Systematic Botany

©2014 by James V. Landrum

All content, both text and visual, not attributed to other sources is hereby ©2014 by James V. Landrum. All images used were taken or drawn by the author, and permission must be obtained to use these images or text.

Cover photograph: Trillium ovatum, a beautiful spring native.
Introduction—why I love plants

I grew up in rural southern Mississippi, and had always been interested in the nature of my area. My favorite tree was an old hickory down in our woods with initials carved by my parents when they were dating back in high school. Our woods gave us blackberries, huckleberries (a small blueberry), wild strawberries, etc.

However, for some reason, I became hooked on fossils. I began my college career as a Geology major with an emphasis in fossils (paleontology), and loved my fossil classes. Just as I was about to graduate, the job market crashed for Geologists, even those with many degrees and years of experience. I decided to finish my B.S. in Biology/Education in order to teach high school for a couple of years to survive until the Geology job market improved, but it never did.

While finishing my B.S., one of the very first plant classes I ever took was a plant biology course, and for the first time since my fossil classes, I didn't have to study to get good grades. This started me thinking about Botany as a major. Later, I took several plant identification courses, but, for some reason, we never went out into the field—instead, plants were brought into the lab for us to work on. Later, in graduate school in Mississippi, I was finally able to take field-oriented courses in plant identification. Some of these were Natural History of Plants (Dr. Sam Rosso), Dendrology (Dr. Jean Wooten), Aquatic Plants (Dr. Wooten), Plant Taxonomy (Dr. Rosso), etc. Those courses were challenging but very rewarding by giving me an in-depth knowledge of the plants around us. To this day, every time I go outside, I'm always among friends—my plant friends.

When I moved to Austin, Texas, to do my Ph.D. work, I moved from the subtropical climate of southern Mississippi to the near-desert conditions around Austin, and thus the plants changed as well—in fact, I had to basically start all over again in learning the various species in that part of Texas. One way I learned these was by taking so many pictures of plants that my wife threatened to break my camera, but it was a good way to learn a few hundred new species. Well, after spending 12 years in Kansas (1997-2009), I had to learn several hundred more new species. In 2009, we moved to WA, which meant I now had to assimilate the roughly 3,300 species found here!

Acknowledgements
First, I have to thank my wife for her patience and time spent helping spot wildflowers over the past few years—without her, none of this would be possible.

Secondly, I have to thank Dr. James Mauseth (University of Texas at Austin) and Dr. Sam Rosso (University of Southern Mississippi) for their patience with me over the years; Dr. Mauseth inspired a love of photography in me and Dr. Rosso’s field trips started me on this journey.
**Table of Contents**

1. **Chapter 1: Classifying Organisms** ................................................................. 5
2. **Chapter 2: Taxonomy** ....................................................................................... 15
3. **Chapter 3: Morphological & Anatomical Traits** ........................................... 20
4. **Chapter 4: Molecular Traits** ............................................................................ 49
5. **Chapter 5: Quick keys to identifying plants** ................................................. 54
Chapter 1: Classifying Organisms

Classification—creating order from apparent chaos

Separating plants based on traits is a common human event; even chimpanzees know which plants are “good” and which are “bad”, and pass this information on to their offspring. Most non-primates use plants mostly as food, but many animals also know which plants to eat if their tummies are upset or if they have a fever. You’ll often see your dog or cat eating grass to calm an upset stomach or as roughage in their diet.

Humans have made an art and a science out of classifying things. From the first farmers some 12,000 years ago to the present, we know which plants are “good” and which are “bad”, but now we also know how each is related to others like it or dissimilar to others.

Naming plants as species goes way back to the ancient Chinese and Egyptian civilizations, where each plant of agricultural or medicinal value was given a specific name. But what about those plants that didn’t fit into those two categories?

History of Plant Classification

I. Early scholars (500BC-1400AD)

About 370BC, a thinker named Plato conceived the idea of typology. In his concept, Plato wrote that the variations we see in living creatures is irrelevant; instead, he proposed that every living organism is constantly striving to achieve its ideal ‘type’, but that no organism will ever reach that goal.

However, his student, Aristotle (384-322BC), wrote a few years later that nature has too much variation for the idea of typology to exist. But about 350BC, Aristotle did try to organize the world he saw around him into a classification scheme based on naturally occurring variations.

He called this scheme “Nature’s Scale”, or in Latin, “Scala Naturae.” In his arrangement, Aristotle placed the non-animal organisms at the bottom of the scale, then the more complicated animals above that, and finally humans at the top of the scale.

Aristotle was later forced to retire from teaching, and his student, an herbalist named Theophrastus, took over his teachings and became the “founding father” of Botany. Theophrastus (371-286 BC) is considered to be the first Western botanist. He was the director of the first Botanical garden in Greece, and later wrote the book De historia Plantarum, a history of the plants of his time; he was the first writer to classify plants by their habits, either as trees, shrubs, or herbs. He noted differences in morphology and fruit types; most importantly, he used the concept of logical division, which eventually led to taxonomic keys and typology; he recognized about 500 of what we would call plant species.

Shortly after that appeared, another early thinker named Dioscorides wrote the all-time bestseller De Materia Medica, a monumental book that detailed the
medicinal uses of 600 plants and grouped the legumes (Fabaceae) together. The incredible impact of Dioscorides’ book is that it became a primary pharmalogical text for the next 1500 years!

De Materia Medica began to be outdated by 1400AD, as more and more plants were being discovered or traded and exchanged between cultures, especially those of Europe, Africa, and Asia. For example, Marco Polo, whose trips took him through Africa, the Middle East, and finally to China, brought back herbs, spices, and seeds of so many exotic plants that it would take another 50 years to catalogue these treasures.

Pliny the Elder (23-79AD) wrote Historia Naturalis, a series of volumes on world knowledge with nine of its 37 volumes devoted to plants.

Magnus (1st century AD) wrote De Vegetabilis, in which he recognized monocots and dicots based on stem anatomy, an incredible feat considering that he only had access to crude magnifying lenses at the time. He also wrote on non-medicinal plants, and used first-hand observations for writing descriptions. He also attempted to classify the known plants of his day.

II. The Herbalists—late 1400s and early 1500s

This time in botany is called the Age of Herbals (1200-1600AD), and led to the idea of the Doctrine of Signatures. This doctrine stated that plants were of certain shapes so that God could show us their intended usage; for example, if a plant looked like a liver, it should be used to treat liver problems. This is where we get many common names for plants, such as liverworts and kidney beans.

The term “herbalist” refers the renewed interest in plants as medicinals. Herbalists were early botanists who tested various plants in medical and non-medical situations in order to determine their properties. They described their plants in very long Latin paragraphs; these long paragraphs often included beautiful illustrations of the plants. Unfortunately, the long paragraphs often kept others from reading too far (not much has changed with regard to that with most students!).

In these Renaissance times, new plants were being traded and exchanged all across Europe, Asia, and Africa. Some notable herbalists were Brunfels, Bock, Cordus, and Fuchs. All of these herbalists recognized about 600 species, and these species didn’t vary that much from Dioscorides’ earlier book.

Cesalpino (1519-1603) is considered to be the first true plant taxonomist; he used the first explicitly artificial classification system, and accurately grouped plants of several modern plant families (Brassicaceae, Fabaceae, and Apiaceae). He also used woodiness as the first divisional step, then flower and fruit morphology.
III. Early Taxonomists (1500s-1778)

By the late 1500s, so many plants were pouring into Europe from explorers and their expeditions that all botanists recognized that some kind of organizing system was needed. Various botanists tried different approaches, but all soon became aware that the 600 species recognized by Dioscorides was just a drop in the bucket compared to the actual number of species present in Europe and other areas.

Another problem in addition to the rapid increase in species number was that of naming. Remember that the herbalists had written very long descriptive paragraphs in Latin for their plants. As more and more species were recognized, scientists realized that they had to shorten the long paragraphs into a form that was more usable for educated readers.

Most early taxonomists tried to shorten plant descriptions down to a sentence or two, and others took it further, as we’ll see.

Bauhin (1560-1624) included about 6,000 species in his Pinax Theatri Botanici, and was the first to use binomial nomenclature (two-name naming system) and to provide a list of synonyms. Synonyms occur when two different names are given to the same species.

John Ray (1627-1705) wrote a book called Historia Plantarum that included 18,000 species. He developed an extensive “natural” classification using many characters based on resemblance. His system used two groups (woody and herbs) further subdivided by flower presence.

Tournefort (1656-1708) developed concept of the genus, which he defined as a group of related or similar species. He created a much simpler classification system than Ray’s, and he believed that flower features should be the basis of a genus, not vegetative features. As a result, he recognized 9,000 species in 700 genera. It was an artificial system that was created to help identify plants coming in from all over the world.

Carl von Linné (Linnaeus) (1707-1778)

Also known as the “father of taxonomy”; he is best known for his consistent use of binomial nomenclature. His system was based on sexual characters, and he was the first botanist to demonstrate that plants have sexes.

His 1753 Species Plantarum is considered the starting point for plant nomenclature. He recognized synonyms, described locations of illustrations, noted original sites of collection, and used an extensive morphological terminology. Linnaeus was trained as a medical doctor, but never practiced, instead preferring to examine plants and animals.

By 1700, there were so many new plants flowing into Europe from the New World that previous classifications were
overwhelmed. He studied flowering plants intensely, and was the first Western scientist to determine that plants had male and female parts, and that these parts were predictable quantities for related plants.

Linnaeus used this scheme and published his *Species Plantarum* in 1753, which was the first book ever to classify all species of known plants! His plant system of naming came to be called binomial nomenclature for the reason that it shortened previously long plant descriptions down to two names, a genus and a specific epithet, which together forms the scientific name (or species) of an organism. It should be noted that Bauhin was the first to do this, but Linnaeus was the first to use it as a means of classifying new plant species as well as old plants.

His classification scheme was based on flower part numbers, and was considered an artificial classification because it set characters in advance without noting other characters; we call this “*a priori*” classification (characters are selected in advance of actually seeing the plants).

Linnaeus’ system worked for a while, but didn’t group plants that were actually related to each other. This happened because many species can have a great deal of variation in flower part numbers even though they are closely related.

Since the time of Linnaeus, botanists have struggled with different ways of classifying plants. In modern times, this has become the science of systematics, which is now based on evolutionary relationships. In modern systematics, we still use “type” specimens that “fix” the idea of what an individual plant species looks like.

