent research concerning the organisms previously known as archebacteria has led to the recognition that these creatures form an entirely distinct kingdom **Archaea**. These include anaerobic bacteria found in harsh oxygen-free conditions and are genetically and metabolically completely different from other, oxygen-breathing organisms. These bacteria, called **Archaebacteria**, or simply Archaea, are said to be "living fossils" that have survived since the planet's very early ages, before the Earth's atmosphere even had free oxygen. This together with the emphasis on phylogeny requiring groups to be monophyletic resulted in a **six kingdom system** proposed by Carl Woese et al. (1977). They grouped Archaebacteria and Eubacteria under Prokaryotes and rest of the four kingdoms Protista, Fungi, Plantae and Animalia under Eukaryotes. They subsequently (1990) grouped these kingdoms into three **domains Bacteria** (containing Eubacteria), **Archaea** (containing Archaebacteria) and **Eukarya** (containing Protista, Fungi, Plantae and Animalia).

Margulis and Schwartz (1998) proposed term **superkingdom** for domains and recognized two superkingdoms: **Prokarya** (Prokaryotae) and **Eukarya** (Eukaryotae). Former included single kingdom **Bacteria** (Monera) divided into two subkingdoms **Archaea** and **Eubacteria**. **Eukarya** was divided into four kingdoms**: Protoctista (Protista), Animalia, Plantae** and **Fungi**.

Several recent authors have attempted to recognize seventh kingdom of living organisms, but they differ in their treatment.

Ross (2002, 2005) recognized Archaebacteria and Eubacteria as separate kingdoms, named as **Protomonera** and **Monera**, respectively again under separate superkingdoms (domains of earlier authors) **Archaebacteria** and **Eubacteria**. He added seventh kingdom **Myxomycophyta** of slime molds under superkingdom Eukaryotes. Two additional superkingdoms of extinct organisms Progenotes (first cells) and Urokaryotes (prokaryotic cells that became eukaryotes):

Superkingdom Progenotes*........first cells now extinct
Superkingdom Archaebacteria
Kingdom Protomonera.....archaic bacteria
Superkingdom Eubacteria
Kingdom Monera........bacteria
Superkingdom Urkaryotes* ...prokaryotic cells that became eukaryotes
Superkingdom Eukaryotes ...cells with nuclei
Kingdom Protista..........protozoans
Kingdom Myxomycophyta.....slime molds
Kingdom Plantae............plants
Kingdom Fungi..............fungi
Kingdom Animalia...........animals

Patterson and Sogin (1992; Figure 1.2) recognized seven kingdoms but include slime molds under Protozoa (Protista) and instead establish **Chromista** (diatoms) as seventh kingdom. Interestingly the traditional algae now find themselves distributed in three different kingdoms: eubacterial prokaryotes (the blue-green cyanobacteria), chromistans (diatoms, kelps), and protozoans (green algae, red algae, dinoflagellates, euglenids).

Cavalier-Smith (1981) suggested that Eukaryotes can be classified into nine kingdoms each defined in terms of a unique constellation of cell structures. Five kingdoms have plate-like mitochondrial cristae: (1) **Eufungi** (the non-ciliated fungi, which unlike the other eight kingdoms have unstacked Golgi cisternae), (2) **Ciliofungi** (the posteriorly ciliated fungi), (3) **Animalia** (Animals, sponges, mesozoa, and choanociliates; phagotrophs with basically posterior ciliation), (4) **Biliphyta** (Non-phagotrophic, phycobilisome-containing, algae; i.e., the Glaucophyceae and Rhodophyceae), (5) **Viridiplantae** (Non-phagotrophic green plants, with starch-containing plastids). Kingdom (6), the **Euglenozoa**, has disc-shaped cristae and an intraciliary dense rod and may be phagotrophic and/or phototrophic with plastids with three-membraned envelopes. Kingdom (7), the **Cryptophyta**, has flattened tubular cristae, tubular mastigonemes on both cilia, and starch in the compartment between the plastid endoplasmic reticulum and the plastid envelope; their plastids, if present, have phycobilins inside the paired thylakoids and chlorophyll c2. Kingdom (8), the **Chromophyta**, has tubular cristae, together with tubular mastigonemes on one anterior cilium and/or a plastid endoplasmic reticulum and chlorophyll c1 + c2. Members of the ninth kingdom, the **Protozoa**, are mainly phagotrophic, and have tubular or vesicular cristae (or lack mitochondria altogether), and lack tubular mastigonemes on their (primitively anterior) cilia; plastids if present have three-envelop membranes, chlorophyll c2, and no internal starch, and a plastid endoplasmic reticulum is absent. Kingdoms 4–9 are primitively anteriorly biciliate. A simpler system of five kingdoms suitable for very elementary teaching is possible by grouping the photosynthetic and fungal kingdoms in pairs. It was suggested that Various compromises are possible between the nine and five kingdoms systems; it is suggested that the best one for general scientific use is a system of seven kingdoms in which the Eufungi and Ciliofungi become subkingdoms of the Kingdom Fungi, and the Cryptophyta and Chromophyta subkingdoms of the Kingdom Chromista; the Fungi, Viridiplantae, Biliphyta, and Chromista can be

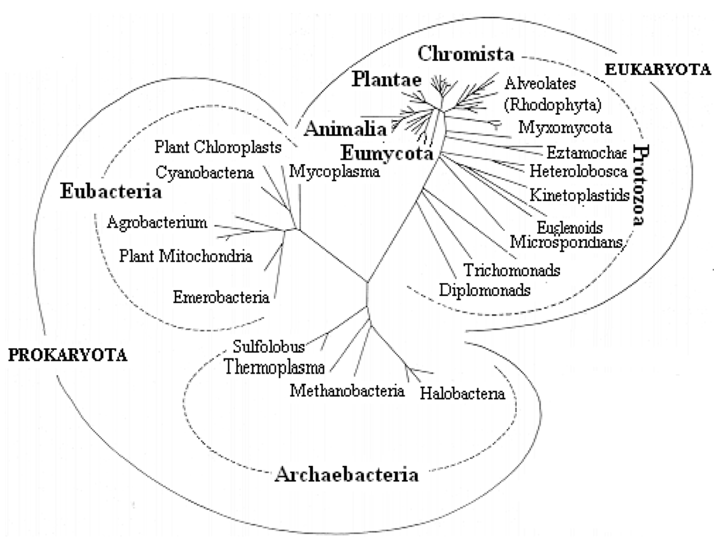

Figure 1.2: Seven kingdoms of life and their possible phylogeny (after Patterson and Sogin, 1992).

subject to the Botanical Code of Nomenclature, while the Zoological Code can govern the Kingdoms Animalia, Protozoa and Euglenozoa.

These 9 kingdoms together with two or one kingdom of prokaryotes total eleven or ten kingdoms of life. Subsequently, however, Cavalier-Smith (1998, 2000, 2004) reverted to six kingdom classification recognizing **Bacteria, Protozoa, Animalia, Fungi, Plantae and Chromista** under two empires Prokaryota and Eukaryota. Prokaryotes constitute a single kingdom, Bacteria, here divided into two new subkingdoms: Negibacteria, with a cell envelope of two distinct genetic membranes, and Unibacteria, comprising the phyla Archaebacteria and Posibacteria. Outline of the classification is as under:

Empire Prokaryota

Kingdom **Bacteria**
- Subkingdom **Negibacteria** (phyla Eobacteria, Sphingobacteria, Spirochaetae, Proteobacteria, Planctobacteria, Cyanobacteria)
- Subkingdom **Unibacteria** (phyla Posibacteria, Archaebacteria)

Empire Eukaryota

Kingdom **Protozoa**
- Subkingdom **Sarcomastigota** (phyla Amoebozoa, Choanozoa)
- Subkingdom **Biciliata**

Kingdom **Animalia** (Myxozoa and 21 other phyla)

Kingdom **Fungi** (phyla Archemycota, Microsporidia, Ascomycota, Basidiomycota)

Kingdom **Plantae**
- Subkingdom **Biliphyta** (phyla Glaucophyta, Rhodophyta)
- Subkingdom **Viridaeplantae** (phyla Chlorophyta, Bryophyta, Tracheophyta)

Kingdom **Chromista**
- Subkingdom **Cryptista** (phylum Cryptista: cryptophytes, goniomonads, katablepharids)
- Subkingdom **Chromobiota**

The name archaebacteria seems to be confusing. They were so named because they were thought to be the most ancient (Greek '*archaio*' meaning ancient) and sometimes labelled as living fossils, since they can survive in anaerobic conditions (methanogens—which use hydrogen gas to reduce carbon dioxide to methane gas), high temperatures (thermophiles, which can survive in temperatures of up to 80 degree C), or salty places (halophiles). They differ from bacteria in having methionine as aminoacid that initiates protein synthesis as against formyl-methionine in bacteria, presence of introns in some genes, having several different RNA polymerases as against one in bacteria, absence of peptidoglycan in cell wall, and growth not inhibited by antibiotics like streptomycin and chloramphenicol. In several of these respects archaebacteria are more similar to eukaryotes. Bacteria are thought to have diverged early from the evolutionary line (the clade neomura, with many common characters, notably obligately co-translational secretion of N-linked glycoproteins, signal recognition particle with 7S RNA and translation-arrest domain, protein-spliced tRNA introns, eight-subunit chaperonin, prefoldin, core histones, small nucleolar ribonucleoproteins (snoRNPs), exosomes and similar replication, repair, transcription and translation machinery) that gave rise to archaebacteria and eukaryotes. It is, as such more appropriate to call archaebacteria as **metabacteria**.

The eukaryotic host cell (Figure 1.3) evolved from something intermediate between posibacteria and metabacteria ("archaebacteria"), which had evolved many metabacterial features but not yet switched to ether-linked lipid membranes in a major way. They would no doubt cladistically fall out as primitive metabacteria, but whether such forms are still extant is uncertain. There are lots of metabacteria out there which are uncultured (only known from environmental sequences) or just undiscovered, so who knows.

The further shift from archaebacteria to Eukaryotes involved the transformation of circular DNA into a **linear DNA** bound with histones, formation of **membrane bound nucleus** enclosing chromosomes, development of **mitosis**, occurrence of **meiosis** in sexually reproducing organisms, appearance of membrane bound organelles such as **endoplasmic reticulum**, **golgi bodies** and **lysosomes**, appearance of **cytoskeletal elements** like actin, myosin and tubulin, and the formation of **mitochondria** through endosymbiosis.

A major shift in this eukaryotic line which excluded animal and fungi, involved the development of **chloroplast** by an eukaryotic cell engulfing a photosynthetic bacterial cell (probably a cyanobacterium). The bacterial cell continued to live and multiply inside the eukaryotic cell, provided high energy products, and in turn received a suitable environment to live in. The two thus shared **endosymbiosis**. Over a period of time the bacterial cell lost ability to live independently, some of the bacterial genes getting transferred to eukaryotic host cell, making the two biochemically interdependent. Chloroplast evolution in Euglenoids and Dinoflagellates occurred through **secondary endosymbiosis**, wherein eukaryotic cell engulfed an eukaryotic cell containing a chloroplast. This common evolutionary sequence is shared by green plants (including green algae; green chloroplast), red algae (red chloroplast) and brown algae and their relatives (commonly

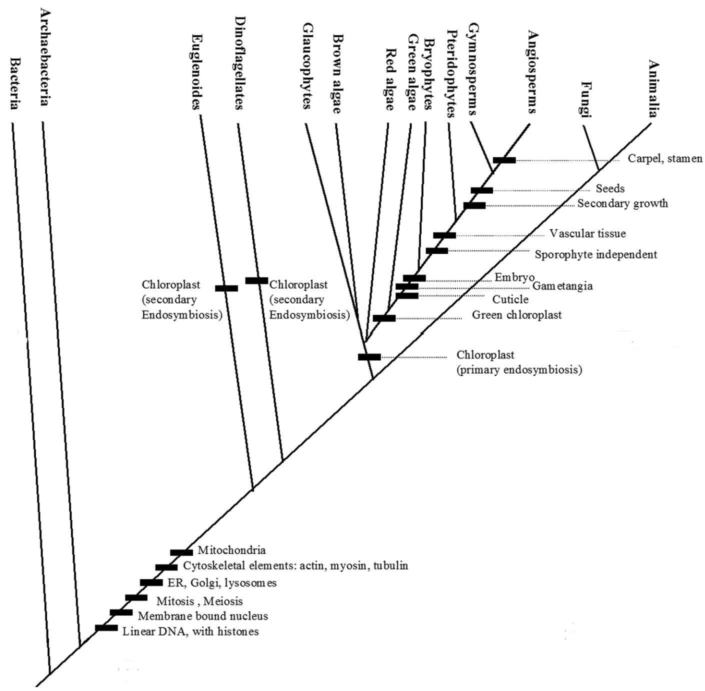

Figure 1.3: Cladogram showing the evolution of major groups of organisms and the associated apomorphies. Chloroplast evolution has occurred twice, once (primary endosymbiosis) eukaryote cell engulfing a photosynthetic bacterial cell, and elsewhere (secondary endosymbiosis) eukaryotic cell engulfing an eukaryotic cell containing chloroplast.

known as stramenopiles; brown chloroplast), in which diversification of chloroplast pigments occurred, along with the thylakoid structure and a variety of storage products.

The Plant Kingdom

It is now universally agreed that members of the plant kingdom include, without doubt the green algae, liverworts and mosses, pteridophytes, gymnosperms and finally the angiosperms, the largest group of plants. All these plants share a green chloroplast. Red algae, Brown algae and Glaucophytes, latter two together known as stramenophiles, also belong to this kingdom. All these groups share the presence of a chloroplast. All green plants share a green chloroplast with chlorophyll b, chlorophyll a, thylakoids and grana, and starch as storage food. Evolution of cuticle combined with gametangia and embryo characterizes embryophytes, including bryophytes, pteridophytes and seed plants. The development of vascular tissue of phloem and xylem, and independent sporophyte characterize tracheophytes including pteridophytes and seed plants. Secondary growth resulting in the formation of wood and seed habit differentiates seed plants. The final evolution of a distinct flower, carpels and stamens, together with vessels and sieve tubes set apart the angiosperms, the most highly evolved group of plants.

Out of nearly 3,74,000 species of plants known nearly 44,000 belong to Algae, 22,500 species belong to usually overlooked mosses and liverworts, 12,000 ferns and their allies, 1,050 to gymnosperms and 295,000 to angiosperms (belonging to about 485 families and 13,372 genera), considered to be the most recent and vigorous group of plants that have occupied earth. Angiosperms occupy the majority of the terrestrial space on earth and are the major components of the world's vegetation.

Brazil and Colombia, both located in the tropics, are countries with the most diverse angiosperms floras and which rank first and second. China, even though the main part of her land is not located in the tropics, the number of her angiosperms still occupies the third place in the world, and has approximately 300 families, 3,100 genera and 30,000 species.

TAXONOMY AND SYSTEMATICS

There are slightly more than one third of a million species of plants known to man today, the information having been accumulated through efforts of several millenniums. Although man has been classifying plants since the advent of civilization, **taxonomy** was recognized as a formal subject only in 1813 by A. P. de Candolle as a combination of Greek words **taxis** (arrangement) and **nomos** (rules or laws) in his famous work *Theorie elementaire de la botanique*. For a long time, plant taxonomy was considered as 'the science of identifying, naming, and classifying plants' (Lawrence, 1951). Since identification and nomenclature are important prerequisites for any classification, taxonomy is often defined as the '***science dealing with the study of classification, including its bases, principles, rules and procedures***' (Davis and Heywood, 1963).

Although **Systematics** was recognized as a formal major field of study only during the latter half of twentieth century, the term had been in use for a considerable period. Derived from the Latin word *systema* (organized whole), forming the title of the famous work of Linnaeus *Systema naturae* (1735), the term Systematics first appeared in his *Genera Plantarum* (1737), though Huxley (1888) is often credited to have made the first use of the term in his article in *Nature* on the systematics of birds. Simpson (1961) defined **systematics** as a '***scientific study of the kinds and diversity of organisms, and of any and all relationships between them***'. It was recognized as a more inclusive field of study concerned with the study of diversity of plants and their naming, classification and evolution. The scope of taxonomy has, however, been enlarged in recent years to make taxonomy and systematics synonymous. A broader definition (Stace, 1980) of **taxonomy,** to coincide with **systematics** recognized it as '***the study and description of variation in organisms, the investigation of causes and consequences of this variation, and the manipulation of the data obtained to produce a system of classification***'.

Realization of the fact that a good number of authors still consider taxonomy to be a more restricted term and systematics a more inclusive one has led recent authors to prefer the term **systematics** to include discussion about all recent developments in their works. Modern approach to systematics aims at reconstructing the entire chronicle of evolutionary events, including the formation of separate lineages and evolutionary modifications in characteristics of the organisms. It ultimately aims at discovering all the branches of the evolutionary tree of life; and to document all the changes and to describe all the species which form the tips of these branches. This won't be possible unless information is consolidated in the form of an unambiguous system of classification. This, however, is again impossible without a clear understanding of the basic identification and nomenclatural methods. Equally important is the understanding of the recent tools of data handling, newer concepts of phylogenetics, expertise in the judicious utilization of fast accumulating molecular data in understanding of affinities between taxa.

Prior to the evolutionary theory of Darwin, relationships were expressed as **natural affinities** on the basis of an overall similarity in morphological features. Darwin ushered in an era of assessing **phylogenetic relationships** based on the course of evolutionary descent. With the introduction of computers and refined statistical procedures, overall similarity is represented as phenetic **relationship**, which takes into account every available feature, derived from such diverse fields as anatomy, embryology, morphology, palynology, cytology, phytochemistry, physiology, ecology, phytogeography and ultrastructure.

With the advancement of biological fields, new information flows continuously, and the taxonomists are faced with the challenge of integrating and providing a synthesis of all the available data. Systematics now is, thus, an **unending synthesis,** a dynamic science with never-ending duties. The continuous flow of data necessitates rendering descriptive information, revising schemes of identification, revaluating and improving systems of classification and perceiving new relationships for a better understanding of the plants. The discipline as such includes all activities that are a part of the effort to organize and record the diversity of plants and appreciate the fascinating differences among the species of plants. Systematic activities are basic to all other biological sciences, but also depend, in turn, on other disciplines for data and information useful in constructing classification. Certain disciplines of biology such as cytology, genetics, ecology, palynology, paleobotany and phytogeography are so closely tied up with systematics that they cannot be practiced without basic systematic information. Experiments cannot be carried out unless the organisms are correctly identified and some information regarding their relationship is available. The understanding of relationships is particularly useful in the applied fields of plant breeding, horticulture, forestry and pharmacology for exploring the usefulness of related species. Knowledge of systematics often guides the search for plants of potential commercial importance.

Basic Components (Principles) of Systematics

Various systematic activities are directed towards the singular goal of constructing an ideal system of classification that necessitates the procedures of identification, description, nomenclature and constructing affinities. This enables a better management of information to be utilized by different workers, investigating different aspects structure and functioning of different species of plants.

Identification

Identification or determination is recognizing an unknown specimen with an already known taxon and assigning a correct rank and position in an extant classification. In practice, it involves finding a name for an unknown specimen. This may be achieved by visiting a herbarium and comparing unknown specimen with duly identified specimens stored in the herbarium. Alternately, the specimen may also be sent to an expert in the field who can help in the identification.

