In the new classification system, the milkweed family, Asclepiadaceae, will be placed in the dogbane family, Apocynaceae. The prostrate milkweed (*Asclepias solanoana*) from Sonoma County is shown here. Photograph by J. Game.

UPCOMING CHANGES IN FLOWERING PLANT FAMILY NAMES: THOSE PESKY TAXONOMISTS ARE AT IT AGAIN!

by Ellen Dean

We had a sense that beloved plant names were at risk when the scientific name of one of our favorite species, *Zauschneria californica* (California fuchsia), became *Epilobium canum*. That change was suggested more than 25 years ago in the mid-1970s when Peter Raven, the current director of the Missouri Botanical Garden, reexamined the relationships among *Epilobium* (willow herb) and relatives. The name *Epilobium canum* was used for California fuchsia in *The Jepson Manual of Higher Plants of California*, which was published in 1993, and that name change had plenty of company. For example, the generic names of many of the species of *Orthocarpus* (owl's clover) morphed into *Castilleja* or *Triphysaria*, while all of our *Stipa* species (needle grass) took on other generic names, such as *Nassella*

If one examines the name change section of *The Jepson Manual* (Appendix III), one finds hundreds of name changes that were incorporated in the 1993 publication. (See Skinner and Ertter, 1993, for a discussion of this topic with regard to rare plants.) Nearly 10 years after the arrival of *The Jepson Manual*, some of us are still reeling from the loss of *Matricaria matricarioides*, the old name for pineapple weed. (What a wonderful name; somehow *Chamomilla suaveolens* will never quite do.) I imagine there are California botanists who don't want to see more name changes any time soon, am I right?

Unfortunately, when it comes to plant taxonomy and classification, more changes are imminent, and these are far reaching, often affecting the families we have all known and loved for centuries. In a paper titled "An ordinal classification for the families of flowering plants," which was published in the fall of 1998 by the Angiosperm (flowering plant) Phylogeny Group (APG), a group of 28 authors proposed a new classification system for flowering plants. The APG system is now being taught in college taxonomy courses, thanks to the publication of *Plant Systematics: A Phylogenetic Approach*, an excellent new plant systematics textbook by Walter Judd et al. (2002). This text incorporates much of the classification put forth in the APG paper, although it has a few surprises of its own.

For those of us who learned the flowering plant classifications of Arthur Cronquist, Armand Takhtajan, or Robert Thorne when we took plant taxonomy in the 1970s or 1980s, this new classification system may come as a bit of a shock. Most articles and books published in this country over the past 20 years (including *The Jepson Manual*) have followed Cronquist's familial classification. As with most flowering plant classification systems produced during the 20th century, Cronquist divided the flowering plants into a nested hierarchy of groups arranged to reflect an approximation of evolutionary relationships. (See sidebar on pages 4–7 for a more in-depth explanation of classification.)

He proposed two classes: the *monocotyledons* (grasses, lilies, and their allies, all of which have one seedling leaf or cotyledon), and the *dicotyledons* (flowering plants with two

CLADISTICS, CLASSIFICATION, AND NAME CHANGES OR TREES THAT HAVE PLANT NAMES AT THE ENDS OF THEIR BRANCHES

Classification is a basic human endeavor; people classify tools, food, and telephone numbers. Our classifications are often hierarchical, that is, they are nested subsets which may be visualized as venn diagrams (Figure 1) or written out as a hierarchical list (Table 1). Plant classifications using common names are mainly made up of folk genera such as "oak" or "maple," and folk species such as "coast live oak" or "big leaf maple," although other categories like "live oak," "shrub," or "tree," may also be used.

By the 16th century, Europeans had begun the task of classifying every plant and animal in the world by giving them a unique Latin description. In his 18th century works, Carolus Linnaeus was the first to popularize a Latin description consisting of only two words, which have become known as the genus name (e.g., *Quercus*, the Latin common name for oaks) and its modifier, the specific epithet (e.g., *alba*, Latin for white).

