Introduction

For information on all aspects of bryology see A. J. Shaw & B. Goffinet (eds.), *Bryophyte Biology*, Cambridge University Press, 2000.

Nomenclature

I have followed the nomenclature of Corley *et al*. (1981) deviating from this where there have been subsequent taxonomic or nomenclatural changes. Only recent synonyms are given except for names used by Dixon & Jameson (1924).

Author abbreviations are those recommended by Brummitt & Powell (1992) although where three or more authors are involved I have used only the first name followed by *et al*. (e.g. Gaertn. *et al*. rather than Gaertn., B. Mey. & Scherb.). Authorities for species are those given on the Missouri Botanic Garden website W^{3}MOST (http://mobot.mobot.org/W3T/Search/most.html). For place of publication abbreviations I have followed Crosby (1999).

Bryologia Europaea citations

Bryologia Europaea was published in 65 fascicles between 1837 and 1855 but not in any systematic order. On the title pages the names P. Bruch, W. P. Schimper and W. T. Gümbel appear. However, the general consensus now is that Gümbel was the illustrator and did not describe any mosses and I have therefore not used his name for any *Bryologia Europaea* citations. The citation of Bruch & Schimper or Schimper alone is also problematic. Bruch died in 1847 and the last part of *Bryologia Europea* did not appear until 1855. I have followed Stafleu & Cowan (1976) who give the date and authorship of each genus in *Bryologia Europaaea*. The frequently used citation BSG should be avoided.

Use of ex and in

'Ex' is used to connect the names of two or more persons, for example Schimp. ex Müll. Hal., the second of whom (C. Müller, Halle) validly published a name proposed by but not validly published by the first person (Schimper). When citing authorities, for example on a moss packet, both names or groups of names should be used.

'In' is used to connect the names of two persons (e.g. Hook. in Grev.) the second of whom (Greville) was the editor or author of a work in which the first person (Hooker) was responsible for validly publishing or making available a name. When citing the authority for a moss name it is not necessary to cite the 'in' name. The 'in' author is only used when the publication is cited.

English names of mosses

I have not given English names of mosses in the text as they are more difficult to remember and often more cumbersome than Latin names. However, there is the absurd requirement in the Wildlife and Countryside Act, 1981, for common names to be used. I have therefore provided a list of preferred English names (pp. 945–964) from Edwards (1999).

Taxonomic categories

In the first edition of this book I adopted a somewhat broader concept of the genus than some other authors of the time but it is now clear that as a result of genetical and other studies this was incorrect, hence the increase in the number of genera from 175 to 214. More equivocal is the status of a number of taxa now recognised as species but treated in the past as varieties or subspecies. However, I have followed, albeit sometimes somewhat reluctantly, current practices in the treatment of such taxa.

Frequency and distribution

The publication of volumes 2 and 3 of the *Atlas of the Bryophytes of Britain and Ireland* (Hill *et al*. 1992, 1994) has provided a much better picture of the frequency and distribution of mosses than was available at the time the first edition of this Flora was written and it has proved possible to give more accurate information on a regional basis. I have used six estimates of frequency : very rare, rare, occasional, frequent, common and very common. To which of these categories a particular species belongs is to some extent a matter of personal opinion but it was felt that this system was more satisfactory than using a multiplicity of phrases such as 'not infrequent', 'not uncommon' etc. that have been used elsewhere.

There are two sets of frequency figures given at the end of the British and Irish distribution information. The first is the number of vice-county records in Britain and Ireland. There are 112 British and 40 Irish vice-counties and one for the Channel islands. As an example, 17, H3, C means the plant has been recorded from 17 British, 3 Irish vice-counties and the Channel Islands.

The second set of figures is the number of 10 km squares of the British Ordnance Survey National Grid and Irish Ordnance Survey/Suirbheireacht Ordonais National Grid from which species have been recorded. The Universal Transverse

Mercator (UTM) grid is used for the Channel Islands. There are about 2640 British 10 km squares, about 1000 Irish and 15 Channel Islands'. Records from 1350 onwards and those pre-1950, indicated by *, are distinguished. Thus, GB873 + 98*, IR86 + 7*, C6 + 2* indicates 73 recent and 98 pre-1950 records from Great Britain, 86 recent and 7 pre-1950 Irish records and 6 recent and 1 pre-1950 Channel Islands' records. These figures have been taken from Hill *et al.* (1992, 1994). The figures for Great Britain and the Channel Islands are a reasonable indication of frequency and whether or not species have decreased. The Irish records are incomplete because of inadequate recent recording in Ireland and many old records are the only ones available and should not be taken as an indication of change in frequency. Altitudinal ranges have also been taken from Hill *et al.* (1992, 1994).