Identification can also be achieved using various types of literature such as Floras, Monographs or Manuals and making use of identification keys provided in these sources of literature. After the unknown specimen has been provisionally identified with the help of a key, the identification can be further confirmed by comparison with the detailed description of the taxon provided in the literature source.

A method that is becoming popular over the recent years involves taking a photograph of the plant and its parts, uploading this picture on the website and informing the members of appropriate electronic Lists or Newsgroups, who can see the photograph at the website and send their comments to the enquirer. Members of the fraternity could thus help each other in identification in a much efficient manner.

Description

The description of a taxon involves listing its features by recording the appropriate character states. A shortened description consisting of only those taxonomic characters which help in separating a taxon from other closely related taxa, forms the **diagnosis**, and the characters are termed as **diagnostic characters.** The diagnostic characters for a taxon determine its **circumscription**. The description is recorded in a set pattern (habit, stem, leaves, flower, sepals, petals, stamens, carpels, fruit, etc.). For each **character**, an appropriate **character-state** is listed. Flower color (character) may thus be red, yellow, white, etc. (states). The description is recorded in semi-technical language using specific terms for each character state to enable a proper documentation of data.

Whereas the fresh specimens can be described conveniently, the dry specimens need to be softened in boiling water or in a **wetting agent** before these could be described. Softening is often essential for dissection of flowers in order to study their details.

Nomenclature

Nomenclature deals with the determination of a **correct name** for a taxon. There are different sets of rules for different groups of living organisms. Nomenclature of plants (including fungi) is governed by the International **Code of Nomenclature for Algae, Fungi and Plants (ICN)** since 2011 (earlier known as International Code of Botanical Nomenclature, ICBN) through its rules and recommendations. Latest Shenzhen Code adopted in 2017 has been published in June 2018, containing several changes in rules and recommendations for these groups. Updated every six years or so, the **Code** helps in picking up a single correct name out of numerous scientific names available for a taxon, with a particular circumscription, position and rank. To avoid inconvenient name changes for certain taxa, a list of conserved names is provided in the Code. Cultivated plants are governed by the International Code of Nomenclature for Cultivated Plants (**ICNCP)**, slightly modified from and largely based on the Botanical Code.

Names of animals are governed by the International Code of Zoological Nomenclature (**ICZN**); those of bacteria by International Code for the Nomenclature of Bacteria (**ICNB**), now called Bacteriological Code (**BC**). A separate Code exists for viruses, named the International Code of Virus Classification and Nomenclature (**ICVCN**).

With the onset of electronic revolution and the need to have a common database for living organisms for global communication a common uniform code is being attempted. The **Draft BioCode** is the first public expression of these objectives. The first draft was prepared in 1995. After successive reviews the fourth draft, named **Draft BioCode (1997)** prepared by the International Committee for Bionomenclature was published by Greuter et al. (1998), latest version **Draft BioCode 2011** (Hawksworth et al., 2011) is available on the web. The last decade of twentieth century also saw the development of rankless **PhyloCode** based on the concepts of phylogenetic systematics. It omits all ranks except species and 'clades' based on the concept of recognition of monophyletic groups. The latest version of PhyloCode (PhyloCode5, 2014) is also available on the web.

Phylogeny

Phylogeny is the study of the genealogy and evolutionary history of a taxonomic group. Genealogy is the study of ancestral relationships and lineages. Relationships are depicted through a diagram better known as a **phylogram** (Stace, 1989), since the commonly used term **cladogram** is more appropriately used for a diagram constructed through cladistic methodology. A phylogram is a branching diagram based on the degree of advancement (**apomorphy**) in the descendants, the longest branch representing the most advanced group. This is distinct from **a phylogenetic tree** in which the vertical scale represents a geological time-scale and all living groups reach the top, with primitive ones near the centre and advanced ones near the periphery. Monophyletic groups, including all the descendants of a common ancestor, are recognized and form entities in a classification system. Paraphyletic groups, wherein some descendants of a common ancestor are left out, are reunited. Polyphyletic groups, with more than one common ancestor, are split to form monophyletic groups. Phenetic information may often help in determining a phylogenetic relationship.

Classification

Classification is an arrangement of organisms into groups on the basis of similarities. The groups are, in turn, assembled into more inclusive groups, until all the organisms have been assembled into a single most inclusive group. In sequence of increasing inclusiveness, the groups are assigned to a fixed hierarchy of categories such as species, genus, family, order, class and division, the final arrangement constituting a system of classification. The process of classification includes assigning appropriate **position** and **rank** to a new **taxon** (a taxonomic group assigned to any rank; pl. **taxa**), **dividing** a taxon into smaller units, **uniting** two or more taxa into one, **transferring** its position from one group to another and **altering** its rank. Once established, a classification provides an important mechanism of information storage, retrieval and usage. This ranked system of classification is popularly known as the **Linnaean system**. Taxonomic entities are classified in different fashions:

1. **Artificial classification** is utilitarian, based on arbitrary, easily observable characters such as habit, color, number, form or similar features. The **sexual system** of Linnaeus, which fits in this category, utilized the number of stamens for primary classification of the flowering plants.
2. **Natural classification** uses overall similarity in grouping taxa, a concept initiated by M. Adanson and culminating in the extensively used classification of Bentham and Hooker. Natural systems of the eighteenth and nineteenth centuries used morphology in delimiting the overall similarity. The concept of overall similarity has undergone considerable refinement in recent years. As against the sole morphological features as indicators of similarity in natural systems, overall similarity is now judged on the basis of features derived from all the available fields of taxonomic information (phenetic relationship).
3. **Phenetic classification** makes the use of overall similarity in terms of a phenetic relationship based on data from all available sources such as morphology, anatomy, embryology, phytochemistry, ultrastructure and, in fact, all other fields of study. Phenetic classifications were strongly advocated by Sneath and Sokal (1973) but did not find much favor with major systems of classification of higher plants. Phenetic relationship has, however, been very prominently used in modern phylogenetic systems to decide the realignments within the system of classification.
4. **Phylogenetic classification** is based on the evolutionary descent of a group of organisms, the relationship depicted either through a **phylogram, phylogenetic tree** or a **cladogram**. Classification is constructed with this premise in mind, that all the descendants of a common ancestor should be placed in the same group (i.e., group should be **monophyletic**). If some descendents have been left out, rendering the group **paraphyletic**, these are brought back into the group to make it monophyletic (merger of Asclepiadaceae with Apocynaceae, and the merger of Capparaceae with Brassicaceae in recent classifications). Similarly, if the group is polyphyletic (with members from more than one phyletic lines), it is split to create monophyletic taxa (Genus *Arenaria* split into *Arenaria* and *Minuartia*). This approach, known as **cladistics**, is practiced by **cladists**.
5. **Evolutionary taxonomic classification** differs from a phylogenetic classification in that the gaps in the variation pattern of phylogenetically adjacent groups are regarded as more important in recognizing groups. It accepts leaving out certain descendants of a common ancestor (i.e., recognizing **paraphyletic** groups) if the gaps are not significant, thus failing to provide a true picture of the genealogical history. The characters considered to be of significance in the evolution (and the classification based on these) are dependent on expertise, authority and intuition of systematists. Such classifications have been advocated by Simpson (1961), Ashlock (1979), Mayr and Ashlock (1991) and Stuessy (1990). The approach, known as **eclecticism**, is practiced by **eclecticists**.

The contemporary phylogenetic systems of classification, including those of Takhtajan, Cronquist, Thorne and Dahlgren, are largely based on decisions in which **phenetic information** is liberally used in deciding the phylogenetic relationship between groups, differing largely on the weightage given to the cladistic or phenetic relationship.

There have been suggestions to abandon the hierarchical contemporary classifications based on the **Linnaean system**, which employs various fixed ranks in an established conventional sequence with a '**phylogenetic taxonomy**' in which monophyletic groups would be unranked names, defined in terms of a common ancestry, and diagnosed by reference to synapomorphies (de Queiroz and Gauthier, 1990; Hibbett and Donoghue, 1998). Angiosperm Phylogeny Group is continuously evolving APG system of classification, latest APG IV (2016) and its variant APWeb IV developed in 2017 are also available on the web.

Classification not only helps in the placement of an entity in a logically organized scheme of relationships, it also has a great predictive value. The presence of a valuable chemical component in one species of a particular genus may prompt its search in other related species. The more a classification reflects phylogenetic relationships, the more predictive it is supposed to be. The meaning of a natural classification is gradually losing its traditional sense. A 'natural classification' today is one visualized as truly phylogenetic, establishing monophyletic groups making fair use of the phenetic information so that such groups also reflect a phenetic relationship (overall similarity) and the classification represents a reconstruction of the evolutionary descent.

Aims of Systematics

The activities of plant systematics are basic to all other biological sciences and, in turn, depend on the same for any additional information that might prove useful in constructing a classification. These activities are directed towards achieving the undermentioned aims:

1. To provide a convenient method of identification and communication. A workable classification having the taxa arranged in hierarchy, detailed and diagnostic descriptions are essential for identification. Properly identified and arranged herbarium specimens, dichotomous keys, polyclaves and computer-aided identification are important aids for identification. The **Code** (ICN), written and documented through the efforts of IAPT (International Association of Plant Taxonomy), helps in deciding the single correct name acceptable to the whole botanical community.
2. To provide an inventory of the world's flora. Although a single world Flora is difficult to come by, floristic records of continents (**Continental Floras; *cf.*** *Flora Europaea* by Tutin et al.), regions or countries (**Regional Floras; *cf.*** *Flora of British India* by J. D. Hooker) and states or even counties (**Local Floras; *cf.*** *Flora of Delhi* by J. K. Maheshwari) are well documented. In addition, **World Monographs** for selected genera (e.g., *The genus Crepis* by Babcock) and families (e.g., *Das pflanzenreich* ed. by A. Engler) are also available.
3. To detect evolution at work; to reconstruct the evolutionary history of the plant kingdom, determining the sequence of evolutionary change and character modification.
4. To provide a system of classification which depicts the evolution within the group. The phylogenetic relationship between the groups is commonly depicted with the help of a phylogram, wherein the longest branches represent more advanced groups and the shorter, nearer the base, primitive ones. In addition, the groups are represented by balloons of different sizes that are proportional to the number of species in the respective groups. Such a phylogram is popularly known as a **bubble diagram**. The phylogenetic relationship could also be presented in the form of a phylogenetic tree (with vertical axis representing the geological time scale), where existing species reach the top and the bubble diagram may be a cross-section of the top with primitive groups towards the center and the advanced ones towards the periphery.
5. To provide an integration of all available information. To gather information from all the fields of study, analyzing this information using statistical procedures with the help of computers, providing a synthesis of this information and developing a classification based on overall similarity. This synthesis is unending, however, since scientific progress will continue, and new information will continue to pour and pose new challenges for taxonomists.
6. To provide an information reference, supplying the methodology for information storage, retrieval, exchange and utilization. To provide significantly valuable information concerning endangered species, unique elements, genetic and ecological diversity.
7. To provide new concepts, reinterpret the old, and develop new procedures for correct determination of taxonomic affinities, in terms of phylogeny and phenetics.
8. To provide integrated databases including all species of plants (and possibly all organisms) across the globe. Several big organizations have come together to establish online searchable databases of taxon names, images, descriptions, synonyms and molecular information.

Advancement Levels in Systematics

Plant systematics has made considerable strides from herbarium records to databanks, recording information on every possible attribute of a plant. Because of extreme climatic diversity, floristic variability, inaccessibility of certain regions and economic disparity of different regions, the present-day systematics finds itself in different stages of advancement in different parts of the world. Tropical Asia and tropical Africa are amongst the richest areas of the world in terms of floristic diversity but amongst the poorest as far as the economic resources to pursue complete documentation of systematic information. The whole of Europe, with more than 30 m square kilometers of landscape and numerous rich nations with their vast economic resources, must account for slightly more than 12 thousand species of vascular plants. India, on the other hand, with meager resources, less than one tenth of landscape, has to account for the study of twice the number vascular plants. A small country like Colombia, similarly, has estimated 4,500 different species, with only a few botanists to study the flora. Great Britain, on the other hand, has approximately 1370 taxa (Woodland, 1991), with thousands of professional and amateur botanists available to document the information. It is not strange, as such, that there is lot of disparity in the level of advancement concerning knowledge about respective floras. Taxonomic advancement today can be conveniently divided into four distinct **phases** encountered in different parts of the world:

Exploratory or Pioneer Phase

This phase marks the beginning of plant taxonomy, collecting specimens and building herbarium records. The few specimens of a species in the herbarium are the only record of its variation. These specimens are, however, useful in a preliminary inventory of flora through discovery, description, naming and identification of plants. Here, morphology and distribution provide the data on which the systematists must rely. Taxonomic experience and judgement are particularly important in this phase. Most areas of tropical Africa and tropical Asia are passing through this phase.

Consolidation or Systematic Phase

During this phase, herbarium records are ample, and enough information is available concerning variation from field studies. This development is helpful in the preparation of Floras and Monographs. It also aids in better understanding of the degree of variation within a species. Two or more herbarium specimens may appear to be sufficiently different and regarded as belonging to different species on the basis of a few available herbarium records, but only a field study of populations involving thousands of specimens can help in reaching at a better understanding of their status. If there are enough field specimens to fill in the gaps in variation pattern, there is no justification in regarding them as separate species. On the other hand, if there are distinct gaps in the variation pattern, it strengthens their separate identity. In fact, many plants, described as species on the basis of limited material in the pioneer phase, are found to be variants of other species in the consolidation phase. Most parts of central Europe, North America and Japan are experiencing this phase.

Experimental or Biosystematic Phase

During this phase, the herbarium records and variation studies are complete. In addition, information on **biosystematics** (studies on transplant experiments, breeding behavior and chromosomes) is also available. Transplant experiments involving collecting seeds, saplings or other propagules from morphologically distinct populations from different habitats and growing them under common environmental conditions. If the differences between the original populations were purely ecological, the differences would disappear under a common environment, and there is no justification in regarding them as distinct taxonomic entities. On the other hand, if the differences still persist, these are evidently genetically fixed. If these populations are allowed to grow together for several years, their breeding behaviors would further establish their status. If there are complete reproductive barriers between the populations, they will fail to interbreed, and maintain their separate identity. These evidently belong to different species. On the other hand, if there is no reproductive isolation between them, over the years, they would interbreed, form intermediate hybrids, which will soon fill the gaps in their variation. Such populations evidently belong to the same species and better distinguished as ecotypes, subspecies or varieties. Further chromosomal studies can throw more light on their affinities and status. Central Europe has reached this phase of plant systematics.

Encyclopaedic or Holotaxonomic Phase

Here, not only the previous three phases are attained, but information on all the botanical fields is also available. This information is assembled, analyzed, and a meaningful synthesis of analysis is provided for understanding phylogeny. Collection of data, analysis and synthesis are the jobs of an independent discipline of systematics, referred to as **numerical taxonomy**.

The first two phases of systematics are often considered under **alpha-taxonomy** and the last phase under **omega-taxonomy**. At present, only a few persons are involved in encyclopedic work and that too, in a few isolated taxa. It may thus be safe to conclude that though in a few groups omega-taxonomy is within reach, for the great majority of plants, mainly in the tropics, even the 'alpha' stage has not been crossed. The total integration of available information for the plant kingdom is, thus, only a distant dream at present. Concerted efforts are essential to focus on unexplored regions and little-known taxa.

Chapter 2
Descriptive Terminology

For better understanding of any plant species, it is essential to know features based on which it can identified in the field. A botanical analysis necessitates the availability of information about its characteristics. The descriptive information about the morphology of a plant (**phytography**) is suitably expressed in semi-technical language through a set of terms, which provide an unambiguous representation of the plant. The descriptive terminology thus precedes any taxonomic or phylogenetic analysis of a taxon. Whereas the vegetative morphology of vascular plants (**Tracheophyes**) uniformly includes information about the organs such as **root**, **stem** as **leaves**, the reproductive morphology may differ in different groups. The Pteridophytes are represented by strobili, cones, sporophylls, microsporophylls, megasporophylls and spores, Gymnosperms by cones, megasporophylls, microsporophylls and seeds. The flowering plants have distinct **inflorescences**, **flowers**, **seeds** and **fruits**. All these organs show considerable variability, amply depicted through a large vocabulary of descriptive terms.

Morphological terminology has been in use for description of species for several centuries and continues to be the principal source of taxonomic evidence. The descriptive terminology is very exhaustive, and as such only the most commonly used terms are illustrated here.

HABIT AND LIFE SPAN

Annual: A plant living and completing its life cycle in one growing season. **Ephemerals** are annuals surviving for one or two weeks (*Boerhaavia repens*).

Biennial: A plant living for two seasons, growing vegetatively during the first and flowering during the second.

Perennial: A plant living for more than two years and flowering several times during the life span (except in monocarpic plants which live for several years but perish after flowering, as in several species of *Agave* and bamboos). In **herbaceous perennials,** the aerial shoot dies back each winter, and the annual shoots are produced from subaerial stock every year, those with a rhizome, tuber, corm or bulb better known as **geophytes**. A **woody perennial,** on the other hand has woody aerial shoots which live for several years. A woody perennial may be a **tree** (with a distinct trunk or bole from the top of which the branches arise—**deliquescent tree** as in banyan, a totally unbranched **caudex** with a crown of leaves at top as in palms, or the main stem continues to grow gradually narrowing and producing branches in acropetal order—**excurrent tree** as in *Polyalthia*) or a **shrub** (with several distinct branches arising from the ground level). A **suffrutescent plant** is intermediate between woody and herbaceous plants, with the basal woody portion persisting year after year whereas the upper portion dies back every year. A weak climbing plant may be woody (**liana**) or herbaceous (**vine**).

It should be noted that the terms herb, shrub, suffrutescent plant and tree represent different forms of habit. Annual, biennial and perennial denote the life span or duration of the plant.

HABITAT

Plants grow in a variety of habitats. **Terrestrial** plants grow on land, **aquatic** plants in water and those on other plants as **epiphytes**. Terrestrial plant may be a **mesophyte** (growing in normal soil), **xerophyte** (growing on dry habitats: **psammophyte** on sand, **lithophyte** on rock). An aquatic plant may be **free-floating** (occurring on water surface), **submerged** or **emersed** (wholly under water), **emergent** (Anchored at bottom but with shoots exposed above water), **floating-leaved** (anchored at bottom but with floating leaves), or a **helophyte** (emergent marsh plant in very shallow waters). A plant growing in saline habitats (terrestrial or aquatic) is known as halophyte, whereas one in acidic soils as **oxylophyte** or **oxyphyte**. **Saprophyte** grow on decaying organic matter, **parasite** lives and depends on another organism. It may be a

partial parasite (Hemiparasite) when it is green, contains chlorophyll and can perform its photosynthesis deriving only water and nutrients from the host plant (*Viscum album*). A total parasite (holoparasite), on the other hand, is generally nongreen, lacks chlorophyll and depends on the host plant for both food and nutrients (*Cuscuta*).

ROOTS

Roots unlike stems lack nodes and internodes, have irregular branching and produce endogenous lateral roots. Upon seed germination, usually the radicle elongates into a primary root, forming a **taproot**, but several other variations may be encountered:

Adventitious: Developing from any part other than radicle or another root.

Aerial: Grows in air. In epiphytes, the aerial roots termed **epiphytic roots** are found hanging from the orchids and are covered with a spongy **velamen** tissue. Orchids also carry some clinging roots which penetrate crevices and help in anchorage.

Assimilatory: Green chlorophyll-containing roots capable of carbon assimilation as in *Tinospora cordifolia*, and many species of Podostemaceae.

