THE SCIENCE OF PHYTOSYSTEMATICS

Phytosystematics is a science within Botany, including traditional **taxonomy**, the description, identification, nomenclature and classification of plants. Its subject is the plant kingdom, and its main goal is to establish a system that reflects relationships between various plant species and plant groups.

In a narrower sense, **systematics** determines the level of relatedness between plants; whereas **taxonomy** classifies related plant groups (taxa) into a hierarchical system. **Phylogenetic systematics** or **cladistics** is the branch of systematics whose primary goal is to reconstruct phylogeny, the evolutionary history (development) of organisms.

Description is the assignment of features or attributes to a taxon (Plural: taxa, meaning defined plant groups). The features are called **characters**.

Identification is the process of associating an unknown taxon with a known one, usually with the help of an **identification key** or taxonomic key. One generally identifies an unknown by first noting its characteristics, that is, by describing it. Then, these features are compared with those of other taxa to see if they conform.

Nomenclature is the formal naming of taxa according to some standardized system. For plants, algae and fungi, the rules and regulation for the naming of taxa are provided by the International Code of Botanical Nomenclature (ICBN). These formal names are known as **scientific names** (see below).

Classification is the arrangement of entities (in our case, plant taxa) into some type of order. The categories (so-called ranks) express relationships between plant taxa.

THE HISTORY OF PLANT SYSTEMATICS

The history of plant systematics stretches from the work of ancient Greek to modern evolutionary biologists. At ancient times, studying of plants was usually treated as part of the study of medicine. Later, classification and description was driven by natural history. The introduction of the theory of evolution, and the professionalization of botany in the 18th and 19th century marked a shift toward the more holistic classification methods, eventually based on evolutionary relationships.

Antiquity

The origins of botanical classification lie in folk taxonomy and ancient Greece. *Theophrastus* (372-287 BC), a student of Aristotle, produced *De Historia Plantarum*, the earliest surviving "book" on plants, where he listed the names of over 500 plant species. However, he did not use a formal classification system, instead he relied on the common groupings of folklore, combined with growth form: trees, shrubs, herbs, perennials.

The *Materia Medica* of *Dioscorides* (1st century BC) was also an important early compendium of nearly 600 plant descriptions, recognizing already some natural groups like conifers, trees with catkins, or grasses.

The book series *Historia Naturalis* of Caius Plinius Secundus (23-79 AD) included a book on botany, describing more than 1000 plant species.

Ibn Sina Bohara (known also as *Avicenna*) (980-1037) published the textbook *Canon Medicinae*, which was a standard medical text in Europe and the Islamic world up until the 18th century. The second volume contained the description of 780 medicinal plants.

Early Modern Period

In the 16th century, works (so-called herbaria) by *Otto Brunfels*, *Hieronymus Bock* and *Leonhart Fuchs* helped to revive interest in natural history based on first-hand observation. *Herbarium* (Plural: herbaria) in this period meant a collection of plant descriptions, illustrated with drawings or woodcuts. With the influx of exotic species in the Age of Exploration (Europeans establishing direct contact with Africa, the Americas, Asia and Oceania), the number of known species expanded rapidly, but most authors were far more interested in the medicinal properties of individual plants than in establishing a classification system.

The most significant herbaria from the 16th century include those of the German authors *Lonicerus* and *Tabernaemontanus*, the Italian *Mattiolo*, the Hungarian *György Lencsés*, *Péter Melius Juhász* and *András Beythe*. From the 17th-18th-century Hungarian authors we can highlight *János Kájoni*, *János Lippay*, *Ferenc Pápai Páriz* and *József Csapó*. The famous Hungarian botanist, *Pál Kitaibel* (1757-1817) described 150 plant species, native to Hungary, for the first time. The most well-known Hungarian herbarium of the 19th century was compiled by *Sámuel Diószegi* and *Mihály Fazekas*.

Artificial Systems

The artificial classification systems were based on **few, arbitrarily chosen features** of the studied plant species and groups.

The most influential books include those of *Andrea Caesalpino* and *Caspar Bauhin*. ***Caesalpino*** (1519-1605) described about 1500 plant species, already recognizing some natural plant families, basing his system on the structure of fruits. ***Bauhin*** (1560-1624) described over 6000 plants, which he arranged into 12 books and 72 sections, based on a wide range of common characteristics. He used an early form of binomial nomenclature, and included synonyms of plant names.

