Management of a Lichen Herbarium

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Introduction

Lichen herbaria store preserved specimens of lichenized (and often lichenicolous) fungi. The main tasks of lichen (and all other) herbaria are as follows:

Taxonomic, chemical and molecular studies

Taxonomic studies must be at least in part based upon herbarium specimens, of which the so called type-specimens are the most important. It is on these that descriptions of new taxa are based, and they serve in perpetuity as the reference for these names. For a new species to be validly published, the herbarium in which the type specimens are lodged must be specified. Locations, contents, acronyms etc. of the world's public herbaria can be found in "Index Herbariorum", compiled by Holmgren et al. 1990. A searchable internet-version is available at: http://www.nybg.org/bsci/ih/.

Most secondary lichen substances remain stable in storage, and hence herbarium specimens are reliable subjects for chemical investigations. The ability of lichen thalli to accumulate pollutants means that older specimens may provide evidence of former environmental conditions.

Improved methods in molecular studies have also led to an increasing use of herbarium specimens (preferably not older than 10 years) as important subjects for taxonomic works. When old herbarium collections (e.g. from the last century) are examined, lichen phylogeny and the long term population dynamics of lichens will become promising fields of study.

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Floristic data Herbarium specimens are an essential basis for the preparation of checklists or floras of particular geographical regions. They can also provide an indication of changes over time in the distributions of species.

Identification Due to the rather complicated morphology of lichens, descriptions (and keys to taxa) are difficult to make or, if done, often are insufficient for a certain recognition of taxa. Illustrations can overcome this problem to some extent, but are unavailable in many cases. Thus, properly identified herbarium specimens are an indispensable tool for a correct identification of unnamed taxa.

Experimental Details

Preparation of lichens

Carefully prepared herbarium specimens are of vital importance for the quality of the whole herbarium. Although the 'Herbarium Handbook' of Forman and Bridson 1998 gives helpful advice on preparing phanerogams, collecting and preserving of lichens is dealt with only cursorily. [Note: While finishing the manuscript a book on 'managing the modern herbarium' (Metsger and Byers 1999) has been published]. General hints regarding the preparation of lichens can be found in, for example, Wirth 1995, Moberg and Holmsen 1992 and Hawksworth 1974. A brief summary of methods for preparing lichens for deposition in a herbarium is given below.

Collecting lichens and preliminary field-preparations Before collecting lichenized fungi (or indeed any biological specimens), the potential rarity of the species should be considered. Many countries require formal collecting permits, and these frequently come with a range of restrictions. In countries where some species are legally protected, collecting of rare, vulnerable or threatened species may be highly restricted or prohibited. Regardless, no collecting should deplete an entire stand.

For epiphytic lichens, the substratum must also be considered, and trees should not be damaged or killed. Depending on the growth habit of lichens and the type of substratum, different collecting-methods are appropriate. Easily removable (large foliose, umbilicate or fruticose) lichens must be collected with their attachment organs (but usually without substratum). Small foliose and all crustose lichens have to be removed with part of the substratum. Stout knifes or caulking irons are used for bark, wood or soil; chisel and hammer help to remove lichens from

hard substrate (e.g. rocks). Fragile lichen species (e.g. Caliciales, or many fruticose taxa if totally dried) should be carefully wrapped in soft paper (e.g. uncoloured toilet paper). Rocks with crustose lichens (especially when wet) must be processed in the same way to avoid mutual abrasion.

Preparation in the laboratory

In order to minimise space-requirements, freshly collected (often slightly to totally wet) specimens of foliose or fruticose lichens should be very slightly pressed and dried between uncoloured paper. With great care, rock substrates may have to be made thinner with a chisel or other specialised cutting equipment (see Figure 1), because too thick specimens unnecessarily can cause additional space problems. Specimens on bark, rock and especially soil are usually fixed to stiff card with wood glue. Additional protection against pressure (especially necessary in case of brittle lichens and/or substrate, e.g. delicate Caliciales, unpressed fruticose lichens or specimens on friable or earthy substrate) can be achieved by glueing small wooden rods (or rings of very strong cardboard) around the substrate or by putting it into small shatter-proof boxes. Never close the boxes before the lichen or the substrate or the glue is totally dry; mould fungi may destroy the whole specimen!

