

“BEING A METHOD PROPOSED FOR THE READY FINDING...TO WHAT SORT ANY PLANT BELONGETH”

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As any ONPS member will attest, it doesn't take many field trips into the prairies and forests of Oklahoma to encounter an unknown plant and have to ask, "What is it?" The easiest way to identify it is disarmingly simple; ask someone who knows! This approach works well when an *expert* is near at hand, ready to name plants. A second approach is to compare the unknown plant with photographs or illustrations in field guides specific for Oklahoma. Unfortunately, the major drawbacks in using such guides are that they typically illustrate only showy-flowered species and may not include all species present in the area. The ideal way to identify an unknown plant is to use a taxonomic key – an artificial analytical device for identification which offers a progressive series of choices between pairs of alternative features (Lawrence 1951). Taxonomists have been writing and using them for centuries as they have inventoried the world's flora (Voss 1952). Go anywhere in the world and if a taxonomic key is available, unknown plants can be identified.

Even after more than 45 years of working as a plant taxonomist, I still take pleasure in the challenge of identifying a totally unknown plant, i.e., one that I have no inkling of what it is. It is a delight to sit down at a dissecting microscope with dissecting needles in hand, to examine the plant's many features, to revel in its beauty and complexity, and to work my way through the key to arrive, eventually, at a

species name. Sometimes my first try is successful, but more often I have to make several or even numerous attempts. However, nothing is more satisfying than to be able to say "Gotcha! I know who you are!" In the following essay, I offer an overview of the origins and evolution of taxonomic keys, aspects of their nature, and suggestions on how to use them successfully.

Origins and Evolution of the Key—

Taxonomic keys have been the mainstays of plant identification for more than 250 years. Their origins, however, are considerably older and can be traced to the classifications of Aristotle and Theophrastus, based on *fundamentum divisionis* or the "principle of division" and those of 17th Century naturalists (Voss 1952; Stuessy 1990). Edward G. Voss, a plant taxonomist and former Curator of the Herbarium at the University of Michigan, published an excellent, comprehensive history of taxonomic keys in 1952. It was a delight to have discovered this paper many years ago, and I have excerpted aspects of it in the following very abbreviated summary. Voss describes how taxonomists such as Robert Morison, John Ray, Augustus Rivinus, and the anatomist Nehemiah Grew presented their classifications (1672, 1686, 1699, and 1682, respectively) in a tabular outline form and used brackets to relate and contrast their groups (essentially diagrams of relationships; Figure).

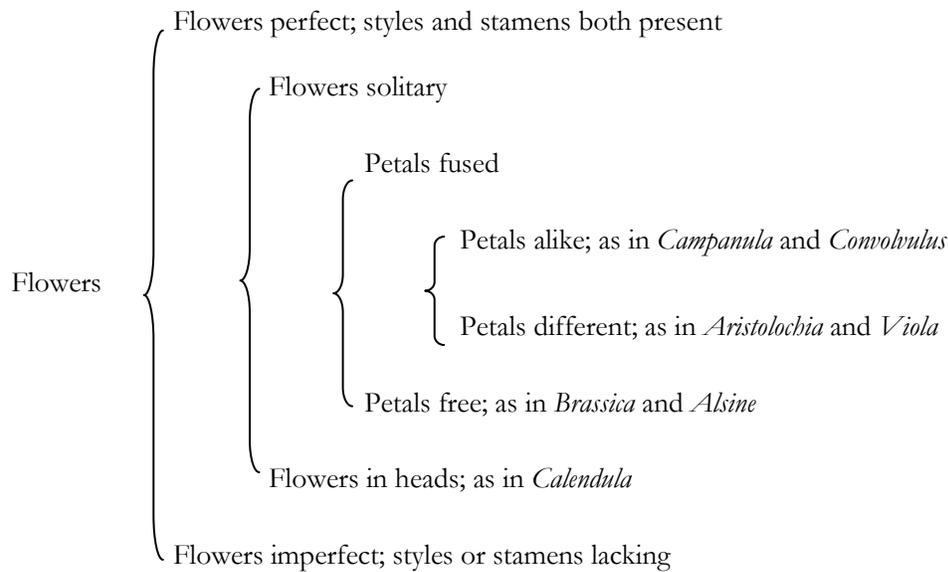


Figure A portion of the classification of John Ray appearing on page 20 of Volume 1 of his *Historia Plantarum* (1686), showing his groups and the brackets used to relate them. Latin text of Ray's groups translated and abbreviated.