Fibrous: Thread like tough roots common in monocots, especially grasses, usually adventitious in nature.

Buttressed: Enlarged, horizontally spread and vertically thickened roots at the base of certain trees of marshy areas.

Fleshy: Thick and soft with a lot of storage tissue. Storage roots may be the modification of taproot:

(i) **Fusiform:** Swollen in the middle and tapering on sides, as in radish (*Raphanus sativus*).

(ii) **Conical:** Broadest on top and gradually narrowed below, as in carrot (*Daucus carota*).

(iii) **Napiform:** Highly swollen and almost globose and abruptly narrowed below, as in turnip (*Brassica rapa*).

Modifications of the storage adventitious roots include:

(i) **Tuberous:** Clusters of tubers growing out from stem nodes, as in sweet potato (*Ipomoea batatas*) and tapioca (*Manihot esculenta*).

(ii) **Fasciculated:** Swollen roots occurring in clusters, as in *Asparagus* and some species of *Dahlia*.

(iii) **Nodulose:** Only the apices of adventitious roots becoming swollen like beads, as in *Curcuma amada* and *Costus speciosus*.

(iv) **Moniliform:** Portions of a root are alternately swollen and constricted giving beaded appearance, as in *Dioscorea alata*.

Haustorial (sucking): Small roots penetrating the host xylem tissue for absorbing water and nutrients as in partial parasites (*Viscum*) or also the photosynthetic materials by penetrating the phloem tissue as well, as in total parasites (*Cuscuta*).

Mycorrhizal: Roots infested with fungal mycelium which helps in root absorption. The fungal mycelium may penetrate cortical cells (**endotrophic mycorrhizae** found in orchids) or may largely form a mantle over the root with a few hyphae

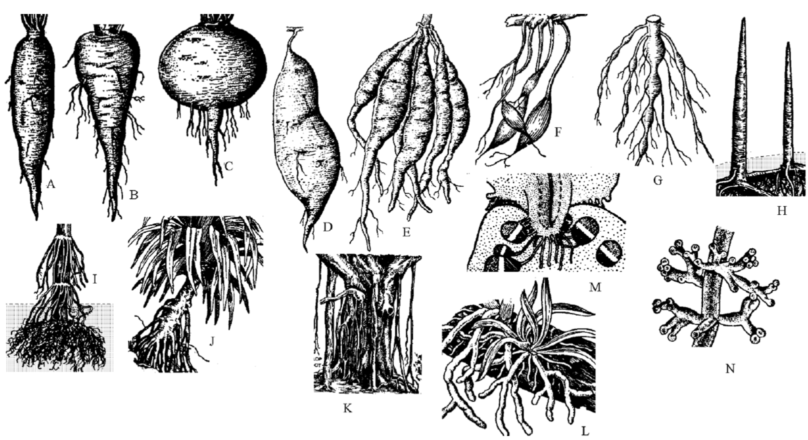

Figure 2.1: Roots. A: Fusiform fleshy root of *Raphanus sativus*; **B:** Conical fleshy root of *Daucus carota*; **C:** Napiform fleshy root of *Brassica rapa*; **D:** Root-tuber of *Ipomoea batatas*; **E:** Fasciculated tuberous roots of *Dahlia*; **F:** Nodulose roots of *Curcuma amada*; **G:** Moniliform roots; **H:** Pneumatophores of *Avicennia*; **I:** Stilt roots of *Zea mays*; **J:** Stilt roots of *Pandanus*; **K:** Prop roots of *Ficus benghalensis*; **L:** Aerial roots of *Dendrobium*; **M:** Haustorial roots of *Viscum,* sending haustoria only into the host xylem; **N:** Mycorrhizal roots of *Pinus*.

penetrating between the outer cells (**ectotrophic mycorrhizae** found in conifers). In specialized **VAM** (**vesicular arbuscular mycorrhizae**) found in grasses, the fungal hyphae penetrate cortical cells, forming a hyphal mass called **arbusculum**.

Respiratory: Negatively geotropic roots of some mangroves (e.g., *Avicennia*) which grow vertically up and carry specialized lenticels (**pneumathodes**) with pores for gaseous exchange. Such roots are also known as **pneumatophores**.

Prop: Elongated aerial roots arising from horizontal branches of a tree, striking the ground and providing increased anchorage and often replacing the main trunk as in several species of *Ficus* (e.g., the great banyan tree *F. benghalensis* in the Indian Botanical Garden at Sibpur, Kolkata). The large hanging prop roots of *Ficus* species are often used in bungee jumping sport.

Stilt: Adventitious roots arising from the lower nodes of the plant and penetrating the soil in order to give increased anchorage as in maize (*Zea mays*), screw-pines (*Pandanus*) and *Rhizophora*.

STEMS

Stems represent the main axes of plants, being distinguished into **nodes** and **internodes**, and bearing **leaves** and axillary **buds** at the nodes. The buds grow out into lateral shoots, inflorescences or flowers.

A plant may lack stem (acaulescent) or have a distinct stem (caulescent). The latter may be aerial (erect or weak) or even underground.

Acaulescent: Apparently a stemless plant having very inconspicuous reduced stem. The reduced stem may often elongate at the time of flowering into a leafless flowering axis, known as **scape** as found in onion.

Arborescent: Becoming tree-like and woody, usually with a single main trunk.

Ascending: Stem growing upward at about 45–60º angle from the horizontal.

Bark: Outside covering of stem, mainly the trunk. Bark may be **smooth**, **exfoliating** (splitting in large sheets), **fissured** (split or cracked), or **ringed** (with circular fissures).

Bud: Short embryonic stem covered with bud scales and developing leaves and often found in leaf axils. Buds are frequently helpful in identification and may present considerable diversity:

(i) **Accessary bud:** An extra bud on either side (**collateral** bud) or above (**superposed bud** or **serial bud**) the axillary bud.

(ii) **Adventitious bud:** Bud developing from any place other than the node.

(iii) **Axillary** (**lateral**) **bud:** Bud located in the axil of a leaf.

(iv) **Bulbil:** Modified and commonly enlarged bud meant for propagation. In *Agave* and top onion (*Allium* x *proliferum*) flower buds get modified into bulbils.

(v) **Dormant (winter) bud:** Inactive well protected bud usually to survive winter in cold climates.

(vi) **Flower bud:** Bud developing into flower.

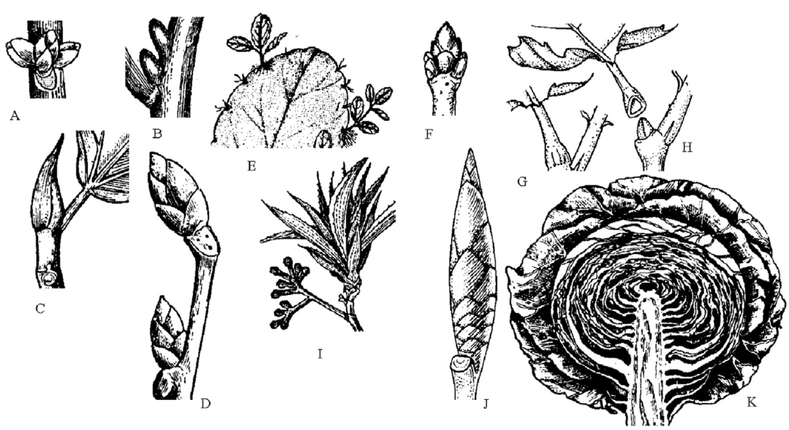

Figure 2.2: Buds. A: Axillary bud with 2 collateral buds in *Acer*; **B:** Axillary bud and a superposed bud in *Juglans regia*; **C:** Scaly bud of *Ficus* covered with bud-scale; **D:** Winter buds in *Salix*; **E:** Vegetative bud with embryonic leaves; **F:** Terminal bud with two collateral buds; **G:** Intrapetiolar bud hidden by petiole base; **H:** Same with petiole removed; **I:** Bulbil developing from one flower of *Agave*; **J:** Pseudoterminal bud, taking terminal position due to death or non-development of terminal bud; **K:** Vegetative bud of *Brassica oleracea* var. *capitata* (cabbage).

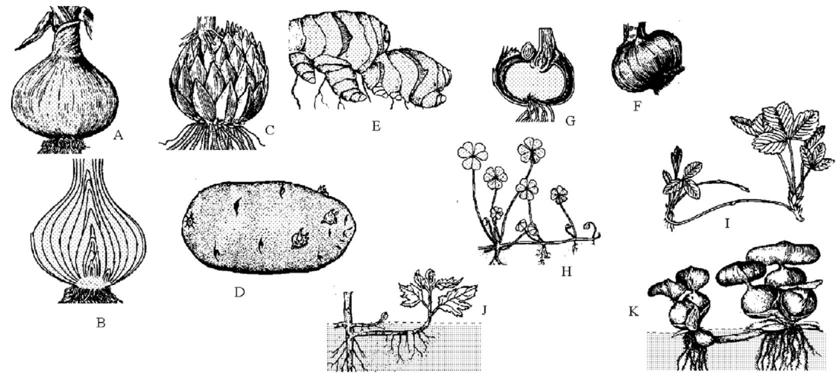

Figure 2.3: Stem, subaerial and underground modifications. A: Tunicated bulb of *Allium cepa*; **B:** Same in vertical section, showing concentric layers of leaf sheaths; **C:** Scaly bulb of *Lilium* with separate fleshy leaf sheaths; **D:** Stem tuber of *Solanum tuberosum* with eye buds; **E:** Rhizome of *Zingiber officinale* with fleshy branched horizontal stem; **F:** Corm of *Crocus sativus* covered with scale leaves; **G:** Same in longitudinal section showing the solid inside as opposed to the bulb; **H:** Runner of *Oxalis,* rooting at nodes; **I:** Stolon of *Fragaria vesca*, arching down to strike roots at nodes; **J:** Sucker in *Chrysanthemum*, underground and rising up to produce shoot; **K:** Offset in *Eichhornia crassipes*, like runner but shorter and thicker.

(vii) **Mixed bud:** A bud bearing both embryonic leaves and flowers.
(viii) **Naked bud:** Not covered by bud scales.
(ix) **Pseudoterminal bud:** Lateral bud near the apex appearing terminal due to death or non-development of terminal bud.
(x) **Scaly (covered) bud:** Covered by bud scales.
(xi) **Terminal bud:** Located at stem tip.
(xii) **Vegetative bud:** Bearing embryonic leaves.

Caulescent: With a distinct stem.

Caudiciform: Low swollen storage stem at ground level, from which annual shoots arise as in *Calibanus* and some species of *Dioscorea*.

Culm: Flowering and fruiting stem of grasses and sedges.

Erect: Growing erect as an herb, shrub or a tree.

Lignotuber: Swollen woody stem at or below ground level, from which persistent woody aerial branches arise, as in *Manzanita*.

Pachycaul: Woody trunk-like stem swollen at base functioning for storage as in bottle tree *Brachychiton*.

Phylloclade (cladophyll): Stem flattened and green like leaves bearing scale leaves as in *Opuntia*. A phylloclade of one internode length found in *Asparagus* in known as **Cladode**.

Pseudobulb: Short erect aerial storage or propagating stem of certain epiphytic orchids.

Subaerial: Generally perennial partially hidden stems:

(i) **Runner:** Elongated internodes trailing along the ground and generally producing a daughter plant at its end as in *Cynodon* and *Oxalis*.
(ii) **Sobol:** Like runner but partially underground as in *Saccharum spontaneum*, and unlike rhizome, not a storage organ.
(iii) **Stolon:** Like runner but initially growing up and then arching down and striking roots in soil as in strawberry.
(iv) **Sucker:** Like runner but underground and growing up and striking roots to form new plant as in *Chrysanthemum* and *Mentha arvensis*.
(v) **Offset:** Shorter than runner and found in aquatic plants like *Eichhornia crassipes*.

Subterranean (underground): Growing below the soil surface and often specially modified:

(i) **Bulb:** A reduced stem surrounded by thick fleshy scale leaves. The leaves may be arranged in a concentric manner surrounded by a thin membranous scale leaf (**tunicated bulb** of onion—*Allium cepa*) or leaves only overlapping along margins (**scaly** or **imbricate** bulb of garlic—*Allium sativum*).
(ii) **Corm:** A vertical fleshy underground stem covered with some scale leaves and with a terminal bud, as in *Gladiolus*.

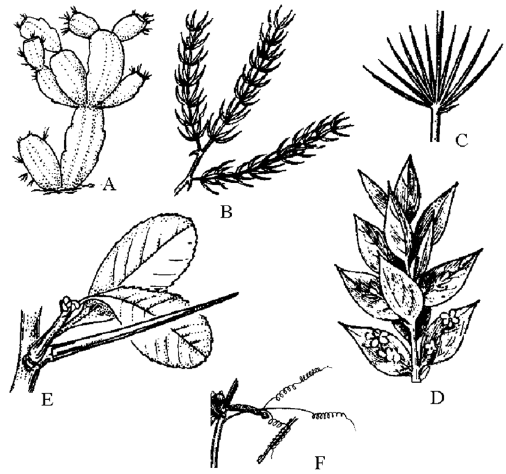

Figure 2.4: Stem, aerial modifications. **A:** Phylloclade of *Opuntia*; **B:** Cladodes in *Asparagus*; **C:** Portion enlarged to show whorl of cladodes in axil of scale-leaf; **D:** Phylloclades of *Ruscus*, leaf-like and bearing flowers; **E:** Thorn of *Prunus*; **F:** Tendril of *Luffa*.

(iii) **Rhizome:** A horizontal dorsiventral fleshy underground stem with nodes and internodes and covered with scale leaves, as in Ginger.

(iv) **Stem tuber:** Underground portions of stem modifies into tubers as in potato.

Thorn: Branch or axillary bud modified into a hard, sharp structure, being deep-seated and having vascular connections as opposed to prickles which are mere superficial outgrowths without vascular connections. Spine is like a thorn but generally weaker and developing from the leaf or stipule. Thorns may bear leaves (*Duranta*), flowers (*Prunus*), or may be branched (*Carissa*).

Weak: Plant not strong enough to grow erect:

(i) **Creeper:** Growing closer to ground and often rooting at the nodes, as in *Oxalis*.

(ii) **Trailer:** Trailing along the surface and often quite long. They are usually **prostrate** or **procumbent,** lying flat on ground as in *Basella*, but sometimes **decumbent** when the tips start growing erect or ascending, as in *Portulaca*.

(iii) **Climber:** Weak plant which uses a support to grow up and display leaves towards sunlight. This may be achieved in several ways:

- (a) **Twiner (stem climber):** Stem coiling round the support due to special type of growth habit, as in *Ipomoea* and *Convolvulus*.
- (b) **Root climber:** Climbing with the help of adventitious roots which cling to the support, as in species of *Piper*.
- (c) **Tendril climber:** Climbing with the help of tendrils which may be modified stem (*Passiflora*, *Vitis*), modified inflorescence axis (*Antigonon*), modified leaf (*Lathyrus aphaca*), modified leaflets (*Pisum sativum*), modified petiole (*Clematis*), modified leaf tip (*Gloriosa*), modified stipules (*Smilax*) or even modified root (*Parthenocissus*).
- (d) **Scrambler:** Spreading by leaning or resting on support, as in Rose.
- (e) **Thorn climber:** Climbing or reclining on the support with the help of thorns, as in *Bougainvillea*.
- (f) **Hook climber:** Climbing with the help of hooked structures (*Galium*).

LEAVES

Leaves are green photosynthetic organs of a plant arising from the nodes. Leaves are usually flattened, either **bifacial** (**dorsiventral**) with **adaxial** side (upper surface facing stem axis) different from **abaxial** side (lower surface facing away from stem axis) or may be **unifacial** (**isobilateral**) with similar adaxial and abaxial surfaces. A leaf is generally differentiated into a **leaf blade** (**lamina**) and a **petiole**. A leaf with a distinct petiole is termed **petiolate**, whereas one lacking a petiole is **sessile**. A petiole A leaf with a distinct petiole is termed **petiolate**, whereas one lacking a petiole is **sessile**. A petiole may be winged (*Citrus*), swollen (*Eichhornia*), modified into tendril (*Clematis*), spine (*Quisqualis*) or become modified into a flattened photosynthetic **phyllode** (Australian Acacia). Two small stipules may be borne at the base of the petiole. The leaf terminology affords a wide diversity. The leaf base may sometimes be sheathing or **pulvinate** (swollen).

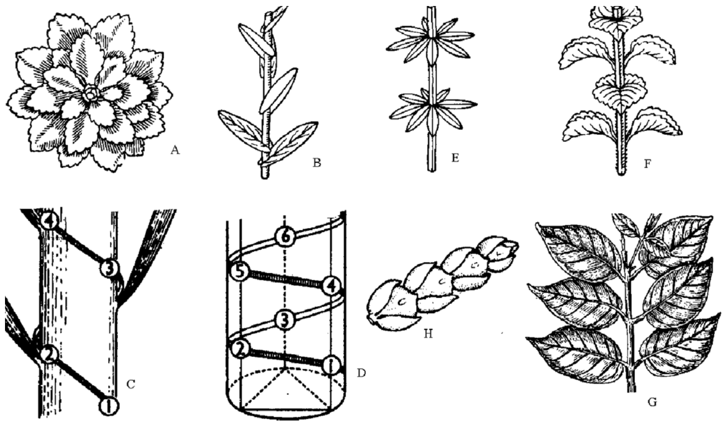

Figure 2.5: Phyllotaxy of leaves. A: Rosulate; **B:** Alternate; **C:** Diagramatic representation of distchous (2-ranked) arrangement; **D:** Diagramatic representation of tristichous (3-ranked) arrangement; **E:** Whorled leaves in *Galium*; **F:** Opposite and decussate leaves of *Lamium*; **G:** Opposite and superposed leaves of *Quisqualis*; **H:** Imbricated leaves.

Leaf Arrangement (Phyllotaxy)

Alternate: Bearing one leaf at each node. The successive leaves usually form a **spiral** pattern, in mathematical regularity so that all leaves are found to lie in a fixed number of vertical rows or **orthostichies**. The arrangement commonly agrees with the **Fibonacci series** (**Schimper-Brown series**), wherein numerator and denominator in each case are obtained by adding up the preceding two (1/2, 1/3, 1+1/2+3 = 2/5, 1+2/3+5 = 3/8, and so on). In grasses the leaves are in two rows (2-ranked, **distichous** or **½ phyllotaxy**), so that the third leaf is above the first leaf. Sedges have three rows of leaves (3-ranked, **tristichous,** or **1/3 phyllotaxy**), the fourth leaf above the first leaf. China rose, and banyan show **pentastichous** arrangement, where the sixth leaf lies above the first one, but in doing so leaves complete two spirals and the phyllotaxy is known as **2/5 phyllotaxy**. *Carica papaya* depicts **octastichous** arrangement, wherein the ninth leaf lies above the first one and three spirals are completed in doing so, thus a **3/8 phyllotaxy**. Leaf bases of date palm and sporophylls of pinecone are closely packed and internodes are extremely short making it difficult to count the number of rows (**orthostichies**). Such an arrangement is known as **parastichous**.

Imbricated: The leaves closely overlapping one another, as in *Cassiope*.

Opposite: Bearing pairs of leaves at each node. The pairs of successive leaves may be parallel (**superposed**) as in *Quisqualis* or at right angles (**decussate**) as in *Calotropis* and *Stellaria*.