When put together, these two words are called the species name (ex. *Quercus alba*). For convenience, Linnaeus placed the species he described into classes based on stamen type, arrangement, and number, which meant that his classes often consisted of unrelated genera and species. His revolutionary innovation was that he provided a rudimentary identification key to the correct class—a huge help in organizing the increasing number of plants that were being collected around the world.

Linnaeus's classification system was replaced by plant classifications that were based on presumed relationships between species. At first these classifications—which were based on as many characteristics of the species as possible—were attempts to understand the order of nature or the plan of a creator. However, by the end of the 19th century, scientists began to incorporate the notion of evolution into classification systems.

The term "phylogeny" was coined to mean "evolutionary history," and a "phylogenetic classifi-

TABLE 1. SIMPLIFIED CLASSIFICATION OF SIX SPECIES OF CALIFORNIA CONIFERS VIEWED AS A HIERARCHICAL LIST

Pines	Foothill pine (*Pinus sabiniana*)
	Sugar pine (*Pinus lambertiana*)
Firs	Silver fir (*Abies amabilis*)
	Red fir (*Abies magnifica*)
Spruces	Sitka spruce (*Picea sitchensis*)
	Brewer spruce (*Picea breweriana*)

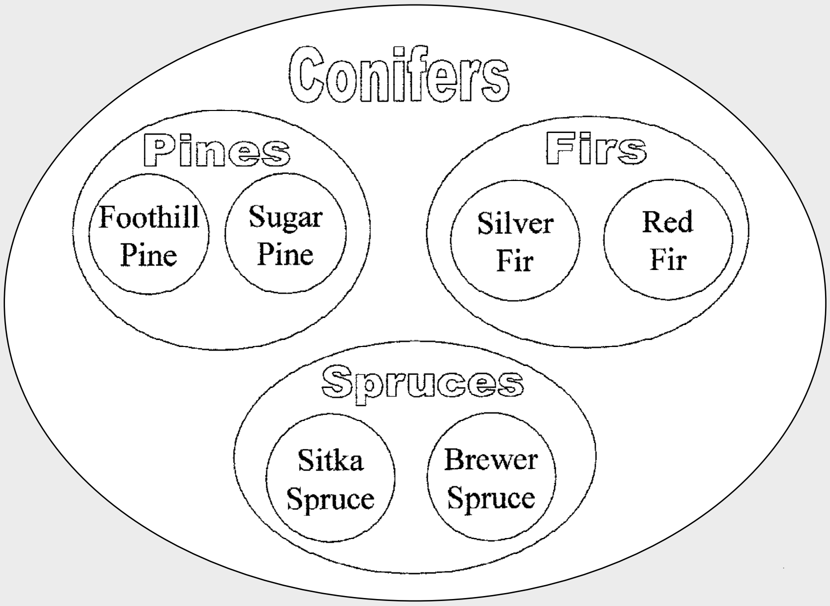


Figure 1. Simplified classification of six species of California conifers viewed as a Venn diagram.

cation” became one that placed species, genera, or families together based on presumed evolutionary relatedness. By the early 20th century, some classifications included drawings of evolutionary trees illustrating the author’s hypothesis of ancestor descendant relationships among the flowering plants. These were called “phylogenetic reconstructions” or “phylogenetic trees.”

In the 1950s, Willi Hennig, a German entomologist, began a school of phylogenetic reconstruction called cladistics. The output of a cladistic analysis is a cladogram, a type of phylogenetic tree. The major contribution of cladistics is the explicit understanding that related species should be grouped based on shared features that are “derived” or different from those possessed by an ancestral population. These shared derived features are termed “synapomorphies.”

For example, the scaly cupule (acorn cap) found in all members of the oak family (Fagaceae) is a morphological synapomorphy for that family (Figure 2). A cluster on a cladogram that includes a branching point (a putative ancestor) and all the descendants above that branching point is termed a “monophyletic group.” One example is the Fagaceae family, which are shown in Figure 2, although not all genera in the family are shown.