Foliose or fruticose lichen thalli and any substratum with lichens on each side must never be stuck directly onto cards. If a sample consists of many small pieces, these can be placed on cardboard between two layers of soft paper, which may prevent displacement. Sometimes it is necessary to group them within a small packet, which can be glued onto the card (see Figure 2a). Arranging packets inside each other should be reduced to a minimum as it slows down the access to the material.

After mounting on card, most lichens are usually placed into folded envelopes (see Figure 2b). Both cards and envelopes need to be of a long-lasting (acid-free) archival quality. It is advisable to print the herbarium name (or acronym) on the outside of every packet and on the cardboard. This prevents confusion when handling specimens from many different herbaria. At least for lichens on rocks and for any fragile material, specimens should be covered with a layer of soft paper (to protect the envelope, the label and the lichen). Duplicates of labels, placed inside the packets, are sometimes used for the same purpose.

For how to handle specimens for determination/examination see "Herbarium Problems".

Fig. 1. Home-made "rock-hacker" with interchangeable chisels and using a typical car "jack".

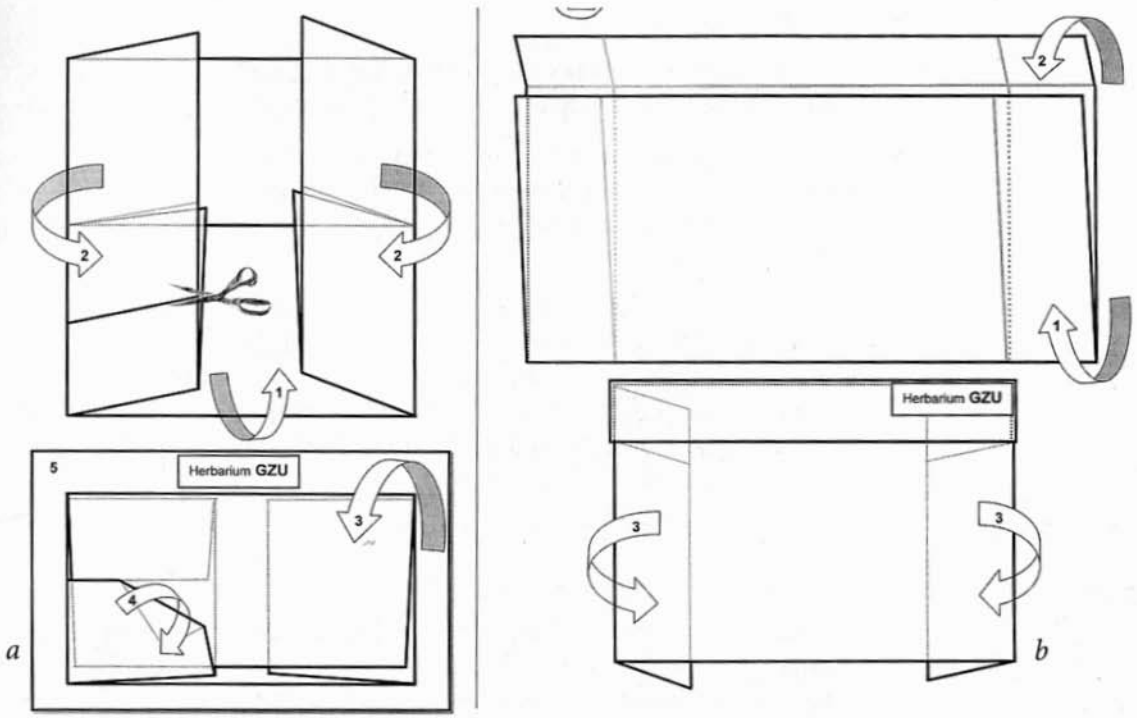

Fig. 2. Suggested design and fold-order for lichen herbarium envelopes. a. Inner envelope, folded (1-4) and glued onto the card (5). This would contain the specimen, or pieces of specimen. b. Typical, folded (1-3) herbarium envelope, within which card and lichen (as per 2a) are placed.

