Week Three: Introduction to Taxonomic Keys

"Very true", said the Duchess: "Flamingos and mustard both bite. And the moral of that is – 'Birds of a feather flock together.'"
"Only mustard isn't a bird", Alice remarked.
"Right as usual, said the Duchess: "what a clear way you have of putting things!"
"It's a mineral, I think," said Alice.
"Of course it is" said the Duchess, who seemed ready to agree to everything Alice said: "there's a large mustard-mine near here. And the moral of that is – 'The more there is of mine, the less there is of yours!'"
"Oh, I know!" exclaimed Alice, who had not attended to this last remark, "it's a vegetable. It doesn't look like one, but it is". --Lewis Carroll, Alice's Adventures in Wonderland

Lab objectives:

- To learn to recognize a few of the common plants of the Sonoran desert
- To learn how a key can help you identify & organize organisms in natural world
- To use a dichotomous key
- To construct your own dichotomous key
- To use library resources to find articles and sources useful to you

Desert plants

At the end of this handout are some useful facts and drawings of the plants we will be working with today. They are all plants that we will encounter on our subsequent field trips to Tumamoc Hill, Greasewood Park and on the lower slopes of Mt. Lemmon. Take time to study these plants, especially those that you do not key out yourself. **We will expect you to be able to identify all of these plants and may quiz you on them in the field, lab, or on exams**.

Why key?

A key is a tool to identify something. Biologists like to use keys because they provide an efficient shortcut to figuring out what an organism's name is. Imagine you lived somewhere with only 3 species of trees. If you wanted to know what the name of one of the trees was, it would be relatively easy—you'd probably find a field guide to the region and compare the pictures to what you saw in front of you. But what if you lived in a place where there were no field guides (most tropical countries where the most identification problems arise). Or, imagine that you lived (as you do) in Southern Arizona. It is spring, after a good season of winter rains, and you hear there are wonderful wildflowers out by Picacho Peak. There you see beautiful arrays of familiar orange California poppies and purplish-blue lupines. However, you spot an especially attractive flower, much less common than the others, and you want to know what it is. When you flip through your field guide you find that a) you can't find an exact match, and b) under the entry for the plant that looks most similar, the field guide says *Erigeron*—35 spp in Arizona. Now what? You are not satisfied knowing that it is "*Erigeron* sp.", but instead you want to know WHICH *Erigeron* it is. That is where keys come in.

What is a key?

A key is a series of statements ("**leads**") describing the **characters** of an object or organism, which are typically paired. Those statements are mutually exclusive alternatives, one of which fits your organism. Your job is to examine the organism you are trying to identify and choose one of the statements that best describes your object. Once you choose one of the alternatives, your key will direct you to another set of mutually exclusive statements. You follow these statements along, eliminating as you do all the statements that don't fit your organism until you arrive at a taxon name.

What are the different kinds of keys?
Most keys are **dichotomous**, meaning that the statements or leads are paired. For instance, an example of a dichotomous lead, might be; "1.a) Leaves covered in sticky resin" versus "1.b) Leaves smooth, not covered in sticky resin". However, some keys (especially recent keys) are acknowledging that the human brain is capable of considering more than 2 alternatives at a time. Here is an example of a trichotomous lead: "2.a) Flowers yellow or white" versus "2.b) Flowers orange or red" versus "2.c) Flowers blue, violet or occasionally green, not yellow, white, red or orange".

Most keys are written out on paper such as those you will use today. However, recently, biologists have realized the applications of computer technology to species identification. New electronic keys are extremely efficient and have the benefit of allowing the user to use the characters she/he can most readily see in the order she/he wants. Now, instead of being forced to go through (and guess on, sometimes) leads having to do with flowers when none are available, one can jump right to the things you CAN see immediately. The computer then eliminates all the taxa that don't fit, and provides a new list of characters to choose from in the order that most efficiently divides the remaining taxa. Try going to the website http://131.230.176.4/cgi-bin/dol/dol_diagkey_home.pl, and click on "Families of Dicotyledons." Take a look through this key, or better yet, pick a plant (any plant) you find outside somewhere and see if you can key it to family using this online electronic key. You may need to have both fruit and flowers on your specimen to use this particular key. The pictures of the characters should help you choose the correct character state at each lead.