A curious leftover from Linnaeus is the scientific naming system; in plants, unlike any other group, the scientific name is composed of genus, species, and authority. Authority names tell you who named something, and can get quite complicated, depending on how many times a plant specimen has been renamed. A simple name would be something like:

*Rosa alba* L.

(Latin for white rose, and L. stands for Linnaeus)

The genus name *Rosa* is always capitalized and underlined (or italicized); the specific epithet *alba* is always lower-case, and is underlined (or italicized) as well. The author’s name is abbreviated, and these abbreviations are kept in many reference books as a list for easy lookup.

A more likely name for a plant would be a little more complex, as systematists like to be as accurate as possible. For example, if several systematists had examined the original “type” specimen that Linnaeus used (this is quite possible; plants from collections in the 1400s are still used as, once dried, they remain very intact), they might rewrite the name a little.

Let’s say that someone named Shoemaker examines the type specimen in 1855, and thinks that it is more like a cherry than a rose, and so he renames it:

*Prunus alba* (L.) Shoemaker

Roberts re-examines this in 1939, and renames it as a true rose:

*Rosa alba* (L.) (ex Shoemaker) Roberts 1939

So, as you see, some names get quite complicated, but the story behind the name changes is kept in the authority names for all time.

IV. Natural Systems (1770s-1880s)
In the late 1700s, the idea dawned on early plant taxonomists to use many characters to group plants to reflect God’s plan of creation, not to reflect lineage.

Adanson (1727-1806) questioned the logical division approach first created by the Greeks, and instead proposed the use of as many characters as possible for grouping plants. He also weighted characters, which meant that he assigned some characters more value than other traits. Later on, modern pheneticists used some of his ideas. He also described groupings like modern orders and some 58 families.

Lamarck (1744-1829), of ‘acquired inheritance” fame, stated criteria for plant identification and developed rules for natural groupings into species, orders, and families; he also developed an analytical method of plant identification. Unfortunately, Lamarck is also known for his inaccurate views on inheritance of traits; he was partially correct, but most biologists have forgotten his valuable contributions to botany.

The de Jussieu family of botanists in France thought that plants that look alike should be grouped together. Several generations published Genera Plantarum, a book which caused natural systems to be accepted. They recognized some 100 orders (~modern families) and divided these into three main groups: acotyledons, monocotyledons, and dicotyledons (which included gymnosperms).

The de Candolles were another French family of botanists. They divided plants into 2 groups: cellulares (nonvascular) and vasculares. They also published the book Podromus, which was an attempt to classify and describe every known plant, but that did not include monocots. They recognized 58,000 species in 161 families. They also put gymnosperms with catkin-producing dicots, and began dicots with the primitive Ranunculaceae.

Endlicher (1805-1849) published Genera Plantarum in which he separated the algae and fungi from higher plants. Brongniart (1801-1876) divided plants into Cryptogamae and Phanerogamae.

Bentham & Hooker also published a book called Genera Plantarum, which gives names and descriptions of seed plants. They divided dicots into (1) polypetalae, (2) gamopetalae, and (3) monochlamydeae, and they recognized 200 families and 7,569 genera. Their books were based on the idea of a fixed species concept, unchanged through time since the Creation.

One good feature of their text is that they prepared descriptions from the plants themselves instead of using the works of previous authors, which was a novel approach, since most botanists kept using the same old descriptions over and over again.

V. Phylogenetic Systems (1880s-present)

Eichler (1839-1887) accepted Darwin’s ideas on natural selection and evolution, and thus he divided plants into cryptogams (thallophytes [algae], bryophytes [mosses and liverworts], pteridophytes, and phanerogams. Angiosperms were divided into monocots and dicots, dicots were divided into Sympetalae and Choripetalae. He did not recognize the idea of secondary reduction (loss of traits after having evolved them), and considered gymnosperms more primitive than angiosperms.

Engler (1844-1930) and Prantl (1849-1893) published Die Natürlivenen Pflanzenfamilie, a series of volumes which proposed that monocots evolved before dicots, and that primitive dicots had simple, unisexual flowers and were similar to catkin-bearing plants; they rejected the idea secondary reduction.
Bessey (1845-1915) trained under Asa Gray (1810-1888), the pre-eminent botanist of North America from 1850 or so to the early 1900s. Bessey considered all angiosperms to be monophyletic, with primitive ranalian dicots (like buttercups) giving rise to all other angiosperms. He proposed that true dicots began with the Magnolia-Ranunculus complex. Bessey also developed several criteria for the evolution of angiosperms, such as the idea that evolution involves degradation and reduction of traits, and that evolution doesn’t proceed at the same rate for all plant organs. Interestingly enough, many of his ideas, considered “strange” at the time, have now been shown to have some validity.

Hutchinson (1884-1972) thought that angiosperms derived from a proangiosperm ancestor (an advanced gymnosperm). The American Cronquist (1919-1992) and the Russian Takhtajan (1910-present), working and publishing in collaboration, recognized about 383 families, with 165,000 species of dicots and 55,000 species of monocots.

<table>
<thead>
<tr>
<th><strong>Engler and Prantl</strong></th>
<th><strong>Bessey</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Primitive characters were no petals, separate carpels, superior ovary, regular flowers, wind-pollination, unisexual flowers with no petals or sepals (ex. catkins in oaks)</td>
<td>Primitive characters were separate petals, superior ovary, woody stems, bisexual flowers with many whorls of petals and sepals, insect-pollination</td>
</tr>
<tr>
<td>Monocots more primitive than dicots, and both arose from different gymnospermous ancestors</td>
<td>Monocots derived from early dicots; strobilus was homologous to the flower</td>
</tr>
</tbody>
</table>
Classification

There are five basic approaches or methods of classification:

1. **Artificial systems**—ex. Linnaeus—in this method, the taxonomist selects a few characters in advance (\textit{a priori}) and rearranges the classification of the species he/she studies on that basis; adequate for 1700s, but soon fell apart as more and more plants arrived from the New World.

2. **Natural systems**—this method involves grouping plants based on many observable features without prior prejudice or bias. In this method, the taxonomist usually selects a few features for assigning rank (ex. anatomy, morphology). Although the rationale for natural systems was to align classification into harmony with nature, the results were usually very subjective.

3. **Phylogenic systems**—this method involves grouping plants with common evolutionary histories, even if the traits present don’t necessarily fit together logically. One example of this would be cacti; since cacti range in appearance from tree forms to tiny button-shaped forms, no sane taxonomist using the natural system would lump these species together, but once the evolutionary history of the cacti was proposed and accepted, this lumping of widely different cacti made sense.

4. **Phenetic systems**—these methods usually excluded evolutionary relationships when first proposed, but later pheneticists used evolutionary traits. Phenetics developed in 1960s and plotted relationships among plants using phenograms (tree-like diagrams). Phenetics was an early attempt to eliminate subjectivity by using many characters, all of which were precisely described and measured, as a means of numerical comparison. However, since related species can vary widely in their expressed characters, this method is not valid and can produce erroneous “trees” of supposed relationships.

5. **Cladistic systems**—these methods actually were proposed in the 1950s, but the mathematics needed to support cladistics systems came much later. Cladistics is a methodology designed to provide a better, less subjective way of determining and showing evolutionary relationships, or “clades.” One of the principles underlying cladistics is that modern organisms cannot coexist with their ancestral groups (in other words, the ancestor has to be dead). Another is that when a species forms (speciation), the ancestor no longer exists.

Cladistics is based on several features: (1) one must determine \textit{primitive} (relictual or plesiomorphic) vs. \textit{advanced} (derived or apomorphic) character states; (2) groupings are based on \textit{shared character states}, so those sharing advanced character states are likely to be more closely related, and (3) relationships are shown in tree-like cladograms which are mathematically derived.

**Modern Classification: Systematics**

Modern systematics is a relatively recent field in biology, and has only reached popular acceptance in the last 30 years. Before that, naming and understanding species and their relationships was left to whomever was the “expert” in that particular area and thus much controversy resulted. Systematics and its techniques arose to eliminate as much subjectivity as possible from the naming and understanding of organismal relationships.

Systematics is composed of \textit{taxonomy} (naming and classifying species), \textit{evolutionary processes} (such as hybridization, speciation, diversity), and \textit{phylogeny} (plant genealogies, origins).
Systematics: the objective study of organismal diversity and interrelationships; includes naming, evolutionary origin, speciation, etc., of taxa (taxa is plural for taxon, or a single ancestor has to be dead). Another is that when a species forms, the ancestor no longer exists.

Cladistics methodology involves based on several steps; in the first step, one must determine which traits are common traits (relictual or plesiomorphic) vs. those traits that are more rare traits (derived or apomorphic).

Since common traits point to a common ancestor, that trait is more likely to be representative of that ancestor and therefore more primitive. Rare traits don’t evolve often, and therefore they are considered to be advanced.

In cladistic methods, the researcher determines the common/primitive traits and rare/advanced traits in the plants he/she studies. These are assigned a value, usually "0" for common (plesiomorphic) traits and "1" for rare (apomorphic) traits, and are placed into a matrix for mathematical comparison. After rigorous examination by algorithms developed for this purpose, an evolutionary tree is generated which may or may not support the hypothesis of the researcher.

For example, humans and chimpanzees share nearly 99% of their genetic information, so less than 1% separates us from chimpanzees—in comparison, humans and gorillas share only about 98%, and humans and orangutans share only about 97.5% of their DNA; thus the logical conclusion is that humans and chimpanzees are each other’s closest living relatives, and
both have a more distant ancestor with gorillas and orangutans.

These relationships are shown in tree-like **cladograms** that are mathematically derived. An example is shown on the cover of this text.

**Classification Levels**

Most biologists follow this arrangement of higher/lower levels of classification for organisms:

- **Kingdom**: the broadest; contains thousands of organisms, all distinct from other kingdoms.
- **Phylum**: contains one or more related classes.
- **Class**: contains one or more related orders.
- **Order**: contains one or more related families.
- **Family**: contains one or more related genera (plural for genus).
- **Genus**: contains one or more related species.
- **Species**: the most narrow in scope; contains one to several dozen species.
Questions for Review

1. If you wanted to group some Martian plants based on whether they were red or blue, what system would this method reflect?

2. Surely there were many Native American, Chinese, and Egyptian botanists/healers that studied plants long before European botanists. Why aren't more early botanists mentioned?

