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THE SIGNIFICANCE AND LEGACY OF *FLORA EUROPAEA* IN THE ERA OF MOLECULAR SYSTEMATICS

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Abstract: *Flora Europaea* (1964–1980, 1993) was a concise, practical taxonomic synthesis of the European flora, based in Britain and Ireland but with a pan-European outlook and international collaboration. It was thus able to reconcile parochial inconsistencies in the treatment of genera and species across Europe, to allow comparisons between geographical regions, and to draw attention to topics for further research. The project encouraged and inspired other initiatives, especially regional Floras, *Atlas Florae Europaeae* and monographic research. Two subsequent developments have challenged the traditional systematic agenda: first, molecular techniques involving DNA sequencing; and second, the increasing use of electronic media. At the same time, taxonomy has retreated from tertiary education. Considerable changes to the *Flora Europaea* volumes would be needed to achieve a worthwhile revision and incorporate the sheer quantity of new taxonomic and floristic data. Having achieved some sort of pan-European taxonomic consensus, a substantial proportion of the original content is now being disregarded in favour of more recent taxonomic revisions. These frequently involve generic and specific splits and changes to once familiar plant names, posing unforeseen consequences for users in other branches of plant science, conservation, phytosociology, medicine and legislation. We need to return to the pragmatic vision inherent in *Flora Europaea*.

Keywords: Floras, taxonomy

Introduction

Flora Europaea [22, 23] was the culmination of centuries of study of the European flora since the Renaissance, when botany emerged from herbalism into a broader modern science. This 5-volume work provided a concise, practical synthesis of the huge body of taxonomic and floristic data available in regional, national and local Floras, and in frequently obscure journals and other botanical and biological publications. *Flora Europaea* has since provided a standard and influential reference work that for the first time encapsulates the flora of the whole of Europe east to the Urals (excluding the Caucasus), with basic taxonomic information for each family, genus and species gathered in one place [1, 24, 25].

By bringing this material together – and there were older voices, in Central Europe especially, who feared they would never succeed – the editors were able to reconcile to a considerable extent many parochial inconsistencies in the treatment of genera and species across Europe, and to allow comparisons to be made between taxa in geographical regions (notably vicarious subspecies, especially *vis-à-vis* the Iberian and Balkan peninsulas). When it was not possible to reach a firm conclusion on the basis of available data, short notes (‘observations’) in the text would draw attention to topics that might require further research and elucidation. In the case of the second edition of volume 1 [21], the only volume to be revised, many of these

matters were resolved – although the revision generated its own new series of notes. Perhaps the greatest achievement of this Flora was that it was completed and published in full, within 20 years, whereas some other large floristic projects remain unfinished

Flora Europaea, its offshoots and its aftermath

All of us owe the remarkable men of the Editorial Committee a great debt. Although a close group of colleagues and friends (their common link was the Botany School at the University of Cambridge) based ‘offshore’ in Britain and Ireland, they always worked closely with European colleagues. With the exception of T.G. Tutin, they were not conventional herbarium taxonomists but all shared the holistic vision of plant systematics, based on the study of taxonomy, ecology and genetics, that evolved in Oxford and Cambridge in the early to mid 20th-century.

