Do plant identification keys enable identification?*

Manfred A. Fischer

Department of Systematic and Evolutionary Botany, University of Vienna, Rennweg 14, A-1030 Vienna, Austria, e-mail: manfred.a.fischer@univie.ac.at

Received: February 09, 2010 ▷ Accepted: February 25, 2010

Abstract. In many Floras, keys rarely reach acceptable scientific standards. Terminology, clarity, coherence, accuracy, style and diction all leave much to be desired and have to improve so that Floras can achieve and match set botanical standards. They should not deter potential users within and outside the realm of botany. Examples of illogical and unpractical keys in some European Floras are provided. The reasons for the existence and preparation of unsuitable keys are discussed; they are mainly based on two different approaches – the holistic outlook adopted by floristic workers and the analytical attitude of scientists.

Key words: descriptive terminology, flora writing, identification keys, nomenclatural author citations

Introduction

The first dichotomous key in a Flora was published by Lamarck 225 years ago (Lamarck 1778; Wagenitz 2003). Since then, there have been many changes. However, there is hardly any literature available on the methods of writing Floras, and, in particular, the preparation of identification keys.

Let us ask outstanding botanists for their opinion on the usefulness of keys, let us ask users of keys as to their ease and convenience, and let us examine keys in current Floras!

Some users would say: "I am too stupid to use keys, I prefer pictures." Or, they would advise: "It is better to consult the herbarium, although keys may sometimes provide hints for shortening your trial and error procedure!"

Is such a sceptical attitude justified? Is the low quality of keys produced responsible for such comments? Is it necessary and is it possible to improve their quality? Do alternatives in the following key (taken from an actual example) support identification with ease and accuracy?

"Leaves linear to lanceolate; ovary subterranean; seeds numerous"
vs.
"Leaves all basal; ovary 3-locular; seeds globose".

An eminent taxonomist and notable author of a large standard Flora once said: Do not complain about illogical, incomplete, inexact keys, but remember writing identification keys is not a piece of science but a piece of art! Plants are extremely variable, they are part of biodiversity, you cannot change them and that's why we love them, that's why we like botany.

However, does the marvellous variation in plant life necessarily imply that keys must be similarly chaotic? Is it appropriate to use illogical and inconsistent methods in order to describe the complexity of biodiversity? Would you agree with a medical doctor using instruments that do not function properly, just because your body is a tremendously complex organ not yet fully understood? Yet many Flora writers consider it acceptable to use methods and concepts abounding in inconsistency and irrational reasoning.

* Based on a lecture presented at the 'Third International Balkan Botanical Congress' in Sarajevo, May 2003.

It is not these shortcomings which make me apprehensive. I lack evidence of serious attempts by botanists to reach common, logical and scientific standards concerning identification keys. One gains the impression that Flora writers are not alarmed or worried but quite content with the present state of chaotic keys and floristic descriptions. If you fail to arrive at a correct identification, it is on account of your imperfect botanical knowledge or the great and unseen variation in plants. Or perhaps the blame lies with the identification keys. Some keys are understandable only to specialists already familiar with the species or the genus.

In many respects, standard Floras are the backbone of botanical research (Tutin & al. 1968–1980, 1993; Stace 1997, 2010). Several contemporary Floras with keys have already been completed or are in full preparation, e.g., FNA Editorial Committee (1993–2007–), Castroviejo & al. (1986–), Hejný & al. (1988–2004–), Jordanov (1963–) , Strid & Tan (1997, 2001), Sell & Murrell (1997–2006), Jonsell (2000–2004–), Species Plantarum: Flora of the World (1999–). New editions have also been prepared (Hegi 1963–2007–; Rothmaler & al. 2005), only a few examples are listed. Of course, not all criticism summarized in the present paper applies to all these Floras some of which are excellent. But is it not worthwhile to try and achieve scientific standards in this field? Do we prefer to maintain Flora writing at a sub-scientific level, so that producing a key is, indeed, a matter of art rather than science? Would it be the computer, unwilling to accept illogical keys in an electronic Flora be the final tool to force botanists to become more logical and scientific in their outlook?