I must stress that these bracketed tables were not keys and their purpose was not identification, but rather classification. As Voss notes, Grew, however, did articulate the idea of using a dichotomous key to identify plants. An appendix to the second part of book four of his *Anatomy of Plants* (1682) is titled "Being a Method proposed, for the ready finding, by the Leaf and Flower, to what Sort any Plant belongeth." In it, he describes how one might go about identifying an unknown plant and lists characteristics of the leaves and flowers that should be used in its identification. It was suggested that his title would be a catchy opening for this essay, and thus I have unabashedly used it.

Although Carolus Linnaeus, typically known as the father of taxonomy, apparently used *clavis*, the Latin word meaning "key," to describe these bracketed diagrams in his 1736 edition of *Bibliotheca Botanica*, the famous French naturalist and early proponent of the theory of evolution, Jean Baptiste de Lamarck, is generally credited with the development and first publication of the strictly dichotomous keys specifically for identification purposes. He used them throughout his *Flore Françoise*

published in 1778. Francis Arthur Bather (1927; cited in Voss 1952), in an address to the Geological Society of London, described the significance of Lamarck's keys in biology by stating:

A key is not a classification, but a method of analysis. The idea was first explicitly brought forward by Lamarck at the very beginning of his career. Having asserted that every species of French plant could be more readily determined by a purely arbitrary analytic key than by the Linnean system with its mixture of supposed reality and ordered arbitrariness he was challenged to produce such a key, and this he did within twelve months...

Since the time of Lamarck, keys have been an essential part of biological endeavor and used for the identification of all living systems. They are now an integral part of the literature of taxonomy, ecology, and indeed any discipline dependent upon plant identification, e.g., range management, wildlife biology, and conservation. Keys for the identification of plant families, genera, and species typically are incorporated in floristic treatments known as floras or manuals. These

works are designed to facilitate identification of the plants in an area and generally comprise the keys, descriptions of the morphology of each taxonomic group, and abbreviated comments about each group's distribution, ecology, flowering time, and taxonomic relationships. Please remember that the word "flora" also is used as a collective noun for all of the plants in an area, i.e., the botanical equivalent of fauna.

Nature of a Key—But what is a key? It is simply a device that presents its user (you) with a progressive series of choices between pairs of alternative, generally mutually exclusive features. For example, you might be asked to examine your unknown plant and to decide whether it is a *tree* OR an *herb*. Selection

1. Plants trees.

2. Leaves opposite; venation palmate. Fruits double samaras. *Acer rubrum* (red maple)

2. Leaves alternate; venation pinnate. Fruits nuts partially enclosed
in involucre caps (acorn). *Quercus stellata* (post oak)

1. Plants herbs.

3. Inflorescences umbels. Leaves alternate.

Corollas rotate. Ovaries inferior. *Polytaenia nuttallii* (prairie parsley)

3. Inflorescences panicles or racemes or spikes.

Leaves opposite. Corollas bilabiate. Ovaries superior.