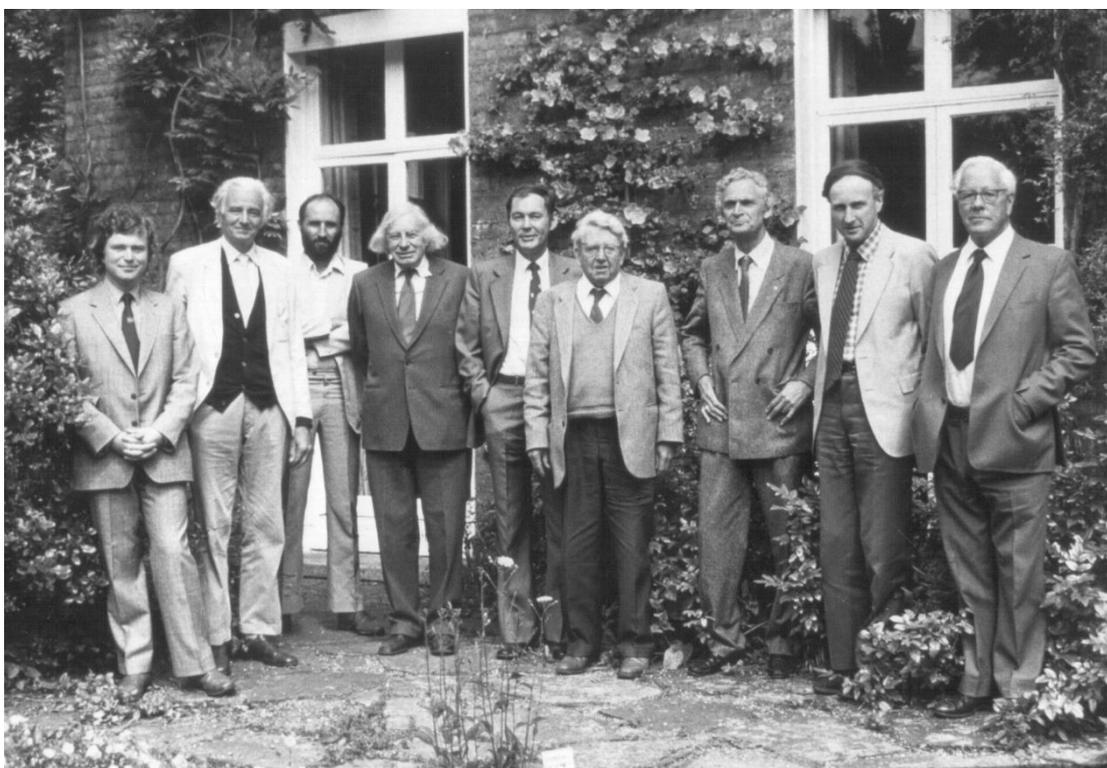


Fig. 1: Flora Europaea Editorial Committee for 2nd edition, volume 1, at Cambridge Botanic Garden, 1986. Photo: Martin Walters. Left to right: J.R. Akeroyd (Research Officer), S.M. Walters, J.R. Edmondson, D.A. Webb, D.M. Moore, T.G. Tutin, V.H. Heywood, A.O. Chater, N.A. Burges (Chair)

They were a mixed group [25], but one that brought a wealth of intellect and ideas to the project (Fig. 1). Tom Tutin (1908–1987, Chairman) was a traditional herbarium taxonomist and author of a classic British Flora, experienced in producing accounts of families and genera (he wrote >1300 species for *Flora Europaea*). Vernon Heywood (b. 1927, Secretary) was deeply immersed in Spain and the Spanish flora; it is much to his credit that Spanish botany, which he inspired and nurtured by encouraging younger colleagues, has emerged since the 1970s as a hot-bed of plant taxonomy and latterly applied taxonomic research in the service of conservation. Alan Burges (1911–2002) was an Australian mycologist who worked for many years in Northern Ireland, David Moore (1933–2013) a cytologist who had studied the flora of temperate South

America, and David Valentine an experimental taxonomist and genecologist. Max Walters (1920-2005) too was an experimental taxonomist; he in particular encouraged the group to engage with colleagues in countries of Eastern Europe then under communist rule. David Webb (1912–1994), a polymath with a zoological background and the Irishman of the team, was a consummate European, with a special fondness for Italy and extensive knowledge of plants, geography and history [4]. He and Walters both spoke several European languages.

The editors corresponded with a Europe-wide panel of regional advisors and employed Research Assistants, who made a substantial contribution to studying taxonomic problems and writing copy for the flora. They were also able to draw upon the expertise of individuals such as P.D. Sell [3] and advisory editors in Europe, including T.W. Böcher, J. Dostál and H. Merxmüller. I was myself *Flora Europaea* Research Officer (1983–1989) for the revision of volume 1 (Burgess was by then Chairman). My task was to review and update the first volume of *Flora Europaea*, originally published slightly hurriedly in time for the 1964 International Botanical Congress in Edinburgh, to add new data and bring it into line with later volumes by eliminating inconsistent or uneven treatment of genera [1].

Not only was *Flora Europaea* itself a success, and for many years was the standard work that most European botanists deferred to and followed, but also it spawned other major compilation projects and regional Floras. *Atlas Florae Europaeae* [16], based in Helsinki and now progressing well through the families covered by *Flora Europaea* volume 2, was conceived in tandem with *Flora Europaea*, although always a separate project. Sadly, a proposed *Icones Florae Europaeae* under Dostál never bore fruit, not least because in 1968 it fell victim to the Soviet Union's suppression of Czechoslovakia's 'Prague Spring' [24]. *The European Garden Flora*, in which Walters was a major player, derives directly from *Flora Europaea*, and the two important regional Floras *Flora Iberica* and *Flora Nordica* both involved botanists, B. Valdes and B. Jonsell respectively, who had worked closely with the *Flora Europaea* team from the 1960s onwards.

