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The Department of Botany at the Natural History Museum Vienna (Herbarium W) – history, status, and a best practice guideline for usage and requests

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Abstract

This paper gives an overview of the Department of Botany (Herbarium W) at the Natural History Museum Vienna; it is the first of its kind in more than 40 years and the first in English. The historical background provides a framework for understanding collections' development and challenges unique to W. Major herbaria incorporated and families lost in World War II are listed and the changing arrangement of the collections over time is highlighted. The collections' long and complex history has always meant that curators were faced with considerable challenges. These have implications both for today's state of the collections and for scientists using them for research. To guarantee reproducibility of that research, correct citation of specimens at W (and elsewhere) is crucial. At W, the system used until the present was to cite acquisition numbers of individual specimens, which were introduced in 1879 for administrative purposes and long thought to represent unique numbers. However, this system has been notoriously difficult to follow for external scientists and considerable series of numbers remained ambiguous without additional knowledge. Therefore, we illustrate and explain the different ways W specimens were acquired, acquisitioned, catalogued, and numbered over time using records in JACQ. This is a consortium of virtual herbaria that started as databasing platform for the herbaria in Vienna (W and WU). To settle ambiguities arising during systematic databasing and digitization efforts, we recently introduced QR-codes and a unique stable identifier system. These identifiers should be used to cite any W specimens from now on. In addition to traditional usage, our specimens are increasingly sampled for molecular research. Since W supports the Convention on Biological Diversity and the Nagoya Protocol, relevant regulations need to be considered when requesting material for any molecular studies. To facilitate requests and utilization of our material for external researchers, we summarize the most important points as a best practice guideline. Finally, the crucial role of volunteer contributions to workflows at W is highlighted. Besides supporting curators and preparators, volunteers also engage in citizen science at the museum.

Key Words: Digitization, JACQ, curation, nomenclatural types, QR codes, persistent unique identifiers

Historical background

The history of botany and botanical collections in Vienna goes back to the end of the 16th century, the late Renaissance, when the Flandrian Charles de l'Ecluse (1526–1609) was employed at the University of Vienna from 1573 to 1588 (NEILREICH 1851, GUGLIA 1973). Although both the concept of a modern botanical garden and that of a scientific herbarium had been established in Italy shortly before by Luca Ghini (1490–1556) and some of his students including Ulisse Aldrovandi (1522–1605) and Andrea Cesalpino

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(1519–1603; MOGGI 2009, but see also SAINT-LAGER 1886), herbaria still played a rather marginal role in the exploration of plant diversity. Botanical gardens filled with living plants collected on expeditions to remote and exotic areas were perceived as much more attractive. In the next two hundred years, however, techniques for preparing herbarium specimens in the field, preserving them mounted on sheets of paper for later study, and keeping the specimens arranged according to a scientific classification system slowly advanced. Keeping and using a herbarium as a reference for scientific studies had become common practice among leading scientists by the 18th century (LINNÉ 1751: 7, 291, 309). This can be inferred from the considerable number of large individual herbaria accumulated during that period. Many of them were later acquired by different European sovereigns and formed the nucleus of later public herbaria. They include those of Joseph Banks (1743–1820) for England (now at the Natural History Museum London – BM), Jean-Baptiste de Lamarck (1744–1829) and Antoine-Laurent de Jussieu (1748–1836) in France (now at the Muséum National d’Histoire Naturelle, Paris – P), Johann Christian Daniel von Schreber (1739–1810) for Bavaria (now at the Botanische Staatssammlung München – M), or Carl Ludwig Willdenow (1764–1812) for Prussia (now at the Botanischer Garten und Botanisches Museum Berlin-Dahlem – B; here and elsewhere the acronyms for herbaria follow THIERS 2020). While other countries already had established public herbaria, in Austria the focus was, until the end of the 18th century, rather on living plants in the imperial gardens, but not dried and pressed plants (FITZINGER 1856). When Emperor Franz Stephan von Lothringen created a natural history collection, the Hof-Naturalien-Cabinet in 1748, it included only minerals and animals of early origin. This explains why Nikolaus Joseph (Freiherr) von Jacquin (1727–1817), an influential pioneer of modern botany in Vienna and correspondent of Carl von Linné (1707–1778), kept specimens collected on the imperial expedition to the Caribbean (1754–1759) in his private herbarium and was able to sell part of it to Joseph Banks in England (CHAMBERS 2007). It was not before 1803 that Franz II, later called Franz I Emperor of Austria, who already owned a diverse private herbarium, started planning a separate section for plants (FITZINGER 1868a) within the Hof-Naturalien-Cabinet. It took four more years until this “Pflanzencabinet” [cabinet of plants] was formally created in 1807. This is the forerunner of the Department of Botany of the Natural History Museum Vienna (NHMW), i. e. primarily the herbarium (W). In 1808, Leopold Trattinick was the first appointed curator of the Pflanzencabinet. A detailed sketch of the history from the beginning to around 1900 is provided by FITZINGER (1856, 1868a, 1868b, 1880, 1881), BECK (1888), and FRITSCH (1901) with later additions by RIEDL (1976) and supplemented here by further references and more recent information from unpublished department files. Table 1 lists (acting) heads since inception.