The use of cladistics in taxonomy did not become popular until the 1980s. Late in the same decade, the use of molecular data to determine relationships between species became commonplace. Scientists now sequence genes to look at the pattern of bases in DNA strands. Patterns between species are compared and analyzed using computerized cladistic analyses or other methods of phylogenetic reconstruction. Well-studied morphological features can also be added to the analyses, and the resulting phylogenetic trees are studied to determine relationships among species, genera, and families.

Current classifications based on cladistic analyses only recognize monophyletic groups of organisms (genera, families, orders). For example, recent classification systems recognize the flowering plants (angiosperms) and monocotyledons, because they form strong monophyletic groups in cladistic analyses (Figure 3). These groups are not only

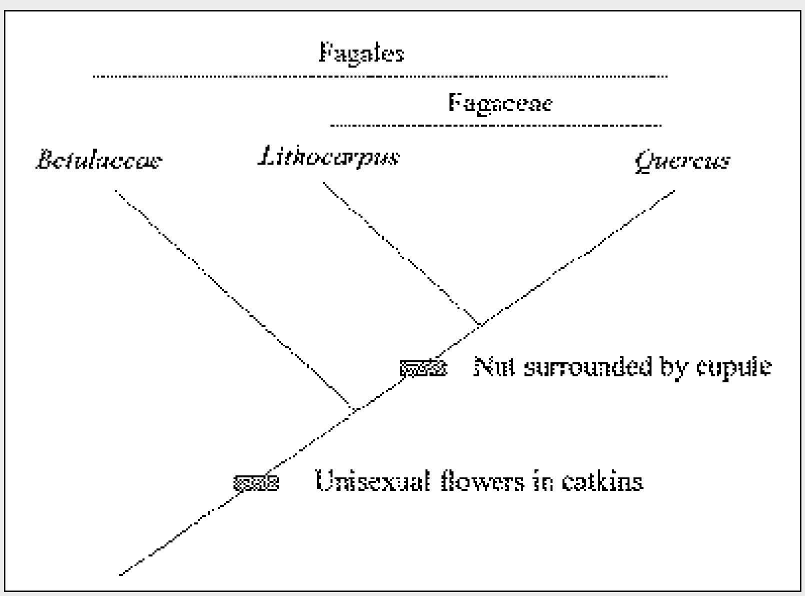


Figure 2. Hypothetical simplified phylogenetic tree of two California plant families in the order Fagales (not all families and genera are shown). Unifying synapomorphies that group members of the Fagales and members of the Fagaceae are indicated on the branches.