When starting to prepare a scientific Flora of Austria (Fischer 1987, 1998; Willner & Fischer 2008; Fischer & Willner 2010) and while editing the Austrian Excursion Flora (Adler & al. 1994; Fischer & al. 2008), our small team of Flora writers realized that there was a possibility to construct scientific keys which are user-friendly but yet lead to a correct identification by both botanists and non-botanists. The keys would cater for the variation in plants in a Flora using a logical and rational approach, and hopefully, any UGO (unidentified growing object) can be named with ease. Examples of such keys are presented in Fischer & Willner 2010; see also http://flora.vinca.at .

Problematic features of identification keys

What are the shortcomings of identification keys and why are so many keys in traditional Floras difficult to use? Some problematic features are now listed.

Theoretical (philosophical) aspects (1–7)

(1) Holistic vs. analytical approach. One main problem is the conflict between the usually holistic, synthetic approach of the Flora writer and field botanist and the analytical design of a key. The systematist must adopt both. After analysis of the details he tries to arrive at a complete picture of his taxon by a synthetic approach, considering all aspects, all relevant characters from growth habit and life-form to morphology, anatomy, ecology, karyotype, genetics and DNA pattern, etc. Flora writers and field botanists must have holistic images of their taxa but scientific researchers in contrast, must be able to analyze the whole.

The Flora writer and field botanist recognize the taxon in its entirety, he or she is often not aware of the diagnostic field characters. Floristic keys, however, must guide the non-expert by providing all relevant details in order to understand and identify the taxon. Field botanists have a well developed visual memory for shapes and structures, they "think" with their eyes, but often they are less gifted for analytical, logical and abstract reasoning. They have an intuitive knowledge of their taxa, they "feel" the differences between taxa, but very often they cannot set out the differences in a concrete manner.

The synthetic and holistic view on the taxa, usual for the Flora writer as well as the field botanist, agrees with the way our mind learns to distinguish and to memorize taxa. A key, however, has to be constructed in the opposite manner: it must be analytical. The holistic approach emphasizes the most conspicuous characters that distinguish similar and/or related taxa. As a consequence, the focus will be on a selection of strikingly different characters instead of on different states of the same character. An (abstract) example:

Species A is characterized by *flowers* purple, *stems* woody at base and *fruits* elongate;

species B differs because its *flowers* are remarkably small, the upper *leaves* apparently glandular-sticky and the *seeds* are black.

If you are going to distinguish these two species, you will bear these obvious characters in mind, and that's quite useful and effective as it will also help you to recall these character-syndromes mentally and in that way to identify both species. If you, however, rely on these disparate characters to produce a key, the key will be a disastrous one because comparison of these characters between the two species is impossible.

(2) Paradoxically, it would seem that key producers or Flora writers do not fully believe in keys. There are many experienced botanists, producers as well as users of keys, who generally doubt the possibility of writing a key which will lead you to a reliable identification. Why? Because inadequate keys are very common and they are used to them and, therefore, they prefer to consult the herbarium. Their floristic nature would doubt the potential of scholarly discussions, scientific terminology and molecular results from a laboratory.

(3) Key users do not protest against bad keys, do not inform their shortcomings to the author but, when failing to achieve results, would not doubt the quality of the key but would instead prefer to ask experienced colleagues and check herbarium material. So, usually there is no feed-back from Flora users to Flora producers. Furthermore, taxonomists do not use keys, especially not those written by themselves because they already know all their taxa, and in case of doubt and queries they refer to their notes, to literature and, of course, consult their herbarium. On the other side, it is a tiresome task for Flora editors to stay in permanent contact with the users and to consider all suggestions for correction carefully.

(4) A scientific task or just copy and paste? Constructing keys is usually not considered to be a serious task, neither by taxonomists nor by ecologists. Such work suffers from the image of simply accumulating data in an old-fashioned field of study lacking innovation. Compiling keys and producing Floras, therefore, is no way to begin or to continue a professional career in scientific botany. However, a Flora is a thorough and critical synthesis of knowledge on all plant taxa in a certain region. Flora writing combines mainly floristics with systematics, morphology, ecology and phytogeography (chorology), but other botanical disciplines are necessary as well. Therefore, it needs experienced workers in all these fields, and usually a supportive team of specialists in these disciplines is ideal. Even more rare is the person with a broad view capable of synthesizing all data arising from such different disciplines.

Floras and identification keys are usually written by taxonomists or by ecologists. The taxonomist knows his taxon (i.e., the family or genus he specializes in) extremely well, at least as herbarium specimens. He cannot imagine persons unfamiliar with his taxon, and, of course, he uses the technical terms developed and applied to his genus. Many aspects and characters are, in his view, not worth mentioning. Thus he is often unable to write a key for the non-specialist. From personal experience, the most difficult and awkward keys are written by taxonomic specialists (see also item 6).