Keys can help you identify anything, and keys can be based on any kind of character you can dream up that is useful. It doesn't have to be plants. There are keys to small mammals based on dental patterns and there are keys to fossil insects based on the kind of leaf damage they created on fossil leaves. You can even make keys based on behavior.

Plant taxonomists have traditionally focused on plant reproductive structures—especially flowers—when building their keys. This is because some people believe that keys should always be synoptical, and plant taxonomy (back to Linnaeus) has focused on floral parts. A **synoptical** key is one that divides taxa according to their relatedness, so that early in the key distantly related taxa are separated out, and by the end of the keying exercise, you are distinguishing between very closely related organisms. The opposite of a synoptical key is an **artificial** key. We will be using artificial keys today. Artificial keys find the most efficient way of dividing things into groups and distinguishing between them, whether or not those groupings reflect the evolutionary history of the organisms or not. Here is an example. You are making a key to the following 4 taxa: 1) an ant, 2) a spider, 3) a fly, and 4) a wasp. A synoptical key would want you to separate out the spider first (it is an arachnid (Class Arachnid) with 8 legs, whereas the others are insects (Class Insecta) with 6 legs). Then you'd have to separate the fly from the other 2, because flies belong to the order Diptera, whereas both ants and wasps are in the order Hymenoptera. Then, finally, you'd distinguish between the ant (Family Formicidae) and the wasp (Family Vespidae). However, an artificial key might recognize that the most obvious way to group these 4 taxa at first glance is according to whether or not they have wings. Thus the first lead could be "1.a) Wings present" versus "1.b) Wings absent". Then it is simple to distinguish the ant and the spider (6 vs 8 legs) and the fly vs the wasp (2 vs 4 wings).

Finally, keys can be arranged in slightly different ways depending on the preference of the author. Each lead in a pair of leads will be followed by a number or letter. When you decide

which of the leads is correct for your organism, you find the pair of leads preceded by the number (or letter) that you finished with in your lead. Pairs of leads may be presented immediately following one another as in this first example (and in our plant key below):

1a.	Bean round	**Garbanzo bean**
1b.	Bean elliptical or oblong	2
2a.	Bean white	**White northern**
2b.	Bean has dark pigments	3
3a.	Bean evenly pigmented	4
3b.	Bean pigmentation mottled	**Pinto bean**
4a.	Bean black	**Black bean**
4b.	Bean reddish-brown	**Kidney bean**

…or they may present the pairs of leads separated by the choices that proceed from the first lead but indented to show which lead goes with which, such as in this example:

A. Bean elliptical or oblong	B
B. Bean has dark pigments	C
C. Bean color is solid	D
C. Bean color is mottled	**Pinto bean**
D. Bean is black	**Black bean**
D. Bean is reddish-brown	**Kidney bean**
B. Bean is white	**White northern**
A. Bean is round	**Garbanzo bean**

How do you use today's key?

1. Either by yourself or in pairs, choose one of the sprigs of plants provided by your TA. Each of you will key 3 or 4 plants.
2. Always start with the first lead. Read **both alternatives** [1. a) and 1. b)] fully and carefully. Choose the lead that best describes your plant. If there is a word in your key you aren't familiar with, look it up in the plant morphology guide available in the lab. Don't guess. If you run into trouble, or are not sure if you understand a term, ask your TA!
3. When you have chosen the lead that fits, look to the right of the lead and read off either a taxon name (yay! you've finished keying the plant) or another number. If you get a number, then find the pair of leads preceded by that number and continue until you reach an identification.
4. When you have keyed out your plant, verify your ID by looking up the plant in one of the field guides to Arizona plants we'll have available in lab. Also, make a sketch of the plant (with its name) in your notebook, being sure to point out some of the features that allowed you to identify it using the key.