The botany section was kept in the same buildings and jointly administrated with the other sections of the Hof-Naturalien-Cabinet in the imperial palace at Hofburg, Josephsplatz. When Stephan Endlicher succeeded Joseph Franz von Jacquin (1766–1839, son of N.J. von Jacquin) as professor for botany at the University of Vienna and director of its Botanical Garden in 1840, he transferred his curatorial duties for the herbarium to Eduard Fenzl. Thus Endlicher, who had donated his herbarium of some 30,000 specimens to the Pflanzencabinet, was cut off from direct access to the material he considered essential for teaching and research. To solve this problem, he managed to get political support for transferring the botany section at the imperial palace to the

Table 1: Acting Heads of the Department of Botany since its foundation either as director, provisional or interimistic head of department and duration of tenure.

(Acting) Heads of the Department of Botany at NHMW	Term of office
Leopold Trattinick (1764–1849)	1808–1835
Stephan Ladislaus Endlicher (1804–1849)	1836–1840
Eduard Fenzl (1808–1879)	1840–1878
Heinrich Wilhelm Reichardt (1835–1885)	1878–1883
Günther Beck von Managetta und Lerchenau (1856–1931)	1884–1898
Alexander Zahlbruckner (1860–1838)	1899–1922
Karl von Keißler (1872–1965)	1923–1938
Karl Heinrich [„Heinz“] Rechinger (1906–1998)	1938–1971
Harald Riedl (1936–)	1972–2001
Martin Lödl (1957–)	2002–2003
Uwe Passauer (1942–)	2003–2004
Ernst Vitek (1953–)	2004–2018
Anton Igersheim (1954–)	2018–2019
Christian Bräuchler (1975–)	2020–

Botanical Garden of the University at Rennweg by 1844/5. By uniting herbarium, botanic garden, and libraries of both institutions, a unique facility for botanical research was created (the first botanical museum in Vienna, later called “Altes [old] Museum”). The physical removal of the botanical objects from the Hofburg was against the will of Carl Franz Anton von Schreibers (1775–1852), influential director of the Hof-Naturalien-Cabinet. Due to this removal, the plant collections were not threatened by the October 31st 1848 fire at the Hofburg (FITZINGER 1881). However, items possibly destroyed and relevant for the botanical collections were archival materials related to Brazilian specimens and other files that may have been kept in von Schreibers’ office, which burnt with all his belongings. After Endlicher’s death in 1849, Fenzl took over his position at the university and garden, while he also remained curator of the herbarium – thus for the first time officially uniting responsibility for all three institutions. After von Schreibers’ retirement in 1851, the Hof-Naturalien-Cabinet was split into three separate administrative units, one of them the “k.k. Botanisches Hofcabinet” [“k.k.” stands for “kaiserliches und königliches”, meaning “imperial and royal”]. Fenzl remained its curator and received the title “Vorstand” [Department Head], replaced by “Director” in 1867 (HAMANN 1976). It was during his term of office when the decision was made to build a new museum for all the emperor’s natural history collections including botany, the “k.k. naturhistorisches Hofmuseum Wien”. Construction works started in 1871 at Ringstrasse and Ferdinand von Hochstetter (1829–1884) was appointed first director of the museum in 1876. When Fenzl died in 1878, Heinrich Wilhelm Reichardt, extraordinary professor at the university, became acting head of the museum’s botany section until 1883. Construction was largely finished in 1881 and in 1884, the herbarium was the first collection to be transferred to the new premises (HAUER 1885), where it was located on the second floor and is kept to this day. In 1885 and by order of the emperor, the “Botanisches Hofcabinet” formed the “Botanische Abtheilung” (Department of Botany) of the new museum (HAUER 1885). The building was, however, not officially open to the public until 10.08.1889.