In the late 17th century, the most influential classification schemes were those of English botanist *John Ray* and French botanist *de Tournefort*. ***Ray*** (1627-1705), who listed over 18,000 plant species in his works, is credited with establishing the monocot/dicot division, and some of his groups, e.g. legumes and grasses, are still valid today. ***Tournefort*** (1656-1708) used an artificial system, in which he classified about 9000 plant species into 698 genera and 22 classes. His system was adopted in France and elsewhere in Europe up until Linnaeus.

The books that had an enormous accelerating effect on natural science and plant systematics in particular, were the works of ***Carolus Linnaeus*** (1707-1778), also known as Carl Linné or Carl von Linné, a Swedish doctor and botanist. *Systema Naturae* (1735) declared the basic classification principles of minerals, animals and plants. ***Genera Plantarum*** (1737) provided the detailed description of plant genera. ***Species Plantarum*** (1753) presented a complete list of the plant species then known to Europe, listing altogether 7700 species and 1100 genera. Each species was given a binomial (consisting of two names) Latin name – for details see the chapter on **binomial nomenclature**. Linné's system also belonged to the artificial systems, which did not express relationships. The principle of classification was mainly based on flower structure, using the number and arrangement of the male and female sexual organs of the plants.

Natural Systems – Modern and Contemporary Periods

In natural systems several outer and inner plant features serve as the basis of classification, such as morphological and anatomical characters; later combined with phytochemical features (characteristic chemical compounds), and most recently even molecular genetic evidence.

Significant contributions to plant classification came from French botanists in the 18th and 19th centuries. *Familles des Plantes* (1763) by *Adanson* applied a wide range of plant features in classification. *Jussieu* distinguished the groups of monocots, dicots and plants with no cotyledons; apetalous, choripetalous and synpetalous plants; and plants with a superior or inferior ovary. The family *de Candolle* created a huge encyclopedic work *Prodromus Systematis Naturalis Regni Vegetabilis* (1823-1873). The Austrian botanist *Endlicher* distinguished the group of Thallophyta (lower plants with undifferentiated bodies) and Cormophyta (vascular plants).

A major influence on plant systematics was the theory of evolution, published by *Charles Darwin* in the *Origin of Species* (1859), resulting in the aim to group plants by their phylogenetic relationships. To this was added the interest in plant anatomy, aided by the use of the light microscope and the rise of chemistry, allowing the analysis of secondary metabolites.

Several authors contributed to developing phylogenetic systems, e.g. the British scientist *Hutchinson* (1884-1972), the Armenian Takhtadjan (1910-2009) and the American botanist Cronquist (1919-1992). In Hungary *Iconographia Florae Hungariae* (1934) was published by *Sándor Jávorka* and *Vera Csapody*, providing detailed descriptions and illustrations of plants in the Hungarian flora. The Hungarian botanist *Rezső Soó* (1903-1980) was the author of *Plant Systematics and Geobotany of the Hungarian Flora and Vegetation*.

Dahlgren (1932-1987) used chemotaxonomic elements extensively in his classification. A dahlgrenogram is a diagram showing the angiosperm orders as "bubbles", in which the number of species involved are indicated by size of the bubbles, whose relative positions reflect phylogenetical relationships. *Hegnauer* compiled volumes (1962-1996) on what compounds have been reported in which taxa.

Modern, so-called complex systems – taking into consideration a wide range of features, including morphological, anatomical, physiological, chemical and molecular characteristics – were created by *Ehrendorfer* (1991), *Thorne* (1992), *Frohne* (1992) and the Hungarian botanist *Attila Borhidi* (1993).

CHEMOTAXONOMY

Chemotaxonomic research involves various branches of chemistry, like analytical and structural chemistry, combined with taxonomic investigation. The basic principle of chemotaxonomy is that characteristic chemical compounds can provide useful additional information in classifying plants. As we have seen before, several taxonomists (e.g. Dahlgren) have applied the results of chemotaxonomic research in establishing their classification system.

Information-carrying molecules, termed **semantides** are crucial in plant classification. We can distinguish three levels of information-carriers: primary semantides (DNA), secondary semantides (RNA) and tertiary semantides (proteins).

Inorganic ions, in the forms of various **crystals** (calcium-oxalate and -carbonate crystals, as well as silicium-dioxide) are quite frequent in plants, but the composition and form of crystals can be characteristic to plant taxa. For example, calcium-oxalate raphids are typical in the orders Asparagales and Orchidales; calcium-carbonate cystoliths occur frequently in Urticales; and silicium-dioxide crystals are often present in Poales.