Key to some common Sonoran Desert plants of SE Arizona

1. a)	Leaves simple.	2
1. b)	Leaves compound.	6
2. a)	Plant a spiny shrub, branching near the base. Branches long (up to ~2 m) and rarely branching. Stems whitish, longitudinally streaked with green. Stems with stout whitish spines every 3-4 cms along stem. Leaves, when present, in axils of spines. Flowers terminal, red, tubular.	*Fouqueria splendens*, "Ocotillo"
2. b)	Plants not spiny. Shrubs < 2 m tall, more densely branched. Stems brown or green. Leaves variously distributed, but not in axils of spines. Flowers yellow or green, not tubular	3
3. a)	Leaves roughly triangular in shape, not deeply lobed.	4
3. b)	Leaves oval, or dissected into deep pinnate lobes, not triangular.	5
4. a)	Leaves pale grey-green to almost white, leaf margin sometimes undulate or slightly lobed. Pale stems exude a yellow resin where damaged. Flowers borne well above foliage. Flowers yellow, resembling a sunflower. Old flower stalks persistent on non-flowering plants.	*Encelia farinosa*, "Brittle-bush"
4. b)	Leaves pale grey-green to dark grey-green, leaf margins finely toothed. Stems do not exude resin. Flowers borne toward branch tips but not conspicuously above foliage. Flowers green, small, and inconspicuous.	*Ambrosia deltoidea*, "Triangle-leaf Bursage"
5. a)	Plants large shrubs, up to ~1.5 m tall. Leaves oval, leathery, secondary veins obscure. Plants dioecious (different male and female plants). Flowers small, yellow. Seed a large, oily nut.	*Simmondsia chinensis*, "Jojoba"
5. b)	Plants small shrubs or sub-shrubs, usually < .5 m tall. Leaves not leathery, deeply divided into pinnate lobes. Plants monoecious. Flowers yellow, clustered into a composite head (like a thistle flower). Seeds small with cottony pappus.	Isocoma tenuisecta "Burro-weed"
6. a)	Leaves opposite, once-compound; leaflets 2 per leaf. Leaves yellowish green and resinous, emitting strong chemical odor when crushed. Fruit a small, white, fuzzy ball.	Larrea tridentata "Creosote Bush"
6. b)	Leaves alternate, twice-compound; leaflets more than 2 per leaf. Leaves grayish-green to pale blue-green, not strongly aromatic. Fruit a legume (like a pea pod).	7
7. a)	Trunk and stems brown except for the newest growth, not photosynthetic. Leaf divided into 4 sections, each section with >10 pairs of leaflets/leaf section.	*Propsopis velutina* "Velvet Mesquite"
7. b)	Trunk and stems green, photosynthetic. Leaf with only 2 major divisions, each section with fewer than 10 pairs of leaflets/leaf section.	8
8. a)	Trunk and stems blue-ish green. Leaflets 4-8 mm long, typically 3 leaflet pairs along rachis. Fruit generally 2-seeded, not strongly constricted between seeds.	*Cercidium floridum*, "Blue Paloverde"
8. b)	Trunk and stems green to yellowish-green. Leaflets 2-3 mm long, typically 4-5 leaflet pairs along rachis. Fruit generally $\geq$3-seeded, strongly constricted between seeds.	*Cercidium microphyllum*, "Foothills Paloverde"

Constructing your own key

Now that you know how a key works, you can make one yourself. The purpose of this next section of the lab is to create a key to the mythical (and extinct?) Dendrogrammaceae. You will take the "taxa" your TA provides you with, and by careful taxonomic study, create a dichotomous key to these organisms. How? There are 2 basic approaches.