Transfer of all herbarium specimens from the university at Rennweg to the new museum building left university staff deprived of essential material needed for comparison, plant identification, and teaching. University staff thus immediately aimed at creating a new herbarium (FRITSCH 1901) and did so in such a short time and with such success, that today the herbarium (WU) is one of the largest held by a university (THIERS 2020). The museum collections on the other hand, lost a major part of the three-dimensional objects for display in the exhibition halls (for example, larger sections of tree trunks or material preserved in spirit) and were also disconnected from an important part of the library that remained property of the university and thus at Rennweg. This was compensated by building up a new carpological collection, one for wood samples and trunk sections, as well as a spirit collection. While the total number of herbarium specimens and other botanical objects in Vienna grew considerably in a very short period, the split of both human and financial resources among two institutions had a negative impact on its significance and importance in the global botanical research and collections landscape. Nonetheless, the sustained activities of botanists in Vienna resulted in the International Botanical Congress held in the city in 1905 (WETTSTEIN et al. 1905). The end of the Habsburg Monarchy after World War I in 1918 marked a major negative turning point for both the development of the collections and the significance of the now renamed “Naturhistorisches Museum Wien” (NHMW) in an international context. The institution not only lost its major sponsor, the Habsburg dynasty, but was also not valued by the new republic due to its association with and being part of the legacy of the empire. Support for personnel and material was reduced or kept at a constantly low level, and until the 1990ies there was no budget for collecting trips. For example, Karl Rechinger’s (1867–1952) trip to Samoa, the Solomon Islands, and the New Guinea archipelago was actually his honeymoon, but like many taxonomists, he used the opportunity to conduct research as well. The trips by his son Karl Heinz Rechinger to Iran, which laid the foundation for the “Flora Iranica” were financed by the officially approved sale of duplicates and other partially private sources.

During World War II, the herbarium was evacuated to six locations in Lower Austria (Gaming, Kirchstetten close to Staats, Klosterneuburg, Lunz, Oberhöflein close to Retz and Purgstall) shortly after March 1943. Unfortunately, the 2,000 fascicles transferred to Oberhöflein Castle in Lower Austria were largely destroyed in 1945, just after the war ended, when a storage hall completely burnt out. Only very few bundles misplaced in other rooms were preserved. Details of the circumstances are provided in PETRAK (1948). The remaining material was returned to the museum by spring 1946. Despite these losses, lack of space again became an issue. In the years 1987 to 1990, a new underground storage vault extending four levels below the NHMW building was created (BRANDSTÄTTER 2012). Although primarily occupied by zoological and geological objects, it also houses the spirit collection of the Department of Botany. In the mid-1970ies, the long standing and much complained about limitations in storage space triggered a survey of the status quo and future needs for the department, and plans were made to improve the situation. Initially, planning was for 50 years in advance, later reduced to 10 years. When it became clear that there would be no viable solution, calculations were limited to specimens already present in the existing rooms, including those improperly stored in high piles of tightly bound bundles on top of the cabinets, which made them largely inaccessible. Actually, at that point, all specimens were still kept in tightly bound