Hill & Preston (1998) carried out an analysis of the geographical relationships of the bryophytes of the British Isles and they recognized 43 floristic elements. The element to which each species belongs is given in italics in the distribution data in this Flora. For further information on this see pp. 936–937.

Information on world distribution comes from Duell (1984, 1985, 1992), supplemented with data from other sources where appropriate. Most distributional information predates recently changed political boundaries; hence the use of Czechoslovakia and Yugoslavia. The term Macaronesia technically covers the extreme S. W. corner of the Iberian Peninsula, Madeira, the Azores, Canary Islands, Salvage Islands, Cape Verde islands and the coastal strip of N. W. Africa. The sense in which I use the term includes what is referred to in German as Lauri-Makaronesien, i.e. the Azores, Madeira and the Canary Islands.

Illustrations

With the exception of a small number of species (*Buxbaumia viridis, Cinclidotus riparius, Cynodontium gracilescens, Grimmia crinita, G. elatior, Lescuraea saxicola, Meesia triquetra, Mnium medium, Neckera pennata, Orthotrhicum gymnostomum, O. shawii, Paraleucobryum longifolium, Schistidium flaccidum, Syntrichia norvegica, Tetrodontium repandum, Trematodon ambiguus, Weissia controversa* var. *wimmeriana*) all figures have been prepared from British and Irish specimens, although some have been augmented by material from other sources, as far as possible from continental Europe. Illustrations from the first edition, except for those of *Tortula* species 12–16, *Protobryum bryoides*, *Pottia* and *Microbryum rectum*, which were drawn by Miss Gillian A. Meadows of the Royal Botanic Garden, Edinburgh, were prepared by Mrs Ruth Smith using a Leitz Laborlux microscope with either a Leitz camera lucida or a Leitz drawing apparatus. Additional drawings for this edition were made by the author using the same equipment. Figure 1 was drawn by Dr S. R. Edwards and the photographs in Fig. 115 were provided by Dr Rosa M[a] Ros of the Universidad de Murcia. For reasons of economy only the minimum of illustrations has been used and habit drawings have for the most part been omitted, being of little use.

They need be of such a size that they take up an amount of space far in excess of their value.

Literature cited

Where a reference is not listed in the Bibliography it is given in full in the text, e.g. A. C. Crundwell, *Trans. Brit. Bryol. Soc.* 4, 67–74, 1965. Where a work is listed in the Bibliography, only name(s) of author(s) and date of publication are cited in the text, e.g. Dixon & Jameson (1924).

Conservation

A number of bryophytes have decreased markedly over the past 100 years and many species are now endangered or at risk. The reasons for this are varied – urbanisation, industrialisation, changing agricultural practices, atmospheric and aquatic pollution and over-collection (see A. J. E. Smith, Mosses, liverworts and hornworts in D. L. Hawkesworth, ed., *The Changing Wildlife of Great Britain and Ireland*, 2000, for the situation since 1973). Care should therefore be taken when collecting bryophytes. If material is sparse only the minimum amount necessary for determination should be collected. This applies particularly to cushion or tuft forming species, some of which, such as *Grimmia* species, are very slow growing. DO NOT REMOVE A WHOLE SPECIMEN IF IT IS THE ONLY ONE GROWING AT A PARTICULAR SITE. A photograph is a very satisfactory alternative as it preserves the original habit and colour of the plant concerned and can also illustrate features of the habitat. For useful information on the photography of bryophytes see S. R. Edwards, *J. Bryol.* **16**, 443–84, 1991.