3. Why did Dioscorides book last so long as the botanical bible in Europe?

4. What prompted the renewed interest in plants in early Renaissance Europe?

<table>
<thead>
<tr>
<th>Plant Group:</th>
<th>Number of Species:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cyanobacteria</td>
<td>1,500</td>
</tr>
<tr>
<td>Prochlorophytes</td>
<td>50</td>
</tr>
<tr>
<td>Dinoflagellates</td>
<td>1,100</td>
</tr>
<tr>
<td>Golden algae</td>
<td>6,000</td>
</tr>
<tr>
<td>Euglenoids</td>
<td>700</td>
</tr>
<tr>
<td>Brown Algae</td>
<td>1,500</td>
</tr>
<tr>
<td>Red Algae</td>
<td>3,900</td>
</tr>
<tr>
<td>Green Algae</td>
<td>7,500</td>
</tr>
<tr>
<td>Charophytes</td>
<td>250</td>
</tr>
<tr>
<td>Non-Vascular Plants</td>
<td>22,000</td>
</tr>
<tr>
<td>Lower Vascular Plants</td>
<td>1,250</td>
</tr>
<tr>
<td>Ferns &amp; Allies</td>
<td>4,020</td>
</tr>
<tr>
<td>Gymnosperms</td>
<td>822</td>
</tr>
<tr>
<td>Flowering Plants</td>
<td>275,000</td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td><strong>325,592!</strong></td>
</tr>
</tbody>
</table>
Chapter 2: Taxonomy

The Idea of the Species

Modern taxonomy can be traced back to the mid-1700s to Linnaeus (Carol von Linne) because Linnaeus was the first to publish plant descriptions based on a hierarchical scheme. He felt that some categorization is necessary for clear communication. His species idea was based on numbers of stamens and carpels.

Linnaeus first believed that the species was an unchanging category, but later changed his mind—he recognized variability in species and was the first to used the category variety (he thought of varieties as minor morphological changes from the original species).

Darwin, in the mid-1800s, felt there was no distinct boundary to a species, and that only trained taxonomists should define species, and that species were used as a convention and were arbitrary concepts.

This idea continues about species definitions. Several researchers have proposed for many years that the species concept is just not a reality and only reflects the human tendency to organize nature.

The Modern “Species”

Today, most researchers consider the species as the basic unit of classification, and it is currently believed to be the basic product of evolution. A species is also believed to be the easiest concept to define.

The modern concept of a species was defined by Ernst Mayr in 1942 by his Biological Species Concept (the BSC): “a species is a group of actually or potentially interbreeding populations which are reproductive isolated from other groups and that produce fertile offspring”; the lack of fertility between groups is basis for species.

Mayr used the example of a mating between a horse and a donkey—the offspring is a mule, which is sterile, thus the horse and donkey are separate species. However, if the mule was fertile, then the horse and donkey could be considered to be of the same species.

Cronquist, in the 1960s, described the problems with BSC as applied to plants:

- it is difficult to determine reproductive isolation in plants—for that, botanists need to go to the field and look for hybridization, and bring organisms into the greenhouse for hybridization tests;
- for plants (and other organisms) sibling species exist—intersterile, but morphological identical; sibling species concept introduced by Dobzhansky (on Drosophila)
- many plant groups that are naturally reproductively isolated (due to distance or different pollinators) can be interfertile in the greenhouse, ex. Orchids.

More recent definitions have removed the “potentially” from the BSC, but that doesn’t solve all the problems. Other problems with BSC applied to plants include:

- natural hybridization between different morphs of plants is common
- polyploidy (diploid egg meets diploid sperm producing tetraploid offspring, which could quickly evolve into a new species OR rehybridize with original populations)
- apomixis (asexual reproduction by using unreduced egg that grows into seed), and
- self-compatibility (leads to changes in reproduction over time, and possibly speciation).

Since the BSC, other species concepts have been proposed:

- Taxonomic species (aka morphological species, phenetic species)—group of morphologically similar individuals different from other groups—emphasis on difference due to non-interbreeding causes; and
- Phylogenetic species—a species is monophyletic (individuals within a group should have a single, common evolutionary ancestor, and at least one derived character that allows separation from other related individuals).

In the 1960s and 1970s, Ehrlich and Raven (who is now head of the Missouri Botanical Garden) proposed that the basic evolutionary unit is the population, and species as we have commonly defined them don’t truly exist.

The Idea of the Genus

Tournefort first proposed the concept of the genus (a group of related species) in the 1600s; however, today, we have a more rigid idea of what a genus is and is not. Thus, we accept three criteria for recognizing a genus:

1. The genus (group of species) should be morphologically distinct;
2. The genus should be reproductively distinct; and
3. The genus should represent a monophyletic group of species.

Binomial Nomenclature

The practice of using two names for a species (the scientific name) originates with Bauhin in the 1600s, but was standardized by Linnaeus in the mid-1700s. In modern times, the scientific name consists of three parts, not two: the genus, the specific epithet, and the authority (which is not usually found in animal classification).

Nomenclature: Common names vs. scientific names

The easiest names to learn for plants are the common names, and the hardest names are the genus and species names. However, common names are not used much by professionals for several reasons:
• Common names vary by region, state, county, or even city; thus, ironwood in Mississippi is not ironwood in Kansas and vice-versa.
• Common names may tell you a descriptive characteristic or two, but the scientific name tells you so much more about the plants (their relatives, their reproduction, their habitats, etc.).
• Common names change over time; scientific names change only after a lengthy process.

6 Principles of Nomenclature:

1. Botanical nomenclature is independent of zoological nomenclature. Thus, the rules for plants don’t apply to the classification of animals. This also means that an animal and a plant can have the same genus or species name; can this cause confusion? Potentially, but there are so few examples of this that, as far as can be determined, the matter has never been one of controversy.

2. Each taxon at the family rank or below is fixed by a nomenclatural type; the rank of species and below (subspecies, variety) is fixed by an actual plant specimen. The idea of a “type” that represents the species is an old one that Western thinkers inherited from Plato (427BC-347BC). Plato believed that variation in organisms was insignificant, and that somewhere there was the “ideal” representative of each type of animal or plant. For plants, when a new species is discovered, the discoverer collects several and designates one of those as the type specimen or holotype. This specimen is the scientific name placeholder, and will represent that species (if the name remains unchanged) forever. Others collected at the same time and place, but that aren’t the type specimen, are called isotypes. Sometimes the holotype is lost or destroyed, as happened all too frequently in World War II in Germany and England. When that happens, one of the isotypes is chosen to be the replacement, and is now called the lectotype.

3. Nomenclature is based on priority of publication. In other words, the scientific name for a plant is accepted to be the one proposed by the botanist who first publishes the species description. In the race to identify and name new plant species, this rule has often resulted in the misnaming or misidentification of species. Another controversial aspect of this rule is the “publication” requirement, which usually meant the publication of a name in a reasonably established journal. Today, however, access to the Internet often has blurred the idea of what is an acceptable publication, and this question has yet to be settled by the official committee for such things, the ICBN (International Code of Botanical Nomenclature).

4. Each taxonomic group can bear only one correct name. In the past, because of communication distances, sometimes several different scientists in different regions or countries would describe the same plant; this rule requires that the first validly published name be the only one associated with the particular species in question. Invalid names or duplicate names for the same plant are called homonyms.

5. All plant scientific names are Latinized. This is one of those rules that seems strange on the surface because hardly anyone speaks Latin or uses Latin enough for this rule to seem logical. However, there are reasons for this. One reason is historical—in the days of Linnaeus, Latin was the language of all educated persons. Another reason is that Latin, considered a “dead” language, has not changed in several hundred years, and is thus a language that will not continue to evolve; this would change plant names after a time, rendering current names potentially useless. Another reason is for ease of communication; if one language is used, then all botanists in every country use it, so that it becomes the universal language for scientific names.

6. These rules are retroactive. This means that these rules apply to all scientific names, past, present, and future, and not to just the ones published after the 1950s (when the ICBN began).

International Exceptions to the ICBN

Unfortunately, prior to the 1950s, many different names existed for the same plants and even the same plant families. The usage of the suffix “-aceae” for family names is fairly recent. Because of this, there are several major families that are known by two or more different names.

Eight plant families have names that contradict the one correct name rule; this is because many Europeans still use the older names:

<table>
<thead>
<tr>
<th>Family Common Name</th>
<th>Old Name</th>
<th>Correct Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sunflower family</td>
<td>Compositae</td>
<td>Asteraceae</td>
</tr>
<tr>
<td>Cabbage family</td>
<td>Cruciferae</td>
<td>Brassicaceae</td>
</tr>
<tr>
<td>Carrot family</td>
<td>Umbelliferae</td>
<td>Apiaceae</td>
</tr>
<tr>
<td>Mint family</td>
<td>Labiatae</td>
<td>Lamiaceae</td>
</tr>
<tr>
<td>Bean family</td>
<td>Leguminosae</td>
<td>Fabaceae</td>
</tr>
<tr>
<td>Grass family</td>
<td>Graminae</td>
<td>Poaceae</td>
</tr>
<tr>
<td>Palm family</td>
<td>Palmae</td>
<td>Areaceae</td>
</tr>
<tr>
<td>St. John’s Wort family</td>
<td>Guttiferae</td>
<td>Clusiaceae</td>
</tr>
</tbody>
</table>

How do I publish a new scientific name?

Publishing new names is a rigorous process, and should be left to the well-trained taxonomists who do this as their careers. It’s a bit like botanical lawyering, in that the process is time consuming and detail-oriented. In general, there are four rules for the process:

- Latin description—each new scientific name must be accompanied by a complete description of the plant in Latin. Botanists will often hire someone to do the description or ask a colleague.
- Rank of taxon—the plant should be given the appropriate taxonomic rank (level).
- **Designate a type specimen**—as noted earlier, this is very important, as it allows future scientists a reference.
- **Publish effectively**—in other words, the name and description should be published in an academic journal that is available to most botanists.

I've collected my plants, now what do I do with them?

The place where plant collections are permanently stored is called a Herbarium. The Washburn Herbarium is located in Stoffer Building and contains about 6,000 plant specimens, some of which are under study right now as possible type specimens from the 1870s and 1880s.

The idea of plant collections (herbaria) arose in the 1400s and 1500s, as new plant specimens are collected from various regions. In the beginning, collected plants were pressed flat on paper or cloth and then sewed into books. Because paper was so expensive back then, the use of paper mounting wasn’t a common feature until the 1740s, when Linnaeus began requiring it.

Herbaria are permanent collections; there are some herbaria dating back to the early 1500s, some 500 years ago! These plants have been carefully maintained and protected, although this is not always easy. Many insects and fungi can destroy an entire herbarium collection if not caught in time or if preventative measures are not taken. For this reason, most collections are kept in metal cabinets full of fungicides and insecticides.