The Flora writer or the ecologist, on the other hand, knows the taxa of his area excellently and recognizes them easily – at least in the field –, he likewise can hardly imagine anybody not knowing them. In addition, he will not care for exact terminology in morphology because he thinks, the more general his descriptions, the better understandable they are for the non-specialists (see also item 13). Keys written by ecologists often also do not care for taxonomic accuracy and tend to neglect biosystematic issues.

(5) Typological thinking. Many authors of keys and descriptions show a more or less evident tendency towards typological thinking: They key and describe typical, ideal taxa and do not consider whether such typical specimens exist in nature or are only rarely met with in the field – because these "ideal taxa" clearly exhibit the essential differences and this way justify, for example, the species rank of weak species. Flora authors also generally neglect variation, they do not adequately indicate the range of variation, they do not like variation because it blurs the beautiful differences! Flora users, however, are unhappy because their identifications lack decisiveness.

(6) Taxonomy vs. identification (science vs. function). Keys written by taxonomists usually aim at combining the key with taxonomy, i.e., the taxa are keyed out according to their taxonomic position but not according to ease of use. Keys should, however, follow exclusively functional, operational principles. This includes not to be afraid of multiple keying out.

Taxonomic information is important, also in a Flora, but it should not be included in a key because this destroys the key by decreasing its user-friendliness.

Information about the (presumed) phylogenetic relationships should be presented separately, e.g., in a taxonomical conspectus of the genus showing subgeneric classification, etc.

(7) Taxonomy vs. nomenclature. A source of confusion is also the listing of nomenclatural author citations which provide no information as to the identity or content of the taxon but often are interpreted – even by professional botanists with little nomenclatural knowledge – in a wrong and misleading manner: "*Scilla* L." surely means the genus *Scilla* with the circumscription by Linnaeus (1753), and "*Achillea millefolium* L." means this species in the sense of Linnaeus! Deploringly, many botanists do not know that according to art. 46.1 ICBN (McNeill & al. 2007), nomenclatural authors are no essential part of the name but should be mentioned only in nomenclatural papers (and in taxonomical ones when taxonomic changes are proposed and the correct name has to be ascertained). There are still botanists unaware of the fact that these author citations do not refer to the taxon but only to its name (to the history of naming) (Garnock-Jones & Webb 1996; Fischer 2000). (There are, unfortunately, only a few Floras which understand this situation, e.g., *An Irish Flora* (Webb & al. 1996).

Author citations without full reference to the original publication of the name, necessary for spotting the nomenclatural type, are thus useless and completely superfluous in a *Field Guide* or an *Excursion Flora*. They are rather dangerous since they are liable to be misinterpreted as mentioned above.

In contrast to the meaningless and confusing author citations, taxonomic information like "s.str." and "s.lat." is very helpful, often essential. And, of course, synonyms are very important for the user, as they help to identify the taxon and to link information between treatments in different books, so, they deserve much attention.

A textbook on principles of angiosperm taxonomy (Davis & Heywood 1963) emphasizes: "It is only names that have types, not species, so that typification is an entirely *nomenclatural* procedure. The type is usually the gathering with which the name is first associated, so that it need not be typical of the species in terms of population variability; it may, in fact, even be an extreme variant. It is therefore no more important *taxonomically* than any other specimen; its importance lies entirely in fixing the application of the name."

In botanical publications it is essential to mention the taxonomical reference for each plant name used in the Methods section (Fischer 2000; Fischer & al. 2008). This cannot, of course, be replaced by nomenclatural author citations! Often this is done by using the phrase "nomenclature follows ...", which is bad practice, because most names are dependent on a taxonomical decision, so, taxonomy is much more relevant than nomenclature. Such bad practice favours the essentially incorrect idea that systematics is nothing but nomenclature.

Technical aspects (8–13)

(8) Terminology has not much advanced since our pioneer Linnaeus (1751), there are still a lot of ambiguities, including discrepancies between phytographic (purely descriptive) and scientific (comparative) morphology (the latter being, of course, substantially different from the traditional descriptive terminology generally used in Floras). There are only few comprehensive studies (e.g., Jackson 1928; *Systematics Association Committee* 1962; Harris & Harris 1994) and the complaint by Schulze (1953) is still of current interest (translated from German): "One should assume that in a field as old as that of descriptive botany (phytography) a usage of the Latin terms unanimously shared by all the different authors should have been developed in time. Everybody dealing with monographs, Floras etc., however, will easily have realized that this is not the case."