Whorled (**verticillate**)**:** More than three leaves at each node as in *Galium*, *Rubia* and *Nerium*.

Radical: Leaves borne at the stem base often forming a rosette (**rosulate**) in reduced stems, as in *Primula* and *Bellis*.

Cauline: Leaves borne on the stem.

Ramal: Leaves borne on the branches.

Leaf Duration

Leaves may stay and function for few days to many years, largely determined by the adaptation to climatic conditions:

Caducuous (**fugacious**)**:** Falling off soon after formation, as in *Opuntia*.

Deciduous: Falling at the end of growing season so that the plant (tree or shrub) is leafless in winter/dormant season. In tropical climate, the tree may be leafless for only a few days. *Salix* and *Populus* are common examples.

Evergreen (**persistent**)**:** Leaves persisting throughout the year, falling regularly so that tree is never leafless, as in mango, pines and palms. It must be noted that whereas the term persistent is used for the leaves, the term evergreen is commonly associated with trees with such leaves.

Marcescent: Leaves not falling but withering on the plant, as in several members of Fagaceae.

Leaf Incision/Type of Leaves

A leaf with a single blade (divided or not) is termed **simple**, whereas one with two or more distinct blades (**leaflets**) is said to be compound.

A **Simple leaf** may be **undivided** or incised variously depending upon whether the incision progresses down to the midrib (pinnate) or towards the base (palmate):

(i) **Pinnatifid:** The incision is less than halfway towards the midrib.
(ii) **Pinnatipartite:** The incision is more than halfway towards the midrib.
(iii) **Pinnatisect:** The incision reaches almost the midrib.
(iv) **Palmatifid:** The incision is less than halfway towards the base.
(v) **Palmatipartite:** The incision is more than halfway towards the base of leaf blade.
(vi) **Palmatisect:** The incision reaches almost the base of leaf blade.
(vii) **Pedate:** Deeply palmately lobed leaves with lobes arranged like the claw of a bird.

A **compound leaf** has incision reaching the midrib (or leaf base) so that there are more than one distinct blades called as leaflets or pinnae. It may similarly be **pinnate** when the leaflets are borne separated along the **rachis** (cf. midrib of simple leaf) or **palmate** when the leaflets arise from a single point at the base. Pinnate compound leaves may be further differentiated:

(i) **Unipinnate (simple pinnate):** The leaflets are borne directly along the rachis. In **paripinnate** leaf (*Cassia*), the leaflets occur in pairs and as such the terminal leaflet is missing and there are even numbers of leaflets. In an **imparipinnate** (*Rosa*) leaf, on the other hand, there is a terminal leaflet, resulting in odd number of leaflets.
(ii) **Bipinnate (twice pinnate):** The **pinnae** (primary leaflets) are again divided into **pinnules**, so that the leaflets (**pinnules**) are borne on the primary branches of the rachis as in *Mimosa pudica*.
(iii) **Tripinnate (thrice pinnate):** The dissection goes to the third order so that the leaflets are borne on secondary branches of the rachis as in *Moringa*.
(iv) **Decompound:** Here the dissections go beyond the third order, as in Fennel. The term is sometimes used for leaves more than once compound.
(v) **Ternate:** The leaflets are present in groups of three. Leaf may be ternate (pinnate with three leaflets, i.e., trifoliate), biternate (twice pinnate with three pinnae and three pinnules) triternate or decompound ternate.

Palmate compound leaf does not have a rachis and the leaflets arise from the top of the petiole:

(i) **Unifoliate:** A modified situation in commonly a trifoliate leaf when the lower two leaflets are reduced, and the terminal leaflet looks like a simple leaf but has a distinct joint at base, as seen in *Citrus* plants.
(ii) **Bifoliate (binnate):** A leaf with two leaflets, as found in *Hardwickia*.

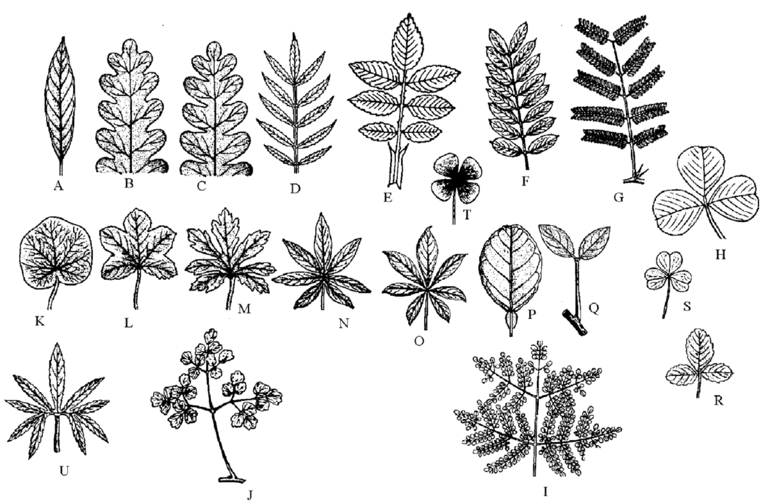

Figure 2.6: Leaf incision. A: Undivided with pinnate venation; **B:** Pinnatifid; **C:** Pinnatipartite; **D:** Pinnatisect; **E:** Pinnate compound-imparipinnate leaf of *Rosa*; **F:** Pinnate compound-paripinnate leaf of *Cassia*; **G:** Bipinnate leaf of *Acacia nilotica*; **H:** Pinnate-trifoliate leaf of *Medicago*, note middle leaflet with longer petiolule; **I:** Tripinnate leaf of *Moringa*; **J:** Triternate leaf of *Thalictrum*; **K:** Undivided with palmate venation; **L:** Palmatifid; **M:** Palmatipartite; **N:** Palmatisect; **O:** Palmate compound-digitate; **P:** Unifoliate leaf of *Citrus*; **Q:** Bifoliate; **R:** Trifoliate leaf of *Trifolium*, note all leaflets with equal petiolules as opposed to pinnate trifoliate leaf; **S:** Trifoliate leaf of *Oxalis*; **T:** Quadrifoliate leaf of *Marsilea*; **U:** pedate leaf of *Vitis pedata*.

(iii) **Trifoliate (ternate):** A leaf with three leaflets, as in *Trifolium*. The trifoliate leaf of *Medicago* and *Melilotus* has terminal leaflet with a longer **petiolule** (stalk of leaflet) than basal leaflets and is accordingly a pinnate trifoliate leaf.

(iv) **Quadrifoliate:** A leaf with four leaflets, as in *Paris* and aquatic pteridophyle *Marsilea*.

(v) **Multifoliate (Digitate):** A leaf with more than four leaflets, as in *Bombax*.

Stipules

The leaves of several species bear two small stipules as outgrowths from the leaf base. Leaves with stipules are termed **stipulate** and those without stipules as **exstipulate**. They show a lot of structural diversity:

Free-lateral: Free and lying on either side of the petiole base, as in china-rose (*Hibiscus rosa-sinensis*).

Adnate: Attached to the base of petiole for some distant, as in Rose.

Intrapetiolar: The two stipules are coherent to form one, which lies in the axil of a leaf as in *Gardenia*.

Interpetiolar: A stipule lying between the petioles of two adjacent leaves, commonly due to fusion and enlargement of two adjacent stipules of different leaves as found in several members of Rubiaceae like *Ixora*.

Ochreate: The two stipules united and forming a tubular structure **ochrea**, found in family Polygonaceae.

Foliaceous: Modified and enlarged to function like leaves as in *Lathyrus aphaca*, where the whole leaf blade is modified into tendril and stipules are foliaceous.

Tendrillar: Stipules modified into tendrils as in *Smilax*.

Spiny: Stipules modified into spines as in *Acacia*.

Leaf Shape (Outline of Lamina)

The shape of leaf/leaflet blade shows considerable variability and is of major taxonomic value.

Acicular: Needle shaped, as in pine.

Cordate: Heart shaped, with a deep notch at base, as in *Piper betle*.

Cuneate: Wedge-shaped, tapering towards the base, as in *Pistia*.

Deltoid: Triangular in shape.

Elliptical: Shaped like an ellipse, a flattened circle usually more than twice as long as broad, as in *Catharanthus roseus*.

Hastate: Shaped like an arrow head with two basal lobes directed outwards, as in *Typhonium*; also referring to hastate leaf base.

Lanceolate: Shaped like a lance, much longer than broad and tapering from a broad base towards the apex, as in bottle-brush plant (*Callistemon citrinus syn: C. lanceolatus*).

Linear: Long and narrow with nearly parallel sides as in grasses and onion.

Lunate: Shaped like half-moon, as in *Passiflora lunata*.

Lyrate: Lyre-shaped; pinnatifid with large terminal lobe and smaller lower lobes, as in *Brassica campestris*.

Oblanceolate: Like lanceolate but with broadest part near apex.

Obcordate: Like cordate but with broadest part and notch at apex, as in *Bauhinia*.

Oblong: Uniformly broad along the whole length as in banana.

Obovate: Ovate, but with broadest part near the apex, as in *Terminalia catappa*.

Ovate: Egg-shaped, with broadest part near the base, as in *Sida ovata*.

Orbicular (rotund): Circular in outline. The peltate leaf of *Nelumbo* is orbicular in outline.

Pandurate: Fiddle shaped; obovate with sinus or indentation on each side near the base and with two small basal lobes, as in *Jatropha panduraefolia*.

Peltate: Shield shaped with petiole attached to the lower surface of leaf (and not the margin), as in *Nelumbo*.

Reniform: Kidney-shaped, as *Centella asiatica*.

Runcinate: Oblanceolate with lacerate or parted margin, as in *Taraxacum*.

Sagittate: Shaped like an arrowhead with two basal lobes pointed downwards, as in *Sagittaria* and *Arum*; also referring to sagittate leaf base.

Spathulate (spatulate): Shaped like a spatula, broadest and rounded near the apex, gradually narrowed towards the base, as in *Euphorbia neriifolia*.

Subulate: Awl-shaped, tapering from a broad base to a sharp point.

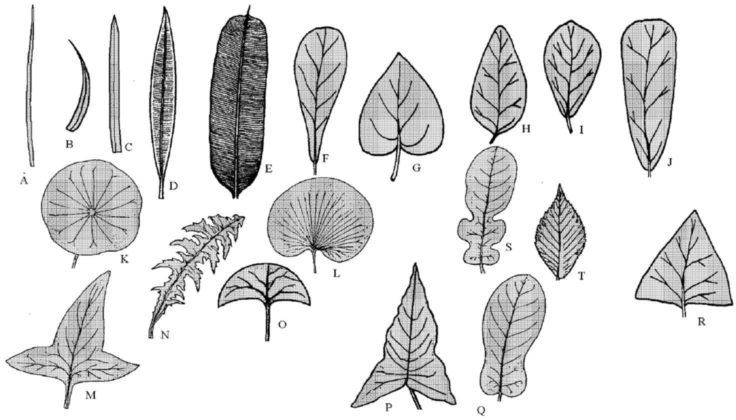

Figure 2.7: Leaf outline. A: Acicular; **B:** Subulate; **C:** Linear, common in grasses; **D:** Lanceolate; **E:** Oblong; **F:** Spathulate; **G:** Cordate; **H:** Ovate; **I:** Obovate; **J:** Oblanceolate; **K:** Peltate; **L:** Reniform; **M:** Hastate; **N:** Runcinate; **O:** Lunate; **P:** Sagittate; **Q:** Pandurate; **R:** Deltoid; **S:** Lyrate; **T:** Elliptic.

Leaf Margin

The edge of a leaf blade is known as margin and may show any of the following conditions:

Crenate: With low rounded or blunt teeth, as in *Kalanchoe*.

Crisped: Margin strongly winding in vertical plane giving ruffled appearance to leaf.

Dentate: With sharp teeth pointing outwards.

Denticulate: Minutely or finely dentate.

Double crenate (bi-crenate): Rounded or blunt teeth are again crenate.

Double dentate: Sharp outward teeth are again dentate. The term **bi-dentate,** though sometimes used here, is inappropriate, as it more correctly refers to a structure bearing two teeth.

Double serrate (bi-serrate): The serrations are again serrate similarly as in *Ulmus*.

Entire: Smooth, without any indentation, as in Mango.

Retroserrate: Teeth pointed downwards.

Revolute: Margin rolled down.

Serrate: With sharp teeth pointing upward like saw, as seen in rose.

Serrulate: Minutely or finely serrate.

Sinuate: Margin winding strongly inward as well as outward.

Undulate (repand, wavy): Margin winding gradually up and down and wavy, as in *Polyalthia*.

Leaf Base

In addition to the terms cordate, cuneate, hastate, sagittate already described above when referring to the leaf base, the following additional terms are frequently used:

Amplexicaul: The auriculate leaf base completely clasps the stem.

Attenuate: Showing a long gradual taper towards the base.

Auriculate: With ear like appendages at the base, as in *Calotropis*.

Cuneate: Wedge shaped, with narrow end at the point of attachment.

Decurrent: Extending down the stem and adnate to the petiole.

Oblique: Asymmetrical with one side of the blade lower on petiole than other.

Perfoliate: The basal lobes of leaf fusing so that the stem appears to pass through the leaf, as in *Swertia*. When the bases of two opposite leaves fuse and the stem passes through them, it is termed **connate perfoliate** as seen in *Canscora*.

Rounded: With a broad arch at the base.

Truncate: Appearing as if cut straight across.

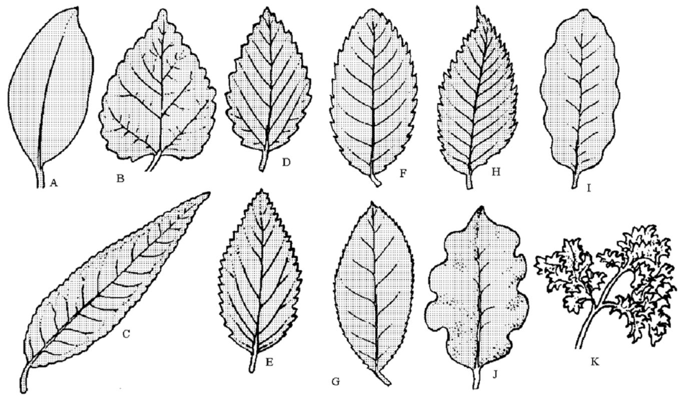

Figure 2.8: Leaf margin. A: Entire; **B:** Crenate; **C:** Crenulate; **D:** Dentate; **E:** Denticulate; **F:** Serrate; **G:** Serrulate; **H:** Bi-serrate; **I:** Undulate; **J:** Sinuate; **K:** Crispate.

Leaf Apex

Leaf apex may similarly present a number of diverse terms:

Acute: Pointed tip with sides forming acute angle, as in mango.

Acuminate: Tapering gradually into a protracted point, as in *Ficus religiosa*.

Aristate: With a long bristle at the tip.

Attenuate: Tip drawn out into a long tapering point.

Caudate: Apex elongated and tail-like.

Cirrhose: With slender coiled apex, as in banana.

Cuspidate: Abruptly narrowed into sharp spiny tip, as in pineapple.

Emarginate: With a shallow broad notch at tip, as in *Bauhinia*.

Mucronate: Broad apex with a small point, as in *Catharanthus*.

Obtuse: Broad apex with two sides forming an obtuse angle, as in banyan.

Retuse: With a slight notch generally from an obtuse apex, as in *Crotalaria retusa*.

Rounded: With a broad arch at the base.

Truncate: Appearing as if cut straight across.

Leaf Surface

The surface of leaves, stems and other organs may present a variety of surface indumentation, whose characteristics are highly diagnostic in several taxa. The surface may be covered by trichomes (hairs, glands, scales, etc.) arranged variously:

Arachnoid: Covered with entangled hairs giving a cobwebby appearance.

Canescent: Covered with grey hairs.

Ciliate: With marginal fringe of hairs.

Floccose: Covered with irregular tufts of loosely tangled hairs.

Glabrate: Nearly glabrous or becoming glabrous with age.

Glabrous: Not covered with any hairs. Sometimes but not always synonymous with **smooth** surface.

Glacous: Surface covered with a waxy coating, which easily rubs off.

Glandular: Covered with glands or small secretory structures.

Glandular-punctate (**gland-dotted**)**:** Surface dotted with immersed glands, as in *Citrus*.

Hirsute: Covered with long stiff hairs.

Hispid: Covered with stiff and rough hairs.

Lanate: Wooly, with long intertwined hairs.

Pilose: Covered with long distinct and scattered hairs.

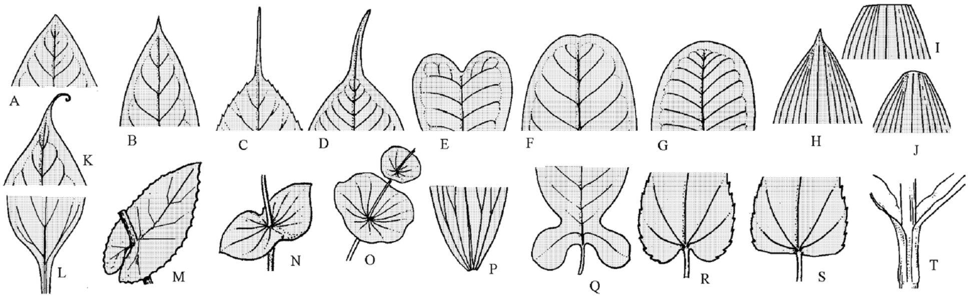

Figure 2.9: Leaf apex and leaf base. Leaf apex. A: Acute; **B:** Acuminate; **C:** Aristate; **D:** Caudate; **E:** Emarginate; **F:** Retuse; **G:** Rounded; **H:** Mucronate; **I:** Truncate; **J:** Obtuse; **K:** Cirrhose. **Leaf base. L:** Attenuate; **M:** Amplexicaul; **N:** Connate-perfoliate; **O:** Perfoliate; **P:** Cuneate; **Q:** Auriculate; **R:** Cordate; **S:** Truncate; **T:** Decurrent.

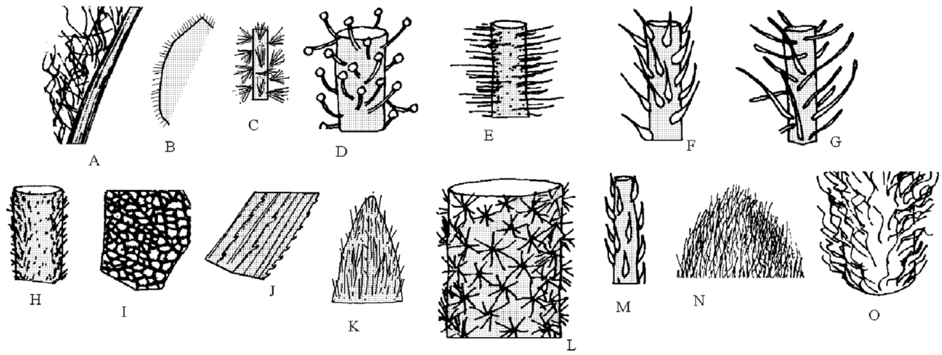

Figure 2.10: Surface coverings. A: Arachnoid; **B:** Ciliate; **C:** Floccose; **D:** Glandular; **E:** Hirsute; **F:** Hispid; **G:** Pilose; **H:** Puberulent; **I:** Rugose; **J:** Scabrous; **K:** Sericeous; **L:** Stellate; **M:** Strigose; **N:** Tomentose; **O:** Villous.