Labelling

Badly labelled or unlabelled herbarium specimens are useless and should be discarded.

The most important data for labels are:

- The name of the taxon
- The location; location details typically include the political region, e.g. country and the precise location, followed by geographical co-ordinates; the actual distance from a large nearby town is often useful, and is preferable to a distance along a road, which may change in the event of road realignment; if the latter is specified, it should be indicated as "road-distance"

- Ecological notes, including substrate
- Date of collection; because different methods of indicating dates exist, it is recommended to give the month in roman numerals (or in letters)
- The collector's name, including collection number
  To make every single specimen unique, the collector should add a successive number (or a non repeating abbreviation of date and field number).
- Reducing subsequent investigation to a minimum, further information on the specimen (e.g. microscopical or chemical features) have to be added, either by writing it directly on the cardboard (this should only be done by the collector him/herself or by preparing annotation slips which are loosely attached to the specimen. Thus, particularly type material can be (and must be!) saved.

Incorporation

After specimens have been decontaminated (see below), they can be incorporated into the herbarium. It is probably best to store lichen-envelopes flat, mounted on a sheet of paper. However, other methods, such as vertical filing of individual packets, are employed in various institutions. The advantage of rapid access to vertically filed specimens is more than offset by the disadvantages. For example, specimens can be easily damaged, and problems arise as a result of different envelope sizes or space may not exist for large envelopes, while small packets tend to slide under larger ones. Horizontally filed specimens can be easily retrieved, and of course any size of envelope can be stuck onto the sheets. However, handling is probably slower and extra costs for folders and cardboard sheets are involved. In case of a flat storage, envelopes or packets may be glued (or even pinned with needles) to sheets or kept loose. As loose packets on sheets tend to fall off, some form of 'fixing-method' is recommended. Depending on the size of the sheets and the envelopes, 2 - 8 packets can be fixed onto a single sheet. Several herbaria prefer to mount only one single envelope on a sheet, which has the advantage that enough space is provided for directly visible annotations, and that envelopes never have to be removed from the sheets. However, specimens stored in this way use much space. Depending on the thickness (and weight) of the specimens, 2 - 5 sheets may be placed inside a stronger and slightly larger folder. Alternatively, a few herbaria use big cardboard-boxes, which may be stacked horizontally. These boxes provide maximum protection for the specimens,

but handling is much less efficient. Where envelopes are glued to sheets but need to be removed for some reason, the sheet is torn from the packet but not *vice versa* to avoid damage (e.g. causing a hole at the back side of the envelope).

Arrangement

Because the classification of lichenized and lichenicolous fungi at the family level and above fungi is in a strong state of flux, I recommend arranging lichen taxa alphabetically by genus and species names respectively. Within each species, a geographical classification may be useful. For example you could use a different colour of species cover for different local region/country/continent. Using an additional striking colour for type-covers will allow easier handling of this most valuable component of the herbarium. In some herbaria, types are stored separately as well as important (mostly old) personal collections or exsiccata material. In case of the latter, I recommend avoiding a separate storage, at least of the numerous recent exsiccata, because it dramatically slows down loan management when it is necessary to search the same taxa in many different places.

Fully databased herbarium information also offers the possibility of keeping specimens in the same order that they are accessioned. This method has the advantage, that all specimens keep their original place even if there are taxonomic changes or space extensions. But again, loan management and identification work with comparison-material is made much more difficult.