Several modern Floras do not explain their descriptive terminology but rely (Castroviejo & al. 1986– ; Strid & Tan 1997, 2001; Sell & Murrell 1997–2006) on references to old standard works (e.g., Jackson 1928) assuming that these works agree. The admirable work *Botanical Latin* (Stearn 1995) explains the various terms used in literature but does not attempt to standardize or even provide suggestions; the same applies to an excellent book on the history of botanical concept and terms (Wagenitz 2003) which, however, avoids involving descriptive (phytographic) terms.

Keys written by taxonomists, especially by a taxonomic specialist on a genus, often do not cater to the demands of a non-specialist, i.e., for the majority of key users. Specialized taxonomists often use a terminology restricted to "their" genus. Hieraciologists and batologists (experts in the genus *Rubus*), for example, often use highly specific terms no other botanist would understand. Such jargon includes homonyms, i.e., words with a different meaning from that used in other genera – the turio in *Rubus* is not the hibernaculum, i.e., a dormant bud for innovation, but the non-flowering stem of the first year.

The "beak" (rostrum) of an umbellifer mericarp starts at 0.5 mm in length; the beak in a *Carex* utricule starts with 2 mm length; that of a cruciferous siliqua starts only from more than 3 mm (a shorter length is not considered to be a beak). The relevant expert knows this and takes it for granted. But would the general flora writer or the average key-user know such if the terminology is not explained? Is it really impossible to use the same technical terms for all vascular plants? The flower in *Gramineae* and *Compositae* is, in English Floras (and recently in some German Floras as well), not referred to as "flower" but "floret" ("Blütchen"); the stem in *Gramineae* is not called "stem" but "culm", glandular hairs in *Hieracium* are not hairs but "glands" ... .

Here are a few examples of terms defined differently by different authors or not defined at all. Some Floras understandably avoid explanation of terminology, but users, especially users of different Floras do not find that so agreeable.

"lanceolate" has three different meanings: the Linnaean (tapering to both sides, broadest in the middle, 6× as long as wide, i.e., very narrowly elliptic); the DeCandollean (Lindleyan and German, broadest in the middle, but 3× as long as wide, i.e., narrowly elliptic) and the Benthamian (A. Gray, "English", broadest below the middle, Schulze 1953, 3× as long as wide); see *Botanical Latin* (Stearn 1995). The definition in modern German language Floras (Rothmaler & al. 2005; Fischer & al. 2008) for "lanceolate" in a wide sense is broadest in the middle, 3–8× as long as wide, but subdivided by 3–4×, "broadly lanceolate"; 4–6×, "lanceolate" in the narrow sense; 4–6×, "narrowly lanceolate".

"dentate" has at least two different definitions: Amazingly, there are remarkable and deplorable differences in various Floras. A random search reveals great differences, e.g., between some British books (Stearn 1995) and Floras (Clapham & al. 1962, 1985), Nordic (Jonsell 2000–2004) and Czech Floras (Hejný & al. 1988–2004; Kubát 2002) on the one hand, and some other British Floras (Stace 1997), Danish (Rostrup & al. 1973, 1977), German (Rothmaler & al. 2005), and Austrian (Fischer & al. 2008) Floras on the other hand. In the first group, the leaf margin is irregularly (Clapham & al. 1962, 1985) or patently (Stearn 1995) serrate or even almost crenate (Hejný & al. 1988–2004; Jonsell 2000–2004). In the latter, more consistent group "dentate" is more correctly typified (in my opinion) by *Epilobium montanum*, i.e., the teeth are acute between round incisions, thus the exact opposite of "crenate".

The terms used in different Floras describing the depth of incisions in divided leaves are as confusing: **palmate / palmatipartite / palmatisect / palmatifid / palmatilobate** (also pinnate / pinnatipartite / pinnatisect / pinnatifid / pinnatilobate) – with their corresponding equivalents in all languages. If I would ask you to define these terms, I would get various answers, ranging from "it all means the same" to strict categorizing.