More generally, *Flora Europaea* has both provided a valuable conceptual framework and stimulated further taxonomic revision, while floristic exploration has continued apace, especially in Mediterranean countries. Some idea of the new information available can be seen by the quantity of data added to the revised volume 1. The number of taxa in the revised volume compared to the first edition expanded by more than 10%, with *c.* 250 species and *c.* 150 subspecies described since 1964 added (with some 20 species deleted or subsumed), together with a number of native or naturalized taxa new to Europe [1, 24]. *Flora Europaea* always took a conservative taxonomic position, and about a third of the newly described taxa, including some recognized in *Atlas Florae Europaeae*, were included either only as observations or in synonymy under other species.

It is now over a decade since that second edition of volume 1, and new information continues to accrue. Already this revised volume is gradually becoming outdated, while large parts of the other four volumes, for which unfortunately the necessary funds were never found to carry out revision, fall well behind current knowledge of the European flora. Taking a rather extreme example, the first two of the ten projected volumes of a much-needed comprehensive Greek Flora [20], and a handsomely illustrated volume on endemic plants [21], effectively render obsolete substantial portions of *Flora Europaea*. New species continue to be described from Greece, with recent analysis showing the flora, the richest in Europe with some 5000 species, to

have 15.6% endemism, most of these endemics, which continue to be described, restricted to small geographical or altitudinal ranges [10].

Plant taxonomy in flux

Webb [25] in a characteristically incisive, erudite and humorous 1978 review of the finished *Flora Europaea* project, observed how he and his colleagues had hopefully sorted out enough information to allow a future generation of botanists to get on with some real taxonomy and detailed botanical studies. This has certainly occurred, as we can see from Greece and elsewhere, although perhaps not always in ways he and his fellow editors might have expected. At the same time plant taxonomy, especially in its traditional forms, is now going through some bad times, largely vanished in France and in decline in Britain (it is no longer possible to obtain a first degree in Botany from a UK university).

The last two decades have seen profound changes in techniques and approaches to the subject, with even cytology far less prominent. On the other hand, numerous problems that long vexed European botanists have been elucidated, both via molecular research and by the increasing use and efficiency of electronic keys and Floras. The development of efficient and much cheaper computing has greatly facilitated the handling of vast datasets, and molecular taxonomy has an academic respectability that traditional taxonomy largely failed to achieve. The wider scientific community perhaps sees it to be fully scientific and objective, replacing the perceived intuitive inconsistencies of earlier generations.

In particular, DNA sequencing and the whole field of molecular systematics have produced a revolution in the classification of even familiar plants. Suddenly the means are available to establish an evolution-based classification, building phylogenies to replace the 18th-century subjectivity of Linnaeus's familiar tried and tested system. Nevertheless, wise councils such as V.H. Heywood have urged caution, emphasizing that these molecular methods should be seen as *techniques* and not themselves become the end rather than the means of taxonomy [13], and it will be some time before taxonomists collectively have the last word. However, the close links between taxonomy and genetics, that fascinating area that once used to be called 'experimental taxonomy', remain central to European systematic studies.

The DNA-based studies of the internationally recognized Angiosperm Phylogeny Group (APG III) [5, 12] have certainly improved our broad knowledge of plant families, and sorted out some uncomfortable family delimitations. I suspect, many traditional taxonomists broadly welcome these changes, not least as one remembers how in the 1960s and 1970s many British botanists and others regarded the Englerian system adopted by *Flora Europaea* as outlandish! Not only were there clearly problems with separating or uniting certain families, but also it was odd that, for example, Cactaceae in Volume 2 was separated from the other Centrospermae or betalain-containing families in Volume 1. Family numbers themselves have expanded. APG III includes 413 families, many more than were recognized in the past, and Heywood *et al.* in a new edition of *Flowering Plant Families of the World* (2007) [14] go further, recognize 506 families, a substantial increase from the 306 families in the original, much reprinted 1978 edition. Monocotyledons and Dicotyledons are now regarded as unsustainable units, but continue to be useful informal concepts. Monocotyledons may come before Dicotyledons at the start of the APG III sequence, but many Floras have done this for years.