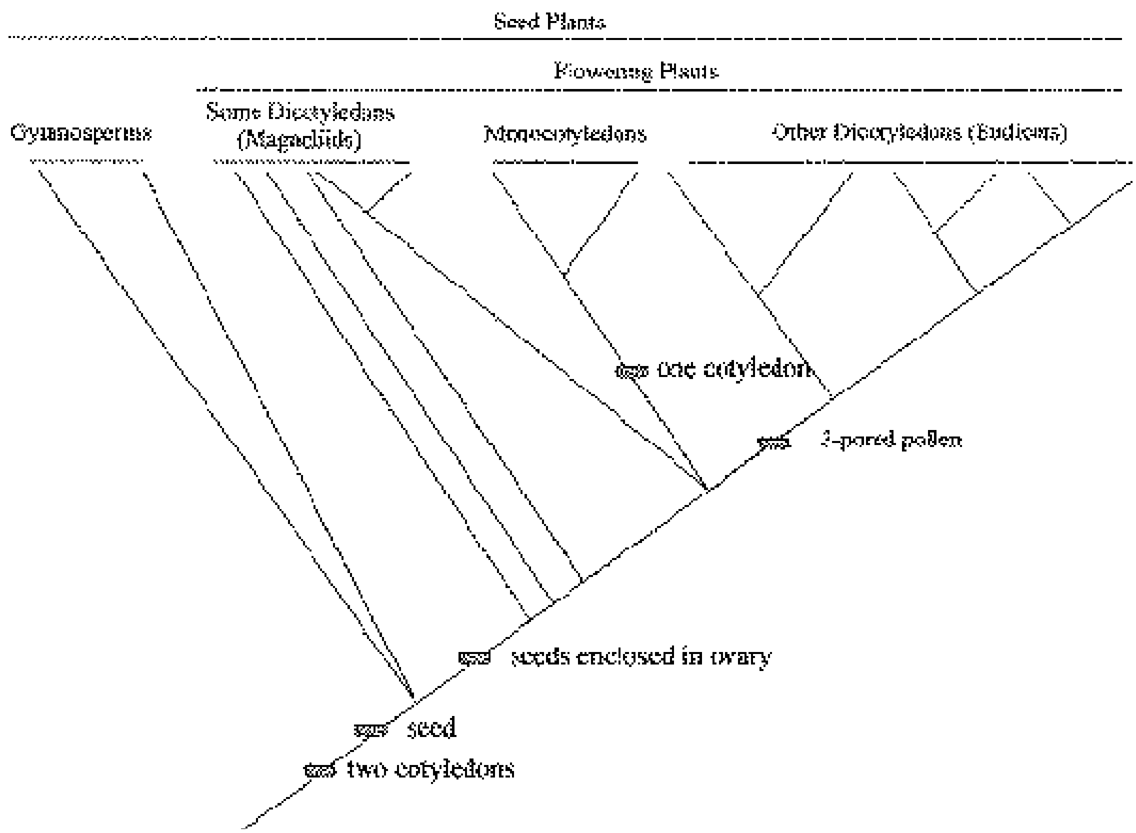


Figure 3. Simplifed phylogenetic tree of seed plants with key synapomorphies indicated on the branches. The innovation of one cotyledon unites all monocotyledons into a monophyletic group. As can be seen from this tree, most seed plants have two cotyledons, therefore the presence of this feature in dicotyledons is an ancestral (not a derived) feature. The dicotyledons, therefore, are not a monophyletic group.

supported by molecular data, but they are defined by important morphological synapomorphies—the ovary in the case of the angiosperms, and one cotyledon in the case of the monocotyledons (Figure 3).

In contrast, current classifications do not recognize the dicotyledons (flowering plants with two cotyledons, the members of which are outlined in Figure 3), for it turns out that the possession of two cotyledons is not novel within the flowering plants; having two cotyledons is an ancient feature that most seed plants share. Cronquist's classification recognized many non-monophyletic groups that were based on shared ancestral features. The elimination of these groups is one reason for the current reshuffling of genera and families.

Cladistic analysis and other types of phylogenetic reconstruction are not perfect, however, because different genes or other characteristics may provide apparent conflicting synapomorphies, producing different phylogenetic trees. In these cases, it is assumed that some such features evolved more than one time or evolved and then reverted to a previous form.

To choose among the hundreds of trees that may be produced by a large analysis, the principle of parsimony is employed. The most parsimonious tree is the shortest tree, requiring the fewest changes in characteristics along the tree branches. The most parsimonious tree, however, is not necessarily the true evolutionary tree. Therefore, as more information is obtained over the next few decades and new and better forms of analyses are employed, the classification of flowering plants will continue to change.

Unfortunately for all of us, when classifications change, sometimes plant names change. Why is this? The naming of plant groups is guided by an international body of taxonomists and a document called the International Code of Botanical Nomenclature (ICBN) which is updated every five or six years. The Code specifies that every species name be tied to a particular herbarium specimen which is called its type specimen, every genus name is tied to a type species name, and every family name is tied to a type genus name.