**Important functions of herbaria (and botanical gardens):**

- They serve as a repository of vouchers and types.
- They are the primary taxonomic information source.
- They allow us to teach using actual specimens, some of which may not longer exist.
- They contain an inventory of geographic ranges and morphological variations.
- They provide a source of plant material for chemical, morphological, and molecular analysis. If needed, we could extract DNA from a 500-year-old specimen and compare it to modern descendants to see how fast evolution happens.
- They allow the conservation of plant species, either by keeping samples of seeds for future use, or these days, as sources of DNA.

I've found a plant, where do I look to identify it?

Botanical literature is rich in resources. For professional consultation, botanists use the following:

- **Reference works**—such as publications of the ICBN, or The Plant Book (Mabberly)
- **Indices**—These are accumulations of plant names; examples include the Index Kewensis (by the Kew Botanical Garden), Index Herbariorum (an index of herbarium names; Washburn’s herbarium is known by the abbreviation WASH), and Gray’s Index (a collection of North American plant names).

**Floras**—floras are collection of plant names from certain areas or regions.

**Manuals**—manuals are much like floras; they usually have a key to species, which may be lacking in a flora.

**Monographs and revisions**—monographs are published by taxonomists, and are a complete examination of a species, genus, etc. A revision is a publication that changes the name(s) of previously accepted species.

**Questions for Review**

1. Plants have specific endings for nearly every level of classification; look at a zoology textbook—do zoologists do something similar?
2. How is the scientific name of a plant different from that of an animal?
3. Why don’t we just standardize the common names of plants?

**Types of types:**

- **Type Specimen**—the representative for a species.
- **Nomenclatural Type**—the type specimen + its official name.
- **Holotype**—1 specimen used by an author as nomenclatural type.
- **Isotype**—duplicates of holotype.
- **Syntype**—1 of 2 or more specimens cited by the author when no holotype was designated but was used for description or citation.
- **Lectotype**—specimen from syntypes that serves as nomenclatural type when no holotype chosen.
Example of a pressed plant.

<table>
<thead>
<tr>
<th>Field</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Family</td>
<td>Aristolochiaceae</td>
</tr>
<tr>
<td>Genus</td>
<td>Asarum</td>
</tr>
<tr>
<td>Species</td>
<td>canadense</td>
</tr>
<tr>
<td>Common Name</td>
<td>wild ginger</td>
</tr>
<tr>
<td>Notes</td>
<td></td>
</tr>
<tr>
<td>Date</td>
<td>8/10/1897</td>
</tr>
<tr>
<td>Collector</td>
<td>unknown</td>
</tr>
<tr>
<td>Location</td>
<td>Topeka</td>
</tr>
</tbody>
</table>
Diagram of a typical plant press. The wood is used for weight to press down on the plant; the cardboard separates the wood from the juicy plant; the felt absorbs water easily, and the newspaper does this as well. Usually the plant is pressed for at least several days, preferably under low heat/bright lights. A common mistake is to remove the plant from the press before it has properly dried.
Chapter 3: Morphological & Anatomical Traits

In order to group related plants, we must first examine those traits that can help us do so. To obtain these traits, many types of characteristics are used. This chapter will give you an idea of some of the many types used in modern systematics.

Characters

It is generally believed that no one character is superior to any other, so for years, plant systematists equated the value of leaf margin variations, ovary position, etc. But systematists always want to have the one answer to their particular research question.

When DNA sequencing became more common in the late 1980s and early 1990s, most systematists breathed a large sigh of relief—finally, they thought, we can solve some of the major questions in plant evolution, such as the origin of the angiosperms. But DNA sequences, although greatly helpful, have not yet fulfilled their potential as the Holy Grail of systematists. We'll examine some reasons why later on in this chapter.

Systematists, as they look for traits to determine plant relationships, want to find traits that are common enough to be useful but not too common so that too many unrelated plants have that trait.

An example of such a trait would be vessel elements—they've evolved very few times in plant history (gnetophytes and flowering plants), but if you study flowering plants only, their presence is not useful for determining more specific relationships, such as the relationship between the leafy and non-leafy cacti. On the other hand, you want to find a trait that is rare enough to suggest distinction or uniqueness for the plants that have that trait.

The main categories for traits are morphology, anatomy, micromorphology, pollen, chromosomes, biochemistry, and molecular (usually meaning DNA sequences).

Morphology

Morphological traits are the easiest to study for botanists. Examples of these traits are leaf types, presence of thorns or spines, hairs, etc. The first morphologically based groupings were written in the 1600s.

Morphology can be divided into two groups: vegetative traits (e.g., leaf margin types) and reproductive traits (e.g., number of stamens).

A. Vegetative Traits

These traits are not associated with the flowers (in angiosperms) or with cones (gymnosperms). Let's examine some of the traits useful for systematics.

1. Stems

Let's start with stems, since stems were the first plant organ to evolve in the vascular plants. Here are some commonly used traits for stems. You shouldn't have to use a microscope to see any of these features. See any available diagrams for examples.

Woody or herbaceous (non-woody)? If woody, are growth rings present? If growth rings are present, are the largest vessels in the springwood or randomly scatter? Succulent or non-succulent? Aerial (above-ground), aquatic, or rhizome (underground) stems? Any modifications like tendrils, tubers, or stolons? Presence of vines or adventitious roots? Is the shoot apical meristem a terminal bud, coming from an axillary bud, or coming from pseudoterminal buds? Are spines, thorns, or prickles present? Is the stem hairy (with trichomes) or smooth (glabrous)? Is the pith whole, hollow, or chambered? Is the stem upright or prostrate?

These are but a few of the many stem traits one could use. For example, if the stem is hairy, there are about eight different types or degrees of hairiness that could be further used.

2. Roots

Roots evolved from stems (roots still have the protostele anatomy). Most systematists don't use root traits since the plant would be dug up in order to see these traits; strangely enough, this often kills the plant.

Usually, for roots, there is one major question: Is the root a taproot, or are fibrous roots present? Since most monocots have fibrous root systems, this is a quick way (although not definitive) to determine if your plant is a monocot or dicot.

3. Leaves

Leaves have been the most studied of vegetative organs, and for good reason, since they are the most distinctive and varied of the vegetative organs. The traits
below are many (but not all) common leaf traits. Please look at any available diagrams to see how these traits appear.

a. Is the Leaf Simple or Compound?

A simple leaf has one blade for each axillary bud. A compound leaf has more than one blade for each axillary bud. There are many degrees of complexity for compound leaves, such as once-compound, twice-compound, pinnately compound, and palmately compound.

Is the Leaf Entire or Lobed/Divided?

In other words, an entire leaf is a leaf that is relatively intact (not broken up into sections); a lobed leaf has distinct sections. If lobed, the leaf could be pinnately lobed (all lobes coming off along the midrib) or palmately lobed (all lobes originating from a central point, usually near the base of the leaf).

c. Leaf Attachment

Is the leaf petiolate (with a petiole) or is it sessile (petiole is absent)? Does the stem appear to pass upward through the blade (= perfoliate)? Does the lower part of the blade encircle the stem (= sheathing)?

Leaf arrangement patterns

Alternate

Opposite

Whorled
Pinnately compound leaves

- even-pinnate
- odd-pinnate
- twice-pinnate (bipinnate)

Palmately compound leaves

- Palmate
d. Leaf Arrangement

The term for the arrangement of leaves on stems is **phyllotaxy**. If the leaves are all clustered at the base of the stem (as in cabbage and lettuce), the leaves are **basal**. If the leaves are on a stem, they’re **cauline**.

Where the leaf attaches to the stem is called a node, so if only one leaf is present at a node, the leaf pattern is **alternate**. If two leaves are at each node, they’re **opposite**, and if more than two leaves are present at a node, they’re **whorled**.

e. Leaf Vein Patterns

First, determine if the leaf has a network of veins (**netted**, usually in dicots) or **parallel** veins (usually in monocots). If the veins are netted, then you should determine if the veins are **pinnate** (branching off along the midrib) or **palmate** (all branching from one point near the base of the blade).

f. Leaf Shape

Conifer leaves are usually needle-like (pines) or scale-like (junipers). Flowering plant leaves show much more variety. Looking from above, you should determine if the blade is **linear** (narrow) or **ovate** (oval). Please see the previous page for illustrations of these leaf types.

If it’s linear, then it may be **oblong** (slightly wider), **lanceolate** (wider at the base and narrowing towards the tip), **elliptic** (like an ellipse), or **oblanceolate** (wider at the tip, narrowing towards the base).

If the leaf is ovate (oval), then the related types are **broadly elliptic** (wide at the base, less wide at the tip), **obovate** (tip wider than base), **orbicular** (nearly circular), and **reniform** (shaped like a kidney bean).

g. Leaf Tips & Bases

The tip of the leaf can give us certain traits as well. If the tip is pointed with the sides forming a <90° angle, then the tip is **acute**. If the tip narrows to a long point, it is **acuminate**. If the angle is >90°, the tip is **obtuse**. The tip could also be **rounded**, **truncate** (flat-ended), or **mucronate** (rounded but with a small sharp tip). You can use the same terms for the leaf bases.

Bases can vary a bit more, however. In addition to the terms above, bases can be **cordate** (heart-shaped), **unequal**, **hastate** (flaring outwards from the midrib), **sagittate** (curving inwards towards the midrib), or **peltate** (like an umbrella).

h. Leaf Edges

The edge of a leaf is the **margin**. Margins vary enormously. An **entire** margin has no modifications. A **crenate** leaf has edges that are rounded. A **serrate** margin is shaped like the cutting edge of a steak knife. A **dentate** leaf margin is one in which the margin is divided into sharp projections. These categories can be further subdivided if necessary.

i. Leaf Hairs

These terms also apply to stem hairs. If no hairs are present, the leaf is **glabrous** (smooth). A **hirsute** leaf is one
with rough or coarse hairs, usually long. A scabrous leaf has tough, smaller hairs that feel like a scrubbing pad. If the hairs branch into star-shapes, the leaf has stellate hairs; if the hairs have glands at their ends, the leaf has glandular hairs.

**B. Reproductive Traits**

Morphologically, the flower has a large suite of characters that are useful for systematic purposes and study. Let’s start with the non-reproductive parts of the flower, the sepals and petals, and then move on to the reproductive parts, the stamens and carpels. After that, we’ll review some general morphological terms for the flower as a whole, and how flowers can be arranged on the stems.