fascicles to save storage space and keep loose parts from falling off, as was common practice until the late 20th century. In 1989, construction works started for an extra roof top floor, which was finished in 1993. By that time, the situation used as a planning reference already was outdated by at least 10 if not 20 years, so it was evident from the beginning that the new space would not suffice. Negotiations how and where to best fit in the botanical material included swapping rooms with other departments and delayed the move until 1995. Among the parts of the department, which moved to the roof top floor, were the cryptogam collections (the largest room), pteridophytes, and angiosperm families Acanthaceae to Lamiaceae (together five rooms), the botanical library (three rooms), and most scientific staff offices. Further, a laboratory, a reading/scanning room, and a social room were newly added. While storage space increased considerably, the department was divided between two floors with long distances between the different areas. During the move, the practice of storing specimens in fascicles was abandoned and they were transferred to archival boxes, which resulted in an additional increase of total volume, but allowed better access to the specimens.

As can be inferred from above, the official name for both the institution and the department changed over time. In addition, many different abbreviations were used (internally and externally) to refer to the herbarium (Figs. 1–4). Therefore, the proposal of using the single letter acronym “W”, for Wien, the German spelling of Vienna, as first suggested by LANJOUW (1937), quickly became the international standard. W has consistently been used in *Index Herbariorum* from the first printed (LANJOUW 1952) to the most recent electronic edition (THIERS 2020).

Development of the collections

Shortly after the foundation of W, several large important herbaria, e. g., those of Franz von Portenschlag-Ledermayer (1772–1822), Leopold Trattinick, and Franz Xaver von Wulfen (1728–1805) were acquired. The collections grew so rapidly that it was impossible to keep pace with their curation – a condition prevailing to this day. In the 1830ies, the available space was filled beyond capacity and in consequence the collections had to be closed to the public. Important acquisitions during the time of Endlicher were his own herbarium (1836), that of Fenzl (1840), and J.F. von Jacquin (1841). A further major gain in 1836 was the addition of c. 40,000 Brazilian plants kept in the “Brasilianisches Museum” [The Brazilian Museum], which existed between 1821 and 1835 and was dedicated to objects collected during the Austrian-Brazilian expedition (1817–1835) (FITZINGER 1880). A detailed list of all collections incorporated until the late 1880ies is provided by BECK (1888).

Since most of the collection of three-dimensional objects remained at Rennweg in 1884, this was quickly replaced, especially since such items were needed for public display at the new museum. By 1893, the new wood collection included ca 2,000 objects (BECK & ZAHLBRUCKNER 1894) and currently has about 6,500 wood samples and trunk sections of ferns and seed plants from all around the world. It also includes iconic pieces listed among the 1,200 exhibition objects recorded in 1893. Two examples are a 3 m tall section of a strangler fig and the trunk of the unusual “living fossil” *Welwitschia mirabilis* HOOK.F. endemic to Angola and Namibia. The latter could not be obtained today, given the species’

high conservation status and priority. The collection growing most quickly was that for dried fruits and seeds and by 1893, around 25,000 samples had accumulated. Today, it includes some 30,000 samples, of which many are also represented by specimens in the phanerogam herbarium (i. e., in addition to the carpological collection). Of special importance here are some gymnosperm cones, because they represent the last pieces of the original material of type specimens that were otherwise destroyed in the 1945 fire (see above). Only a small portion of the spirit collection was exhibited in 1893, which today counts c. 2,000 samples. Among these are important specimens from the Juan-Fernandez-Islands and the families Annonaceae, Ebenaceae, and Lamiaceae.