Herbarium Problems

Decontamination / herbarium conditions

Deep freezing (below -20°C for three days) is the most widely used method for decontaminating incoming herbarium material. In addition, the whole herbarium unit should be fumigated periodically (e.g. every second year) although the need for this varies very much with local conditions such as humidity and the prevalence of certain insect pests. Nowadays very volatile gases (e.g. hydrogen phosphide) are used, which minimise health problems, but require a carefully sealing of every single room. Naturally this process is only undertaken by professionals!

Although lichens are known to be rather resistant to pests, soralia and algal layers of some nitrophilous taxa (e.g. Physciaceae and Teloschistaceae) can be entirely devoured. The main culprits are bark lice [*Liposcelis*

spec. div. ("book lice")] and also skin beetles [dermestids, e.g. *Anthrenus museorum* ("museum beetle") and *Anthrenus verbasci*]. These insects mostly live and breed inside a herbarium, whilst others (e.g. mites) are carried in with freshly collected material. If specimens are not decontaminated, the mites can continue feeding for a while (until they and the lichens are dried up). In very damp conditions, the most serious damage can occur through an attack on the specimen label and the glues, rather than on the specimen itself. Among others, silverfish (*Lepisma* spec. div.) and several bark lice (see above) may cause such damage.

Best protection against mould growth (and pest feeding) is provided by storage in constant environment rooms with constant temperature (20–23°C) and low humidity (40-60%).

Storage space

The efficiency of a herbarium is much influenced by the structure of the storage space. Important cost factors are the time needed for inserting and retrieval of specimens and the required building space. Herbarium cases not higher than a person can reach from the floor and nearby working tables (equipped with good microscopes) can help to optimise labour efficiency, both of herbarium staff and scientists (in smaller herbaria this may be only one person). Nowadays building space is often saved by the installation of "compactor systems", using mobile cases running on tracks.

Material acquisitions versus space-problems

Active herbaria not only have the duty to house old material but should also try to acquire freshly collected samples, which represent invaluable genetic resources in the future. Material from the area where the herbarium is situated is often procured by a local staff. Species from distant parts of the world are frequently acquired via exchange with other herbaria, e.g. by means of issuing exsiccata material or duplicate collections.

Although storage of duplicate material is said to involve extra resource consumption for maintaining the same amount of scientific information, the morphological (and chemical) spectrum of species is much better demonstrated with several collections of the same taxon.

However, to expand collections always seem to be in permanent need of additional space. Therefore there are few herbaria in the world that do

not suffer from a space shortage. New and improved storage systems (see above) may partly be of help, but in many cases only extensions or even new herbarium buildings can solve the problem. The need to defend the importance of herbarium collections to politicians and senior managers is very much a way of life for most herbarium curators.

Examination and sampling

Caution: Handle specimens with greatest care!

Once dried, a specimen should not be rehydrated with tap water, as chlorides and fluorides can alter its colour or chemical composition (even the purest water may cause a small change in thallus colour). Chemical spot tests with standard reagents such as potassium hydroxide (KOH, "K"), calcium- (or potassium-) hypochlorite ("C") and paraphenylendiamine ("PD"), must never be made directly on the whole specimen. These tests may destroy not only the lichen samples but also envelopes and labels. Many valuable specimens have been damaged by sometimes even famous scientists due to thoughtless handling of these chemicals. Spot tests are easily done on a white background with a tiny fragment of lichen dipped in a small drop of reagent. In case of PD, place a few small crystals into a drop of pure water or alcohol before adding the lichen. Any sampling of thallus-fragments for morphological, chemical or molecular studies has to be undertaken with extraordinary diligence: Especially for TLC and HPLC examination and for genetic analyses, the amount of removed material has to be kept as small as possible and the sampling-position must be indicated. Please note, that herbaria often prohibit this kind of removal from type material. Any new information which has been gathered from the specimen should obviously be added to the label.