1. **Sepals**

   The sepals are usually the more leaf-like parts of a flower, and if present, occupy the lowermost position. They can range from completely green to completely pigmented, depending on the species. Some flowers have more than one whorl of sepals; thus, all the sepals considered together are called the calyx.

   The individual sepals vary from species to species. Sepals that are fused side-to-side are connate; if not, they are called distinct. Many flowers no longer produce sepals at all, especially the wind-pollinated flowers.

2. **Petals**

   Petals are often the most noticeable parts of flowers, mainly as a result of evolution for pigmented attraction devices for insects and other animal pollinators. They are usually differently pigmented than the sepals, but not necessarily so; in fact, sometimes the transition between sepals and petals is not very evident, as in the flowers of cacti.

   Petals, like sepals, can be connate or distinct. Often connate petals form a tube that surrounds and protects the stamens and carpels, as in the morning glories. The tube can be toothed (small sharp projections) at the tips, lobed (divided into distinct lobes), or campanulate (bell-shaped). All the petals of a flower are collectively called the corolla.

   The number of petals (and sepals) can also be informative. Monocot flowers usually have three petals or petals in multiples of three (6, 9, 12, etc.). Dicots usually have four or five petals or their multiples.

   Taken together, the sepals and petals form the perianth. If one examines the perianth from above, one of two types of symmetry may be noticed. Flowers that can only be divided by one line to make two equal halves are termed bilateral (zygomorphic).

3. **Stamens**

   Stamens are less used than most other flower parts for systematics, but they can be an invaluable source of data. Each stamen has two parts, the stalk-like filament and the pollen-producing end called the anther. Like sepals and petals, stamens can be separate or distinct, or fused (connate). All the stamens together are collectively known as the androecium.

   Stamens can be present but not be fertile; these don’t produce pollen and are called staminodes. Some flowers use staminodes as a food source for hungry pollinators. In some flowers, the sepals, petals, and stamens all fuse to form what’s called a floral cup or hypanthium. Flowers containing only stamens and no carpels are termed staminate flowers.

4. **Gynoecium**

   The gynoecium is the collective term for all the carpels in a flower. Each carpel has three parts, the stigma (where pollen attaches), style (where pollen tubes grow down), and the ovary (where the egg and future seeds are kept). Some flowers have only one carpel per flower, whereas others have multiple carpels.

   If multiple carpels are present, they may be fused only at their bases or completely fused. Usually, the number of stigma lobes is equal to the number of fused carpels present.

   The position of the carpel relative to the other flower parts can be a good trait for systematists as well. If all other flower parts originate below the base of the carpel, the carpel is superior; if the carpel is sunken into the receptacle below where the other flower parts originate, that carpel is inferior. Please note that the terms “superior” and “inferior” refer only to position, and are not value terms.

**Other Flower Traits**

The flower is full of informative traits for taxonomists. Note that I used the term taxonomists, since traits useful for identification are not always useful evolutionary traits for systematists.

An example of this can be found in the Ranunculaceae, the buttercup family; in this family, the presence of modified flower genes creates the strikingly different flower types present. Thus, the varied flower types are useful for classification and separation of genera within the family, but may not be as useful in evolutionary terms, since all members of this family inherited one, original version of the genes that control flowering (which has changed over time to produce the present flower forms).
Leaf Shapes

- **Ovate**: (widest near base)
- **Obovate**: (widest near tip)
- **Elliptic**: (widest near center)
- **Oblong**: (sides parallel)

Leaf Tips

- **Acute**: (<90°)
- **Obtuse**: (>90°)
- **Acuminate**: (<45°)

Common Leaf Bases

- **Acute**: (<90°)
- **Cuneate**: (>45°)
- **Obtuse**: (>90°)
- **Sagittate**: (arrowed)
- **Lobate**: (eared)
One of the first traits to examine in a flower is the presence/absence of all four flower parts (sepals, petals, stamens, carpels). A flower with all four parts is a complete flower; if any part is missing, the flower is incomplete. Complete flowers are usually considered to be a relictual trait, since the specialization of flower parts can often lead to one or more parts being deleted over evolutionary time.

Why specialize? Specialization can lead to more efficient pollination and fertilization processes, such as in the wind-pollinated plants like grasses; these plants often have no sepals or petals, since those structures are used to attract insect or other animal pollinators.

Another trait of importance is whether the flower is perfect (having both stamens and carpels) or imperfect (lacking either stamens or carpels). If the flower is imperfect, it is either staminate (having only stamens) or carpellate (having only carpels).

Can a flower be missing both reproductive parts? Yes! Flowers of plants like Hydrangea spp. are divided amongst those that are reproductive and those that are decoys for pollinator attraction. In this case, the selective advantage of this approach is that the plant doesn’t have to expend as much energy in order to make the decoy flowers; if it produced the same number of flowers but all were reproductive, the energy consumption would increase greatly.

Lastly, the placentation (position of the seeds inside the mature ovary) can be useful for identification of species and genera. If the seeds are attached directly to the ovary wall, or from ovary wall projections, the placentation is parietal; if in the middle with the ovary divided into segments (like an orange), the placentation is axile; and if in the middle without segments present, the placentation is free central.

Arrangement of Flowers
The pattern of flowers is also useful; flower arrangement patterns can be very diagnostic for a family or genus. Flowers may be solitary on a stem, or may occur in groups (inflorescences). See the diagram for an illustration of the various types of inflorescences.

Fruits
Eventually, the ovaries of carpels will mature and expand. The ovaries carry the next generation, the seeds. The type of fruit present on a plant can often be as diagnostic as flowers; for example, in the bean family, the fruit type is a legume. The presence of a legume automatically tells you that your plant is in that family, even when no flowers or leaves of that plant are present. See the fruit classification chart for the various fruit types.
Anatomical Traits

Anatomical traits have been used since Magnus (1st century AD) viewed stems in cross-section using crude magnifying lenses. However, not much interest was evident in internal plant structures, at least for classification purposes, until the 1850s in Europe and North America. Anatomical traits can be very useful for determining relationships, but one disadvantage is that usually some type of magnifying instrument is needed; another disadvantage is that in order to view the anatomy, you have to cut open the plant.

Roots are quite homogeneous, in general, and thus don’t provide as many traits for classification as we’d like; however, stems and leaves do contain many diagnostic features. For example, in stems the presence of a protostele refers you to a lower vascular plant, whereas the presence of a pith (=siphonostele) is a feature of the ferns and seed plants. If the plant is a flowering plant, then the arrangement of vascular bundles can determine if the plant is a dicot (bundles in a ring) or monocot (“scattered” bundles).

For leaves, many traits are present anatomically. The pattern of veins often forms a “fingerprint” for most species, although some effort is needed to see these veins. More effort is needed to determine if vessel elements are present in the xylem of stems and leaves, or whether C3 or C4 leaf anatomy is present.

Thus, the general rule is that anatomical traits can be very diagnostic; however, the effort needed to determine these traits often deters systematists from using them.

Micromorphological

Micromorphological traits are those in which high magnification is needed to view the traits. These traits include those evident by pollen (the surface and outer layer patterns), seeds (one seed leaf=monocot, two seed leaves=dicots), etc.

Some warnings are needed here: in general, the preparation of these plant tissues can distort characters, resulting in sampling errors. The developmental stage or season can alter the appearance of characters. Often, character states sometimes difficult to define or determine. Finally, the efforts required finding these traits result in an increased cost (solutions, lab equipment, microscopes, etc.).

One micromorphological source that has proven relatively inexpensive to assess, while at the same time providing a rich source for traits, is pollen. Pollen first became a diagnostic tool for plant relationships in the 1930s, and this field is called palynology. There are four general areas in pollen that provide traits: the apertures (number, type, whether monosulcate, tricolpate, monoletal, etc.), the internal wall structure or tectum characteristics, the sculpturing (the external part of the tectum; very important for pollination), and the pollen shape (triangular, round, oval, etc.).

Questions.

1. Can a leaf be palmately compound with pinnate venation?
2. How is a spike different from a raceme? From an umbel? From a corymb?
3. Why don’t more taxonomists use fruit traits instead of flower traits?
Flowers: Top, lily flower with labeled parts; bottom photographs show variations of the top.
Reproductive Biology

Reproductive biology is an incredibly fascinating aspect of flowering plants—even the ancient Babylonians, some 3500 years ago, knew that date palms only produced fruits when the yellow powder (pollen) was applied to the flowers of the female trees.

Since most fruits are derived as a byproduct of pollination, pollination biology is of great importance to agriculture and vital to the maintenance of plant diversity.

Most humans are aware of wind pollination through allergies (hay fever) to these pollen grains; however, most humans blame plants like goldenrod (*Solidago*; Asteraceae), which are insect-pollinated and therefore unlikely to produce the light pollen needed for wind pollination to occur—here the culprit is ragweed (*Ambrosia*; Asteraceae), which is wind pollinated but also grows near goldenrod plants.

The flower, in one sense, is simply an adaptation to increase the likelihood of pollination. Thus, since there are a multitude of possible pollinators (animals, wind, water, etc.), there are just as many flowers that take advantage of them. The major pollinators are wind, water, and animals; let’s examine them and the flowers that use these pollinators.

**Wind Pollination**

The fossil record shows us that insect pollination evolved first, about 300 million years ago, using beetles or beetle relatives to transfer pollen from the male cones of plants at that time. Even today, cycads still use rainforest insects to transfer their pollen from cone to cone.

At some unknown point, conifer ancestors began to use wind to transfer pollen, and, later, so did the angiosperm ancestral line. Today, some 150 million years after flowering plants first arise, many have chosen the wind pollination strategy, for better or for worse.

Adapting to a wind pollination strategy involves some major changes for a flowering plant:

- producing much more pollen, perhaps by reducing the size of the pollen grain to increase buoyancy in the air or creating air spaces within the pollen grain;
- adapting the stigmas to be ‘stickier’ or larger in order to receive the pollen
- loss of the sepals and/or petals, since pollinator attraction is no longer an issue
- producing either male or female flowers, but not bisexual flowers, to increase the resources devoted to pollen production or reception
- reduction in the size of the flowers—this allows more flowers to be produced with the same amount of resources, increasing the chances of producing viable seeds.

One aspect of wind pollination is where it occurs—hardly any tropical species are wind-pollinated, whereas many temperate species are. One idea behind this general rule is that in the tropics, so many insects or other animals are available to serve as pollinators that the evolutionary changes needed for wind pollination are not initiated or beneficial.