Long-established families (i.e. those retaining historical names) such as Brassicaceae or Cruciferae and Fabaceae or Leguminosae remain, if placed at slightly different positions within the new family order. Apiaceae (Umbelliferae) emerges as last in the scheme, no longer familiarly at ‘the end of volume 2’ of *Flora Europaea*, being regarded as more advanced than even Asteraceae or Compositae. Other changes, helpful or otherwise, include:

- Chenopodiaceae is subsumed within Amaranthaceae, which may reflect the evolutionary situation, but the result of the merger is to create a larger family out of two already critical and often misidentified families.
- Scrophulariaceae, previously something of a compromise of different flower form and life history, has been divided, with several genera absorbed for example into Plantaginaceae. This may appear strange, but intuitively a speedwell (*Veronica*) resembles in many respects, even to the non-professional botanist, a colourful plantain (*Plantago*); and *P. media* is insect-pollinated.
- The parasites of Orobanchaceae now have their own family, finally separated from Scrophulariaceae, together with photosynthetic hemi-parasites such as *Rhinanthus* and *Melampyrum*. This too seems logical.
- Liliaceae has been divided into convenient units, a process that had been developing for some decades, with most Transylvanian species, for example, now in Asparagaceae.

These changes are now widely accepted and it is likely that Floras and herbarium curators will increasingly take on board the APG III system.

A plethora of name change

More significantly, molecular research is also leading to the re-classification of familiar European genera. The trend to split genera is bound to cause confusion: generic name changes, as the Flora Europaea Editorial Committee insisted to contributors, should never be taken lightly (any proposed change was circulated as a formal memo for approval by the Committee). Changes are inevitable but too many among familiar genera and species confuse most users outside the rarified world of professional taxonomy. As phylogeny redraws the existing system, its practitioners should remain mindful of the consequences of these changes, which affect not just taxonomy users but also the vegetation taxa used in phytosociology.

The more showy ornamental genera particularly engage the attention of taxonomists. The constant re-classification of orchids, especially by British botanists, maybe reflects a feature of taxonomy that Walters himself pointed out that plants of commercial or horticultural interest tend to be over-classified. I remember one of my university professors, taxonomist and geneticist P.E. Gibbs, remarking how in the 1940s and 1950s, while botanists in the USA were pushing back the frontiers of genetics and taxonomy, British botanists were “counting spots on orchid labella”. Nothing changes perhaps, especially in the Mediterranean where German botanists especially keep adding to the tally of *Ophrys* species. That said, hard as it may be for some to absorb, much of the evidence is convincing, and *Anacamptis morio* rather than *Orchis morio* is logical, certainly if it is compared with a scarce variant of *A. pyramidalis* (var. *emarginata* Zapal.) with an undivided lip. More significant to the wider scientific and commercial world, molecular techniques are clarifying relationships in grass genera such as *Festuca*, *Lolium* and *Vulpia* (Poaceae), a complex group of enormous economic and ecological importance. In all

some 10-20% of grass genera may change their names. Asteraceae too is seeing considerable changes to genera in delimitation and nomenclature.

Some name changes do work smoothly. To take a small example, *Gentianopsis ciliata*, which differs from *Gentianella* in several features of morphology and pollen and chromosome number, was originally transferred from *Gentianella* by a botanist from China, where several members occur of this largely Asiatic and North American genus. Sound evidence exists also to replace the name *Echium russicum* with *E. maculatum*, yet a proposal to transfer this to the genus *Pontechium* on molecular grounds [15] seems a step too far. It adds little nothing to our knowledge and understanding of the species and might cause confusion to those responsible for its legal protection – note that Transylvania holds the largest EU populations of this dry grassland rarity listed on Annex II of the Habitats Directive.

All of us are of course guilty of changing names. In adopting *Persicaria* for showy-flowered species formerly included within *Polygonum* and including the giant knotweeds in *Fallopia*, for a new Polygonaceae identification handbook [2], I follow widespread acceptance of these generic names based on sound evidence from several disciplines, although unlike botanists in North America I retain *Bistorta* and *Aconogonum* as sections within *Persicaria*. The *Flora Europaea* editors were too cautious and did not allow these changes in the revised vol. 1.