Although many important collections were acquired in the century following 1845, one major legacy has to be highlighted, for it at least doubled if not tripled the holdings of W at that time (BECK 1889, BECK & ZAHLBRUCKNER 1894: 67–68). Heinrich Gustav Reichenbach (1824–1889), an Orchidaceae expert, bequeathed his herbarium to W under the condition that the orchids remain inaccessible for the next 25 years. Altogether, Reichenbach's herbarium was estimated to include 700,000 specimens (general herbarium: 360,000, "English exotic plants" (presumably exotic plants grown at botanic gardens, such as Kew): 30,000, orchids: 80,000, ferns: 4,000, various separate collections: 146,000, older collections (estates): 80,000) stored in c. 5,550 tightly bound fascicles of unmounted material (as compared to the 4,700 fascicles of mounted specimens that formed the general herbarium of W by that time). Integrating the non-orchid part into the general herbarium took about 4 years (BECK & ZAHLBRUCKNER 1894). After the end of the Habsburg Monarchy, the collections kept growing, but the fire at Oberhöflein in 1945 reduced the holdings by about a sixth. Although losses at W could never be estimated precisely, a list of the families (following the concept of DALLA TORRE & HARMS 1900–1907) completely or partially destroyed was provided by PETRAK (1948; see table 2).

Nonetheless, in some cases specimens of groups otherwise lost somehow survived (e. g., because they were on loan during the time of evacuation). Examples are the genera *Roupala* (Proteaceae), *Callianthemum* (Ranunculaceae), and, as outlined by TILL (1994), type specimens in Bromeliaceae. Therefore, it is recommended to either check the actual holdings for specific requests by physically visiting W or discussing other possibilities with the curators.

Just after the war, staff at W tried to quickly compensate for this considerable loss of partially irreplaceable material. A major contribution was the purchase of the herbaria of Alfred Ernst Hirth (1861–1942), Ernst Korb (1873–1945), and Johann Vetter (1865–1945) comprising some 100,000 specimens. On the other hand, Karl Heinz Rechinger gifted major batches of separate herbaria to other institutions, which had remained unopened on top of the cabinets at W for a long time. He contributed to the newly founded herbarium of the University Aarhus (AAU) and to that of Berlin (B) to compensate for their dramatic losses in WW II. W's holdings increased substantially in the last decades thanks to the intensive collecting work of K.H. Rechinger, material of the Flora Iranica region sent as gift for determination, the addition of larger private herbaria from Karl Ronniger (1871–1954) and lately Franz Speta (1941–2015), among others. As a result, W is today among the top ten largest herbaria in the world with an estimated 5.5 million objects. The thousands of precious drawings and illustrations acquired by W over time (e. g., from the collections of Ferdinand Lucas Bauer (1760–1826), N.J. von Jacquin, and

Table 2: Alphabetical list of families (following DALLA TORRE & HARMS 1900–1907) destroyed in part or completely in the fire at Oberhöflein in May 1945. Names in italics represent fossil taxa. Names added in brackets refer to the classification of APG IV (2016) for angiosperms and CHRISTENHUSZ et al. (2011) for gymnosperms.