Loan Management

All material sent by post, for example on loan or the return of a loan, as a gift or as an exchange, must be carefully packaged. Dried lichen thalli are usually very brittle, and easily damaged or even destroyed, and therefore must be protected from crushing, shaking or mutual abrasion. It is best to keep each envelope under a slight pressure inside the parcel. To avoid damage, never send specimens, particularly type material, in padded bags, but always in stiff cardboard boxes. Loan forms, or similar documents for gifts and exchange, which have to be acknowledged and sent

back by the borrower, must be included. The necessary data for such documentation are:

- Address (including herbarium acronyms) of both sender and recipient
- Date of dispatch
- Loan-number (preferably containing the year)
- Detailed list of specimens; the list of specimens should include at least the names and numbers of specimens and a unique detail for every single specimen, e.g. running herbarium number or collection number etc.
- Loan period
- Advice for handling

It may also be useful to make copies of the borrowed specimen labels, or other records and place them in the herbarium collection where specimens have been removed; this alerts other users that some specimens may be absent.

It is strongly recommended that incoming material from other herbaria or returned loans are deep frozen before further handling or reincorporation. Before acknowledging the enclosed form, the material must be checked against the given list. In the case of an incoming return of loan, determination/confirmation slips (hopefully added to the specimen) should be glued to the outside of the envelope to assist the correct filing on reincorporation of the specimen into the herbarium. The determination slip (with the names of taxon, revisor and date of revision) must be as small as possible to leave space for further revisions. Hand-written determination slips should be avoided.

Working steps for loan management

Outgoing loan

1. Search for requested material in the herbarium.
2. Carefully remove specimen from the herbarium sheet.
3. Copy the labels and place the copies at the site of the removed specimens, or, in case of an electronic management system, make the appropriate database entries.
4. Print loan forms and add them to the specimens and files respectively.

5. Pack the specimens.
6. Prepare the shipping papers and mail the parcel.

Outgoing return of loan

1. Check the borrowed specimens against original documentation.
2. Add (small !) determination/confirmation/annotation labels to every specimen (should already have been done by the person requesting the loan).
3. Print return-of-loan forms and add them to the specimens.
4. Pack the specimens.
5. Prepare the shipping papers and mail the parcel.

Incoming loan

1. Check the condition of the package and specimens, and compare the documentation with the actual content.
2. Send acknowledgement-form to the sender, retaining one copy, or acknowledge the receipt by e-mail.
3. Deep-freeze the parcels.
4. Hand over the specimens to the scientists and remind them to handle the specimens with great care and to keep to the terms and conditions of the loan.

Incoming return of loan

1. Check the condition of the package and specimens, and compare the documentation with the actual content.
2. Send acknowledgement-form to the sender, retaining one copy, or acknowledge the receipt by e-mail.
3. Deep-freeze the parcels.
4. Remount any damaged specimens.
5. Glue revision and confirmation labels on the outside of every envelope.
6. Remove the stored copies of labels and/or make the database entries and corrections.
7. Reincorporate the material into the herbarium.

Computer-Assisted Herbarium Management

Table 1. Some database systems for herbarium management and their internet address