Both approaches start with a careful study of characters—essentially a grown-up version of "which one of these is not like the others?" Try to find as many useful characters as possible. A character is NOT useful when every taxon has it in identical form. For instance, if you were writing a key to the students in this class, an example of an *UN*-useful character would be "Legs present, 2 in number" versus "Legs absent". We all have legs so that doesn't help identify any one or subset of us. Conversely, something that each of us has in all *different* ways is not useful unless that character can be grouped into some more useful division. For instance, trying to divide the entire class based on the type of car driven would probably be a bad character to pick because, chances are, we all drive different kinds of cars. However, by modifying that car character lead to say "car made before 2000" vs "car 2001 or older" you might divide up the room in a useful fashion.

Once you have carefully examined your taxa and made a list of the useful characters you can use, it is time to start building your key. The most efficient way to lead your key-users to a determination is by dividing taxa in halves. What character does about half of your taxa have and the other half not have? Try writing your first lead based on this character. Next, look at one of those sub-groups. What character best divides them into roughly equal halves? Build the second lead for that group based on that character and so on until you are distinguishing between individual species. Realize that there may be more than one way to arrive at a species ID. Some species might be so variable that they could "fall out" through a variety of pathways to the correct ID.

The second basic approach also begins after a careful examination of your taxa and can sometimes be used in conjunction with the halving method. It is less efficient, but sometimes useful when you have one or a few taxa that are just so weird or different that they mess up the whole dividing into halves exercise. When this is the case, try "pulling off" those oddities first. For instance, if all the species except for one has a 2 cm long bill, a blue crest, and green feet, and then this one species has a 13 cm long bill, a red and orange crest, and black feet, it might make sense to just get that guy out of the way first. Then you can devote your attention to the halving business.

Here are a few rules of good key building. Please try to follow them.

1. Always make your leads **parallel**. That is, if you mention bill length, crest color and foot color in the first part of your lead, mention the alternative states for ALL THOSE and ONLY THOSE characters in your alternate lead. Address characters in the same order.
2. Omit unnecessary words. Avoid full sentences.
3. Place nouns first, followed by adjectives (e.g., Crest blue, bill 12-14 cms long).

Where possible, see if you can use terms that we have mentioned in class!

TRIANGLE-LEAF BUR SAGE *Ambrosia deltoidea*

Sunflower (Compositae) Family

A small, evergreen, perennial shrub growing on gravelly slopes and bajadas from 1,000 to 3,000 ft. elevations. Leaves are light gray-green to dark gray-green; triangle-shaped; pointed toward the tips; leaf margin is finely toothed; size ranges from 2 cm to 5 cm in length. Leaves curl and become dry and brittle during drought. This plant may appear in almost pure stands or in quite dense stands in association with the Paloverde and Saguaro Community of the foothills region. The flower is colorless and develops into a bur fruit. The pollen of the plant is one of the heaviest contributors to hay fever during the early spring (blooms from December to April).

Note:
a) Shape and size of leaf.
b) Margin (edge) of leaf (is it smooth or toothed?).
c) General size of plant.
d) Scattered and abundant distribution (look in any direction to see this plant).

*WHITE BRITTLEBUSH (Encelia farinosa)

Sunflower (Compositae) Family

A low (30-45 cm) branching dome shaped shrub growing in clumps or individually on rocky, dry slopes up to 3000 feet elevation. The large oval shaped leaves are gray-green when young, but turn nearly white with age. The bright yellow flowers appear from November to May.