I came across several interesting practical examples of name changes at both generic and specific level at first hand on a visit to Southern Greece in November 2013, with a party from the Alpine Garden Society, to see the wealth of autumn-flowering bulbs ('bulbs' *sensu lato*). It became clear that many *Cyclamen* and *Narcissus* species had undergone name change. The common species *Scilla autumnalis* is now *Prospero autumnale* and has been split into segregate species, mainly on the basis of established knowledge of the variable chromosome numbers. On the other hand *Crocus*, although it has certainly accrued taxa, remains more or less stable (even the *Iris*-like *C. banaticus* in Romania has not been separated, no DNA differences having been recorded). Ironically in his excellent and beautifully illustrated work *A field guide to the Bulbs of Greece* [11], widely consulted by the group, experienced botanist and excursion guide C. Grey-Wilson takes a pragmatic approach to the taxonomy of these often variable plants. He wisely, for instance, keeps *Chionodoxa* apart from *Scilla* (there is enough botanical evidence to subsume *Chionodoxa* within *Scilla*, but many horticulturists retain them as distinct genera), and takes a pragmatic view of DNA-based orchid taxonomy.

Our party was mostly composed of non-professionals, knowledgeable but prepared to rely uncritically on the judgment of professional botanists. Several were in the nursery trade and grew bulbs for most or part of their income. They were content to accept whatever name changes were being used "in the books". This may reflect a shift in the whole process of taxonomy. In Britain and Ireland especially, the move by the professionals towards wholly laboratory-based procedures that attract taxonomy funding has been disrupted the traditional pattern of non-professional and botanists in academic institutes complementing each other's work. Amateur botanists now mostly record, as ancillary 'citizen scientists', a term widely employed in the UK.

Maintaining a *Flora Europaea* ethos

In a greatly changed world, so many of the principles that remarkable editorial team of *Flora Europaea* conceived and followed 60 years ago are still relevant. We should do well to follow them, for example, by consistently taking a conservative, but flexible and open-minded,

approach to taxonomy and much else, appealing as Webb did to tradition and common sense. Webb for instance always saw Europe in a historical context, hence his use of evocative but historically significant descriptors such as Bohemia, Macedonia, White Russia, and Banat and Transylvania. The post-1990 redrawing of the map of Europe would have held no terrors for him and the other editors – in his wise partition of Russia into its component geographical territories (Rs), Webb (following to great extent the published *Flora URSS*) divided the Soviet Union into its component parts that have now re-asserted themselves.

There is another lesson in the treatment of non-native species in Europe and in Floras generally. The *Flora Europaea* team took great care over the treatment of aliens (another of Webb's responsibilities). The guidelines he adopted, basically that aliens should be established for a number of years or be establishing themselves in many places, are a firm basis for the inclusion of species that have an evolutionary impact (such as the transfer of GM genes from cultivated to wild *Brassica* species) of aliens is as important as the practical consequences.

Finally, it is clear to those of us who worked on *Flora Europaea* or other projects with a broad overview of the European flora must think seriously about adopting a much narrower species concept. A modest expansion of numbers of plants recognized in Europe will not so much reflect an over-explored, over-classified flora as a general increase in accepted numbers of plant species that we need to accept worldwide. Botany is following zoology in taking a harder look at the very definition of species [13], and here again the molecular data are taking the lead. Even without redefining specific limits, certain groups defy traditional taxonomic treatment, such as some taxa that have evolved in the geographically dynamic scatter of islands in the Aegean Sea that have experienced millennia of climate- and sea-level changes, for example revealed by studies of *Leopoldia*, the tassel hyacinth group of *Muscari*, which has a distinguishable race on many of the islands. Even *Nigella*, revealed in a classic study by A. Strid [19], although classifiable, shows a complex pattern of such variation. Whatever the true number of species (and sub-species), however, as we see from the numbers of endemics, nobody can now doubt that Greece has one of the most important floras on Earth, and occupies a special place in global biodiversity. Even in well-studied parts of Europe, problems remain, for example the kidney-vetches (*Anthyllis vulneraria*), which the late J. Cullen wisely treated as a *Rassenkreis* of subspecies across Europe and the Mediterranean region [8].