4. Stems square. Inflorescences spikes. Fruits nutlets. *Prunella vulgaris* (heal-all)

4. Stems terete. Inflorescences panicles or racemes.

Fruits capsules. *Penstemon oklabomensis* (Oklahoma beardstongue)

The pair of alternative features at each fork is termed a couplet, and the alternatives of a single couplet are called leads or legs. To facilitate use of the key, the couplets typically are successively indented to the right, with both leads of a single couplet equally indented and generally numbered. After observing the unknown plant's features, you commence keying at couplet 1 by reading both leads and making a decision as to which lead applies. After one of the two leads has been selected, you proceed to the first indented couplet immediately under it. The couplets under the non-selected lead are disregarded because the features listed aren't those of your unknown plant. You continue reading the leads of successive couplets, observing the plant's

of the applicable alternative character state leads you to other pairs of alternative character states, e.g., *petals yellow* OR *petals white* or *leaves simple* OR *leaves compound*, and ultimately to the unknown plant's scientific name. Using a key is thus analogous to following a forking path with each fork forming a "Y". To reach the proper destination, i.e., identification of the unknown plant, you must take the correct path (choose the applicable character state) at each fork. I liken a key to a Victorian maze with its numerous forking paths among screens of boxwood or hazel. Correct choices made at each fork lead one to the center or exit. For example, a key to five Oklahoma species might read as follows:

features, and making choices until a scientific name is reached.

Thus, using the key above, if you observe that your unknown plant is an herb with terete stems, opposite leaves, panicles, bilabiate corollas, superior ovaries, and capsules, you identify it as *_?_* (see the last paragraph of this essay to check your identification). I have to admit that a glossary of taxonomic terms is indeed handy to have available when you first begin keying. Technical descriptive terms—the bane of beginners—are essential to ensure accuracy and brevity. However, the more you use a key, the more familiar the terms will become, and your reliance on the glossary will quickly decline.

Types of Keys—The key presented above is an indented key, so named because each successive couplet is indented to the right. In contrast, a bracketed key has couplets that are not indented but rather you are directed to the appropriate succeeding couplet via a number at the right-hand margin. The leads of each

couplet are always together. Use of a bracketed key is the same as for an indented key and involves observing the plant's features, reading both leads, and making a choice. A bracketed key to the same five species appears below.

- | | |
|--|---|
| 1. Plants trees. | 2 |
| 1. Plants herbs. | 3 |
| 2. Leaves opposite; venation palmate. Fruits double samaras. | <i>Acer rubrum</i> (red maple) |
| 2. Leaves alternate; venation pinnate. Fruits nuts partially enclosed in involucre (acorn). | <i>Quercus stellata</i> (post oak) |
| 3. Inflorescences umbels. Leaves alternate. Corollas rotate. Ovaries inferior. | <i>Polytaenia nuttallii</i> (prairie parsley) |
| 3. Inflorescences panicles or racemes or spikes. Leaves opposite. Corollas bilabiate. Ovaries superior. | 4 |
| 4. Stems square. Inflorescences spikes. Fruits nutlets. | <i>Prunella vulgaris</i> (heal-all) |
| 4. Stems terete. Inflorescences panicles or racemes. Fruits capsules. | <i>Penstemon oklahomensis</i> (Oklahoma beardstongue) |

Thus if you observe that your unknown plant is an herb with alternate leaves, umbels, rotate corollas, and inferior ovaries, you will identify it as ? (see the last paragraph of this essay to check your identification).

As is obvious, the bracketed key saves considerable space because the couplets are not indented to the right with the lines of text getting shorter. However, using it is time-consuming. Every couplet must be read in order, it is harder to locate succeeding couplets, and it is harder to retrace one's previous decisions. In an indented key, you quickly skip the couplets that are not applicable and have a better overview of what decisions you have made previously. As you become familiar with more plants and see their names in the couplets, you develop a sense of whether you are on the "right" path in identifying your unknown plant.

Branching by repeatedly forking into pairs of mutually exclusive leads (choices), indented and bracketed keys are termed dichotomous keys (from the Greek *dicho* meaning "in two" or "split"). Choosing between only two character states is perhaps an innate part of the human intellect. We tend to like true and false questions, we cheer the teams of the

Superbowl, and we label movies good or bad. We therefore feel comfortable using dichotomous keys. However, taxonomic keys written in the 1800s and early 1900s were not always strictly dichotomous. Some authors occasionally included trichotomous, tetrachotomous, and even pentachotomous couplets. As you might expect, the third, fourth, and fifth alternatives might easily be overlooked thus leading to errors in identification of the unknown plant. Fortunately, the dichotomous key has become the standard.