The Joint Nature Conservation Council has produced a Red List of British Mosses (Church *et al.*, 2001), giving extinct, critically endangered, endangered and vulnerable species. This list is given on pp. 936–938 and I have indicated in the list those species that it is a criminal offence under the Wildlife and Countryside Act, 1981 to collect. However, this 1981 list of mosses is unsatisfactory as it seems to be a random selection of rare species made without reference to competent field bryologists. Also, some of the species listed cannot be identified without collecting a specimen, hence the strictures on care in collecting. Recently, a database of threatened bryophytes was set up (see N. G. Hodgetts, *Bull. Br. Bryol. Soc.* **80**, 52–9, 2003).

Collection and preservation of material

An adequate specimen for determination should be collected, bearing in mind the above comments on conservation, which will show part or whole of the growth form of the moss. A search should be made for perichaetia and perigonia and sporophytes as these may be useful or essential for identification. For mosses

growing in temporary or unstable habitats it is useful to collect 5 mm or so of the substrate beneath the plant so that rhizoidal gemmae if present are collected.

If specimens cannot be examined immediately they should be air dried as plants left in wet paper packets, polythene bags or dishes of water often grow etiolated shoots and may become mouldy. Specimens are best put in appropriately labelled newspaper or paper packets (not envelopes which undo if wet). They should not be pressed as pressed mosses often do not recover their original shape when remoistened. Once dried, mosses can be kept indefinitely. Specimens even a hundred or more years old will assume their original form when moistened, although they may have lost their original coloration.

Bryophytes are best kept in flat paper packets on which collection data and any other relevant information (name, habitat, altitude, locality, grid reference, collector, collection number, date) can be written. Packets may conveniently be made from A4 sheets of non-acid paper. The bottom one-third of the sheet is folded upwards, the two sides folded inwards thus forming a pocket to contain the specimen. The top third is then folded over and information can be written on the upper side.

Examination of material

Specimens or portions of specimens should be moistened before dissection as dry mosses are often brittle. Where difficulty is experienced with remoistening dried plants, as with members of the Fissidentaceae, Mniaceae and Polytrichaceae, the process can be expedited by adding a little household detergent to the water used.

Dissection of specimens is best carried out using a dissecting microscope as most mosses are too small to do this satisfactorily with the naked eye. For study of leaf shape, cells, etc. leaves should be removed from stems, care being taken that complete leaves are detached as basal and alar cells are often important in identification. It should be remembered that auricles if present, as in *Plagiomnium* and *Plagiothecium*, may remain attached to the stem, so it is useful to mount a piece of stem, from which leaves have been stripped, on a slide to check this.

Cutting sections

The following method, modified from an account by Dr S. R. Edwards (pers. commun.), allows good transverse sections of about 10 μm thickness to be taken from any required part of a moss leaf or stem. If possible, a dissecting microscope should be used.

For leaf sections selected, moist leaves should be arranged parallel to each other on a glass slide, with the parts to be sectioned aligned as arrowed in Fig. 1(a). A second slide is laid over the leaves, so that its long edge is also aligned with the parts to be sectioned (Fig. 1(b)). Firm pressure is applied to the upper slide by the