Aizoaceae	Casuarinaceae	Grubbiaceae	Monimiaceae	Proteaceae
Alismaceae (Alismataceae)	Centrolepidaceae (Restionaceae)	Haemodoraceae	Moraceae	Rafflesiaceae
Amarantaceae	Ceratophyllaceae	Hydnoraceae	Musaceae	Ranunculaceae
Amaryllidaceae	Cercidiphyllaceae	Hydrocharitaceae	Myricaceae	Rapateaceae
Anonaceae	Chenopodiaceae	Iridaceae	Myristicaceae	Restionaceae
Aponogetonaceae	Chloranthaceae	Juglandaceae	Myzodendraceae (Misodendraceae)	Salicaceae
Araceae	Commelinaceae	Julaniaceae (Anacardiaceae)	Najadaceae (Hydrocharitaceae)	Santalaceae
Aristolochiaceae	<i>Cordaitaceae</i>	Juncaceae	Nyctaginaceae	Saururaceae
Balanophoraceae	Cyanastraceae (Tecophilaceae)	Juncaginaceae	Nymphaeaceae	Sparganiaceae (Typhaceae)
Balanopsidaceae (Balanopaceae)	Cycadaceae (incl. Zamiaceae)	Lacistemaceae	Olacaceae	Stemonaceae
Basellaceae	Cyclanthaceae	Lactoridaceae (Aristolochiaceae)	Opiliaceae	Taccaceae (Burmanniaceae)
Batidaceae (Bataceae)	Cynocrambaceae (Rubiaceae)	Lardizabalaceae	Palmae (Arecaceae)	Taxaceae (incl. Podocarpaceae)
<i>Bennettitaceae</i>	Cyperaceae	Lauraceae	Pandanaceae	Thurniaceae
Berberidaceae	Didiereaceae	Leitneriaceae (Simaroubaceae)	Phylodraceae	Triuridaceae
Betulaceae	Dioscoreaceae	Lemnaceae	Phytolaccaceae	Trochodendraceae
Bromeliaceae	Eriocaulaceae	Liliaceae (incl. most Asparagales and Liliales)	Pinaceae (incl. Araucariaceae, Cupressaceae, Sciadopityaceae)	Typhaceae
Burmanniaceae	Fagaceae	Loranthaceae	Piperaceae	Ulmaceae
Butomaceae	Flagellariaceae	Magnoliaceae	Polygonaceae	Urticaceae
Calycanthaceae	Ginkgoaceae	Marantaceae	Pontederiaceae	Velloziaceae
Cannaceae	Gnetaceae	Mayacaceae	Portulacaceae	Xyridaceae
Caryophyllaceae	Gomortegaceae	Menispermaceae	Potamogetonaceae	Zingiberaceae

H.G. Reichenbach) were transferred to the NHMW Archive for the History of Science upon its foundation, to guarantee their best possible conservation. Currently, only those mounted on herbarium sheets (either with or without plant parts) and drawings essential for work in the cryptogamic collection are kept in the herbarium.

Arrangement of the collections

The herbarium is roughly divided in two parts – cryptogams (algae, fungi, lichens, liver- and hornworts, mosses) and phanerogams (traditionally including angiosperms and gymnosperms, at W formally also ferns). Both parts are jointly administrated but have

been differently managed over time resulting in differences in arrangement, curation and acquisition practice.

Until the late 1830ies, the herbarium was kept in several separate collections, all arranged differently. In 1837, Endlicher started reorganizing all parts into a general herbarium that he aligned by families and genera according to his own classification system (ENDLICHER 1836–1841). Reorganization had well proceeded when the material was transferred to Rennweg in 1844/5 and was continued there in the years after. This arrangement was abandoned in 1885 for the “true” phanerogams (excluding ferns) in favor of the system of BENTHAM & HOOKER (1862–1883), with the genera subsequently numbered as listed in DURAND (1888). This organization was kept until the treatment of DALLA TORRE & HARMS (1900–1907) became available. Transition between these two systems possibly was made as early as the 1920ies, but definitely was finished before the 1943 war time evacuation, as the names of families listed as lost by PETRAK (1948) correspond to DALLA TORRE & HARMS (1900–1907). When parts of the botanical collections were transferred to additional new rooms at the roof top floor in 1995, it was decided to rearrange the material once more completely. Initially, phanerogam families and genera were those accepted by BRUMMITT (1992), with the exception of Asteraceae that followed BREMER (1994). All taxa were aligned alphabetically at the rank of family and below. This system was chosen to allow for tracing a given name intuitively without previous knowledge or further instructions. A further novelty was the use of red folders for type specimens, a standard that had not been adopted for W until then. It was also decided not to separate the type specimens, allowing visiting researchers to find all relevant material in one place. In the absence of a stable family level classification, pteridophytes were arranged alphabetically by genus. While the considerable changes towards a more natural family level classification system based on molecular evidence (such as APG I–IV, 1993–2016) have largely not been adopted, some rearrangements at genus level have been ingested in the ordering system rather arbitrarily. In addition, at species/genus level, a number of regional treatments such as “Flora Iranica” (RECHINGER et al. 1963–2015), “Flora Europaea” (TUTIN et al. 1964–1980, 1993), “Flora Iberica” (CASTROVIEJO et al. 1986–2012), and the field guide to the flora of Austria (FISCHER et al. 2008) were used as references. This resulted in a mixed arrangement of various systems, which is sometimes difficult to follow and is one of the major reasons for the current efforts to compile a comprehensive taxonomic catalogue as a precursor for digitization of the collections.