Puberulent: Minutely pubescent.
Pubescent: Covered with soft short hairs.
Rugose: With wrinkled surface.
Scabrous: Surface rough due to short rough points.
Scurfy: Covered with scales.
Sericeous: Covered with soft silky hairs, all directed towards one side.
Stellate: Covered with branched star-shaped hairs.
Strigose: Covered with stiff appressed hairs pointing in one direction.
Tomentose: Covered with densely matted soft hairs, wooly in appearance.
Velutinous: Covered with short velvety hairs.
Villous: Covered with long, fine soft hairs, shaggy in appearance.

The hairs covering the surface may be **unicellular** or **multicellular**, **glandular** or **nonglandular**. The hairs may be unbranched or branched variously. They may bear one row of cells (**uniseriate**), two rows (**biseriate**) or several rows (**multiseriate**). Some species of plants, especially some acacias bear specialized glands **domatia** at the leaf base, which house ants which protect plants from herbivores.

Venation

The distribution of vascular bundles that are visible on the leaf surface as veins constitutes venation. Dicots exhibit a network of veins (**reticulate venation**); whereas monocots usually have non-intersecting parallel veins (**parallel venation**). Each type of venation may encounter a single **midrib** from which the secondary veins arise (**Unicostate** or **pinnate**), or more than one equally strong veins entering the leaf blade (**multicostate** or **palmate**). In ferns and *Ginkgo*, the venation is **dichotomous** with forked veins.

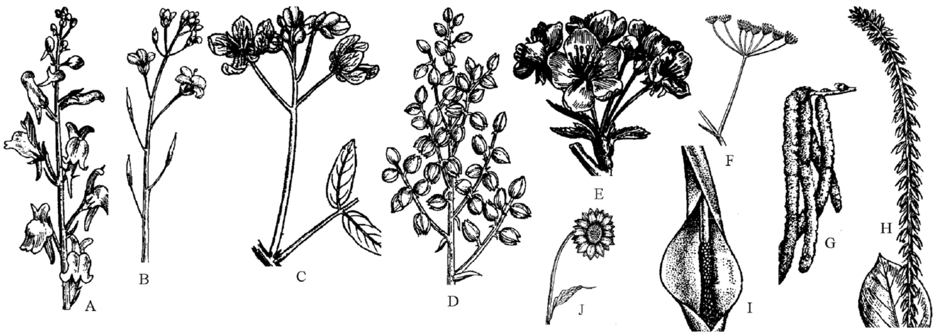

Figure 2.11: Inflorescence: racemose types. A: Raceme of *Linaria*; **B:** Corymbose raceme of *Brassica*; **C:** Corymb of *Cassia*; **D:** Panicle of *Yucca*; **E:** Umbel of *Prunus*; **F:** Compound umbel of *Foeniculum*; **G:** Catkins of *Betula*; **H:** Spike of *Achyranthes*; **I:** Spadix of *Colocasia*; **J:** Capitulum of *Helianthus*.

INFLORESCENCE

Inflorescence is a modified shoot system bearing flowers (modified shoots). The term inflorescence appropriately refers to the arrangement of flowers on the plant. The flowers may either occur singly (in leaf axils—**solitary axillary** or terminal on the stem—**solitary terminal**) or may be organized into distinct inflorescences. Two principal types of inflorescences are differentiated. In **racemose** (**indeterminate** or **polytelic**), inflorescence the axis is of unlimited growth, apical bud continuing to grow, thus bearing oldest flower towards the base and youngest towards the top. In **cymose** (**determinate** or **monotelic**) inflorescence, on the other hand, the main axis has limited growth, being terminated by the formation of a flower, and as each level of branching bears one flower, there are generally a limited number of flowers, and the oldest flower is either in the centre, or flowers of different ages are mixed up. An inflorescence is sometimes carried on a leafless axis. Such a leafless axis arising from aerial stems is termed a **peduncle** (inflorescence pedunculate) and the one arising from basal rosette of leaves as **scape** (inflorescence scapigerous).

Racemose Types

The following variations of the **racemose** type are commonly encountered:

Raceme: A typical racemose inflorescence with single (unbranched) axis bearing flowers on distinct pedicels, as in *Delphinium*.

Panicle: Branched raceme, the flowers being borne on the branches of the main axis, as in *Yucca*.

Spike: Similar to raceme but with sessile flowers, as in *Adhatoda*.

Spadix: Variation of a spike where the axis is fleshy and the flowers are covered by a large bract known as **spathe**, as found in *Alocasia* and *Arum*.

Corymb: Flat-topped racemose inflorescence with longer lower pedicels and shorter upper pedicels so that all flowers reach the same level, as in *Iberis amara*.

Corymbose-raceme: Intermediate between a typical raceme and a typical corymb, all flowers not managing to reach the same height, as in *Brassica campestris*.

Catkin (ament): A spike-like inflorescence of reduced unisexual flowers, as in *Morus*.

Umbel: Flowers arising from one point due to condensation of axis, with oldest flowers towards the periphery and youngest towards the center as in the family Apiaceae (Umbelliferae). **Compound umbel** has branches bearing the umbels also borne in umbellate manner.

Head: Flat-topped axis bearing crowded sessile flowers as in *Acacia* and *Mimosa*.

Capitulum: Flat-topped inflorescence like head (and often known as head) but with distinct ray florets and disc florets (one or both types), surrounded by involucre bracts (phyllaries), as found in the family Asteraceae (Compositae).

Cymose Types

A cymose inflorescence may be primarily differentiated on account of bearing one or more determinate branches arising below the terminal flower at each level:

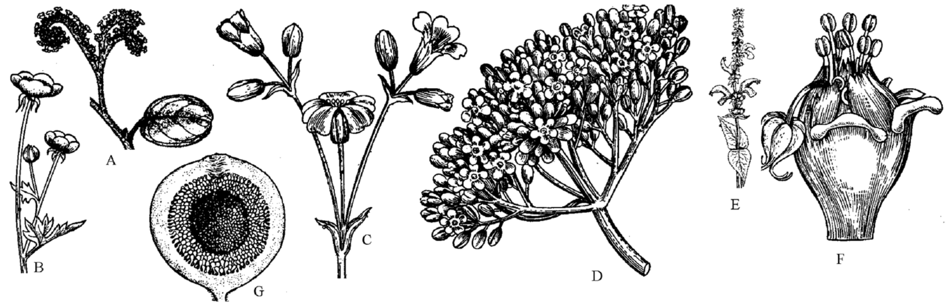

Figure 2.12: Inflorescence: cymose and specialized types. **Cymose types. A:** Helicoid cyme of *Heliotropium*; **B:** Scorpioid cyme of *Ranunculus bulbosus*; **C:** Biparous cyme of *Dianthus*; **D:** Multiparous cyme of *Viburnum*. **Specialized types**. **E:** Verticillaster of *Salvia*; **F:** Cyathium of *Euphorbia*; **G:** Hypanthodium of *Ficus cunia*.

Monochasial (Uniparous) cyme: One branch arising at each node so that when the **sympodial** (false) axis differentiates, a limited number of bract-opposed flowers (instead of many and axillary in raceme) are formed. Two types of monochasia are found:

(i) **Helicoid cyme:** Successive branches (each forming one flower) are borne on same side so that the inflorescence is often coiled, as in the family Boraginaceae (e.g., *Myosotis*).

(ii) **Scorpioid cyme:** Successive branches (each forming one flower) are borne on alternate sides. In **rhipidium** found in *Solanum nigrum,* all the flowers lie in same plane as the main axis.

Dichasial (Biparous) cyme: Two branches arising below the apical flower at each level so that the flower is between the fork of two branches, as in *Stellaria* and *Dianthus*.

Polychasial (multiparous) cyme: More than two branches arising at each node below the terminal flower so that a broad inflorescence of several flowers is formed, as in *Viburnum*.

Cymose cluster: Cymose group of flowers arising from a point due to reduction of axis.

Cymose umbel: Looking like an umbel but formed by grouping together of numerous cymes so that the flowers of different ages are mixed up, as found in *Allium*.

Specialized Types

In addition to the typical determinate and indeterminate types, some mixed and specialized types are also encountered:

Cyathium: Complex type of inflorescence met in genus *Euphorbia*, having a cup-shaped involucre (formed by fused bracts) usually carrying five nectaries along the rim and enclosing numerous male flowers (in scorpioid cymes, without perianth and bearing a single stamen) in axils of bracts and single female flower in the centre.

Verticillaster: Characteristic inflorescence of family Lamiaceae. Each node of the inflorescence bears two opposite clusters of dichasial cymes, subsequently becoming monochasial as the number of flowers in each cluster exceeds three. Due to the condensation of the axis, flowers of different ages appear to form a false whorl or **verticel**.

Hypanthodium: Typical inflorescence of figs having vessel like receptacle with a small opening at the top and bearing flowers along the inner wall.

Thyrse: A mixed inflorescence with racemose main axis but with cymose lateral clusters as seen in grape vine.

FLOWER

A flower is a highly modified shoot bearing specialized floral leaves. The axis of the flower is condensed to form **thalamus** (**torus** or **receptacle**) commonly bearing four whorls of floral parts: **calyx** (individual parts sepals), **corolla** (individual parts petals), **Androecium** (individual parts stamens) and **Gynoecium** (individual parts carpels). In some plants, the calyx and corolla may not be differentiated and represented by a single or two similar whorls of **perianth** (individual members **tepals**: a term formerly restricted to petal like perianth of monocots). The flower is usually carried on a **pedicel** and may or may not be subtended by a reduced leaf known as **bract**. The pedicel may sometimes carry small **bracteoles** (if present usually two in dicots, one in monocots). As a general rule, members of different whorls alternate each other. The terms associated with the general description of flower in usual sequence includes:

Bract

Bracteate: Flower in the axil of a bract.
Ebracteate: Bract absent.
Bracteolate: Bracteoles present on pedicel.

Pedicel

Pedicellate: Pedicel distinct, often longer than flower.
Subsessile: Pedicel much shorter, often shorter than flower.
Sessile: Pedicel absent.

Complete: All the four floral whorls present.

Incomplete: One or more floral whorl lacking.

Symmetry: Symmetry of a flower is largely based on relative shapes and sizes of sepals (or calyx lobes) in calyx whorl and/or relative shapes and sizes of petals (or corolla lobes) in the corolla whorl.

Actinomorphic: Symmetrical flower which can be divided into equal halves when cut along any vertical plane. In practice an actinomorphic flower has all parts of the calyx and all parts of the corolla (or all parts of perianth) more or less of the same shape and size.

Zygomorphic: Asymmetrical flower, which may be divided into equal halves by one or more but not all vertical planes. In practice such flower has parts of calyx and/or corolla (or perianth) of different shapes and sizes.

Sexuality

Bisexual (perfect): Bearing both stamens and carpels.
Unisexual (imperfect): Bearing either stamens or carpels.
Staminate (male)**:** Bearing stamens only.
Pistillate (female)**:** Bearing carpels only.
Dioecious: With male and female flowers on the same plant.
Monoecious: With male and female flowers on different plants.
Polygamous: With male, female and bisexual flowers on the same plant.

Insertion: Insertion of floral parts on the thalamus not only determines the shape of the thalamus, it also reflects on the relative position of floral whorls, as also whether the ovary is superior (and, consequently, other whorls inferior) or inferior (and, consequently, other whorls superior):

Hypogynous: The thalamus is convex so that the other floral parts are inserted below the ovary. The ovary in this case is **superior** and other floral whorls inferior. There is no hypanthium.

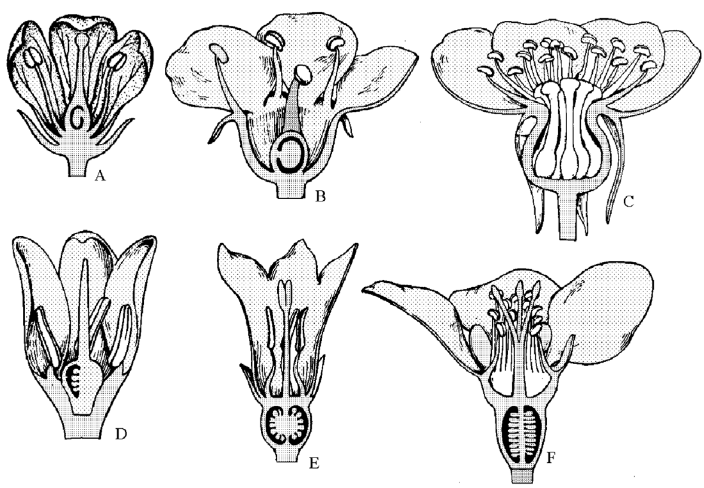

Figure 2.13: Insertion of floral parts. A: Hypogynous with superior ovary; **B:** Perigynous with cup-shaped hypanthium and superior ovary; **C:** Perigynous with flask-shaped hypanthium, ovary superior; **D:** Perigynous with partially immersed semi-inferior ovary; **E:** Epigynous with inferior ovary, without free hypanthium above the ovary; **F:** Epigynous with inferior ovary and with free hypanthium above the ovary.

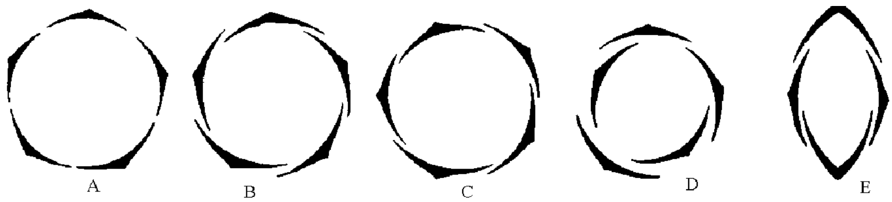

Figure 2.14: Aestivation of calyx and corolla parts. A: Valvate; **B:** Twisted; **C:** Imbricate; **D:** Quincuncial imbricate; **E:** Vexillary.

Perigynous: The thalamus is depressed to the extent that the level of ovary is lower than the other whorls and the thalamus forms either a saucer-shaped, cup-shaped or flask-shaped **hypanthium**. It must be noted that although hypanthium surrounds the ovary, it is free from the ovary, the other floral whorls are borne along the rim of the hypanthium, yet the ovary is morphologically still superior and other floral whorls inferior. The ovary may sometimes be partially immersed and thus **semi-inferior**.

Epigynous: The hypanthium is fused with the ovary, so that the other floral whorls appear to arise from the top of the ovary. The ovary is obviously **inferior** and other floral whorls superior. There may or may not be a free hypanthium above the ovary; in the former case, other floral parts appear to arise from the top of ovary.

Pentamerous: Five members in each floral whorl (excluding stamens and carpels), typical of dicots.

Tetramerous: Four members in each floral whorl, as in crucifers.

Trimerous: Three members in each floral whorl, as in monocots.

Cyclic (tetracyclic): Calyx, corolla, androecium and gynoecium in four separate whorls.

Spirocyclic: Calyx and corolla cyclic but stamens and carpels spirally arranged, as in Ranunculaceae.

Calyx

Description of the calyx starts with the number of sepals in same whorl (5—typical on dicots, 3—typical of monocots), in two whorls (2+2, as in crucifers) or forming two lips (1/4 in *Ocimum*, 3/2 in *Salvia*):

Polysepalous (aposepalous, chorisepalous): Sepals free, and consequently more than one units (poly—many).

Gamosepalous: Sepals fused. Once the calyx is gamosepalous, it commonly gets differentiated two parts: calyx tube, the fused part and calyx lobes (no longer sepals), the free part. The shape of the calyx tube should be described. It may be **campanulate** (bell-shaped as in *Hibiscus*), **urceolate** (urn-shaped as in fruiting calyx of *Withania*), **tubular** (tube-like as in *Datura*), or **bilabiate** (two-lipped as in *Ocimum*).

Caducous: Falling just after opening of flowers.

Deciduous: Falling along with petals in mature flower.

Persistent: Persisting in fruit.

Accrescent: Persisting and enlarging in fruit.

Aestivation: Arrangement of sepals (or petals) in the flower bud. Term **vernation** is used exclusively for arrangement of young leaves in a bud. The following main types of aestivation are met:

(i) **Valvate:** Margins of sepals or calyx lobes not overlapping.

(ii) **Twisted:** Overlapping in regular pattern, with one margin of each sepal overlapping and other being overlapped.

(iii) **Imbricate:** With irregular overlapping. In **Quincuncial imbricate,** two sepals are with both margins outer, two with both margins inner, and fifth with one outer and one inner margin.

Description of aestivation may be followed by color of sepals (green or petaloid), and whether they are inferior or superior.

Corolla

Description of the corolla follows the same pattern as calyx except that **bilabiate** corolla may be 4/1 or 3/2, corolla may be **polypetalous** (**apopetalous**, **choripetalous**), or **gamopetalous** (**sympetalous**), corolla tube may be additionally **infundibuliform** (funnel-shaped) as in *Datura*, **rotate** (tube very short with large lobes spreading out at right angle to the tube like spokes of a wheel), as in *Solanum*, or **salverform** (**salver-shaped**, **hypocrateriform**), as in *Catharanthus*. The junction of corolla tube and lobes (constituting **limb**) is known as **throat**. Petals may sometimes be narrowed into a stalk

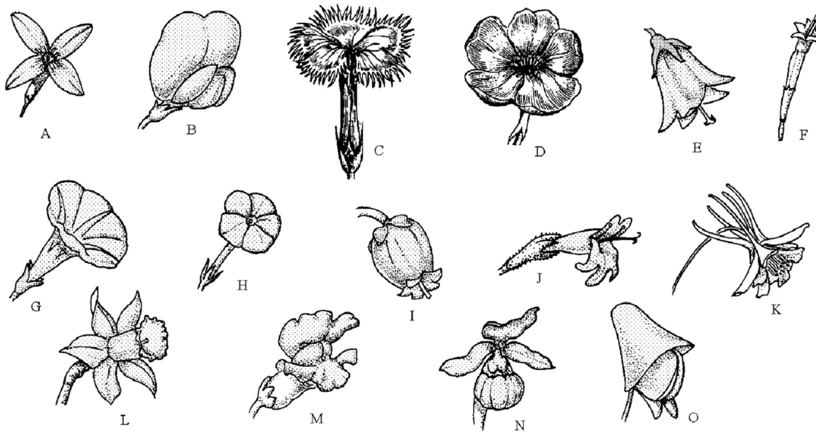

Figure 2.15: Corolla types. A: Cruciform; **B:** Papilionaceous; **C:** Caryophyllaceous; **D:** Rosaceous; **E:** Campanulate; **F:** Tubular; **G:** Infundibuliform (Funnel-shaped); **H:** Hypocrateriform; **I:** Urceolate; **J:** Bilabiate; **K:** Spurred (Calcarate); **L:** Coronate; **M:** Personate; **N:** Calceolate; **O:** Galeate.

termed as **claw**, the broader part then constituting the limb. Specialized types of corolla are encountered in Brassicaceae (**cruciform**—four free petals arranged in the form of a cross), Caryophyllaceae (**caryophyllaceous**—five free clawed petals with limb at right angles to the claw), Rosaceae (**rosaceous**—five sessile petals with limbs spreading outwards) and Fabaceae (**Papilionaceous**—resembling a butterfly with single large posterior petal **vexillum** or **standard**, two lateral petals **alae** or **wings**, and two anterior petals slightly united to form **keel** or **carina;** the aestivation is **vexillary** or descending imbricate, with the standard being the outermost, overlapping two wings, which in turn overlap keel). The petals may similarly be variously colored. In some cases, sepals or petals may bear a small pouch a condition known as **saccate** (lateral sepals of *Brassica* or corolla of *Cypripedium*—is more like slipper and called **calceolate**). Sometimes the base may be produced into a tube like structure known as **spur** (corolla as **calcarate**) as in *Delphinium* and *Aquilegia*. In some flowers (*Aconitum*), the corolla may be shaped like a helmet, when it is termed as **galeate**.