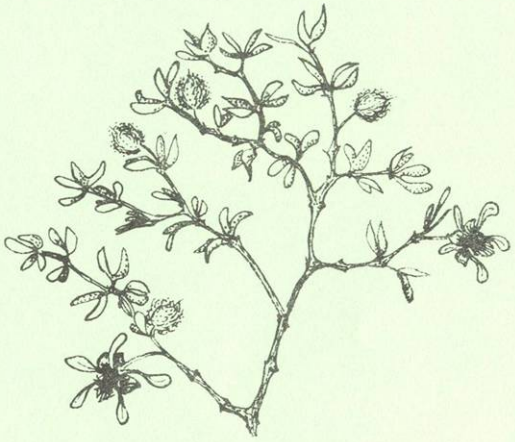
Note: a) Shape, size and color of leaves.

CREOSOTEBUSH (Larrea tridentata)

Caltrops (Zygophyllaceae) Family

A medium to large, many branched, evergreen shrub growing on dry plains (desert floor) and lower bajadas from sea level to 4,000 ft. Creosotebush occurs in the driest and hottest areas of North America in fine textured soils where very little else is able to grow. The leaves are composed of two wing-like leaflets and are thick, bright green and have a waxy or lacquered appearance. The leaflets are about .5 to 1 cm long. The bright yellow flowers may appear at various times during the year, but most commonly during the spring. The fruits (seeds) appear as small, white, fuzzy balls. The Creosotebush provides a characteristic desert odor following precipitation.

Note:
a) Size of paired leaflets.
b) Waxy appearance of leaflets.
c) Spherical, white, fluffy fruits on some branches.
d) Overall appearance of branches.

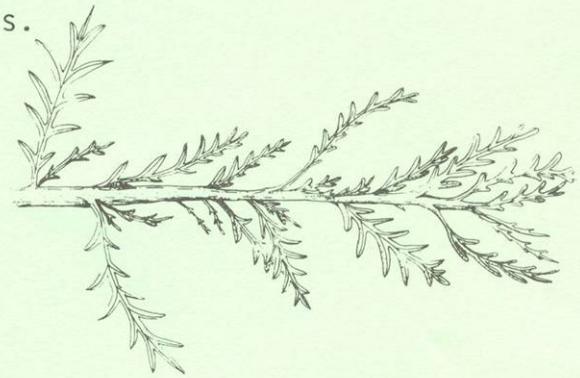


BURRO-WEED (*Isocoma tenuisecta*

Sunflower (Compositae) Family

A small (30-45 cm) herbaceous-like bush growing in distinct clumps. Bright green leaves are deeply lobed (= "tenuously" dissected). Flowers are yellow and appear August through October.

Note:
a) Size, shape, and color of leaves.
b) General form of plant.



*JOJOBA (Simmondsia chinensis)
Box (Buxaceae) Family

A medium size evergreen shrub growing along dry slopes from 1000 to 5000 feet elevation. Leaves are large (2-4 cm long) thick and leathery, elongate oval in shape. Plants are of separate sexes, the female plant producing (after flowering from December to July) a nut (an acornlike capsule) containing a single seed. The somewhat bitter tasting (due to tannin content) nut may be eaten. The nut also contains a liquid wax which is being used in a limited candle making industry by certain Indian tribes in Arizona. This wax is also a possible sperm whale oil substitute, if the plants can be commercially grown.

Note: a) Size, shape, color, and texture of leaves.

*Does not grow on the study site area.

(14) OCOTILLO (Fouquieria splendens)
Candlewood (Fouquieriaceae) Family

A medium to large shrub with many long, whiplike, unbranched thorny stems growing on dry mesas and along rocky slopes from sea level to 5000 feet. Ocotillo is often referred to as a cactus because of its quite thorny stems, but this is a misnomer; it is not a cactus. The dense, bright red spike of flowers at the tips of the stems appear from April to June and sometimes following the summer "monsoons." The spatula shaped leaves are drought deciduous, but they may be replaced within a few days following substantial rainfall during any of the warmer months of the year. The green bark contains chlorophyll.

Note: a) Long slender branches with many still spines.
b) Rather large leaves (by comparison with other plants seen so far) near each spine, if present.