Inconsistencies, ambiguities are often met in very common terms like **"leaf"**. Is a leaf always a true leaf (a foliar leaf), or is it a phyllum or phyllary (including cataphylls and hypsophylls)? What is a bract and a bracteole? Does the "leaf" include the petiole or does "leaf" refer only to the lamina (blade)? Do Flora writers care for scientific comparative morphology (at variance with phytography)? The flower whorls in *Labiatae* are, morphologically speaking, false whorls, because they are pairs of opposite congested cymes.

What is a liana? (woody or not?); what means "caespitose"?; how is left-hand and right-hand twining defined? Even definitions of superior and inferior ovary differ in Floras and in morphological and taxonomical textbooks.

Generally, the user of a Flora, as for any technical book, is urged to observe the technical terms carefully, he learns to distinguish between bracts and bracteoles, leaves and leaflets, pedicels and peduncles, etc., he understands that similarly sounding terms have different meanings. Therefore, I feel it is rather confusing to use different terms which are synonymic, even if they are correctly applied (e.g., achene =? cypsela, awned = aristate, beaked = rostrate, branched = ramose, bristly = setose, decumbent =? procumbent =? prostrate, pointed = acute, sheathed = vaginate, stiff = rigid, tapering = attenuate, etc.). To add to confusion there are several linguistic problems in terminology in the national languages Floras are written in.

(9) Consistency of terms and phraseology. It should be evident (but for many Flora writers it is not) that the unit of measurement should not alter within the same key (e.g., cm or mm). Generally, mere variation of expression for the same organ or feature is strictly to be avoided in a technical context. There exists a key which changes the way of counting leaflets of pin-

nate leaves within the same genus. To be sure, you can count the individual leaflets or the pairs of leaflets. Evidently, that author believed in the mental dexterity of the user otherwise determining the subspecies of *Anthyllis vulneraria* would be all too simple.

Inappropriate repetitions and redundancy is not simply a waste of paper and time but, in many cases, confusing, annoying and misleading. In a species key and in species descriptions, generic and family characters should be strictly avoided because they blur essential information. The differential characters become hidden behind those characters which apply to the whole genus or even family.

Our method of mentioning characters according to the taxonomical hierarchy (i.e., no inclusion of family characters with generic and species-specific characters) provides also a better survey on the distribution of characters among the taxa.

Variatio delectat? In a superbly illustrated Flora of a part of Germany I found a key and descriptions of a very small genus, comprising two species only, where the author uses four different terms for the fruit (three of them correct, one erroneous): "Frucht" (fruit), "Früchtchen" (fruitlet), "Nüsschen" (nutlet) and (!) "Same" (seed).

(10) Concise vs. comprehensive. "The shorter the key – the better" is the dangerous motto of Flora users, Flora writers and publishers. To mention only few characters is simple for the author as well as for the user of the key. But it is not acceptable for the accuracy of the identification. Flora users, particularly ecologists demand simple keys, and Flora writers often answer that call. To remember a single differential character makes botany seem easy but increases the risk of misidentification. Vegetative characters must not be forgotten, they are particularly important for ecologists who often have to recognize species in their sterile state.

(11) Qualitative vs. quantitative characters. Some Flora writers prefer qualitative characters ("inflorescence elongated") and relative qualifications ("rather big", "conspicuous" etc). These are often useful but should be replaced or at least accompanied by absolute metric data. Many authors love comparisons with objects of everyday life or useful plant organs, like hazel nuts, peas and cherries. Being orientated to a native flora they have forgotten that in cultivated plants there are numerous cultivars with variation, for example, in the size of a cherry.

20a Catkins slender. Fruits narrow. Style long .... ***S. alpina***

20b Catkins stout. Fruits wide. Style short .... ***S. breviserrata***

If you are familiar with all the species of this genus, you can understand quite well what the author means.

(12) Separation of absolutely diacritic characters from overlapping ones. In each lead (numbered paragraph) of a (dichotomous) key, the differential characters presented are of two different types: those stating an absolute difference, i.e., not overlapping ("diacritic" characters, e.g., "flower 5–10 mm" vs. "flower 12–18 mm") and those with an overlapping range ("completive" characters: "flower 5–10 mm" vs. "flower 8–15 mm"). Both are important and necessary, but for the user the diacritical characters are all important when checking which alternative fits the specimen. In most keys, an exception being the *Key to the flora of the Czech Republic* (Kubát 2002), these two types of diagnostic characters are not clearly distinguished.