A geographic separation was never established and limited to very few selected regions for the last 200 years. While it was abandoned for the Brazilian material received from the “Brasilianisches Museum” upon integration into W from 1836 on, the specimens from the Flora Iranica Region (and for a while also part of the Greek material) were kept separate until the treatment of the respective groups were published. Today, this material is integrated in the general collections but in separate folders stamped “Regio Florae Iranicae”. The only further exceptions with geographical arrangement are the specimens lacking any identification (“indet” folders), which are sorted by continent and country at the very end of each family. Since this allowed easy access for visitors focusing their research on a particular region and thanks to the determined efforts of Bruno Wallnöfer for more than 25 years, the number of these specimens was reduced significantly. Of the formerly separate herbaria, that of Neilreich (with its own running numbers), which is an important reference for the flora of Vienna and Lower Austria,

is the only one remaining so for historical reasons. Most others have been integrated in the general herbarium and today are scattered throughout. However, a considerable number of large collections, such as the herbaria of Schottenstift monastery (Vienna), St. George's College (Istanbul), Karl Ronniger (Vienna), and Franz Speta (Linz) could not be fully incorporated yet and await processing.

The W cryptogam collection is kept separately from the phanerogams, on the rooftop floor. The cryptogams are grouped into algae, fungi, hornworts and liverworts (as Hepaticaceae), lichens, and Musci, with some of the groupings reflecting older ideas about systematics. The collections are further divided into three blocks: 1) the type collection, 2) the general collection, and 3) special collections including certain types of preparations such as microscope slides, photographic slides, drawings, and other materials, as well as several individual herbaria of various collectors kept separately. Some of the most important of the separate sets are “bryophytes” from Julius Baumgartner (1870–1955) and Viktor Ferdinand Schiffner (1862–1944), diatoms from Albert Grunow (1826–1914), fungi from Franz Petrak (1886–1973), and lichens from Urbain Jean (Abbé) Faurie (1847–1915) and Alexander Zahlbruckner (1860–1938). This highlights that W cryptogams include several important historical collections from the 19th and 20th centuries and are therefore rich in type material. These separate collections are organised (or not) according to a variety of sometimes idiosyncratic systems, which can be alphabetical, numbering, or systematic. Within the type and general collections, specimens are filed alphabetically by genus within the relevant higher taxonomic groups and by species within genus. In the type collection specimens are filed according to basionym. However, it is possible that as such unidentified types may still be filed within the special or general collections. As the filing is alphabetical and does not follow a particular classification system for any given group in the general collection, it is important to supply a list of all possible names for a requested taxon by thoroughly researching the relevant primary literature and using online resources such as AlgaeBase (GUIRY & GUIRY, 2020), DiatomBase (KOCIOLEK et al. 2020), and Index Fungorum (<http://www.indexfungorum.org/>).

The Grunow diatom collection is one of the most complex in the cryptogams. The materials are organised by two different numbering systems, where one is needed to find objects in the other. Grunow's diatom collection includes a variety of objects (RECHINGER 1915), such as loose diatomaceous earth, sediment prepared on glass and mica, thousands of drawings, microscope slides, and other materials, which are filed according to either ‘de Toni’ or ‘Grunow’ numbers. The latter refer to sample numbers Grunow assigned and listed in his catalogue (frequently also called “accession books”). ‘De Toni’ numbers refer to the numbering system used in the three sections of de Toni's *Sylloge Algarum* on Bacillarieae (DE TONI 1891, 1892, 1894). For instance, at W the detailed technical drawings Grunow prepared for his species descriptions are organised by ‘de Toni numbers’. The drawings in turn, cite the ‘Grunow number’, which is necessary to find the original material or relevant microscope slides organised according to these numbers. Both the ‘de Toni’ and the ‘Grunow numbers’ are yet again different from any collection numbers assigned by original collectors, as Grunow worked with material from various other diatomists, including George Arnott Walker Arnott (1799–1868), Louis Alphonse de Brébisson (1798–1888), Per Teodor Cleve (1840–1905), Ferdinand Hauck (1845–1889), Henri van Heurck (1839–1909), Friedrich Traugott Kützinger (1807–1893), and others (RECHINGER 1914). So far, there is no resource cross-referencing ‘Grunow sample