Present inner to corolla in some cases is an additional whorl generally attached to the throat of the corolla (or inner whorl of the perianth). Such a whorl is known as **corona** and may be consisting of appendages from perianth (*Narcissus*), corolla (corolline corona as in *Nerium*) or from stamens (staminal corona as in *Hymenocallis*). The flower is known as **coronate**.

Perianth

The description of **perianth** in the flowers lacking distinct calyx and corolla follows the same pattern specifying the number, number of whorls, perianth being **polyphyllous** (**apotepalous**) or **gamophyllous** (**syntepalous**), aestivation, and the color of the perianth. The parts when free are called **tepals** in place of sepals or petals.

Androecium

Stamens representing the androecium present a more complicated architecture as compared to sepals and petals. Each stamen has an **anther**—typically tetrasporangiate with two anther sacs (microsporangia) in each of the two anther lobes—carried on a **filament**. The two anther lobes are often joined with the help of a **connective**, which in some primitive families, is a continuation of the filament. The description of androecium, likewise, starts with the number of stamens in a single or more whorls. Major descriptive terms include:

Fusion: Stamens may generally be free, but if fused it can take a variety of forms:

Polyandrous: Stamens free throughout.

Monadelphous: Filaments of all stamens united in a single group, as in family Malvaceae.

Diadelphous: Filaments of stamens united in two groups, as in *Lathyrus*.

Polyadelphous: Filaments united in more than two groups, as in *Citrus*.

Syngenesious (**synantherous**)**:** Filaments free but anthers connate into a tube, as in family Asteraceae.

Synandrous: Stamens fused completely through filaments as well as anthers, as in *Cucurbita*.

Epipetalous: Filaments attached to the petals, a characteristic feature of sympetalous families.

Epiphyllous (epitepalous): Filaments attached to the perianth.

Relative size: Stamens in a flower are generally of the same size, but the following variations may be encountered in some flowers:

Didynamous: Four stamens, two shorter and two longer, as in *Ocimum*.

Tetradynamous: Six stamens, two shorter in outer whorl and four longer in inner whorl, as in crucifers.

Heterostemonous: Same flower with stamens of different sizes, as in *Cassia*.

Diplostemonous: Stamens in two whorls, the outer whorl alternating with petals as in *Murraya*.

Obdiplostemonous: Stamens in two whorls but outer whorl opposite the petals, as in the family Caryophyllaceae.

Antipetalous: Stamens opposite the petals, as in the family Primulaceae.

Bithecous: Stamen with two anther lobes (each anther lobe at maturity becomes unilocular due to coalescence of two adjacent microsporangia) so that anther is two-celled at maturity.

Monothecous: Stamen with single anther lobe so that mature anther is single-celled, as in family Malvaceae.

Attachment: Common modes of attachment of filament to the anther include:

(i) **Adnate:** Filament continues into connective which is almost as broad, as found in *Ranunculus*.

(ii) **Basifixed:** The filament ends at the base of anther (when connective extends up to base of anther)or at least base of connective (when anther lobes extend freely below the connective). The resultant anther is erect, as in *Brassica*.

(iii) **Dorsifixed:** Filament attached on the connective above the base. The resultant anther is somewhat inclined, as in *Sesbania*.

(iv) **Versatile:** Filament attached nearly at the middle of connective so that anther can swing freely as, in *Lilium* and grasses.

Dehiscence: Anther dehiscence commonly occurs by the formation of sutures along the point of contact of two anther sacs, but considerable variation in their location may be found:

Longitudinal: The two sutures extend longitudinally, one on each anther lobe as in *Datura*.

Transverse: Suture placed transversely, as in monothecous anthers of family Malvaceae.

Poricidal (apical pores): Anther opening by pores at the tip of anther, as in *Solanum nigrum*.

Valvular: Portions of anther wall opening through flaps or valves, as in *Laurus*.

Centripetal: Developing from the outside to the inside so that the oldest stamens are towards the periphery.

Centrifugal: Developing from centre towards the periphery, so that the oldest flowers are towards the centre.

Included: Stamens are shorter than the corolla.

Exserted: Stamens protruding far beyond the petals as in Umbellifers.

Introrse: Slits of the anther facing towards the centre.

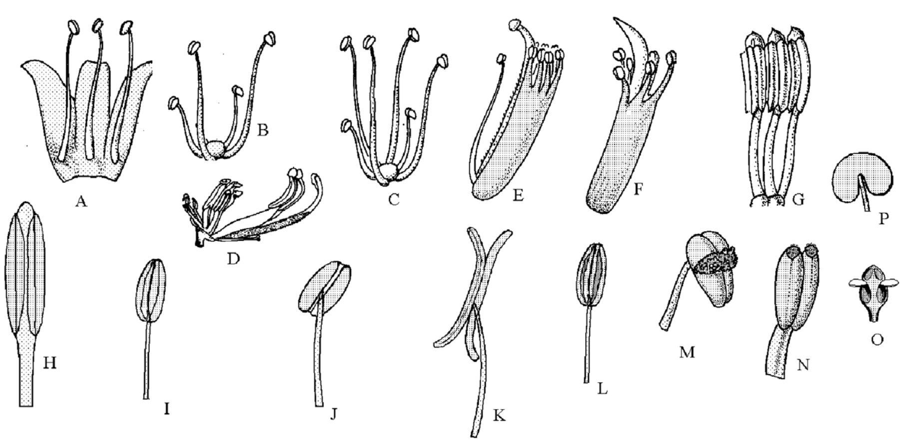

Figure 2.16: Androecium types. A: Epipetalous staments. **Length**. **B:** Didynamous; **C:** Tetradynamous; **D:** Heterostemonous. **Fusion**. **E:** Diadelphous; **F:** Monadelphous; **G:** Syngenesious. **Attachment**. **H:** Adnate; **I:** Basifixed; **J:** Dorsifixed; **K:** Versatile. **Dehiscence**. **L:** Longitudinal; **M:** Transverse; **N:** Poricidal; **O:** Valvular; **P:** Monothecous reniform anther.

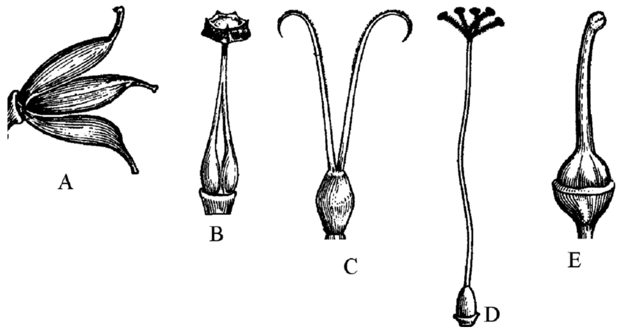

Figure 2.17: Carpel fusion. A: Apocarpous; **B:** Apocarpous with fused styles and stigmas (which, in turn, also fused with anthers to form gynostegium); **C:** Syncarpous with free styles and stigmas (synovarious); **D:** Syncarpous with free stigmas (synstylovarious); **E:** Syncarpous.

Extrorse: Slits of the anther facing towards outside.

Androphore: Extension of thalamus bearing stamens.

Gynostegium: Structure formed by the fusion of stamens with the stigmatic disc, as in family Asclepiadaceae.

Gynostemium: Structure formed by fusion of stamens with gynoecium, as in family Orchidaceae.

Gynoecium

Gynoecium represents a collection of carpels in a flower. The distinction between **carpel** and **pistil** is often ambiguous. In reality the carpels are components of a gynoecium whereas the pistils represent visible units. Thus, if carpels are free, there would be as many pistils (**simple pistils**). On the other hand, if the carpels are united (and obviously more than one), the flower would have only one pistil (compound pistil). Each carpel is differentiated into a broad basal **ovary** containing **ovules**, an elongated **style**, and pollen-receptive apical part **stigma**. Any attempt to describe gynoecium requires a transverse section through the ovary. An additional longitudinal section is always helpful.

Carpel Number and Fusion

A flower having more than one separate pistils would have as many carpels, which are free. On the other hand, if the pistil is one, there could either be one carpel, or more than one fused carpels. A section through the ovary helps to resolve the matter in most cases. If the ovary is single chambered, the number of rows of ovules (placental lines) would equal the number of united carpels. A solitary carpel would obviously have a single chamber with a single ovule or a single row of ovules. On the other hand, if ovary is more than one chambered, it obviously has more than one carpel, and the number of chambers would indicate the number of carpels. There are, however, atypical cases. Single chambered ovary may have a central column bearing ovules (since septa disappeared), or in a single chambered ovary there

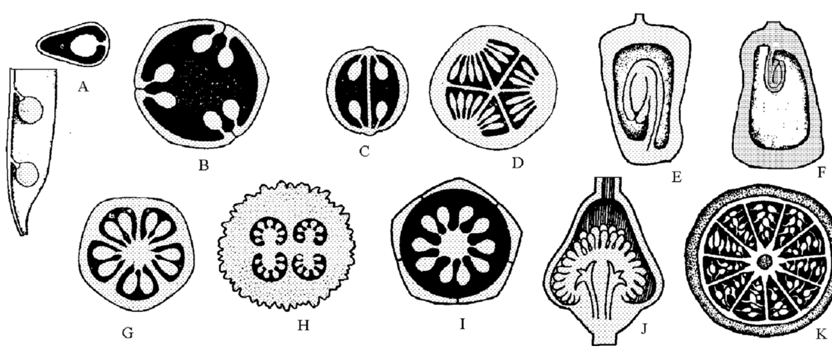

Figure 2.18: Placentation. A: Marginal; **B:** Parietal with 3 carpels; **C:** Parietal with false septum in crucifers (parietal-axile); **D:** Parietal with false septa in cucurbits; **E:** Basal; **F:** Apical; **G:** Axile; **H:** Axile with false septa in *Datura*; **I:** Free central with usual central column attached at the base and top of the ovary; **J:** Free central in Primulaceae in Longitudinal section showing placental column projecting from the base; **K:** Superficial in *Nymphaea*.

may be single large ovule because all others (from one or more placental lines) have disappeared. In both these cases, the number of carpels can be known by counting the number of free styles, or if style is one the number of stigmas or stigmatic lobes. In extreme cases, even this may not help, as in *Anagallis arvensis*, when the number of suture lines on the fruit would help. The number of carpels is represented as **monocarpellary** (carpel one), **bicarpellary** (carpels two), **tricarpellary** (carpels three), **tetracarpellary** (carpels four), **pentacarpellary** (carpels five), and **multicarpellary** (carpels more than five). The number of chambers similarly are represented as **unilocular**, **bilocular**, **trilocular**, **tetralocular**, **pentalocular** and **multilocular**. Gynoecium with free carpels is **apocarpous**, whereas one with fused carpels (at least ovaries fused) as **syncarpous.** Syncarpous gynoecium may have free styles and stigma (**synovarious**) or free stigmas (**synstylovarious**) or all fused.

Placentation

Placentation refers to the distribution of placentae on the ovary wall and, consequently, the arrangement of ovules. The following major types are found:

(i) **Marginal:** Single chambered ovary with single placental line commonly with single row of ovules, as in *Lathyrus*.

(ii) **Parietal:** Single chambered ovary with more than one discrete placental lines as, in family Capparaceae. In family Brassicaceae, the ovary later becomes bilocular due to the formation of a false septum, the ovules present at the junction of septum and ovary wall, a condition often known as **parietal-axile**. In some members of Aizoaceae, the ovules arise from inner ovary walls of septate ovary, a condition known as **parietal-septate**. In family Cucurbitaceae, the three parietal placentae intrude into ovary cavity and often meet in the centre making **false-axile** placentation.

(iii) **Axile:** Ovary more than one chambered and placentae along the axis as in *Hibiscus*.

(iv) **Free-central:** Ovary single chambered, ovules borne along the central column, as in family Caryophyllaceae.

(v) **Basal:** ovary single chambered, with single ovule at the base, as found in family Asteraceae (Compositae).

(vi) **Superficial:** Multilocular ovary with whole inner wall of ovary lined with placentae as in *Nymphaea*. In **laminar** placentation, the ovules arise from surface of septa.

Style and Stigma

Simple: Single style or stigma resulting from single carpel or fused styles or stigmas.

Bifid: Style or stigma divided into two as in family Asteraceae.

Terminal style: Arising from the tip of ovary, the most common type.

Gynobasic style: Arising from central base of the ovary, as in family Lamiaceae.

Capitate: Stigma appearing like a head.

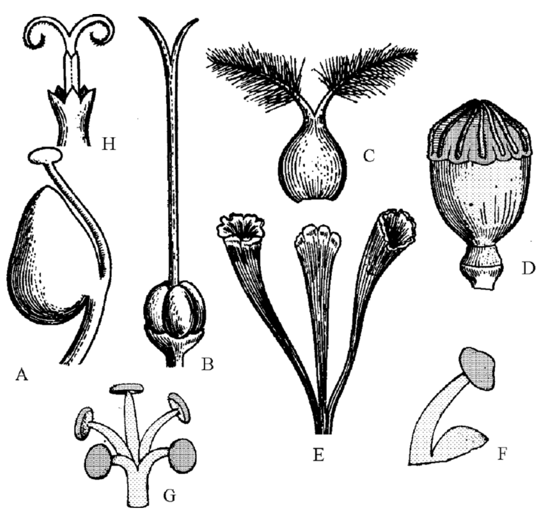

Figure 2.19: Style and stigma. A: Lateral style; **B:** Gynobasic style; **C:** Bifid feathery stigma in Poaceae; **D:** Sessile and radiate stigma of *Papaver*; **E:** Tripartite funnel-shaped stigma of *Crocus*; **F:** Capitate stigma of *Alchemilla*; **G:** Discoid stigmas of *Hibiscus*; **H:** Bifid stigma in Asteraceae.

Lateral style: Style arising from the side of the ovary, as in *Mangifera* and *Alchemilla*.
Stylar beak: Persistent style, extended into a long beak.
Pistillode: Sterile pistil, devoid of any fertile ovules, as in ray floret of radiate head of *Helianthus*.
Radiate stigma: Sessile disc like with radiating branches, as in *Papaver*.
Stylopodium: Swollen basal part of style surrounded by nectary persisting in fruit of umbellifers.
Sessile stigma: Seated directly on ovary, style being reduced as in *Sambucus*.
Discoid stigma: Disc-shaped stigma.
Globose stigma: Stigma spherical in shape.
Plumose stigma: Feathery stigma with trichome-like branches as in Poaceae and Cyperaceae.

Ovule

Ovule represents megasporangium, attached to the placenta by **funiculus**, which joins the ovule at the **hilum**. Base of the ovule is known as **chalaza**, and the tip as **micropyle**. Ovule has a female gametophyte (**embryo sac**) surrounded by nucellus, in turn, enveloped by two **integuments**. The following terms are commonly associated with ovules:
Orthotropous (atropous): Straight erect ovule with funiculus, chalaza and micropyle in one line, as in family Polygonaceae.
Anatropous: Inverted ovule with micropyle facing and closer to funiculus, as in *Ricinus*.
Amphitropous: Ovule placed at right angles to the funiculus, as in *Ranunculus*.
Campylotropous: Curved ovule so that micropyle is closer to chalaza, as in Brassicaceae.
Circinotropous: Funiculus very long and surrounding the ovule, as in *Opuntia*.
Hemianatropous (hemitropous): Body half-inverted so that funiculus is attached near middle with micropyle terminal and at right angles.
Bitegmic: Ovule with two integuments, common in polypetalous dicots.
Unitegmic: Ovule with single integument, common in sympetalous dicots.
Crassinucellate: Ovule with massive nucellus, found in primitive polypetalous dicots.
Tenuinucellate: Ovule with thin layer of nucellus, as in sympetalous dicots.

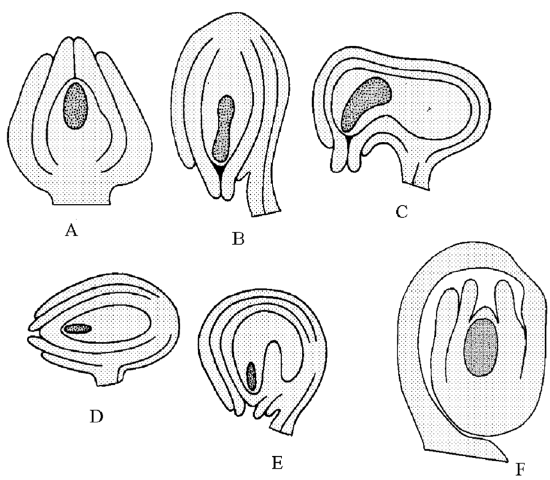

Figure 2.20: Ovules. A: Orthotropous; **B:** Anatropous; **C:** Campylotropous; **D:** Hemianatropous; **E:** Amphitropous; **F:** Circinotropous.

FRUITS

A fruit is a matured and ripened ovary, wherein the ovary wall gets converted into the fruit wall **pericarp** (differentiated into outer **epicarp**, middle **mesocarp** and inner **endocarp**), and the ovules into seeds. Three main categories of fruits are recognized: **simple fruits** developing from a single ovary of the flower, **aggregate fruits** developing from several free carpels within the flower, and **composite fruits** involving several flowers or the whole inflorescence.

Simple Fruits

A simple fruit develops from a flower having a single carpel or several united carpels so that the flower has a single ovary. Such a fruit may be dehiscent opening by a suture exposing seeds or remain indehiscent.

Dehiscent Fruits

Such fruits are generally dry and burst along the suture to release their seeds. Common types are enumerated below:

Follicle: Fruit developing from superior monocarpellary ovary and dehiscing along one suture, as in *Consolida*.

Legume or pod: Fruit developing like follicle from monocarpellary superior ovary but dehiscing along two sutures, as in legumes.

Lomentum: Modified legume, which splits transversely at constrictions into one- or many-seeded segments, as in *Mimosa*. Sometimes considered as a type of schizocarpic fruit.

Siliqua: Fruit developing from bicarpellary syncarpous superior ovary, which is initially one chambered but subsequently becomes two chambered due to the formation of a **false septum**, visible on the outside in the form of a rim known as **replum**. The fruit dehisces along both sutures from the base upwards, valves separating from septum and seeds remaining attached to the rim (replum), characteristic of the family Brassicaceae. The fruit is narrower and longer, at least three times longer than broad, as in *Brassica* and *Sisymbrium*.

Silicula: Fruit similar to siliqua but shorter and broader, less than three times longer than broad as seen in *Capsella*, *Lepidium* and *Alyssum*. Silicula is commonly flattened at right angles to the false septum (*Capsella*, *Lepidium*) or parallel to the false septum (*Alyssum*).

Capsule: Fruit developing from syncarpous ovary and dehiscing in a variety of ways:

- **Circumscissile (pyxis):** Dehiscence transverse so that top comes off as a lid or operculum, as in *Anagallis arvensis*.
- **Poricidal:** Dehiscence through terminal pores as in poppy (*Papaver*).
- **Denticidal:** Capsule opening at top exposing a number of teeth as in *Primula* and *Cerastium*.
- **Septicidal:** Capsule splitting along septa and valves remaining attached to septa as in *Linum*.
- **Loculicidal:** Capsule splitting along locules and valves remaining attached to septa, as in family Malvaceae.
- **Septifragal:** Capsule splitting so that valves fall off leaving seeds attached to central axis as in *Datura*.