(13) Logic, accuracy, style and diction. Several skills are necessary for producing a good key – capability for logical and scientific thinking, meticulous attention to detail, knowledge of relevant current literature, ability to understand the requirements of the reader/user who may not be familiar with concepts obvious to the author. The ability to describe complex structures and phenomena with clarity is important. Many pitfalls can easily be avoided by careful editing. An example (actual extract from an existing Flora) is presented:

"Leaves up to 6 cm long" vs. "Leaves up to 12 cm long". If your leaf measures 5 cm it fits both categories.

"Leaves and young branches pubescent" vs. "Leaves glabrous when old; branches slightly pubescent only when young".

"With a basal rosette" vs. "Stem leafy".

For a good key and descriptions it is useful to follow the same sequence when describing characters, this is far too often neglected.

Combining scientific exactness with clarity for a non-botanically trained user is possible but needs special attention. Terms like shoot (including the leaves) and stem (axis) must not be confused, the same is true for

corolla vs. perigone, fruit vs. seed, berry vs. drupe, etc. Complex structures like the cyathium of *Euphorbia* must be explained in a way easily comprehensible for non-botanists ("seemingly a hermaphroditic flower") and for the botany student who should not be punished for his advanced knowledge ("flower-like inflorescence composed of ...").

Examples of keys needing improvement

The following examples are taken from published keys, many of them in notable and familiar works.

(1) Comparison of two closely related species of *Draba*

Probably, you will not believe it but this is an example from a well-known and comprehensive, multi-volume *Flora of Central Europe* (in translation).

I have underlined those characters which do not indicate if a difference is intended (or whether it is just a matter of different wording to the same effect). I have printed in **bold letters** the "one-sided" character states absent in the other species. The broken line indicates the inconsistent sequence of characters compared.

"2 mm long" vs. "up to 2.6 mm long" for the length of stamens are not helpful alternatives.

	D. fladnizensis	***D. carinthiaca* = *D. siliquosa***
Plant	perennial, pulvinous.	perennial, caespitose.
Shoots	numerous, enveloped by leaf remains.	abundantly branched, enveloped by dead fibrous leaf remains.
(Roots)	with **greyish-brownish** tap-root.	**thin,** spindle-like.
Basal leaves	in a rosette, oblong-obtuse, entire, 0.5–1 cm long, margin ciliate, with long, rather stiff, simple hairs, surface usually with hairs, surface usually glabrous, **thickish, shiny**.	in a rosette, lanceolate, usually entire, with few stellate hairs, margin ciliate with simple hairs, 1 cm long.
Stem	usually unbranched, up to 6 cm tall, leafless or with 1 to 2 leaves, glabrous.	**ascendent,** 3–8 cm tall, usually unbranched, with stellate hairs at base, upper part glabrous.
Stem leaves	oblong-ovate, sessile, small.	1–2, sessile, linear-lanceolate, but rounded at base.
Raceme	corymbose, with 2 to 12 flowers.	many-flowered, corymbose
Pedicels	1–2 mm long, **glabrous**.	1–3 mm long
Sepals	glabrous, 1.8 mm long, with whitish scarious margin, **oblong-ovate**.	1–1.8 mm long, **obtuse**, dorsally pubescent, with whitish scarious margin.
Petals	greenish-whitish, 2.2 mm long, broadly oblong.	white, 2–3 mm long, obovate, **slightly emarginate**, shortly ungulate.
Longer stamens	2 mm long.	up to 2.6 mm long.
Filaments	basally not dilated.	not dilated.
Infructescence	elongated.	elongated.
Fruiting pedicels	2–5 mm long, erecto-patent, **often congested and thus umbel-like.**	erecto-patent, 3–5 mm long, **glabrous.**
Silicula	oblong-elliptic, **flat**, 3.5–5.5 mm long.	oblong-elliptic, 3–8 mm long, 1.5–2 mm wide, **glabrous**.
Style	very short.	almost absent.
Seeds	ovoid, 1 mm long, golden-brown, flat.	ovoid, brown, **with black hilum**, flat, 0.8 mm long.

(2) Descriptions of two closely related species

This example is also taken from an existing (published) key.