Indented and bracketed keys are also known as single-entry or single-access keys in that they have a single starting point – the character or characters of couplet 1. There is just one route or sequence of characters leading to the identification of an unknown plant. If one or more characters appearing in the couplets of the key are not available to the user, identification of an unknown plant becomes more difficult and sometimes impossible. An alternative to the dichotomous key is the multiple-entry or multiple-access key. Also known as a polyclave or polyclave key, the multiple-entry key, as its name suggests, allows the user to select the

characters used to identify an unknown plant from a character set that describes the plants of an area or taxonomic group such as family or genus. Initially, these character sets were tables or charts with plant names forming a matrix with a list of many different character

states. The names of species not possessing the features of the unknown plant at hand were crossed out until only one name remained. A polyclave key to the five species previously appearing in the indented and bracketed keys is given below.

	<i>Penstemon oklabomensis</i>	<i>Prunella vulgaris</i>	<i>Acer rubrum</i>	<i>Polytaenia nuttallii</i>	<i>Quercus stellata</i>
Plants trees	-	-	+	-	+
Plants herbs	+	+	-	+	-
Stems terete	+	-	+	+	+
Stems square	-	+	-	-	-
Leaves opposite	+	+	+	-	-
Leaves alternate	-	-	-	+	+
Venation palmate	-	-	+	-	-
Venation pinnate	+	+	-	+	+
Inflorescences umbels	-	-	-	+	-
Inflorescences panicles	+	-	-	-	-
Inflorescences racemes	+	-	+	-	-
Inflorescences spikes	-	+	-	-	-
Corollas rotate	-	-	-	+	-
Corollas bilabiate	+	+	-	-	-
Ovaries superior	+	+	+	-	-
Ovaries inferior	-	-	-	+	+
Fruits double samaras	-	-	+	-	-
Fruits nuts	-	-	-	-	+
Fruits nutlets	-	+	-	-	-
Fruits capsules	+	-	-	-	-

If you observe that your unknown plant is an herb with square stems, opposite leaves, spikes, bilabiate corollas, superior ovaries, and nutlets; you will identify it as ? (again, see

the last sentence of this essay to check your identification).

As you will note, your unknown plant can be identified by a single character. As you

might expect, however, identification by inspection in a polyclave key becomes harder as the number of species and the number of characters increase. In reality, seldom will a single character state be sufficient to identify an unknown. Thus, the process of progressive elimination was subsequently simplified by the use of cards with “windows” inserted at various points or their edges punched or notched to reflect different characters and character states. Each card represented a single species. The cards were stacked (in any order) and then retained or eliminated depending upon the character state appearing in the “window” or punched/notched edge until a single card remained and identification was thus accomplished (Hansen and Rahn 1969; Jones and Luchsinger 1986).

Although polyclave keys appeared as early as the 1930s, it was not until the 1960s that they became widely used (Morse 1971). In the late 1960s and early 1970s, taxonomists began to use computer-punched cards in place of the window or notched-edge cards (Pankhurst 1974). The advent of computers and the ability to incorporate and manipulate a plethora of characters, character states, and species greatly expanded the use of polyclave keys and today all use computer algorithms (Simpson 2006). Two approaches are employed in these computer-assisted keys. One is essentially a computerized version of the punch card system with species being eliminated by their incorrect character states when compared to the unknown plant. The second is slightly different in that it employs probabilities or likelihood ratios to indicate the species that have been eliminated and those likely to match the unknown (Jones and Luchsinger 1986).

Successful Use of a Key—Although a taxonomic key looks intimidating at first, its use is quite easy. For individuals who have not used one before, the following suggestions are offered.

- When attempting to identify an unknown plant, you should use, whenever possible,

the keys appearing in a flora written specifically for your area or state.