If one wants to use the family name Scrophulariaceae for a particular group of genera, then the type genus *Scrophularia* (bee plants) needs to be one of the genera that is in the group. Similarly, if one wants to use the generic name *Scrophularia* for a particular group of species, then the type species *Scrophularia nodosa* must be included in that group of species. If one wants to use the name *Scrophularia californica* for a particular group of populations, then one needs to make sure that the type specimen of that name matches plants from those populations.

Sometimes, the same entity (a species, genus, or family) has more than one published name. In that case, which name does one choose? Here, we turn once again to the ICBN which says that we must use the oldest published name beginning from 1753 (the publication date of Linnaeus's *Species Plantarum)*, unless taxonomists vote to conserve a later name. This is known as the principle of priority.

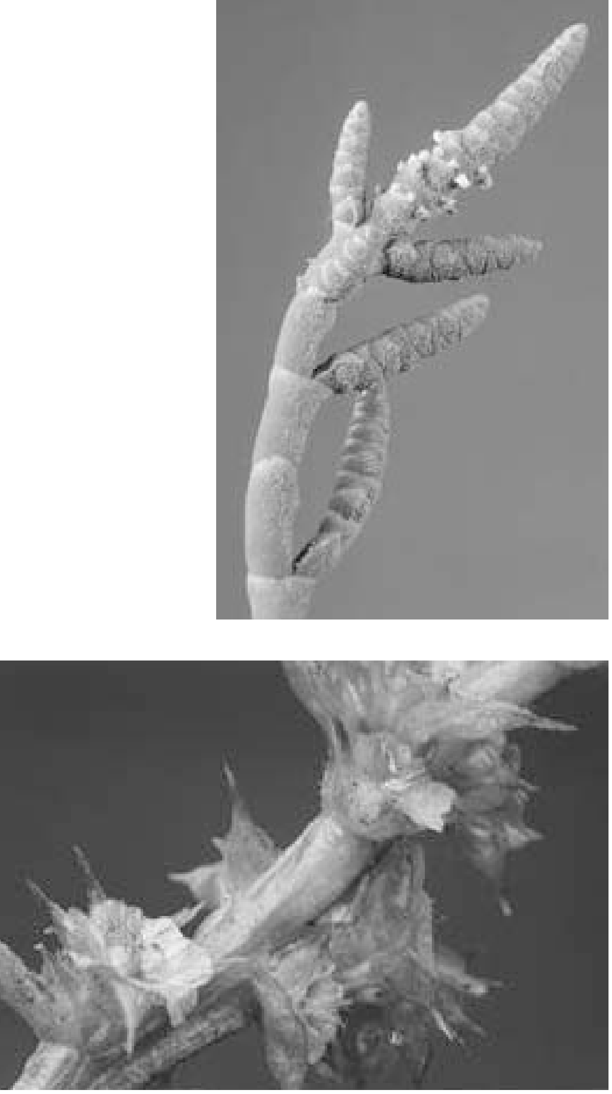
With the combination of new molecular data, the wide use of cladistic analyses, strict adherence to the rules of cladistic classification, and the application of the rules of the ICBN, you can now see how we have arrived at a point in botanical history where the names of flowering plant groups are changing drastically. We have come a long way in our understanding of the evolution of the flowering plants, and these changes are, we hope, inching us toward a truly phylogenetic system of classification.

Aceraceae (*Acer macrophyllum* or big-leaf maple shown here) is now placed in the Sapindaceae, a mostly tropical family. Photograph by G. Webster.

seedling leaves). These classes were each divided into a nested hierarchy of subclasses, orders, families, genera, and species. The groups at each level of the hierarchy were defined using all the evidence available at the time. Even so, there were families, orders, or subclasses that were known to be problematic (not clearly defined), and it was certain that further work was needed to clarify their evolutionary relationships.

In the late 1980s, with the increasing use of molecular data analyzed using cladistics, journal articles pointing out the shortcomings of previous classification systems began to appear. The authors published branching diagrams called cladistic trees, and based on the branching pattern of the trees, "monophyletic" groups of related species, genera, and families were carved out (see sidebar on pages 4–7).