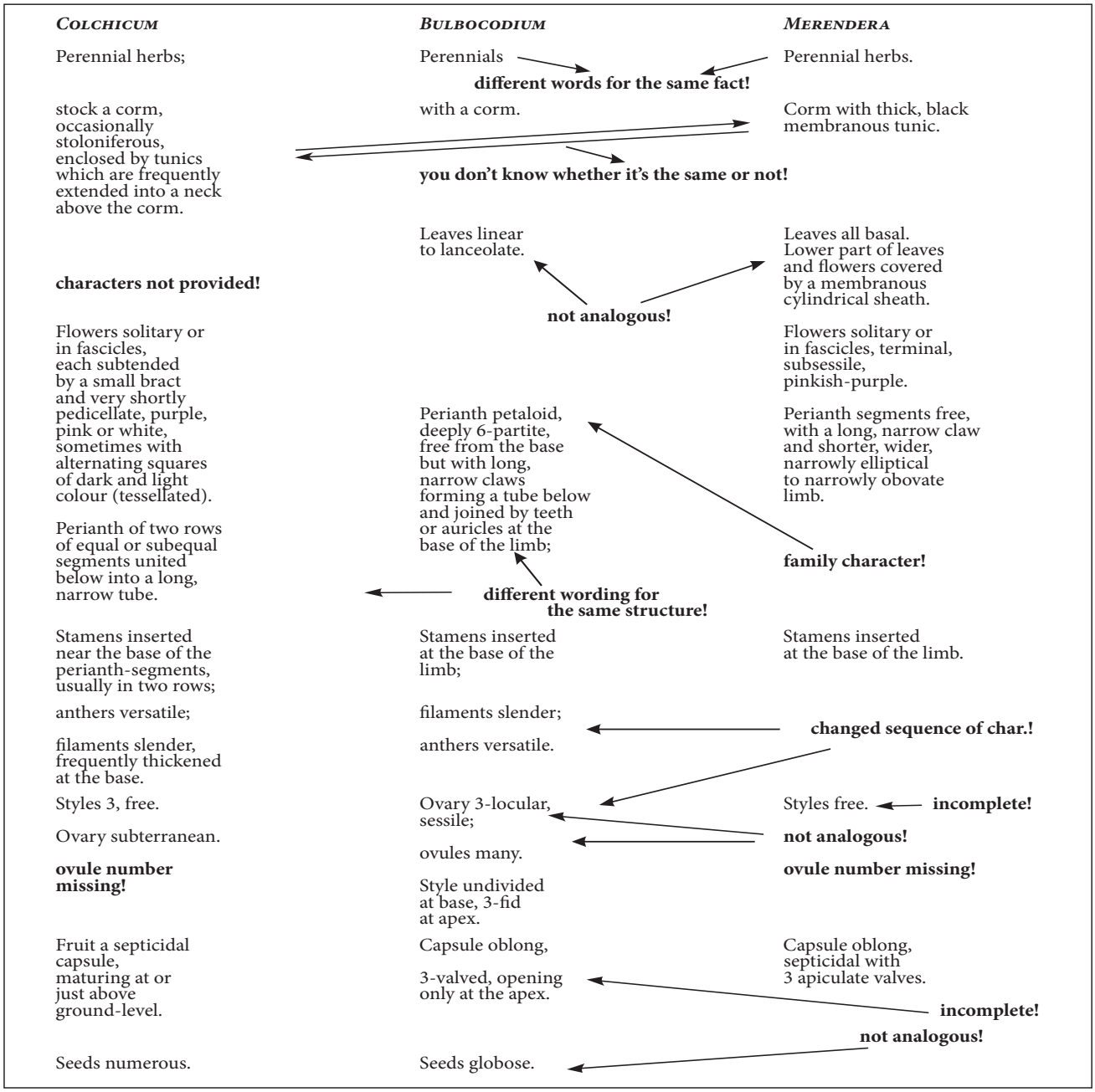
Perennial with woody rootstock; stems several, slightly woody at base, ascending to suberect, slender, 20–60(–100) cm, quadrangular, sparingly branched, glabrous except for the ± densely puberulent base; whole plant dull green, not glaucous.

and (a related species)

Loosely caespitose perennial herb, often with slightly woody, rooting stem bases; whole plant grass-green to greyish-green, sometimes slightly glaucous-pruinose; stems (5–)10–30(–35) cm, decumbent to ascending, quadrangular, scarcely branched, puberulent towards base (hairs less than 0.1 mm), glabrous in upper part.