Examples of such books are George Goodman’s (1958) *Spring Flora of Central Oklahoma* and *Keys and Descriptions for the Vascular Plants of Oklahoma* (Tyrl et al. 2010). The latter is a precursor to the *Flora of Oklahoma* which is being written by a consortium of state botanists. If a local flora is not available, a regional (*Flora of the Great Plains* 1986) or continental (*Flora of North America North of Mexico* 1993+) treatment can be used. Remember my earlier statement about being able to go anywhere in the world and if a key is available, unknown plants can be identified? Keys are available for just about everywhere!

- Before beginning to key, spend a few moments becoming familiar with your unknown plant. Look at characters such as those cited in the keys given above. Dissect a flower or two. You will find that keying is typically faster and easier if you have many of the plant’s features already in mind.
- Always read both leads of a couplet and, if necessary, again observe the plant carefully before making a decision as to which lead best describes your unknown plant. Although the first lead of a couplet may be applicable, the second may be better.
- Sometimes the leads of a single couplet will be separated by numerous other couplets. Use the numbers at the beginning of the leads to locate them.
- Be sure that you read each lead carefully and fully understand it. In the indented and bracketed keys given above, note that the different characters in the leads are separated by periods; whereas, semicolons are used to separate different states of one character, and commas are used for clarity. In other keys, semicolons are used to separate characters, and commas are used to separate character states.

- Be sure that you understand the meanings of the terms used in each couplet. Use a glossary; most manuals have one.
- Be as careful and accurate as possible in making your observations. Use a magnifying lens to observe (and discover the beauty of) smaller features of the plant's surfaces, flowers, and fruits. Use a ruler to measure widths and lengths accurately; don't estimate. Sometimes the difference between two species is just a few millimeters.
- Whenever possible, do not base your selection of a lead on a single observation. Always try to examine more than one leaf or flower or fruit or surface. Remember that plants are living systems and as such sometimes vary in their features. For example, one flower may have four petals whereas all the others have five, or a normally alternate-leaved plant may have an occasional node with opposite leaves.
- When the name of a family, genus, or species is reached in the key, you should compare the features of the unknown plant with the group's morphological description in a manual and, if available, a botanical illustration. If they match, identification is accomplished. If they don't match, you should reexamine the features of the unknown plant and begin keying again. Be sure to, again, carefully read both leads of each couplet before selecting one.
- You undoubtedly will, at some point, encounter a couplet for which the selection of a lead is tenuous. When this happens, you should follow both leads and their following couplets. When you arrive at your two "answers," read the descriptions of both groups in order to determine which best describes your unknown plant. Often, the key will "tell you" whether you have selected the appropriate lead. If the subsequent couplets pose leads that are totally inapplicable to your unknown, it is likely

that you have chosen the wrong lead and you need to return to the original couplet and take the other lead.

- You also will likely encounter a couplet that cites a character that your unknown plant does not have, e.g., fruits or roots. Just ignore it and rely on the other characters listed in the couplet, or again follow both leads as described above.

Satisfaction—As I stated at the beginning of this essay, I find it most satisfying to be able to say to an unknown plant, "I now know who you are!" I hope that someday you will have that same feeling of satisfaction.

With respect to possibly your first keying experiences, were you successful in identifying the three unknown plants? Based on the characters listed (your observations), the first unknown plant you keyed was *Penstemon oklabomensis*, a species endemic to the state that flowers from April to June and is characteristic of the mid to late stages of plant succession in prairies. The second unknown plant was *Polytaenia nuttallii*, a member of the Apiaceae or carrot family, and typically is encountered as scattered plants or small populations in dark loamy or clay soils of Oklahoma's prairies. The third unknown plant was *Prunella vulgaris*, a member of the Lamiaceae or mint family, and generally encountered as individual plants or small populations in the moist soils of partially shaded forests or woods throughout the eastern half of the state.

Best wishes for your future keying experiences!

Acknowledgements—I thank Sheila Strawn, Paula Shryock, and an anonymous reviewer for their assistance in the preparation of this essay.

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