Even the **products of primary metabolism**, like simple sugars or sugar alcohols, as well as polysaccharides can aid classification. For example, sorbitol is characteristic in the family Rosaceae. Various fructose polymers are stored as nutrients (being an alternative to the more common starch accumulation): kestose in the family Poaceae, and inuline in Asteraceae.

The presence of **secondary metabolites** is highly significant in various medicinal plants, since in the majority of cases these metabolites act as the active compounds. Lipids (fatty acids and their esters); terpenoids (e.g. as components of essential oils and saponins); phenoloids (e.g. tannins and flavonoids); and nitrogen-containing substances (alkaloids and cyanogenic compounds) are all essential both for plant classification and pharmacological effect.

Chemotaxonomic features can be important on **various levels of plant classification**. Certain chemical compounds are characteristic for whole orders, others are valid at the family level, while still others can be the special feature of a single genus or even species. For example, the presence of various polyacetylenes is characteristic in the order Asterales, while iridoids are typical in Gentianales. The essential oil in the family Lamiaceae is composed mainly of monoterpenes, whereas in Asteraceae sesquiterpenes are dominant. Within the genus of horsetails, marsh horsetail (*Equisetum palustre*) accumulates toxic amounts of the alkaloid palustrine, while field horsetail (*E. arvense*) is not toxic and can be used for medical purposes.

The active compounds of a plant species are responsible for its physiological effect. Certain chemical compounds, e.g. alkaloids, always have a strong physiological effect, which is, however, dose-dependent. For example, small doses of the alkaloids atropine and scopolamine – frequent in the nightshade family (Solanaceae) – can be used for therapeutic purposes, but in high doses they are hallucinogenic and toxic. Pyrrolizidine alkaloids are typical in the borage family (Boraginaceae) and the aster family (Asteraceae). Due to their presence, these plants cannot be used internally, because in excessive amounts they can be carcinogenic and hepatotoxic.

Chemotaxonomy has its relevance for plant breeding, as well. For example, various poppy hybrids and varieties were developed, containing a special alkaloid spectrum or varying amounts of certain alkaloids. Breeding activity resulted in so-called morphine poppy, tebaine poppy and codeine poppy.

The presence (or absence) and the amount of active compounds is often determined by the life cycle of a plant. For example, various phenophases (like the phase before bloom, the phase of bloom, and the phase after bloom) can be characterized by varying amounts of protoanemonine in the representatives of the buttercup family (Ranunculaceae).

CLASSIFICATION

Classification is the arrangement of taxa into some type of order. The purpose of classification is to provide a system for cataloguing and expressing relationships between these entities. Taxonomists have traditionally agreed upon a method for classifying organisms that utilizes categories called **ranks**. Plant taxa are classified hierarchically by rank, in which a higher rank is inclusive of all lower ranks.

As we have seen earlier, a taxon is a group of organisms treated at a given rank. Thus, in the example of Table 1., presenting the major taxonomic ranks, Spermatophyta is a taxon placed at the rank of phylum; Dicotyledonopsida is a taxon placed at the rank of class; Polygonaceae is a taxon placed at the rank of family, etc.

Table 1. The primary taxonomic ranks accepted by the International Code of Botanical Nomenclature.

Major Taxonomic Ranks	Taxa
Kingdom	Plantae
Phylum (Division)	Spermatophyta
Class	Dicotyledonopsida
Order	Polygonales
Family	Polygonaceae
Genus (Plural: genera)	*Rumex*
Species (Plural: species)	*Rumex acetosa*

Note that taxa of a particular rank generally end in a particular suffix (Table 2.).

Table 2. Taxonomic ranks recognized by the ICBN. **Principal ranks** are in bold. <u>Secondary ranks</u> are underlined.

TAXONOMIC RANKS	ENDING	EXAMPLE TAXON
Kingdom	(various)	**Plantae**
Phylum (Division)	**-phyta**	**Spermatophyta**
Subphylum (Subdivision)	-phytina	Angiospermatophytina
Class	**-opsida**	**Dicotyledonopsida**
Subclass	-idae	Asteridae
Order	**-ales**	**Asterales**
Suborder	-ineae	Asterineae
Family	**-aceae**	**Asteraceae**
Subfamily	-oideae	Asteroideae
<u>Tribe</u>	-eae	Heliantheae
Subtribe	-inae	Helianthinae
Genus	(various)	***Helianthus***
Subgenus	(various)	*Helianthus*
<u>Section</u>	(various)	*Helianthus*
<u>Series</u>	(various)	*Helianthus*
Species [abbr. sp. (sing.), spp. (pl.)]	(various)	***Helianthus annuus***
Subspecies (abbr. subsp. or ssp.)	(various)	*Helianthus annuus* ssp. annuus
<u>Variety</u> (abbr. var.)	(various)	*Helianthus annuus* var. *annuus*
<u>Form</u> (abbr. f.)	(various)	*Helianthus annuus* f. *annuus*