Schizocarpic Fruits

This fruit type is intermediate between dehiscent and indehiscent fruits. The fruit, instead of dehiscing, rather splits into number of segments, each containing one or more seeds. Common examples of schizocarpic fruits are:

Cremocarp: Fruit developing from bicarpellary syncarpous inferior ovary and splitting into two one seeded segments known as **mericarps,** as in umbellifers.

Carcerulus: Fruit developing from bicarpellary syncarpous superior ovary and splitting into four one seeded segments known as nutlets, as in family Lamiaceae.

Double samara: Fruit developing from syncarpous ovary, two or four chambered, pericarp of each chamber forming a wing, fruit splitting into one-seeded winged segments as in maple (*Acer*). It must be noted that **single samara** of *Fraxinus*, is a single-seeded dry winged indehiscent fruit and not a schizocarpic fruit.

Regma: Fruit developing from multicarpellary syncarpous ovary and splitting into one-seeded **cocci,** as in *Ricinus* and *Geranium*.

Indehiscent Fruits

Such fruits do not split open at maturity. They may be dry or fleshy:

Dry indehiscent fruits: Such fruits have dry pericarp at maturity, and are represented by:

- **Achene:** Single seeded dry fruit developing from a single carpel with superior ovary. Fruit wall is free from seed coat. Achenes are often aggregated, as in family Ranunculaceae.
- **Cypsela:** Single seeded dry fruit, similar to (and often named achene) but developing from bicarpellary syncarpous inferior ovary, as in family Asteraceae.
- **Caryopsis:** Fruit similar to above two but fruit wall fused with seed coat as seen in grasses.
- **Nut:** One-seeded, generally large fruit developing from multicarpellary ovary and with hard woody or bony pericarp, as seen in *Quercus* and Litchi.

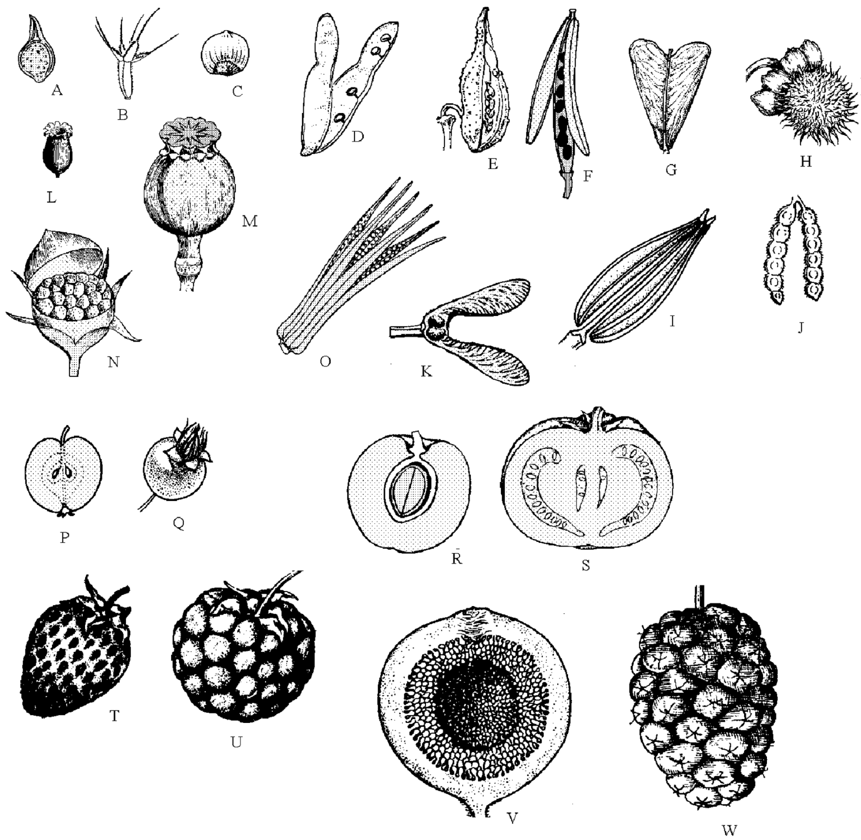

Figure 2.21: Fruits. A: Achene of *Ranunculus*; **B:** Cypsela of *Ageratum* with scaly pappus; **C:** Nut of *Castanea*; **D:** Pod of *Pisum*; **E:** Single follicle of *Calotropis*; **F:** Siliqua of *Brassica*; **G:** Silicula of *Capsella bursa-pastoris*; **H:** Capsule of *Datura*; **I:** Cremocarp in umbellifers; **J:** A pair of lomentum fruits in *Mimosa*; **K:** Double samara of *Acer*; **L:** Capsule of *Primula* dehiscing by apical teeth (denticidal); **M:** Operculate capsule of *Papaver* with poricidal dehiscence; **N:** Pyxis of *Celosia* with circumscissile dehiscence; **O:** Capsule of *Abelmoschus esculentus* with loculicidal dehiscence; **P:** Pome of *Malus pumila*; **Q:** Hip of *Rosa* with etaerio of achenes inside; **R:** Drupe of *Prunus*; **S:** Berry of *Solanum lycopersicum*; **T:** Pseudocarp of *Fragaria*, an accessary fruit with etaerio of achenes; **U:** Etaerio of drupes in *Rubus*; **V:** Syconium of *Ficus* developing from hypanthodium inflorescence; **W:** Sorosis of *Morus*.

Utricle: Like nut but with papery often inflated pericarp as in *Chenopodium*.

Fleshy indehiscent fruits: Such fruits have fleshy and juicy pericarp even at maturity. Common examples are:

Drupe: Fruit with usually skinny epicarp, fibrous or juicy mesocarp and hard stony endocarp, enclosing single seed, as seen in mango, plums and coconut.

Berry: Fruit with uniformly fleshy pericarp with numerous seeds inside, as seen in *Solanum*, tomato and brinjal.

Pepo: Fruit formed from inferior ovary of cucurbits with epicarp forming tough rind.

Hesperidium: Fruit developing from superior ovary with axile placentation, epicarp and mesocarp forming common rind and endocarp produced inside into juice vesicles, as seen in citrus fruits.

Pome: Fruit developing from inferior ovary, an example of **accessory (false) fruit,** wherein fleshy part is formed by thalamus and cartilaginous pericarp is inside, as seen in apple.

Balausta: Fruit developing from inferior ovary, pericarp tough and leathery, seeds attached irregularly, succulent testa being edible, as seen in pomegranate (*Punica granatum*).

Aggregate Fruits

Aggregate fruits develop from multicarpellary apocarpous ovary. Each ovary forms a fruitlet, and the collection of fruitlets is known as **etaerio**. Common examples are **etaerio of achenes** in Ranunculaceae, **etaerio of follicles** in *Calotropis*,

etaerio of drupes in raspberry (*Rubus*) and **etaerio of berries** in *Polyalthia*. In Rose the etaerio of achenes is surrounded by a cup like hypanthium forming a specialized accessory fruit known as **hip**. The fruit of strawberry (*Fragaria*), though also an etaerio of achenes, is an accessory fruit, the edible part being the fleshy thalamus.

Multiple (Composite) Fruits

A multiple fruit involves ovaries of more than one flower, commonly the whole inflorescence. Common examples are:

Sorosis: Composite fruit develops from the whole inflorescence and floral parts become edible, as seen in *Morus* (having fleshy perianth but dry seeds) and *Artocarpus* (with fleshy rachis, perianth and edible seeds).

Syconium (**syconus**)**:** Fruit developing from hypanthodium inflorescence of figs. There is a collection of achenes or drupes (surrounded by endocarp) borne on the inside of fleshy hollow receptacle.

FLORAL FORMULA

The floral formula enables convenient graphical representation of essential floral characteristics of a species, mainly incorporating its sexuality, symmetry, number and fusion of floral parts and ovary position. It is more convenient to represent Calyx by K (or CA), Corolla by C (or CO), Perianth by P, Androecium by A and Gynoecium by G. The number of parts in a floral whorl are indicated by a numeral (as such when free, but when united within parentheses or a circle). Adnation between whorls is indicated by a curve (above or below). Inferior ovary has a line above G, while the superior ovary has one below.

Representative floral formulae of some species of angiosperms are presented in Figure 2.22. Alongside each floral formula is given a list of features of the species on which the floral formula is constructed.

FLORAL DIAGRAM

The floral diagram is a representation of the cross-section of the flower, floral whorls arranged as viewed from above. The floral diagram not only shows the position of floral parts relative to the mother axis and each other, but also their number, fusion or not, overlapping, the presence and position of bracts, insertion of stamens, the number of anther sacs, whether the anthers are extrorse or introrse, and more importantly, a section through the ovary, depicting the type of placentation, the number of ovules visible in a section, and the presence or absence of a nectary. It also if some stamens are nonfunctional (represented by staminodes) and whether the ovary is functional or represented by a pistillode.

The branch (or the inflorescence axis) bearing the flower is known as **mother axis**, and the side of flower facing it as **posterior side**. The bract, if present is opposite the mother axis, and the side of flower facing it is the anterior side. The remaining components of the flower—depending upon whether they are closer to the mother axis or the bract—occupy postero-lateral and antero-lateral positions, respectively. The members of different floral whorls are shown arranged in concentric rings, calyx being the outermost and the gynoecium the innermost. A large majority of dicot flowers are pentamerous, and as such the five members of each whorl (excluding gynoecium in the centre) are arranged such a way that four of them occur in pairs (members of each pair occupying complementary position) the fifth one is the odd member. It is also to be remembered that in large majority of dicots (except Fabaceae and few others), the odd sepal occupies posterior position (of the remaining four, two form antero-lateral pair, and the remaining two the postero-lateral pair). The different whorls usually alternate each other, and accordingly the odd petal occupies anterior position, the petals alternate with sepals. The stamens accordingly alternate with petals and are opposite the sepals. In flowers with two whorls of stamens, the outer whorl alternates with petals, whereas the inner is opposite the petals (because it alternates with the outer whorl of stamens). The stamens are represented in the floral diagram by anthers, each with two anther lobes (shown by a deep fissure) and latter, in turn, with two anther sacs (with a less deep cleft). The lobes face towards the outside in extrorse anthers and towards the ovary in introrse anthers. Epipetalous stamens are shown by a line joining the anthers with the petals. A few representative types of floral diagram are shown in Figure 2.23.

The floral diagram summarizes the information about the presence or absence of bracts and bracteoles, number, fusion and aestivation of sepals and petals (or tepals if there are no separate sepals and petals, as shown in Moraceae). The calyx and corolla forming bilabiate arrangement are appropriately shown with the number of lobes in upper and lower lip (as seen in Lamiaceae). The stamens with united filaments are depicted by joining anthers via lines (diadelphous condition in Fabaceae-Faboideae), whereas the united anthers are shown by physically touching anther margins. In families with complex floral arrangement such as the cyathium in *Euphorbia*, floral diagram for the entire cyathium may be drawn, supplemented by floral diagrams of male and female flowers. In family Poaceae also, it is helpful to make a floral diagram for the whole spikelet (shown in *Avena sativa*), or separate diagrams for male and female spikelets if the male and female flowers occur in separate inflorescences or at least separate spikelets (shown in *Zea mays*).

Family	***Species***	***Floral Formula***	
Solanaceae	*Solanum nigrum*	$\oplus$ ⚥ $K_{(5)}\overset{\frown}{C_{(5)}A_{5}}G_{(\underline{2})}$	Flowers actinomorphic, bisexual, sepals 5 united, petals 5 united, stamens 5 free epipetalous, carpels 2 united, ovary superior.
Lamiaceae	*Ocimum basilicum*	% ⚥ $K_{(1/4)}\overset{\frown}{C_{(4/1)}A_{2+2}}G_{(\underline{2})}$	Flowers zygomorphic, bisexual, calyx bolabiate, upper lip 1 lobed lower 4 lobed, corolla bilabiate, upper lip 4 lobed lower 1 lobed, stamens 4 didynamous epipetalous, carpels 2 united, ovary superior.
Brassicaceae	*Brassica campestris*	$\oplus$ ⚥ $K_{2+2}C_{4\times}A_{2+4}G_{(\underline{2})}$	Flowers actinomorphic, bisexual, sepals 4 fee in 2 whorls, petals 4 cruciform, stamens 6 tetradynamous, carpels 2 united, ovay superior.
Fabaceae	*Lathyrus odoratus*	% ⚥ $K_{(5)}C_{1+2+(2)}A_{1+(9)}G_{\underline{1}}$	Flowers zygomorphic, bisexual, sepals 5 united, petals 5 free papilionaceous, stamens 10, diadelphous 9 united 1 free, carpel 1, ovary superior.
Malvaceae	*Hibiscus rosa-sinensis*	$\oplus$ ⚥ Epi $K_{5\text{-}7}K_{(5)}C_{5}A_{(\infty)}G_{(\underline{5})}$	Flowers actinomorphic, bisexual, epicalyx 5-7 free, sepals 5 united, petals 5 free, stamens many monadelphous epipetalous, carpels 5 united, ovary superior.
Asteraceae	*Helianthus annuus*	**Ray floret** % ♀ $K_{pappus}C_{(5)}A_{0}G_{(\overline{2})}$ **Disc floret** $\oplus$ ⚥ $K_{pappus}\overset{\frown}{C_{(5)}A_{(5)}}G_{(\overline{2})}$	Flowers of 2 types. Ray florets zygomorphic, pistillate, calyx represented by pappus, petals 5 united, stamens absent, carpels 2 united, ovary inferior. Disc floret actinomorphic, bisexual,calyx represented by pappus, corolla 5 united, stamens 5 epipetalous united (syngenesious), carpels 2, united, ovary inferior.
Chenopodiaceae	*Chenopodium album*	$\oplus$ ⚥ $P_{(5)}A_{5}G_{(\underline{2})}$	Flowers actinomorphic, besexual, tepals 5 united, stamens 5 free, carpels 2 united, ovary superior.
Caryophyllaceae	*Stellaria media*	$\oplus$ ⚥ $K_{5}C_{5}A_{5+5}G_{(\underline{3})}$	Flowers actinomorphic, bisexual, sepals 5 free, petals 5 free, stamens 10 in two whorls, carpels 3 united, ovary superior.

Figure 2.22: Floral formulae of some representative species of few families of angiosperms depicting diversity of features depicted. The important features on which each formula is based are shown in the right column.

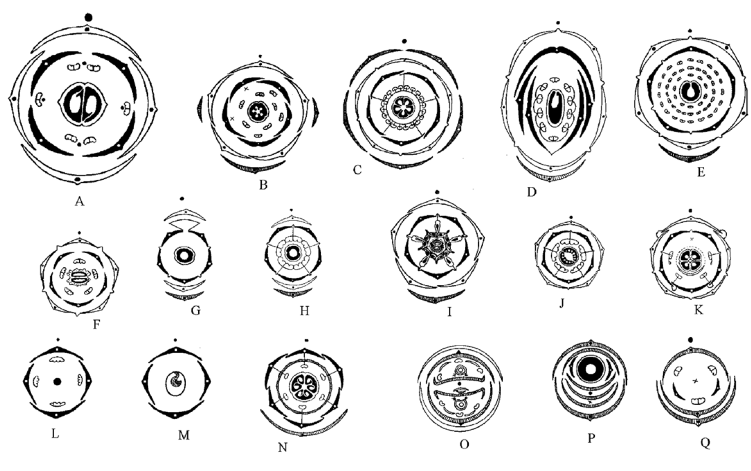

Figure 2.23: Floral diagrams of some representative members of major families. A: *Brassica campestris* (Brassicaceae); **B:** *Stellaria media* (Caryophyllaceae); **C:** *Hibiscus rosa-sinensis* (Malvaceae); **D:** *Lathyrus odoratus* (Fabaceae-Faboideae); **E:** *Acacia nilotica* (Fabaceae-Mimosoideae); **F:** *Foeniculum vulgare* (Apiaceae); **G:** Ray floret of *Helianthus annuus* (Asteraceae); **H:** Disc floret of *H. annuus*; **I:** *Calotropis procera* (Apocynaceae-Asclepiadoideae); **J:** *Withania somnifera* (Solanaceae); **K:** *Ocimum basilicum* (Lamiaceae); **L:** Male flower of *Morus alba* (Moraceae); **M:** Female flower of *M. alba*; **N:** *Narcissus pseudo-narcissus* (Amaryllidaceae); **O:** *Avena sativa* (Poaceae), floral diagram of spikelet; **P:** *Zea mays* (Poaceae), floral diagram of female spikelet; **Q:** *Z. mays*, floral diagram of male spikelet.

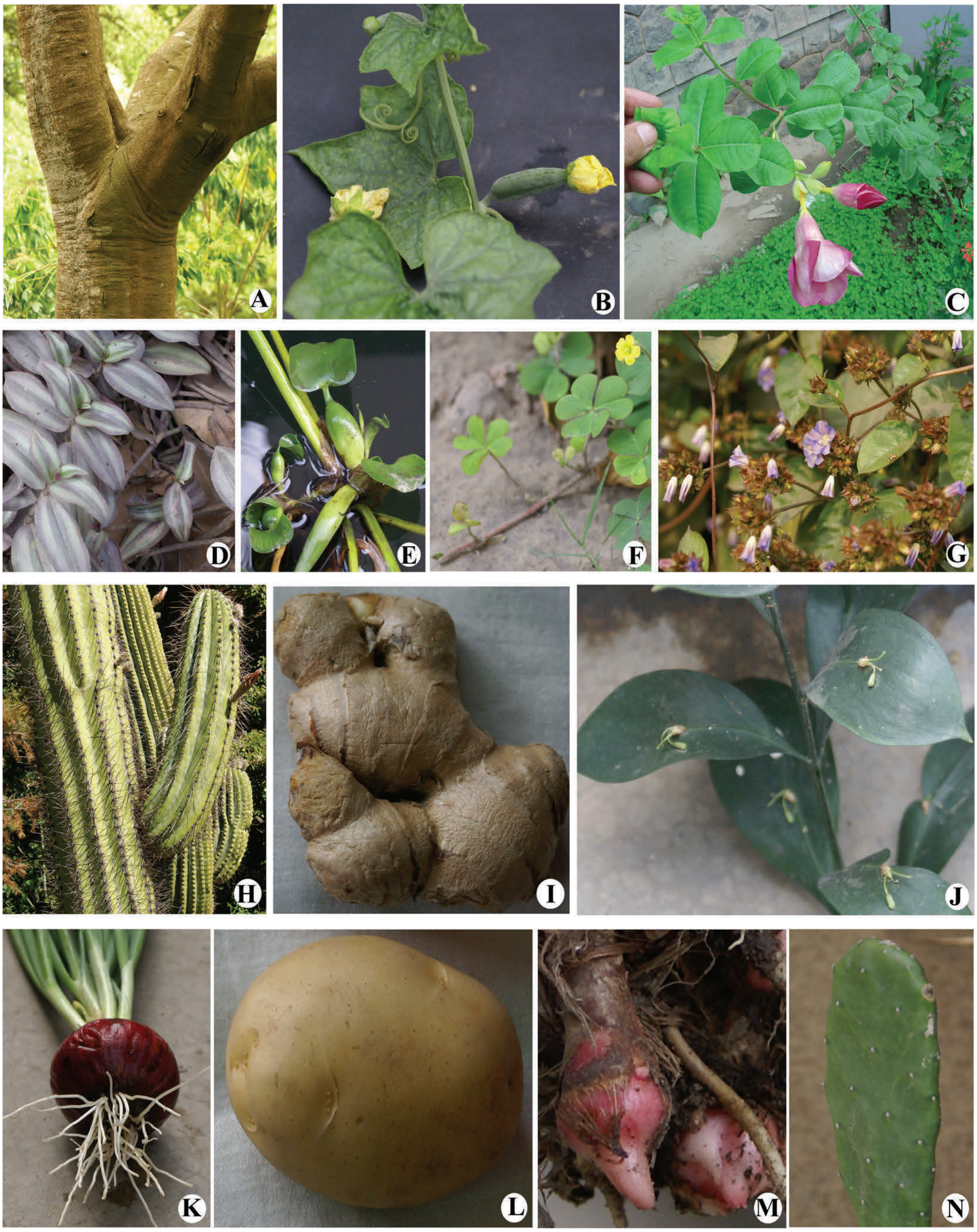

Figure 2.24: Stems. A: Arboreus stem (trunk) of *Cyclobalanopsis glauca*; **B:** Tendril climbing stem of *Luffa cylindrica*; **C:** Scandent stem of *Allamanda violacea*; **D:** Creeping stem of *Zebrina pendula*; **E:** Offset of *Eichhornia crassipes*; **F:** Runner of *Oxalis corniculata*; **G:** Twining stem of *Jacquemontia pentantha*; **H:** Succulent stem of *Echinopsis terescheckii*; **I:** Rhizome of *Zingiber officinale*; **J:** Phylloclade of *Ruscus aculeatus*; **K:** Bulb of *Allium cepa*; **L:** Tuber of *Solanum tuberosum*; **M:** Corm of *Alocasia*; **N:** Phylloclade of *Opuntia elatior*.