Plants still evolve today, not only in island systems, but also in a Europe increasingly dominated by anthropogenic habitats [6]. Traits such as heavy-metal and salt-tolerance may have emerged largely due to human pollution of the environment. Here is a source of considerable adaptive and genetic differentiation in plants that taxonomy has largely missed, although ecotypic variants may well involve into new taxa or even endemics. The most distinct and precious UK endemic, Lundy cabbage (*Coincya wrightii*) restricted to a few cliffs of a small granite island off S.W. England, gives every appearance of being an ecotypic derivative of a group of related, mostly Spanish taxa. Note that the conservation community as well has sometimes failed to grasp the significance of the ability of plants to evolve in response to dynamic and sometimes hostile environments, rather than merely slide into extinction.

I firmly believe we do need a new formal *Flora Europaea* to identify, catalogue and showcase the genera, species and (with our increased knowledge) intraspecific variants of Europe, obviously following APG III but still pragmatic as regards genera and species. We need stability but must not be static. Flora writers should above all remember their users, not just a

dwindling band of taxonomists but also a whole constituency of fellow scientists, especially ecologists and phytosociologists, as well as those in other disciplines. Perhaps most important to address are those in government and legislation, medicine and pharmacology, who will always demand sound botanical information. Nor should we forget the large non-professional public, including naturalists, gardeners and conservationists. In this context, an often overlooked work, *The European Garden Flora*, covers all ornamental Angiosperms cultivated in European gardens [9], a huge genetic resource (the *Plant Finder* list in Britain includes over 70,000 taxa, many of them rare cultivars [7]). These need to be catalogued and described alongside their wild relatives.

It would be good to see something of the old *Flora Europaea* organization brought back to involve younger generation. Today's botanists already exchange considerable electronic correspondence and information – on a scale that would have been impossible thirty years ago – but it would be good to see a 'club' that met regularly to discuss and plan for the future. During the 1960s and 1970s these sort of meetings gave rise to *Flora Europaea* symposium volumes, which may vary in quality but overall bring together contributions that discuss stimulating ideas and topics in several areas of taxonomy and related sciences. These volumes derived from a series of international conferences, coupled with field excursions, held in different European territories. The editors especially enjoyed the 1963 meeting in Romania [18], with memorable journeys by bus and train to academic centres and field sites under the expert tutelage of Professors Boşcaiu and Pop.

We must nurture and stimulate the next and future generations of plant taxonomists and Flora writers. We certainly need these individuals and their special skills, even if we cannot at present offer them a conventional career. We shall also, for the foreseeable future, need the products of their labours. We live in an age that is moving towards electronic books, but many believe there will always be the need for hard copy, as with *Flora of North America*, *Flora of Pakistan*, and *Flora of China*. These huge works are published as conventional multi-volume Floras while at the same time are freely available online, backed up by extensive searchable data-sets. Such amalgamation of traditional and contemporary approaches falls within the true and, one hopes, lasting spirit of *Flora Europaea*.

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IMPORTANȚA ȘI MOȘTENIREA LĂSATĂ DE *FLORA EUROPAEA* ÎN ERA SISTEMATICII MOLECULARE

(Rezumat)

Flora Europaea (1964–1980, 1993) este o sinteză taxonomică practică și concisă a florei Europei, cu origini în Anglia și Irlanda, însă cu perspective pan-europene și colaborare internațională. Scopul acesteia a fost să rezolve neconcordanțele în ceea ce privește genurile și speciile europene, să permită realizarea de comparații între regiuni geografice, furnizând astfel subiecte de cercetare viitoare. Proiectul a încurajat și inspirat alte inițiative, în special flore regionale, *Atlas Florae Europaeae* și cercetare monografică. Au existat două căi de dezvoltare care au cauzat schimbări în sistematica tradițională: tehnicile moleculare prin secvențarea ADN-ului și utilizarea mult mai frecventă a mediului electronic. În același timp, taxonomia nu a mai fost introdusă ca disciplină în învățământ. În aceste condiții, ar fi necesare numeroase schimbări în volumele *Florei Europaea* pentru a încorpora datele floristice și taxonomice noi pentru actualizarea informațiilor. O parte substanțială a conținutului acesteia nu mai este utilizată în prezent datorită reviziilor taxonomice recente. Acestea comportă mai ales divizări generice și specifice și schimbarea denumirii plantelor, cu consecințe neprevăzute asupra utilizatorilor din alte ramuri ale științei plantelor, conservării, fitosociologiei, medicinei și legislației. Este nevoie să se revină la viziunea pragmatică inerentă a *Florei Europaea*.