One of the most thought-provoking articles was written by Mark Chase et al. (1993). In it, the authors produced cladistic trees based on chloroplast gene data that called into question a number of Cronquist's subclasses and orders, not to mention the validity of the dicotyledons as a taxonomic group. As the 1990s continued and the use of DNA sequence data by plant scientists became widespread, articles questioning the make-up of



***Salicornia*, pickleweed (top) and *Salsola*, Russian thistle (bottom) of what was the Chenopodiaceae. Some genera in this family may end up in the Amaranthaceae. Photographs by L. Wheeler.**

various plant families appeared. This research culminated in the publication of the APG paper in 1998 and the textbook by Judd et al. in 1999 (revised in 2002).

Although many plant families recognized in *The Jepson Manual* are changed to some degree in the new classification system (Table 2 is an attempt at a complete listing), some families are affected more than others. The Scrophulariaceae (and closely related families such as Plantaginaceae, Orobanchaceae, Callitrichaceae, and Hippuridaceae) and the Liliaceae are radically reshuffled or broken down into different subunits (see articles by Olmstead and Kelch in this issue). The Lamiaceae and Verbenaceae also get reshuffled, but the genera involved in the reshuffle are not commonly found in California.

Other *Jepson Manual* families will simply disappear in the new classification system, "gobbled up" by closely-related families of which they are just a more specialized member. Hydrophyllaceae and Lennoaceae are included in Boraginaceae; Empetraceae and Epacridaceae are placed in Ericaceae; and Aceraceae and Hippocastanaceae are being included in a mostly tropical family that wasn't even included in *The Jepson Manual*—the Sapindaceae (which includes golden rain tree).

In addition, the Chenopodiaceae are placed in Amaranthaceae, Asclepiadaceae in Apocynaceae, Lemnaceae in Araceae, Capparaceae in Brassicaceae, Punicaceae in Lythraceae, Martyniaceae in Pedaliaceae, Philadelphaceae in Hydrangeaceae (a family not included in *The Jepson Manual*), and Cuscutaceae in Convolvulaceae. The Malvaceae become the equivalent of the Cronquistian order Malvales, "inhaling" Sterculiaceae (the chocolate family, which includes our flannelbush, *Fremontodendron*) as well as the mostly tropical families Tiliaceae and Bombaceae (neither of which are in *The Jepson Manual*).

Some of the mergers mentioned above are expected, because boundaries between the families in question have been muddy for some time. For instance, some teachers out there may breathe a sigh of relief at the combination of Chenopodiaceae and Amaranthaceae. In other cases, the families that are disappearing consisted of only one genus, and so the addition of that genus to a closely-related family is really not that radical a change.

The converse happens as well. Some families are being narrowed, with an errant genus being removed and placed in a family of its own. For example, *Sparganium* is taken out of Typhaceae and placed in its own family, *Ruppia* is excluded from Potamogetonaceae, *Halesia* is being taken out of the Styracaceae, and *Sambucus* and *Viburnum* are being taken out of the Caprifoliaceae and placed in the Adoxaceae.

The bottom line is that change is coming, and if you think that you are in trouble, just think what it will be like trying to incorporate some of these changes into the filing system at the UC Davis Herbarium! We are still trying to curate our collections to agree with some of the name changes in *The Jepson Manual* (we just finished changing *Haplopappus* to *Ericameria*). However, we cannot stick our heads in the sand, because some recent US guidebooks have already begun to incorporate the proposed family name changes, and it looks like we may have to learn to accept that *Triteleia laxa* (Ithuriel's spear) is now in the Themidaceae ("What?" you say).

Of course, only time will tell how much of the APG system will really be accepted by the scientific community, not to mention lay botanists, especially when our current flora of California follows Cronquist. But if these strange family names begin to appear in California local floras, garden books, and articles, you can haul out this article and use Table 1 to translate into "Jepsonese."