Another reason is that, with the warmer temperatures of the tropics, the increased amount and increased duration of vegetation would inhibit the air flow needed for successful wind pollination. In contrast, temperate plants are mostly deciduous, and thus drop their leaves before winter begins, and usually don’t releaf until late spring.

In these plants, flower production for wind pollination usually occurs before leafing out happens, again, to take advantage of the lack of leaves that would otherwise create air flow problems for these plants.

One example of a wind-pollinated plant would be maple trees; they produce hundreds of small male or female flowers in the early spring. Another would be corn plants; the male flowers are clustered together at the top of the plant into a ‘tassel’, and the female flowers are much lower on the plant, and are clustered into ‘ears’.

The pollen drops from the tassel onto the waiting female flowers below, which can be a problem for wind-pollinated plants—this is called self-pollination, and many different ways have evolved to get around this event (which can lead to a buildup of deleterious genes over time). For corn, the male flowers and female flowers of an individual plant mature at a slightly different time in hopes of preventing self-pollination.
Water Pollination

Plants that are water-pollinated are often plants that have moved back into the water from their previously land-based lifestyle, and, as such, these plants have had to re-adapt their pollination strategies.

Some plant have evolved quite elaborate methods for insure pollination, such as the ribbon weed (*Vallisneria*; Hydrocharitaceae). This plant creates separate female and male clusters of flowers; the female flowers are produced on a stem, whereas the male flowers are released as independent floating pollination structures that eventually break the surface and sail over to the female stigmas for pollination.

All flowers have to worry about predation upon their flowering parts, and aquatic plants are particularly at risk since their pollen often floats in or on top of the water. Thus, one major goal for aquatic pollination is predator-avoidance; this is often accomplished by releasing pollen at night.

Another goal is to use the same principles as wind-pollinated flowers—that is, eliminate sepals and petals, and evolve flowers that are either staminate or carpellate, and let the energy of the water carry pollen to the stigma.

Animal Pollination

Animal pollination evolved first, or so the fossil record indicates. Of the animals that pollinate, the largest group consists of the insects (but not the arthropods). Other animal pollinators include mammals such as bats, and birds such as the hummingbirds. Here are some major animal pollinators and their flower requirements/adaptations:

- **Bees** visit brightly-colored (usually blue or yellow), rarely red because bees see red as black. Often these flowers have lines or spots that point the bees to the nectar; some flowers, in ultraviolet light that bees see, have nectar guidelines; these flowers usually have sweet scents.
- **Butterflies** and their first cousins, the **moths**, have similar mouthparts and physiologies, but completely different schedules. In general, moths pollinate odoriferous, white or yellow flowers, and day moths and butterflies pollinate bright-colored tube flowers. Butterflies are usually day-active, but moths are usually night-active—you may not think that this makes a difference, but moth-pollinated flowers no longer have to worry about producing bright colors, since the moths are more attracted to scent. Both pollinators like sweet-scented flowers with fused petals that form a tube, at the base of which are nectaries which provide a sugar solution for the pollinators. The mouthparts of butterflies and moths are coiled into a spring-like bundle, and when these mouthparts uncoil, the tubular flowers allow them to feed more efficiently.
- **Birds** are also interesting pollinators; some birds are famous for their pollination abilities, like the hummingbirds. Hummingbirds prefer reddish or orangish tubular flowers that have little or no odor because hummingbirds have poor smell abilities. Other birds may not be good pollinators, but instead, good dispersers of fruits and seeds.
- **Bats**, for example, fruit bats in the tropics, can also serve as pollinators. Bat-pollinated flowers open mostly at night, and have a dull color. They are usually large enough to allow the bat to stick most of its head in the flower because the bat eats the pollen for protein; but enough pollen survives and sticks to the mouths of the bats and is later transferred to other flowers.
- **Ants** can pollinate flowers by sipping the nectar and traveling from flower to flower, pollinating them. They can also protect their food sources; for example, the acacia tree (a relative of our redbud and locust trees) of Africa has evolved thorns that become hollow. The ants live in the thorns, and protect the tree from herbivores, while also pollinating the flowers by collecting pollen grains from the flowers to feed to their larvae. Some flowering plants have evolved protein-secreting tissues to reward their ant pollinators; these tissues are called Beltian bodies.
- **Beetles** pollinate flowers that have strong, yeasty, spicy, or fruity smells; beetles can’t see very well, thus other light-dependent clues are lost on them, so beetle-pollinated flowers aren’t bright. These flowers lure beetles to them by providing abundant pollen or by providing protein bodies that accumulate in special flaps of tissue on petals.
- **Flies** can also be pollinators. Flowers that use flies as pollinators have the odor of rotten meat to attract these flies. The flies come to lay their eggs, which often are destroyed by plants chemical defenses. These flowers tend to be dull-red in color in order to simulate the color of meat.
- **Wasps** are very good pollinators, and many have established amazing relationships with their flower partners. Some orchids evolve anthers and stigmas that resemble female wasps; these modified flowers also release a similar pheromone to attract male wasps.
Coevolution between pollinators and the pollinated

The relationship between the major pollinators (insects) and the flowers they pollinate has been a rocky one—usually this relationship has been viewed as beneficial to both (= mutualism). A great example of a mutualistic pollination pair would be the figs and asps—this relationship is so strong that, if the wasp species disappears, the fig trees they pollinate also become extinct.

However, not all pollination pairs are mutualistic; for example, the yucca plant is pollinated by the yucca moth, whose eggs are deposited inside the ovary. As the eggs hatch, the larvae consume some (but not all) of the yucca seeds.

Enough seeds survive to allow the yucca to continue to exist through time. Perhaps this is how wind-pollination arose all those millions of years ago—maybe wind-pollination avoids the threat of insect damage done during or after pollination?

Self-Incompatibility

One of the major problems of having bisexual flowers is the possibility of self-pollination, in which the pollen of the anther from the same flower lands on the stigma. Although plants tend to be more genetically flexible in this regard than other kingdoms, the main reason that self-pollination, in the long run, is not a great idea is due to a phenomenon called inbreeding depression. Inbreeding depression is when self-pollination, over time, results in a buildup of deleterious genes that can affect the reproductive potential of the plant.

To overcome self-pollination, several methods have been evolved. One method is **protogyny**, in which the stigma of a flower becomes receptive to pollen before the anthers produce viable pollen; this keeps that flower’s pollen from being the first to pollinate the flower.

Another method is **protandry**, in which the stamens mature well before the stigma is ready to receive the pollen.

One unique approach to avoid self-pollination is **heterostyly** (the production of two different types of bisexual flowers): the **thrum flower** and the **pin flower**.

The pin flower has the style and stigma elongated beyond the petals (usually fused) and the stamens are much lower in the floral tube. The thrum flower has the stamens elevated to the end of the floral tube, and the stigma is much shorter and inside the floral tube.

Although self-pollination is possible in the thrum flower, the stigma is receptive to pollination a few days before the stamens produce pollen—additionally, the pollen is mechanically unable to attach to the stigma. Thus, in theory, these approaches keep self-pollination to a minimum.

Another way to keep a plant from ‘selfing’ is to evolve compatibility barriers that are based on **genetics**, either at the pollen-stigma interface or at some point later in the embryonic development.

Gametophytic isolation, such as the pollen-stigma interface, is much more common than sporophytic isolation (at the embryonic stage), and involves which alleles are presented as the pollen germinates on the stigmatic surface.

Since pollen is haploid, it will present only one of the possible alleles; the only pollen that is ‘allowed’ to germinate and fertilize the egg is the pollen grain that presents an allele that is not present in stigma (see diagram).
Hypothesized evolution of the stamen (top) and carpel (bottom). The stamen evolved from a microsporangial bearing leaf by the enrolling of the outer leaf margins around the microsporangia. A similar enclosure process happened to form the carpel—the megasporangial bearing leaf slowly enrolled around the megasporangia to provide protection.
Longitudinal section through a young flower showing the development of the four major flower parts (sepals, petals, stamens, carpels).

The position of the ovary in relation to the other flower parts is one way to separate out various species, genera, and families. Left: a hypogynous flower; all other parts originate below the base of the ovary. Right: An epigynous flower; all other parts are position at or above the base of the ovary.
A transverse section of a young flower. Note the positions of the major flower parts and how these compare to the longitudinal section earlier in the chapter.

Comparison of dicot (left) and monocot (right) flowers in transverse section. Dicots usually have flower parts in multiples of 4 or 5, and monocots in multiples of 3; why is the dicot flower strange in this regard?
Longitudinal section of a nearly mature flower—is this flower hypogynous or epigynous?
The flowering plant stamen consists of a filament and an anther. The anther is a collection of usually four microsporangia, in which microspore mother cells undergo meiosis to produce microspores (n). The microspores (pollen grains) will undergo one mitotic division to produce two cells, the tube cell and the generative cell (usually contained within the tube cell itself). The tapetum nourishes the formation of
Typical pollen grain (above). Right, pollen wall detail. Illustration of the pollen coat morphology. The exine is the entire outer layer, consisting of the tectum, pores, and bacula, and an inner layer called the endexine. The intine layer lies well below the endexine.
Top: pollen is carried to the stigma; if compatible, the tube cell breaks through the pollen coat and begins its long journey down the style and into the ovary. Bottom: tube cells are able to produce the long pollen tube because they digest style cells as they grow downward.
Top: carpel transverse section showing ovules. Bottom: closeup of the top photograph.
Diagram showing the processes of pollination and fertilization of the egg by one of the sperm nuclei. The results is a triploid (3N) endosperm nucleus and a diploid (2n) zygote.
Top: the formation of the megagametophyte (female gametophyte). Bottom: a mature megagametophyte.
Illustrations of the fertilization process. Top: After the sperm has fertilized the egg, and the second sperm has fused with the polar nuclei, embryonic development can begin. Bottom left: the first division of the new zygote forms the basal cell, which will anchor the zygote as it develops into an embryo. Bottom right: the zygote then rapidly divides to form the
Top: the young embryo and its parts. Bottom: a mature embryo in the seed.
Placentation types; placentation refers to the position of the seeds. Top: free central placentaion; middle: parietal placentaion; and bottom: axile placentaion.
Fruit Classification

I. Simple fruits--derived from only 1 ovary (or from fused ovaries) of one carpel (or fused carpels)

A. Fleshy fruits

   1. berries--entire pericarp is fleshy--tomato, blueberry, banana; some modified types of berries:
      a. pepo--cucumbers, watermelons, pumpkins
      b. hesperidium--citrus fruits