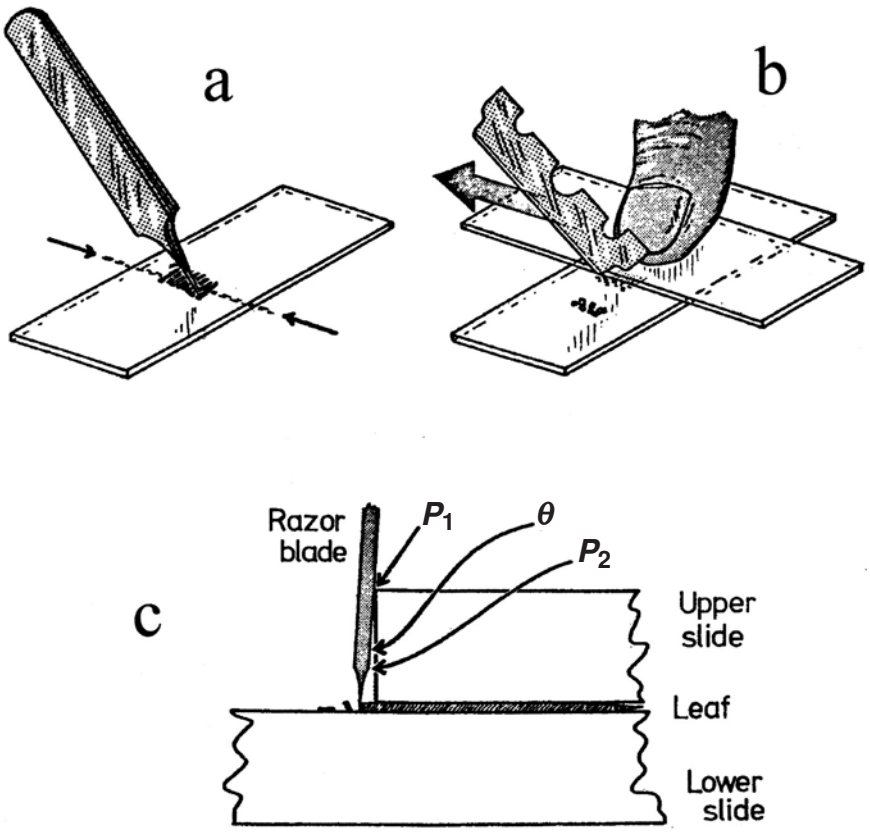

Fig. 1 Diagram illustrating technique for section cutting. (a) arrangement of leaves on lower slide; (b) cutting sections; (c) angle of tilt, θ, of razor blade. P_1 and P_2 are fulcrums.

finger of one hand (Fig. 1(b)), and half a double-edged razor blade is drawn with the other hand across the leaves, using the upper slide as a guide (Fig. 1(b)). Only a corner of the blade is used, with an angle of elevation of the blade of about 15°–20°. This should give a perfectly clean cut.

Sections are made by adjusting the angle of tilt of the razor blade for each successive cut. The first cut is made with the blade at an angle of about 15°–20° from the vertical. This angle is progressively reduced with each successive cut. This is shown diagrammatically in Fig. 1(c), where θ is the angle of tilt and P_1 is the fulcrum. Depending upon the change in the angle of tilt with successive cuts, so the thickness of sections can be controlled. After the tilt of the blade has passed 0° (vertical), the fulcrum moves down to P_2 (Fig. 1(c)), resulting in a finer control over the thickness of the last few sections. Pressure on the blade has to be judged by experience, but it should be no more than is necessary to cut the leaves. One blade corner may provide many series of sections and only with very

old and fragile material should a fresh corner be used for each operation. With a little practice excellent sections can be cut.

For small leaves and sections of stems or branches, as in *Sphagnum*, the same technique is used. But stems or branches are laid side by side.

Measurements

Height of plants is height of the gametophyte and excludes any sporophytes that may be present. Leaf length is from middle of insertion to apex unless otherwise stated (in some mosses with hyaline leaf apices). Cell dimensions are from middle lamella (or where it would be if visible) to middle lamella. Capsule length is from mouth to junction between neck and seta.

Using the keys

It is important that with each dichotomy of a key both parts are read carefully and particular note taken where 'usually' and 'or if' occur. Once a plant has been named it is essential that the specimen is carefully compared with the specific description and illustration before any firm conclusion is reached as to its identity.

Key to genera

It must be stressed that the generic key is merely a guide to the allocation of specimens to genera and is far from infallible. Unfortunately, many characters that are useful in classification, such as peristome structure, sex and DNA sequences, may not be available in material collected or may only be useable with highly sophisticated technical equipment. Also, differences in appearance that enable an expert to determine a moss in the field with a hand lens cannot be described in quantitative or qualitative terms and it is necessary to rely on characteristics such as excurrence of costae or degree of papillosity that are open to misinterpretation or ambiguity. Whilst every effort has been made to avoid the use of vague or relative characters, because of the poor distinctions between some genera, such as some members of the Brachytheciaceae or Pottiaceae, precise definition is impossible. Where generic distinctions are based on the sporophyte, as in the Funariaceae, it may not be possible to identify sterile material.

Where a species may exhibit both alternatives of a dichotomy, e.g. excurrence/non-excurrence of the costa or margins plane/recurved, allowance has been made as far as possible in the keys. However, allowing for every eventuality would make the key inordinately long and when in doubt it may be necessary to try both alternatives of a dichotomy.