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TABLE 2. PRELIMINARY SUMMARY OF FAMILIES IN *THE JEPSON MANUAL* AND THEIR NAME CHANGES ACCORDING TO THE APG* SYSTEM

	APG System (1998)	**Judd, et al. (2002)**
MONOCOTYLEDONS		
Alismataceae		
Aponogetonaceae		
Araceae	Includes Lemnaceae, but excludes Acoraceae.	Same as APG.
Arecaceae		
Commelinaceae		
Cymodoceaceae		
Cyperaceae		
Hydrocharitaceae		
Iridaceae		
Juncaceae	No change?	Perhaps not monophyletic, but no change yet.
Juncaginaceae		
Lemnaceae	Included in Araceae.	Same as APG.
Liliaceae	Narrowed to exclude many genera; see Kelch article on page 23.	Same as APG.
Orchidaceae		
Poaceae		
Pontederiaceae		
Potamogetonaceae	Includes Zannichelliaceae, but excludes Ruppiaceae.	Excludes Ruppiaceae.
Scheuchzeriaceae		
Typhaceae	Excludes Sparganiaceae.	No change.
Zannichelliaceae	Included in Potamogetonaceae.	No change.
Zosteraceae		
DICOTYLEDONS		
Acanthaceae		
Aceraceae	Included in Sapindaceae.	Same as APG.
Aizoaceae		
Amaranthaceae	Broadened. Includes all Chenopodiaceae except Sarcobataceae.	Includes all Chenopodiaceae.
Anacardiaceae		
Apiaceae	Narrowed. *Hydrocotyle* and related transferred to Araliaceae.	Broadened. Includes all genera Araliaceae.
Apocynaceae	Broadened. Includes Asclepiadaceae.	Same as APG.
Aquifoliaceae		
Araliaceae	Broadened. Includes *Hydrocotyle* and related genera.	Included in Apiaceae.
Aristolochiaceae		
Asclepiadaceae	Included in Apocynaceae.	Same as APG.
Asteraceae		
Balsaminaceae		
Basellaceae		
Bataceae		
Berberidaceae		

*Angrosperm Phylogeny Group

TABLE 2, ***continued***	**APG System (1998)**	**Judd, et al. (2002)**
Betulaceae		
Bignoniaceae		
Boraginaceae	Broadened. Includes Hydrophyllaceae and Lennoaceae.	Includes Hydrophyllaceae except for Hydroleaceae; mentions that Lennoaceae may also be part of Boraginaceae.
Brassicaceae	Broadened. Includes Capparaceae.	Same as APG.
Buddlejaceae		
Burseraceae		
Cabombaceae	Included in Nympheaceae.	Same as APG.
Cactaceae		
Callitrichaceae	Included in Plantaginaceae; see article by Olmstead (this issue on page 13).	Same as APG.
Calycanthaceae		
Campanulaceae		
Cannabaceae		
Capparaceae	Included in Brassicaceae.	Same as APG.
Caprifoliaceae	Excludes *Sambucus* and *Viburnum* (which are included in the Adoxaceae); excludes Linnaeaceae.	Excludes *Sambucus* and *Viburnum* (Adoxaceae) but includes Dipsacaceae and Valerianaceae.
Caryophyllaceae		
Celastraceae	Broadened to include Hippocrateaceae.	Same as APG.
Ceratophyllaceae		
Chenopodiaceae	Included in Amaranthaceae, with the exception of Sarcobataceae.	Included in Amaranthaceae.
Cistaceae		
Convolvulaceae	Broadened to include Cuscutaceae and Dichondraceae.	Same as APG.
Cornaceae	Broadened to include other non-California genera.	Same as APG.
Crassulaceae		
Crossosomataceae		
Cucurbitaceae		
Cuscutaceae	Included in Convolvulaceae.	Same as APG.
Datiscaceae		
Dipsacaceae	No change.	Included in Caprifoliaceae.
Droseraceae		
Eleagnaceae		
Elatinaceae		
Empetraceae	Included in Ericaceae.	Same as APG.
Ericaceae	Broadened; includes Empetraceae and other non-California genera.	Same as APG.
Euphorbiaceae		
Fabaceae		
Fagaceae		
Fouquieriaceae		
Frankeniaceae		
Garryaceae		
Gentianaceae		
Geraniaceae		