(10) _____

(08) _____

(21) _____

(02) _____

FOOTHILL PALOVERDE (Cercidium microphyllum)

Pea (Leguminosae) Family

A tree or large shrub, common along rocky hillsides (bajadas*) and mesas from sea level to 4000 ft. elevation. The smooth bark (particularly when young) is a "yellow-green" and is photosynthetic. Twigs and branches end in spines. The branches are more stiff and bristly than the Blue Paloverde. The compound leaves are composed of many very tiny (2-3 mm) drought deciduous leaflets. Pale yellow flowers appear from April through May, and develop into (4-8 cm) long pods which have constrictions between the seeds.

Note:
a) Smooth yellow-green bark on trunk and branches.
b) Spine-tipped twigs (dried twig ends form sharp point).
c) Tiny size of leaflets and their arrangement, the constricted seed pods.
d) General area where tree is growing.
e) General size and shape of tree.

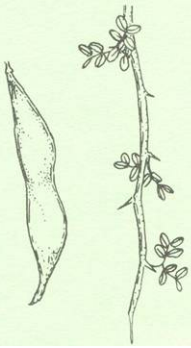
*The bajada is a region defined as the gentle outwash slopes at the base of a mountain.

(07) BLUE PALOVERDE (Cercidium floridum)

Pea (Leguminosae) Family

A small tree or large shrub, common along washes and desert floodplains from sea level to 4000 ft. elevation. The smooth bark (particularly when young) is characteristically a "blue-green" color and is photosynthetic. The twigs and branches have a soft or limber "feel" as compared to the Foothill Paloverde which is stiff and "bristly." Twigs are armed with short straight spines. Leaves are bipinnately compound with the leaflets 4 to 8 mm in size (larger than the very tiny leaflets of the Foothill Paloverde). The leaves are drought deciduous. Bright yellow flowers occur from March to May. Seed pods are (8-10 cm) long, and flat (1-1½ cm wide, without constrictions) containing seeds which were used by the local Indians for food.

Note:
a) Smooth blue-green bark on trunk and branches.
b) Small spines at some nodes on branches.
c) Size of leaflets (compare with the Foothill Paloverde).
d) General area where tree is growing.

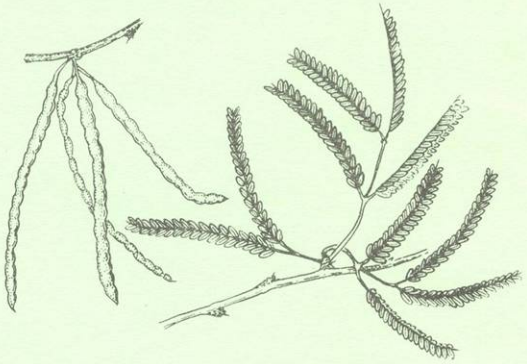


VELVET MESQUITE *Prosopis velutina*

Pea (Leguminosae) Family

A large shrub (or small to medium sized tree) growing primarily along washes and other drainage ways but also occurring in flat grasslands and along slopes from sea level to 5,500 feet. The bark is rough and gray to black in color. Leaflets (10-20 pairs) of the compound leaves are 1.5 x 3.7 mm and light gray green in color. Short straight spines occur in pairs at the twig nodes. Flowers consist of a long (5-7 cm), fuzzy hanging cylindric spike, greenish yellow in color. The mesquite flower furnishes nectar to honey bees which produce a "mesquite honey" enjoyed by many people. Fruits are long (10-20 cm) pods, edible by animals, and the mesquite beans were made into a meal by the Indians. The root system may penetrate to a depth of 150 feet to obtain water, allowing the mesquite to exist in some of the driest habitats.

Note: a) Rough dark colored bark on trunk and gray smooth bark of twigs.
b) Size and arrangement of the leaflets, and spines.



Your name: _____
Your Section: _____

Key to the plants in the Dendrogrammaceae