In acrocarpous mosses leaf characters are based upon leaves from the upper part of the stem or comal leaves but care should be taken that perichaetial or perigonial

leaves are not used as these may differ in shape and areolation from stem leaves. In pleurocarpous mosses stem and branch leaves may be very different in form, especially in the Brachytheciaceae, and leaf characters refer to stem leaves unless otherwise stated.

Where there is an overlap in dimensions such as cell size, only with very few exceptions are specimens encountered with the dimensions exactly in the overlap range. Thus if cells in one taxon are given as 8–16 μm and in a second as 14–24 μm the majority of cells in the first will be less than 14 μm long and those in the second mostly more than 16 μm long.

Keys to species

The same remarks apply to the keys to species, although in most instances the characters are more clear cut and misinterpretation less likely. However, difficulty may be experienced with genera such as *Bryum*, *Didymodon* and some Brachytheciaceae.

It must be remembered that this is a regional flora and that some of the key dichotomies will not necessarily work elsewhere. Thus in the generic key in dichotomy 86, *Coscinodon* is separated from *Grimmia* and *Schistidium* by having plicate leaves, but in Continental Europe *Coscinodon humilis* Milde lacks leaf plicae and *Grimmia caespiticia* (Brid.) Jur. has strongly plicate leaves.

Abbreviations

auct.	Auctor(es), author(s)
C	Channel Islands (referring to the vice-county or the number of 10 km grid squares in the Channel Islands)
c.	*circa*, approximately
cm	centimetre
GB	Great Britain (referring to the number of 10 km grid squares in Great Britain)
H	Hibernia, Ireland (referring to number of vice-counties in Ireland)
IR	Ireland (referring to the number of 10 km grid squares in Ireland)
KOH	Potassium hydroxide (2% solution)
m	metre
m	m-chromosomes, micro-chromosomes
n	the functional haploid chromosome number
q.v.	*quod vide*, which see
s.s.	*sensu stricto*, in the strict sense
ssp.	subspecies
var.	variety
x	basic haploid chromosome number
μm	micron, 1×10^{-6} m, $^{1}/_{1000}$ mm; colloquially 'mu'
±	more or less
*	following a chromosome number, means based on British or Irish material
*	following number of grid squares, meaning pre-1950 records

Conspectus of classification

Traditionally, the division Bryophyta has included three classes, Hepaticopsida or Marchantiopsida (liverworts), Anthocerotopsida (hornworts) and Musci (mosses). Recent evidence, however, suggests that at an early stage in the evolution of terrestrial plants the liverworts diverged from other land plants, then hornworts diverged and finally mosses (see Willis & McElwain, 2002). Thus, the original concept of the division Bryophyta as consisting of three classes cannot be maintained and it is here considered to consist only of the mosses.

Until the beginning of the 1980s the classification of mosses was based upon the morphology and anatomy of the gametophyte and sporophyte and it was sometimes a matter of dispute as to which of the two should be used for a particular group. Over the past 20 years or so new techniques have been developed, especially DNA sequencing, which provide information on the genetic relationships of taxa. This has confirmed some older classifications but others have been shown to be incorrect. The classification of mosses is now in a state of flux as a result of the development of these new techniques, Rather than using a traditional classification, such as that used by Corley *et al.* (1981), which is clearly very out of date, I have followed the tentative classification of D. H. Vitt (in Shaw & Goffnet, 2000). However, it is likely that further studies will lead to refinements, and even major changes, to this classification.

Division Bryophyta (Musci)

Class 1. Sphagnopsida
Order 1. Sphagnales
Family 1. Sphagnaceae
1. Sphagnum
Class 2. Andreaeopsida
Order 2. Andreaeales
Family 2. Andreaeaceae
2. Andreaea
Class 3. Polytrichopsida
Order 3. Polytrichales
Family 3. Polytrichaceae
3. Pogonatum
4. Polytrichastrum
5. Polytrichum
6. Oligotrichum
7. Atrichum
Order 4. Tetraphidales
Family 4. Tetraphidaceae
8. Tetraphis
9. Tetrodontium
Family 5. Oedipodiaceae
10. Oedipodium