TABLE 2, *continued*	**APG System (1998)**	**Judd, et al. (2002)**
Grossulariaceae		
Gunneraceae		
Haloragaceae		
Hippocastanaceae	Included in Sapindaceae.	Same as APG.
Hippuridaceae	Included in Plantaginaceae; see article by Olmstead (this issue on page 13).	Same as APG.
Hydrophyllaceae	Included in Boraginaceae.	Same as APG.
Hypericaceae	Included in Clusiaceae.	Same as APG.
Juglandaceae		
Koeberliniaceae		
Krameriaceae		
Lamiaceae	Broadened to include many Verbenaceae.	Same as APG.
Lauraceae		
Lennoaceae	Included in Boraginaceae.	Mentioned as perhaps belonging in Boraginaceae.
Lentibulariaceae		
Limnanthaceae		
Linaceae		
Loasaceae		
Lythraceae	Broadened; includes Punicaceae, Sonneratiaceae, and Trapaceae.	Same as APG.
Malvaceae	Broadened, includes Sterculiaceae, Tiliaceae, and Bombacaceae.	Same as APG.
Martyniaceae	Included in Pedaliaceae.	Same as APG.
Meliaceae		
Menyanthaceae		
Molluginaceae		
Moraceae		
Myoporaceae		
Myricaceae		
Myrtaceae		
Nyctaginaceae		
Nymphaeaceae	Broadened. Includes Cabombaceae.	Same as APG.
Oleaceae		
Onagraceae		
Orobanchaceae	Broadened to include root parasites of the Scrophulariaceae; see article by Olmstead (this issue on page 13).	Same as APG.
Oxalidaceae		
Paeoniaceae		
Papaveraceae		
Philadelphaceae	Included in Hydrangeaceae.	Same as APG.
Phytolaccaceae		
Pittosporaceae		
Plantaginaceae	Broadened to include genera of traditional Scrophulariaceae; see article by Olmstead (this issue on page 13).	Same as APG.
Platanaceae		
Plumbaginaceae		
Polemoniaceae		

TABLE 2, *continued*	**APG System (1998)**	**Judd, et al. (2002)**
Polygalaceae		
Polygonaceae		
Portulacaceae	No change?	Discusses the possibility that the family is not monophyletic.
Primulaceae		
Punicaceae	Included in Lythraceae.	Same as APG.
Rafflesiaceae		
Ranunculaceae		
Resedaceae		
Rhamnaceae		
Rosaceae		
Rubiaceae		
Rutaceae		
Salicaceae		
Santalaceae	No change?	Discusses the possibility that the family is not monophyletic.
Sarraceniaceae		
Saururaceae		
Saxifragaceae		
Scrophulariaceae	Narrowed; see article by Olmstead (this issue on page 13).	Same as APG.
Simaroubaceae	Narrowed to exclude genera not found in California.	Narrowed to exclude genera not found in California.
Simmondsiaceae		
Solanaceae		
Staphyleaceae		
Sterculiaceae	Included in Malvaceae.	Same as APG.
Styracaceae	Narrowed. Excludes Halesiaceae.	Same as APG?
Tamaricaceae		
Thymelaeaceae		
Tropaeolaceae		
Ulmaceae	Narrowed. Excludes Celtidaceae.	Same as APG.
Urticaceae		
Valerianaceae	No change.	Included in Caprifoliaceae.
Verbenaceae	Narrowed; excludes many genera now placed in the Lamiaceae; also excludes Avicenniaceae.	Same as APG.
Violaceae		
Viscaceae	Included in Santalaceae.	No change.
Vitaceae		
Zygophyllaceae	Circumscription changed.	A few genera placed in the Peganaceae.

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