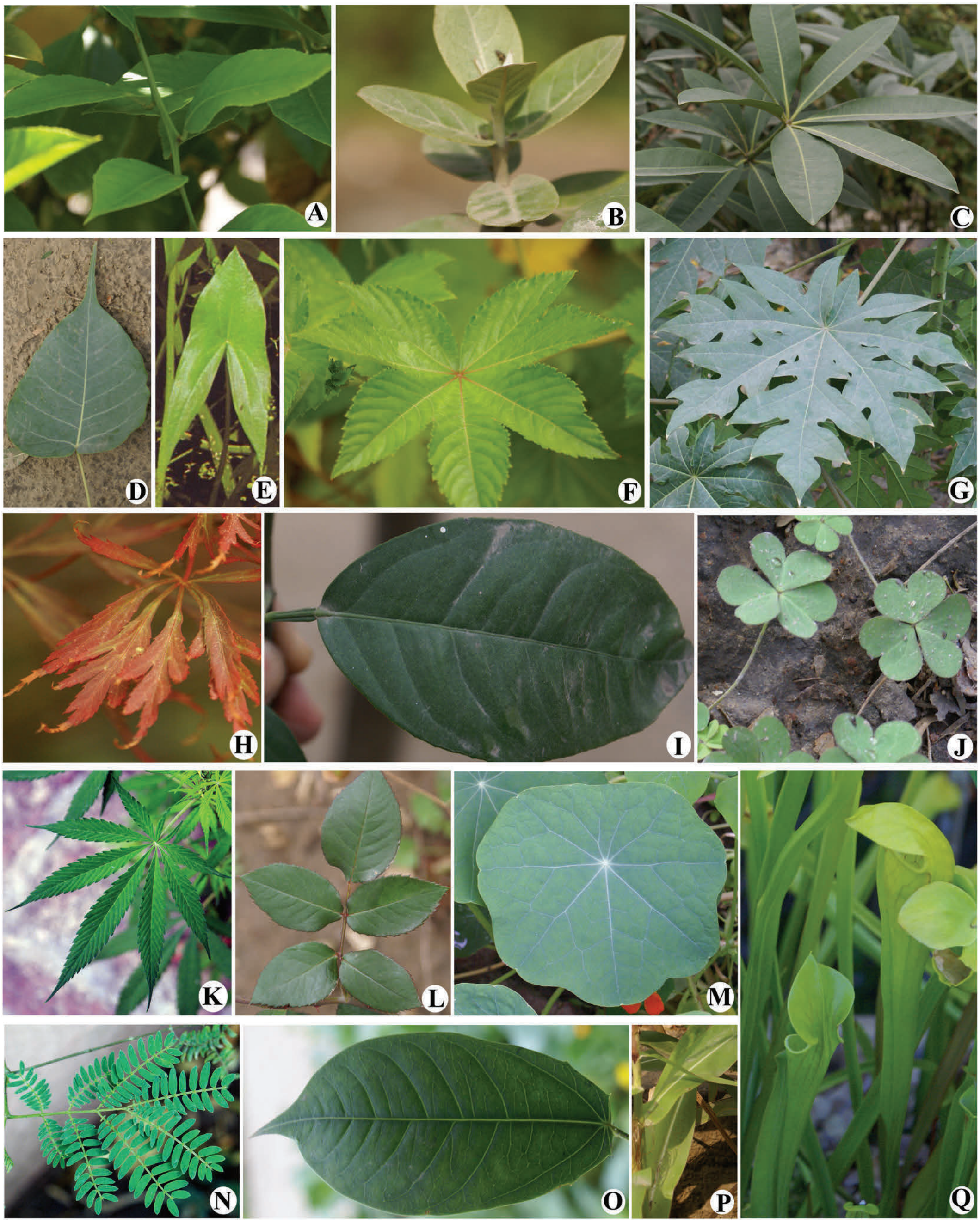

Figure 2.25: **Leaves. A:** Alternate phyllotaxy in *Citrus*; **B:** Opposite decussate phyllotaxy in *Calotropis procera*; **C:** Whorled phyllotaxy in *Alstonia scholaris*; **D:** Ovate long acuminate leaf of *Ficus religiosa*; **E:** Sagittate leaf of *Sagittaria sagitifolia*; **F:** Palmately lobed leaf of *Rubus trifidus*; **G:** Palmately lobed leaf-lobes further pinnately lobed in *Carica papaya*; **H:** Palmate leaf of *Acer palmatum*; **I:** Unifoliate compound leaf of *Citrus medica*; **J:** Palmately trifoliate compound leaf of *Oxalis corniculata*; **K:** Palmate compound leaf of *Cannabis sativa*; **L:** Pinnate compound leaf of *Rosa*; **M:** Peltate orbicular leaf of *Tropaeolum majus*; **N:** Bipinnate compound leaf of *Leucaena leucocephala*; **O:** Panduraeform leaf of *Jatropha panduraefolia*; **P:** Grass leaf with leaf sheath and free lamina of *Zea mays*; **Q:** Pitcher leaf of *Sarracenia flava*.

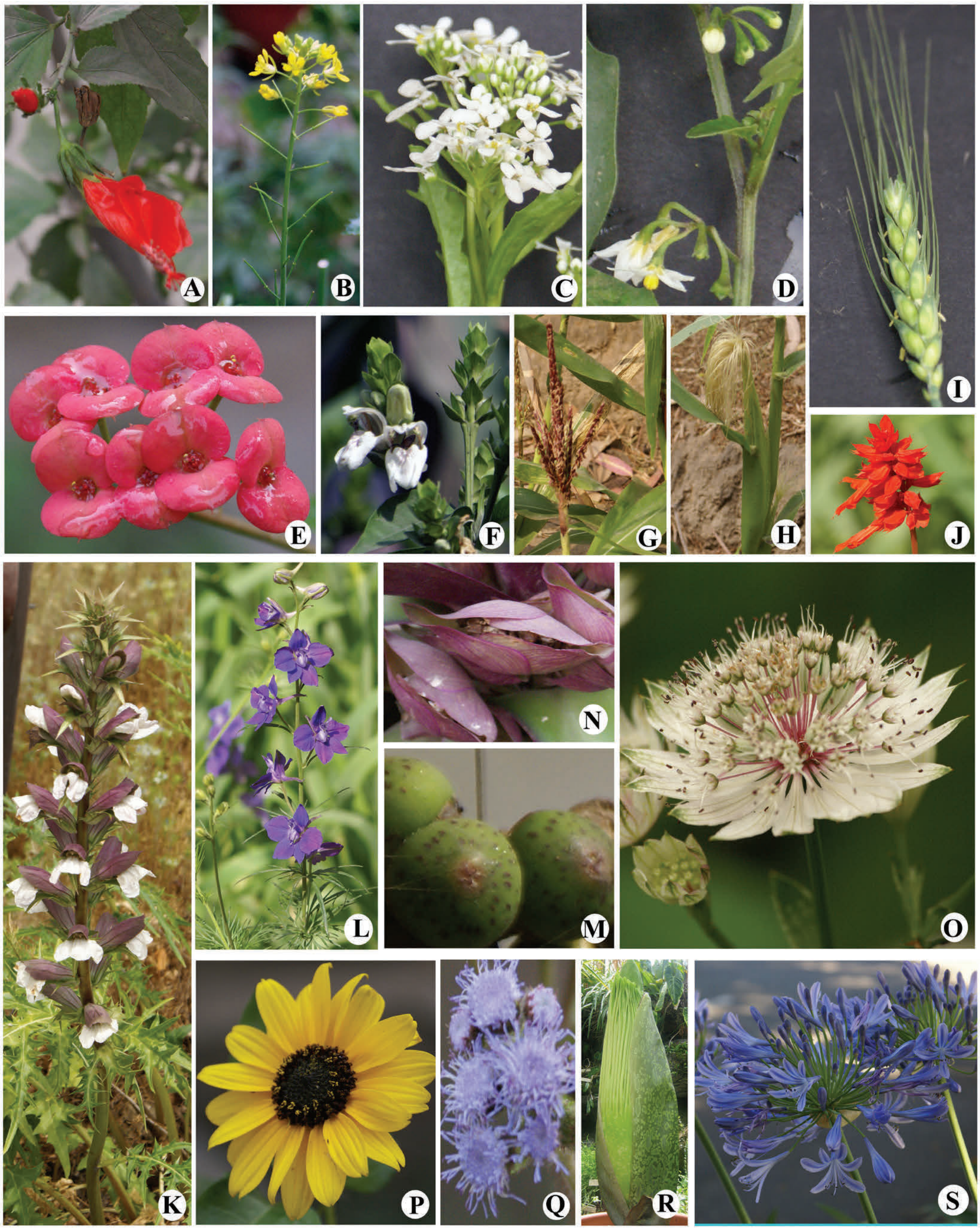

Figure 2.26: Inflorescences. A: Solitary flower of *Malvaviscus arboreus*; **B:** Corymbose-raceme of *Brassica campestris*; **C:** Corymb of *Iberis amara*; **D:** Rhipidium of *Solanum nigrum*; **E:** Cyathium of *Euphorbia milii*; **F:** Spike of *Adhatoda vasica*; **G:** Panicle of spikelets of *Zea mays*; **H:** Cob (spike of spikelets) of *Zea mays*; **I:** Spike of spikelets of *Triticum aestivum*; **J:** Raceme of verticillasters in *Salvia splendens*; **K:** Spike of *Acanthus spinosus*; **L:** Raceme of *Delphinium ajacis*; **M:** Hypanthodium of *Ficus religiosa*; **N:** Cymose cluster with spathaceous bracts of *Tradescatia spathacea (syn: Rhoeo discolor)*; **O:** Umbel of *Astrantia major*; **P:** Radiate capitulum of *Helianthus debilis*; **Q:** Discoid capitulum of *Ageratum houstonianum*; **R:** Spadix of *Amorphophalus titanum*; **S:** Cymose umbel of *Agapanthus umbellatus*.

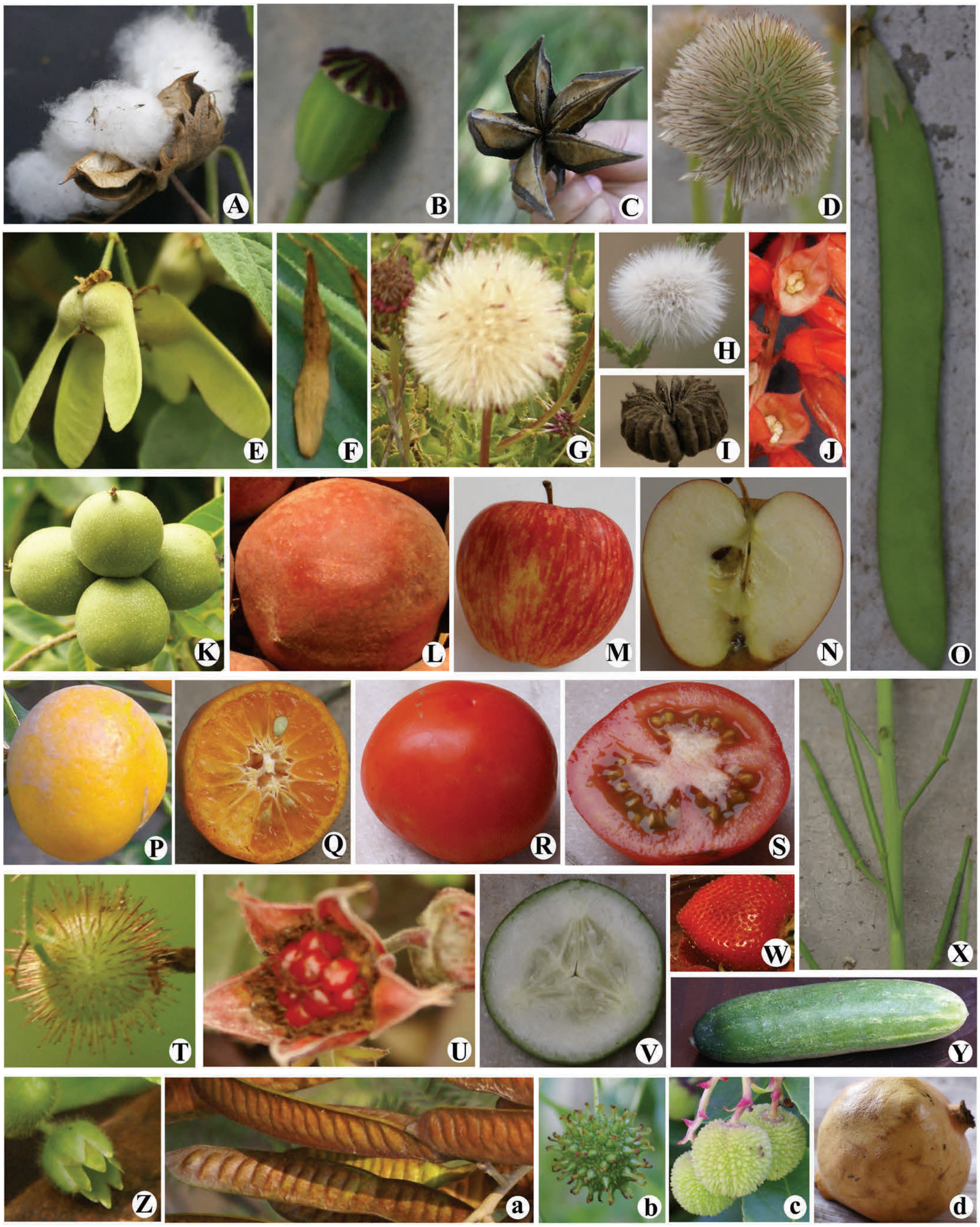

Figure 2.27: **Fruits. A:** Dehisced capsule of *Gossypium hirsutum* with exposed hairy seeds; **B:** Capsule of *Papaver orientale*; **C:** Dehisced capsule of *Chiranthodendron pentadactylon*; **D:** etaerio of achenes of *Anemone occidentalis*; **E:** Double samara of *Acer griseum*; **F:** Pod of D*albergia sissoo*; **G:** Cypsela of *Haplopappus macrocephalus*; **H:** Cypsela of *Sonchus oleraceous*; **I:** Schizocarp of *Abutilon indicum*; **J:** Carcerulus of *Salvia splendens*; **K:** Drupe of *Juglans nigra*; **L:** Drupe of *Prunus persica*; **M:** Pome of *Malus pumila*; **N:** Same in Longitudinal section; **O:** Pod of *Clitoria ternatea*; **P:** Hesperidium of *Citrus sinensis*; **Q:** Same in Transverse section; **R:** Berry of *Lycopersicon esculentum*; **S:** Same in Transverse section; **T:** Berry of *Ribes menziesii*; **U:** Etaerio of drupes of *Rubus nepalensis*; **V:** Pepo of *Cucumis sativus* in Transverse section; **W:** Whole pepo; **X:** Accessory fruit of *Fragaria vesca*; **Y:** Siliqua of *Brassica campestris*; **Z:** Dehisced capsule of *Stellaria media*; **a:** Pod of *Leucaena leucocephala*; **b:** Multiple fruit of *Liquidambar styraciflua*; **c:** Multiple fruit of *Arbutus unedo*; **d:** Balausta of *Punica granatum*.

Chapter 3

Process of Identification

Recognizing an unknown plant is an important constituent taxonomic activity. A plant specimen is identified by comparison with already known herbarium specimens in a herbarium, and by utilizing the available literature and comparing the description of the unknown plant with the published description/s. Since the bulk of our plant wealth grows in areas far removed from the centers of botanical research and training, it becomes imperative to collect many specimens on each outing. For proper description and documentation, these specimens must be suitably prepared for incorporation and permanent storage in herbarium. This goes a long way in compiling floristic accounts of the different regions of the world. The availability of the specimens in the herbaria often provides reasonable information about the abundance or rarity of a species and helps in preparing lists of rare or endangered species and provides sufficient inputs for efforts towards their conservation.

SPECIMEN PREPARATION

A specimen meant for incorporation in a herbarium needs to be carefully collected, pressed, dried, mounted and finally properly labelled, so that it can meet the demands of rigorous taxonomic activity. Specimens, properly prepared, can retain their essential features for a very long period, proving to be immensely useful for future scientific studies, including compilation of floras, taxonomic monographs and, in some cases, even experimental studies, since the seeds of several species can remain viable for many years even in dry herbarium specimens.

Fieldwork

The fieldwork of specimen preparation involves plant collection, pressing and partial drying of the specimens. The plants are collected for various purposes: building new herbaria or enriching older ones, compilation of floras, material for museums and class work, ethnobotanical studies, and introduction of plants in gardens. In addition, bulk collections are done for trade and drug manufacture. Depending on the purpose, resources, proximity of the area and duration of studies, fieldwork may be undertaken in different ways:

Collection trip: Such a trip is of short duration, usually one or two days, to a nearby place, for brief training in fieldwork, vegetation study and plant collection by groups of students.

Exploration: This includes repeated visits to an area in different seasons, for a period of a few years, for intensive collection and study, aimed at compilation of floristic accounts.

Expedition: Such a visit is undertaken to remote and difficult area, to study the flora and fauna, and usually takes several months. Most of our early information on Himalayan flora and fauna has been the result of European and Japanese expeditions.

Equipment

The equipment for fieldwork may involve a long list, but the items essential for collection include plant press, field notebook, bags, vasculum, pencil, cutter, pruning shears, knife and a digging tool (Figure 3.1).

Plant Press

A plant press consists of two wooden, plywood or wire mesh planks, each 12 inches × 18 inches (30 cm × 45 cm), between which are placed corrugated sheets, blotters and newspaper sheets (Figure 3.2). Two straps, chains or belts are used to