FLORIN Information System is designed to deal with a wide range of data about plants: taxonomy and nomenclature, geographic distribution (incl. distribution maps generated automatically), herbarium and living collections, detailed information about plants collected in the wild, bibliographic data, plant images, etc.	http://www.florin.ru/florin/
The PANDORA taxonomic database system is designed for biodiversity research projects, such as floras or monographs, and is the official database used at the Royal Botanic Garden Edinburgh (RBGE) for taxonomic data sets. It can also be used for maintaining catalogues of collections such as herbarium specimens and a herbarium label printing system is included.	http://www.rbge.org.uk/pandora.home
SysTax is a botanical information system based on ORACLE. It supports a wide range of systematical work in botany and can also be used for the administration of botanical gardens, herbaria and other plant collections.	http://www.biologie.uni-ulm.de/systax/index.html
TRACY is a system for the management of herbarium collections. It is not a huge, all inclusive database tool. Rather it was specifically designed to facilitate rapid entry of specimen data by relatively un-skilled operators, and to provide mechanisms that allow complex queries of the data to be carried out with a minimum of training.	http://www.csdl.tamu.edu/FLORA/input/inputsys.html
The University of California Davis Herbarium Management System serves 4 functions: 1. Maintains herbarium incoming and outgoing shipments. 2. Creates herbarium labels and maintains that information. 3. Maintains herbarium library (books and journals) collections. 4. Maintains herbarium support society (e.g. creates mailing labels; membership lists)	http://herbarium.ucdavis.edu/herbaccess/databaseinfo.htm
BIOTA (The Biodiversity Database Manager) helps manage specimen-based biodiversity and collections data by providing an easy-to-use graphical interface to a fully relational database structure. Specimen loan management system, label-printing and label text export facilities are supported.	http://viceroy.eeb.uconn.edu/Biota
KE EMu - Electronic Museum management system for Museums, Art Galleries, Herbaria, and Botanic Gardens	http://www.ke.com.au/emu/index.html

Table 1. Continuous

MUSE - The KUNHM MUSE Project is an effort to provide software for the curation of natural history collections. It is designed explicitly to manage natural history collections and is based upon the experience of curators and collections managers. Built in taxonomic dictionaries are available for several taxonomic disciplines	http://www.biodiversity.uno.edu/muse/
BRAHMS (Botanical Research And Herbarium Management System) has been developed to support three closely related and overlapping activities: 1. the curation and management of botanical collections in herbaria (general accessions management, loans, exchanges, labels, determination slips and lists, visitor services, internet services, etc.). 2. the production of taxonomically oriented outputs (revisions, monographs, taxonomic checklists, taxonomic synopses, etc.). 3. the production of geographically oriented outputs (geographic checklists, floras, biodiversity surveys, etc.).	http://www.brahms.co.uk/

Database-systems for herbarium management

The need to manage extensive amounts of data has forced many herbaria to develop their own database systems. Some of these programs are now freely available via the internet. A collection of software developed for the purpose of databasing biological objects can be found under: http://www.bgbm.fu-berlin.de/TDWG/acc/Software.htm. The catalogue also contains database programs especially written for herbarium management (see Table 1).

Most of the cited programs also create and print out formatted labels from the database, probably their most common use. Some herbaria have developed one-off packages to service their particular needs, and these may be linked to other data-handling or -mapping programs. Databased label information allows retrieval of specimens using more criteria, which is of particular interest for lichen herbaria. For example, specimens often contain several species in addition to the one under whose name they are stored (e.g. lichenicolous fungi and their host, or two sparse thalli of rare, interwoven taxa, which can not be separated).

When starting a project to database all herbarium specimens, one should consider that within a herbarium the percentage of correctly determined species (and subspecies and varieties) varies from 100 % to less than 10 %, for example in some genera of Verrucariales or in leprarioid lichens. As even many genera of macrolichens (e.g. *Usnea, Bryoria, Cetre-*

Table 2. List of some lichen herbaria with access to their database via the internet (A comprehensive list of botany related URL's is kept under: http://www.botany.net/IDB/botany.html (Brach, A.R. & S. Liu (1996–)).