   2. drupes--part of the pericarp is fleshy, the other part is harder--ex. peaches, plums, cherries, blackberries, almonds, olives, coconuts, pecans, walnuts

B. Dry fruits

1. Dehiscent (those that split at maturity to release the seeds within)

   a. follicle--splits along 1 seam, ex. magnolias, milkweeds
   b. legumes--splits along 2 seams; ex. beans
   c. capsule—most common dehiscent fruit; ex. yucca, okra, cotton

2. Indehiscent (those that don’t split at maturity)

   a. achene--small, dry 1-seeded fruit-ex. sunflower; seed attached to ovary wall at only 1 point
   b. caryopsis (grain)--small, 1-seeded fruit-seed is fused to ovary wall; ex. corn, wheat, rice
   c. nut--large, dry 1-seeded fruit; ex. acorns, hazelnuts, chestnuts

II. Compound fruits
How is the fruit formed?

1 flower
(1 ovary or fused ovaries/carpels)

1 flower + other tissues
(ex. Stem)
(accessory fruit)
(apples, pears)

>1 flower
(multiple fruit)
(ex. Corn, pineapple)

Aggregate
(fused or multiple ovaries/carpels,

Simple

Fleshy

Entirely fleshy:
Berry
Pepo

Partially fleshy:
Drupe

Dry

Dehiscent:
Follicle
Capsule

Indehiscent:
Achene
Caryopsis
SAMPLE SPECIMEN DATA SHEET

___________ Leaf venation (parallel or netted)
___________ monocot or dicot? Monocot flower part numbers 3’s, Dicot in 4’s, 5’s
___________ woody or herbaceous
___________ leaf arrangement (alternate, opposite, whorled)
___________ leaves simple or compound?
___________ if simple, sessile or petiolate? if compound, pinnate or palmate?
___________ if pinnate, 1X, 2X, even, odd?
___________ leaf margin?

Calyx (all sepals)
___________ sepal #
___________ separate or fused?
___________ unusual features?

Corolla (all petals)
___________ petal #
___________ separate or fused?
___________ actinomorphic or zygomorphic?
___________ unusual features?

Androecium (all stamens)
___________ stamen #
___________ attachment (ovary base, corolla tube, etc.)
___________ opening by pores or lines? _______ #locules
___________ #ovules per locule
___________ ovary superior, inferior, perigynous
___________ unusual features?
___________ flowers perfect, imperfect?
___________ if imperfect, monoecious or dioecious?
___________ inflorescence type
___________ fruit type

Family: _________________________
Genus: _________________________
Species: _________________________
Chapter 4: Molecular Traits

Cytology

In the 1930s, science was finally beginning to understand the cell cycle and the structure of chromosomes (although not DNA). Systematists began to apply this knowledge to the gathering of diagnostic traits. This field became known as cytotaxonomy, and dealt with morphology of the cell and its contents, as well as the chromosome number. Gametes (sex cells) are usually haploid (having one of each chromosome), while most non-sex cells are diploid (two of each chromosome) or tetraploid (four of each chromosome).

One feature of plants astonished these scientists—the fact that plants are flexible in terms of number of chromosome sets than other organisms. For example, it is not uncommon to see polyploid plant cells, but a polyploid animal cell probably wouldn’t survive very long. It is estimated that nearly 95% of ferns are polyploid, with haploid numbers of chromosomes up to 630! In angiosperms, an estimated 40% are polyploid, and in gymnosperms, about 60% are polyploid.

A subdiscipline in cytology in the 1930s was cytogenetics, which was concerned with chromosome behavior at meiosis. These systematists would study this behavior by using chromosome smears.

Molecular Traits

Molecular traits consist of the information gained from analyzing the proteins, RNA, and DNA of organisms. Proteins were the first to be included as indicators of evolutionary relationships; it wasn’t until the mid-1980s that DNA and RNA became much more accessible for most scientists. In the mid-1980s, the process called PCR (polymerase chain reaction) was introduced to systematics.

Gel electrophoresis was another breakthrough for molecular biology; an agarose gel is loaded with DNA chunks, and an electrical current is passed through the gel. The DNA, being slightly negative chemically, travels along the current towards the positive end of the gel, thus achieving separation of the DNA by molecular weight and complexity. Once the DNA is separated, stained, and photographed, the pattern of restriction enzyme fragments can be assembled into a restriction enzyme map of each species you’re testing. Although a crude comparison, these maps can be informative, although they are time-consuming and sometimes difficult to map without advanced software or facilities.

Another method is to perform a RAPD analysis of the DNA. RAPD stands for Randomly Amplified Polymorphic DNA. This method is similar to a restriction enzyme approach, with the exception that RAPDs are much faster, much simpler, and more reliable. RAPDs are commonly called DNA fingerprinting, since they produce a pattern of inherited DNA bands; thus RAPDs are useful for population studies (e.g., which plants are passing on their genes in a population), and species-species level comparisons. RAPDs are not as useful for comparisons of high-
ranking taxa, such as those at the family or order level and above. 

RFLPs, or restriction fragment length polymorphisms, is becoming a more common approach to congeneric and intraspecific comparisons. In this method, restriction enzymes are used to digest the DNA and the resulting gel banding patterns are compared. These can often be used for large scale population studies.

Polymerase Chain Reaction (PCR) begins with the DNA of interest, additional bases, and enzymes called polymerases, which match single bases and the template DNA to make new copies. In a few hours, thousands of copies can be made from a very tiny amount of DNA.

Some Common Type II Restriction Enzymes:

<table>
<thead>
<tr>
<th>Enzyme</th>
<th>Cuts DNA at:</th>
<th>Source:</th>
</tr>
</thead>
<tbody>
<tr>
<td>EcoR1</td>
<td>GAATTC</td>
<td><em>E. coli</em></td>
</tr>
<tr>
<td>BamH1</td>
<td>GGATCC</td>
<td><em>Bacillus amylofaciens</em></td>
</tr>
<tr>
<td>HindIII</td>
<td>AAGCTT</td>
<td><em>Haemophilus influenzae</em></td>
</tr>
</tbody>
</table>
Sources of DNA in Plants: Size (in base pairs) Inherited from:

<table>
<thead>
<tr>
<th>Source</th>
<th>Size (in base pairs)</th>
<th>Inherited from</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chloroplast</td>
<td>135,000-160,000</td>
<td>Maternal (usually)</td>
</tr>
<tr>
<td>Mitochondrion</td>
<td>200,000-2.5 mill</td>
<td>Maternal (usually)</td>
</tr>
<tr>
<td>Nucleus</td>
<td>1.1 mill to 1.1 bill</td>
<td>Both parents</td>
</tr>
</tbody>
</table>

1. DNA is isolated from chloroplast, mitochondrion, or nucleus & then cut with restriction enzymes.
2. DNA is stained with bluejuice (as a marker and to weigh it down into the well of the gel).
3. DNA loaded into gel and current is switched on.

A top view after gel is finished and stained with ethidium bromide or blueview DNA stains. We can use these patterns for phylogenetic analysis, or, more preferably, cut out these bands and sequence them to find out the exact bases present. The more base sequenced, the more accurate the analysis.
Cotton has a very interesting history; most cotton-producing plants are diploid (2n=26); however, one group of tetraploid genera (2n=52) found in the tropics of the New World and in Hawaii have inherited 2 sets of chromosomes (A+D; in orange above), one from a New World genotype (D) and one from an African genotype (A). Here are the results found by Wendel et al. in determining this unique ancestry:

<table>
<thead>
<tr>
<th>Genome Type</th>
<th>Location</th>
<th>2n#</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Africa</td>
<td>26</td>
</tr>
<tr>
<td>B</td>
<td>Africa</td>
<td>26</td>
</tr>
<tr>
<td>C</td>
<td>Australia</td>
<td>26</td>
</tr>
<tr>
<td>D</td>
<td>New World</td>
<td>26</td>
</tr>
</tbody>
</table>
DNA Sequences
The most useful data is derived from the actual DNA sequence. This is mostly performed today using automated DNA sequencers, large complex machines that break down and reassemble DNA, producing the actual sequence as a result. The advantages to this method are (1) extremely accurate results, (2) allows comparisons of taxa at all taxonomic levels, and (3) the DNA data also gives you protein information.

Once the sequences of a gene, intron, or restriction fragments of several species are known, the next step is alignment. Many software packages exist to help you with this step. The DNA sequence is copied, then pasted into the software, and the software can align hundreds, thousands, or millions of bases with other sequences. For example:

Cactus DNA

Ice plant DNA

Moss rose DNA

Here, the software uses the first sequence as the standard for comparison, and aligns the other DNA sequences accordingly. The software lets you know which bases don’t match up, either by underlining them or in some other manner. Notice that the ice plant DNA has two variations not present in the cactus, and that the moss rose DNA has only one variation different from the cactus DNA.

In addition, DNA sequencing can also tell you if the DNA has rearrangements like inversions; an example of this would be if the gene sequence of one species is A-B-C-D-E and its closest relative is A-B-C-E-D. Another common rearrangement is a duplication event; for example, if the gene sequence is A-B-C-D-E and offspring have A-B-C-D-E-C-D-E.

Translocations can also occur, in which chromosomes (during meiosis) switch areas containing several genes; for example, in humans, one cause of Down syndrome is the translocation of a part of chromosome 14, which turns that translocated part into a satellite fragment, causing fragment to act like a third #21 chromosome.

One important systematic trait is the determination of deletion events in the DNA sequence. Here we’re talking about large segments of DNA that are missing from one species, genus, family, etc. For example, in the Cactaceae, the two subfamilies Opuntioideae and Cactoideae have a large deletion in common; this section of deleted DNA is still present in the more relictual subfamily Pereskioideae, and thus represents an apomorphic (advanced) trait for those two subfamilies, linking them evolutionarily (unless they came from different cactus ancestors and this deletion occurred in parallel, but that’s a whole other problem).

Lastly, sequencing the intron (non-coding) DNA areas can provide a molecular clock of sorts for the species you’re studying, since these non-coding areas can build up many mutations and variations without affecting the exon (coding DNA) segments. It is generally accepted that one base mutation occurs every thousand years, thus two related species with 1200 base mutation differences are thought to have originated from a common ancestor some 1,200,000 years ago. Be forewarned that this idea of a molecular clock is somewhat controversial, and there are many arguments on both sides.