(3) Another example

To demonstrate what "systematics" mean to Flora authors (and plant systematists?) and to define the common and the differential characters of the following three closely related genera (in more modern classifications merged into a single genus in the family *Colchicaceae* or *Liliaceae* s.l.), we take a look at an important *European Flora*:



Characteristics of the keys in the "*Flora of Austria*" project (Fischer & Willner 2010)

These principles are (tentatively) realized in the *Austrian Excursion Flora* (Fischer & al. 2008) and in a taxonomic publication (Albach & Fischer 2004). See also examples in Fischer & Willner (2010).

Our keys are in general, strictly practical, regardless of taxonomy. They are dichotomous and non-indented The requirements of the key user are uppermost and predominate. Taxonomic information, necessary also for Flora users, is provided separately.

All the descriptions of species (and subspecies) are incorporated into the keys (as in many *Excursion Floras*), so there are no separate species descriptions as in the normal "large" Floras. Information on phenology, pollination and dispersal ecology, distribution, ecological habitats, ethnobotany, economic use, systematics and evolution, literature references, etc. (= "Further Data"), is kept separate.

In order to arrange the key and to display the relevant diagnostic characters clearly and conspicuously, we divide them into diacritic and completive ones (first mentioned in Technical aspects item 12)

"Diacritic" characters are the non-overlapping, i.e., acknowledged and reliable diagnostic key-characters of the lead in question; they are arranged (sequenced) according to their importance and for the convenience of the user (i.e., those more difficult to observe are listed last).

"Completive" (additional) characters are all differential characters with overlapping states and include all characters not mentioned in the above key leads but necessary for a complete description of the taxon (supplemented by detailed characters like microscopic and chemical ones); they are arranged in an accepted phytographic sequence (root – stem – leaves – inflorescence – flower – fruit – seed).

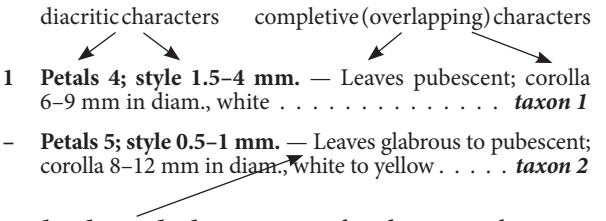
In the keys, the "diacritic characters", are separated (by layout or typographic measures) from the "completive characters" which are often "one-sided" [i.e., relevant for one lead of the couplet only]. This also applies to leads resulting in a taxon name instead of a number. The completive characters are parallel only in double-result leads.

The completive characters ensure a full description of the final taxon (e.g., the species), together with the characters used in the key and the descriptions of the superordinate taxa. In other words: A full description of the species is provided by the combination of family description + generic description + subgeneric description (if any) + characters presented in the key leads + the completive characters accompanying the species name.

Consequently, there is no superfluous repetition of family characters in the generic descriptions or of generic characters in the species keys. As there exist no species descriptions it follows that there is also no repetition of characters already mentioned in the key.

Obligatory characters are all differential characters necessary for the identification of at least one of the species treated in the key. In general obligatory characters must be provided for all species. This is necessary to allow full comparison of each species with another species. In many Floras this is not possible because you are constrained by the minimum characters presented only in a key. Flora users are often familiar with this annoying situation where in the "species descriptions" you fail to find those characters you need for comparison with another species, but instead discover the same characters already cited in the key.

To illustrate these principles with a theoretical example:



An **ultralong dash** separates the diacritic characters from the completive characters [in the *Austrian Excursion Flora* (Fischer & al. 2008)].

Using the ultralong dash, it is immediately apparent which characters are the decisive (diacritic) ones. In

traditional keys you cannot tell whether a character is an exclusively differential one or an overlapping one or if it is mentioned only because it is common to all following species.

As the three traits (leaf indumentum, corolla size and colour) vary in *taxon 2* they are not considered diacritic characters but completive ones. The variation of the characters in *taxon 2* must be stated clearly.

If leaf indumentum and corolla colour are not variable in both taxa 4 and 5 but are distinguishing characters, these characters should not be summarized and, therefore, should not be phrased as follows:

– Leaves glabrous to pubescent; corolla white to yellow **6**

6 Leaves glabrous; corolla white . . . . . ***taxon 4***

– Leaves pubescent; corolla yellow . . . . . ***taxon 5***

Acknowledgements. I am very much indebted to Kit Tan for editing the text.

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