ASU (Tempe, U.S.A.)	http://mgd.NACSE.ORG/cgi-bin/qml2.0/arizona/arizonaHerb.qml
BG (Bergen, Norway)	see below under "Norwegian lichen database"
ESS (Essen, Germany	http://www.uni-essen.de/botanik/herb-bot.htm
HBG (Hamburg, Germany)	http://www.rrz.uni-hamburg.de/biologie/ialb/herbar/hbg_l2.htm
MIN (Minesota, U.S.A.)	http://www.tc.umn.edu/~wetmore/Herbarium/HERBHOME.htm
Norwegian Lichen Database. The database compiles six independent databases from four herbaria (BG, hb. Holien, O, UPS) and is able to create distribution maps.	http://www.toyen.uio.no/botanisk/bot-mus/lav/soklavhb.htm
O (Oslo, Norway) (lichen types; see also above under "Norwegian lichen database")	http://www.toyen.uio.no/botanisk/bot-mus/lav/sok_ltyp.htm
S (Stockholm, Sweden)	
species list of lichens	http://www.nrm.se/kbo/saml/lichen.html.en
type-database	http://www.nrm.se/kbo/saml/lavtyp.html.en
Olof Swartz' lichen types (scanned images of specimens and labels)	http://linnaeus.nrm.se/botany/kbo/sw/welcome.html.en
Erik Acharius' lichen types (scanned images of specimens and labels)	http://linnaeus.nrm.se/botany/kbo/ach/welcome.html.en
TSB (Trieste, Italy)	http://www.univ.trieste.it/cgi-bin/g/bot/leggi
UPS (Upsala, Sweden) (see also above under "Norwegian lichen database")	http://www.evolmuseum.uu.se/fytotek/
US (Washington, U.S.A.)	http://nmnhgoph.si.edu/gopher-menus/U.S.NationalHerbariumLichenTypeSpecimens.html
private herbarium of Professor M.R.D.Seaward (U.K.)	http://www.brad.ac.uk/acad/envsci/infostore/herbarium/LICHEN.html

Table 3. Continuous

Versamap for Windows is suitable for drawing maps of continents or large countries	http://www.versamap.com/webdoc10.htm
The GEOnet Names Server (GNS) provides access to the National Imagery and Mapping Agency's (NIMA) database of foreign geographic feature names.	http://164.214.2.59/gns/html/index.html
Geographic Names Information System (United States and Territories)	http://mapping.usgs.gov/www/gnis/gnisform.html
Coordinates of worlds bigger cities	http://www.gwdg.de/~unolte/AVG/lexikon/tab13b.html
Miscellaneous useful links and access to e-mail addresses and homepages:	
Index Herbariorum !! (updated every few months)	http://www.nybg.org/bsci/ih/ih.html
Lichenologists' and Mycologists' E-mail Address List	http://www.mycology.net.index.html
IAL (International Association of Lichenologists). New entries, cancellations and changes of address, phone and fax number, e-mail, homepage and scientific interests are personally done by the lichenologist)	http://www.botany.hawaii.edu/lichen/default.htm
Electronic discussion group devoted to lichens.	send mail "subscribe LICHENS-L Your Name" to: listproc@hawaii.edu
English German dictionary	http://dict.leo.org/
EURODICAUTOM (a multilingual terminological database which contains technical terms, abbreviations, acronyms and phraseology)	http://eurodic.ip.lu/cgi-bin/edicbin/EuroDicWWW.pl
Searchable database of Universities around the world	http://geowww.uibk.ac.at/univ/

lia, Lobaria etc.) include chemically defined taxa, many determinations (particularly those without any chemical investigations) should be accepted with some hesitation.

Maintaining the database involves not only adding new data but also the rather time-consuming and expensive task of keeping the whole system up to date. This includes correction of revised taxa, installing new software updates and upgrades, and shifting to more advanced database-systems.

Herbaria on-line

As internet data transfer becomes more advanced, more herbaria are offering online access to their database systems. An incomplete compilation of important lichen herbaria that are online is presented in Table 2. Lists of stored taxa and very detailed data (including label text etc.) can be requested. Type databases are especially useful for taxonomists and strong efforts should be undertaken to connect all such databases to a single network. Some institutions are already striving to connect database systems of different biological collections for large geographical areas, e.g. "NatureWeb" for central Europe (http://www.natureweb.at/), and "BioCISE" for the European community (http://www.bgbm.fu-berlin.de/biocise/).

Other uses of the internet

In addition to the cited internet addresses for database systems (Table 1) and online-herbaria (Table 2), Table 3 presents some further useful links for curators of lichen herbaria.

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