One exception to these rank endings of taxa is the acceptance of eight *alternative* family names, none of which end in “-aceae”. These are:

- Leguminosae (= Fabaceae)
- Cruciferae (= Brassicaceae)
- Umbelliferae (= Apiaceae)
- Guttiferae (= Clusiaceae/Hypericaceae)
- Labiatae (= Lamiaceae)
- Compositae (= Asteraceae)
- Gramineae (= Poaceae)
- Palmae (= Arecaceae)

The prefix *sub-* can be used to denote taxa below one of the major ranks (e.g. subclass, subfamily). A **subspecies** (abbreviated as “ssp.”) or **variety** (abbreviated as “var.”) name is a **trinomial** (three names), e.g. *Cannabis sativa* ssp. *indica* or *Chenopodium ambrosioides* var. *anthelminthicum*. In these examples, the subspecific epithet is *indica*; the varietal epithet is *anthelminthicum*.

BOTANICAL NOMENCLATURE

Scientific Names

Scientific names are, by convention, in the Latin language. Every taxon (Plural: taxa), whether species, genus or family, can bear only one correct scientific name.

The scientific names of plant species are **binomials**, i.e. composed of two names. The binomial convention was first consistently used by Carolus Linnaeus, who is often referred to as the “father of taxonomy”. Prior to the use of binomials, the designation of species was inconsistent and may have utilized several words.

As an example of a binomial, the species commonly known as “dogrose” has the scientific name *Rosa canina*. The first name of the binomial, *Rosa* in this case, is the **genus name**, and is always capitalized (begins with an upper case letter).The genus name may be abbreviated by its first letter, but only if it was mentioned in the same text previously, and on this previous occasion it was spelled out in its entirety. Thus, the above scientific name may be abbreviated as *R. canina*. The second name of the binomial, *canina* in this example, is the **species name** (specific epithet), which is not capitalized (begins with a lower case letter). Binomial species names are usually italicized.

Common Names

In addition to scientific names, many taxa also bear **common names** (also called vernacular names), which are generally used by people within a limited geographic region. Common names are not formally published and are not governed by rules. Scientific names are much preferable to common names for several reasons.

First, **only scientific names are universal**, the same name used world-wide; common names may vary from region to region, even within a country. For example, species of the genus *Ipomoea* are known commonly as “morning glory” in the United States, but as “woodbine” in England. Differences in language, will, of course, further increase the number of different common names.

Second, **common names are not consistent**. One taxon may bear more than one common name, these often varying in different regions. For example, *Aconitum* species are known by several common names, like “aconite”, “monk’s hood”, “wolfsbane” or “devil’s helmet”. Alternatively, a single common name may refer to more than one taxon. “Hemlock” may refer to two quite different plants, either a species of *Tsuga*, a coniferous tree of the Abietaceae, or *Conium maculatum*, an herb of the Apiaceae (the extract of which Socrates drank in execution).

Third, **common names tell nothing about rank** and often nothing about classification, whereas scientific names automatically indicate rank and yield at least some information about their classification. For example, “goosefoot” tells nothing about rank; it could be variety, genus, species or family. However, one immediately knows that *Chenopodium album* is at the rank of species, and is a close relative to other species of *Chenopodium*, like *Ch. ambrosioides* or *Ch. bonus-henricus*.

Fourth, many, if not most, organisms have **no common name in any language**; thus scientific names alone must be used to refer to them. This is especially true for plants that are nonshowy, occur in remote areas, or belong to groups whose members are difficult to distinguish from one another.

AUTHORSHIP

All scientific names at and below the rank of family have an **author**, the name of the person who first validly published the name. For example, the full name (including authorship) of the family Rosaceae is “Rosaceae Jussieu”, because the French botanist, de Jussieu first formally named the family. The full name of hop (*Humulus lupulus*) is *Humulus lupulus* L. **–** L. being the abbreviation for Linnaeus, who gave the scientific binomial name to this plant species.

Although authorship is part of a scientific name, and should be cited in all scientific publications, in practice the author is not typically memorized or recited as part of a scientific name. In the present textbook also, author names are omitted, only the binomial name is given for each plant species.