Commonly Used Genes in Plants
1. The chloroplast genome as a whole—several recent studies show that geographically separate populations of the same species can have huge differences in their overall chloroplast genome by using restriction site analysis. The usual cause of such large differences is hybridization between very closely related species.
2. rbcL—this is a chloroplast gene that codes for the larger subunit of the enzyme ribulose bisphosphate carboxylase, the enzyme that rips carbon from carbon dioxide during the Calvin cycle. It’s about 1428 base pairs long, making it easy to align using software, and occurs in cyanobacteria and all photosynthetic eukaryotes. It is extremely useful at higher levels (orders and above), but has a very slow mutation rate, which can cause problems in applying its meanings at lower levels—in other words, below the order level, the rbcL sequences are probably identical or nearly identical.
3. ndhF—this chloroplast gene codes for the subunit F of the NADP dehydrogenase enzyme. This gene varies quite a bit, and is more useful at the generic and family levels.
4. rpoA, rpoC—chloroplast genes that code for subunits of the RNA polymerase II enzyme.
5. matK—a chloroplast intron that codes for the maturase gene in a longer gene (trnK).
6. ITS—these are internal transcribed spacer (ITS) sequences located between the genes that code for the ribosomes of plants. These small sequences undergo rapid evolution, and since they are transcribed but not translated, their mutations are allowed to happen at a higher rate.

Why are there no nuclear genes listed here? Well, the nuclear DNA of flowering plants can have up to 45,000 genes (cottonwood trees, for example), many of which are too highly conserved to be of much use phylogenetically. However, as the years pass, more and more data will be gathered from these genes and used to reconstruct the phylogeny of plants.

Questions:
1. Which of the other taxonomic traits might be more useful to you if you’re out in the field identifying plants? Why?
2. How could cytogenetics be used to classify plants?
3. Which would be more useful for comparing two unknown families, cytogenetics, pollen, or molecular traits?
4. What are the advantages of using DNA sequence data? The disadvantages?
5. Why do most taxonomists rely on morphological traits instead of DNA traits?
Chapter 5: Quick keys to identifying plants

This chapter is by no means a complete list or guide to the plants we might see; some plants only show up every few years. Another note: many ornamental trees and shrubs won’t show up in this key because they are not native to this area, but have been brought in as decorative plants.

Quick Key for Families
1. Plants without flowers, but with needle or scale leaves, cones may be present……………………….Key 1
1.’ Plants with flowers, netted or parallel leaf veins……………………….Key 4

Key 1
1. Cones present, wood present……………………….Key 2
1.’ Cones absent, no wood……………………….Key 3

Key 2—Gymnosperms
1. Leaves fan-shaped with dichotomous veins……………………….Ginkgo biloba
1.’ Leaves not fan-shaped……………………….2
2. Leaves scale-like, cones seem bluish-gray & berry-like……………………….Eastern Red Cedar
2.’ Leaves needle-like……………………….3
3. Leaves arising from obvious fascicles (short shoots)……………………….Pine
3.’ Leaves not arising from fascicles……………………….5

4. Leaves divided into small, feathery leaflets……………………….Bald Cypress
4.’ Leaves not divided; instead, tough, narrow……………………….Spruce

Key 3—Ferns or Lower Vascular Plants
1. Frond divided into many leaflets; spores present on underside of leaflets……………………….Fern
1.’ No frond present; lateral sporangia present on stem, not leaf……………………….Lower Vascular Plant

Key 4—Flowering Plants
1. Plant a tree or woody vine……………………….Key 5
1.’ Plant not a tree or woody vine; herbaceous……………………….Key 6

Key 5—Woody Trees, Vines
1. Plant a tree……………………….Key 7
1.’ Plant a vine……………………….Key 8

Key 6—Non-woody flowering plants
1. Plant with parallel leaf veins, sepals/petals in 3’s or multiples……………Key 9—Monocots
1.’ Plant with netted leaf veins, sepals/petals in 4’s, 5’s, or multiples………Key 10—Dicots

Key 7—Woody flowering trees
1. Leaves compound……………………….2
1.’ Leaves simple……………………….5
2. Stems with prickles; small trees & shrubs; 5-petals……………………Rosaceae
2.’ Stems not as above……………………….3
3. Small shrubs/trees; leaflets narrow & serrated; stems 1-3” in diameter……………………Anacardiaceae
3.’ Large trees, often >1” in diameter……………………….4

4. Leaves opposite……………………….Oleaceae
4.’ Leaves alternate……………………….Juglandaceae

5. Leaves serrated, cord-like veins, small, rounded green fruits…………………..Celtidaceae
5.’ Leaves not as above……………………….6

6. Leaves with base sides not matching……………………….Ulmaceae
6.’ Leaves with matching bases……………………….7

7. Leaves with various shapes on same tree……………………….8
7.’ Leaves with consistent shapes on same tree……………………….9

8. Leaves simple, bilobed, and trilobed; margins serrated……………………….Lauraceae
8.’ Leaves as above but margins smooth……………………….Moraceae
9. Leaves deeply divided (but not compound) ..........10
9.’ Leaves not deeply divided..........................11

10. Leaves longer than wide, with rounded, deeply divided lobes, some with spines......Fagaceae
10.’ Leaves as above but appear palmately compound...........Sapindaceae

11. Stems with spines/thorns......................Saxifragaceae
11.’ Stems without spines/thorns...........12

12. Stems with chambered piths, large purple berries........Phytolaccaceae
12.’ Stems not as above.............13

13. Leaves lobed (not deeply); veins palmate........14
13.’ Leaves not lobed.............................................15

14. Leaves usually with 3 large lobes, leaf more than 6" wide......Platanaceae
14.’ Leaves usually with 3-5 small lobes, leaf less than 6" wide......Sapindaceae

15. Leaves triangular.................................16
15.’ Leaves not triangular.......................17

16. Leaves with serrated margins, tree near water; seeds in cottony mass........Salicaceae
16.’ Leaves can be serrated (sometimes doubly), bark can peel........Betulaceae

17. Leaves very narrow, linear, tree in or near water........Salicaceae
17.’ Leaves not as above..................18

18. Leaves extremely large (>1’ long) and heart-shaped; fruits are long, brown capsules...Bignoniaceae
18.’ Leaves not as above...........19

19. Flowers with 3 sepals, 6 petals; fruit large, light green, edible........Annonaceae
19.’ Trees not as above...................20

20. Leaves longer than wide but not narrow; very waxy; carpels arranged in cone......Magnoliaceae
20.’ Leaves not as above...............21

21. Leaves very small, dark maroon, thorns present........Berberidaceae
21.’ Leaves green, veins parallel margin, small flowers.......Cornaceae

Key 8—Flowering Woody Vines
1. Flower orange, tubular, 5 lobed, leaves compound...........Bignoniaceae
1.’ Flowers not apparent............2

2. Leaves palmately compound with leaflets 5.........Rosaceae
2.’ Leaves not as above...........3

3. Leaves compound with 3 leaflets........Anacardiaceae
3.’ Leaves not compound; veins parallel; spines present..........Smilacaceae

Key 9—Monocots
1. Plants grass-like with very small flowers......................Key 11
1’. Plants may be grass-like but flowers are obvious........2

2. Sepals/Petals recognizable as such..................3
2.’ Sepals/Petals modified into other structures..........4

3. Stamens 6, ovary superior, sepals like petals......................Liliaceae
3.’ Stamens 3, ovary inferior, sepals point downwards.....................Iridaceae

4. Sepals green, petals blue/purple, stamens 6, superior ovary......Commelinaceae
4.’ Sepals pigmented, stamens 3, ovary inferior..........Orchidaceae

Key 10—Dicots
1. Flowers regular..................Key 12
1.’ Flowers irregular...............Key 13

Key 11—Grass-like flowering plants
1. Stems triangular.............Cyperaceae
1.’ Stems round...................2

2. Female flowers in large 'corndog' like clusters at top of stem....Typhaceae
2.’ Female flowers not as above........3

3. Leaf bases surround stem but aren’t fused; stems mostly hollow........Poaceae
3.’ Leaf bases not as above; stems not hollow........Juncaceae

Key 12—Dicots with regular flowers
1. Flower parts in 4’s or multiples.......................2
1.’ Flower parts in 5’s or multiples.......................4

2. Petals separate, in cross-shape, 6, stamens, ovary superior.............Brassicaceae
2.’ Petals fused, in tube or connected to tube, ovary inferior.............3

3. Petals lobed, sepals lobed, stigma 4-lobed & cross-shaped..............Onagraceae
3.’ Petal tube lobed, sepals fused, stigma not cross-shaped..............Rubiaceae

4. Ovary superior..........................5
4.’ Ovary inferior..........................7

5. Flowers with stamens fused to style..........................Malvaceae
5.’ Flowers with stamens not fused to style..........................6

6. Stems with prickles..........................Rosaceae
6.’ Stems without prickles..........................7

7. Flowers in umbels or compound umbels......................Apiaceae
7.’ Flowers not in umbels.................................8

8. Flowers fused into tube.................9
8.’ Flowers not fused.................................10

9. Stem a vine............................................Convolvulaceae
9.’ Stem not a vine; spines present on leaves; leaves alternate........Solanaceae

10. Sepals absent; petals enlarged as membranes (often); 6-9 stamens........Polygonaceae
10.’ Flowers not as above..............................11

11. Tubular flowers; ovary deeply 4-lobed; single style................Boraginaceae
11.’ Flowers not as above..............................12

12. Leaves alternate; stamens 8-10; 5 sepals united at base..............Ericaceae
12.’ Leaves opposite; 5-10 stamens; petals often notched...............Caryophyllaceae
Key 13—Irregular flowers with 5 petals or lobes

1. Petals fused..........................2

1.’ Petals not fused.....................3

2. Stems squarish; aromatic leaves; petal lobes form upper/lower lips........Lamiaceae

2.’ Stems not square; leaves not aromatic; petals not in lips...............Scrophulariaceae

3. Sepals fused at base; stamens many; leaves trifoliate or compound........Fabaceae

3.’ Sepals not fused at base; stamens 5; leaves heart- or triangular-shaped....Violaceae

Families with unusual flower arrangements:

Heads—disk and ray flowers usually present; green bracts underneath head...Asteraceae

Floral cup—cyathium—ovary 2- or 3-lobed; latex often present.................Euphorbiaceae

Flowers in rounded clusters; latex present; sepals point down, petals up....Asclepiadaceae

Flowers vary greatly; many superior carpels; sepals replace petals........Ranunculaceae