numbers' and collection numbers by other collectors. In addition, Grunow's diatom collection, drawings, and sample catalogue were accessioned in 1901 and therefore have W acquisition numbers. However, there are differing numbering systems, as the drawings were accessioned by the Archive for the History of Natural Science, a separate department within the museum, while the diatom samples and slides were acquisitioned by W. During Riedl's tenure as Director of Botany, the accession books were transferred to the Archive, but were later returned to the cryptogam collection, as they are essential for locating and citing specimens. This example illustrates how complex it was in the past to find the correct identifier for citing objects at W in publications (see more detailed discussion below). Meanwhile, Grunow's accession books and other materials have been digitized and work is in progress to make them available online.

Curatorial challenges and implications for external requests

As mentioned above, classification systems used as a basis for arrangement of the collections changed over time. Together with changing curatorial filing routines (partially adapted through case-by-case decisions), this resulted in a sometimes complex situation.

With respect to the curatorial status of the collections, the situation is rather complex as well for various reasons. Aside from the lack of digitization for a substantial volume of the collections, which does not allow for quick database searches, major points are the sheer dimension and the long history of W. Placement of a specimen under a particular name in the collections could thus be affected by:

- 1) taxonomic concepts of specialists,
- 2) regional floristic treatments (often not concordant with specialists' view),
- 3) amount of material for a given taxon (i. e. taxa with many specimens are more difficult to translocate within the collection than taxa with few specimens, and therefore may more likely remain under a synonym placement),
- 4) lack of common, aligned curatorial routines (the general approach was to file specimens under the last name verified by experts, but in practice this could not consistently be followed for various reasons).

Due to the growth of the collections paralleled with the additional duties of curatorial staff (e. g., currently 3.5 full time equivalents for curation of c. 5.5 million objects, external requests, digitization, research, outreach, and other duties in the museum), time was always limited to systematically work on an individual specimen level in depth. All these factors lead to non-consistent filing of material that did not stick to a single classification system.

As a result, material of one and the same taxon may be stored under different and even "incorrect" names. Tracing material can be straight forward, but it may also require much additional information from multiple sources and an understanding of the development and history of the collections. To alleviate this situation and support our daily curatorial work, we are currently compiling a comprehensive digitized catalogue of scientific names representing all folders in our collections. At a later stage, this will be made available publicly. To aid material requests as a user, please refer to the section on 'best practice guideline for usage and requests of our collections' below.

Catalogues, acquisition books and numbering systems

Newly acquired collections have been systematically registered from the beginning. This included counting of species and specimens and where possible also a taxonomic catalogue. Though catalogues from the early years are not complete, it is clear that starting from 1820 latest, a running number was given to each batch of specimens acquired from a single source. These numbers were composed of the year of integration into the collections and sequential Roman numerals separated by “/” (see e. g., Fig. 4D). These batch numbers have, however, only occasionally been noted on the component herbarium sheets. For each of the batches, an entry in an annual list included the total number of species, collector/provider, provenance, and price. A taxonomic list for each entry was generated except for large collections that were donated without a catalogue (e. g., those of Endlicher, Fenzl, and others) or in times where several larger batches were bought.

The larger herbaria received initially were marked in (red) ink (Fig. 1A: W0069087, Herbarium Endlicher; Fig. 1B: W0021249, Herbarium Fenzl) and/or with printed labels (Fig. 1C: W0078941; Herbarium Jacq.f. [J.F. von Jacquin; the son]). The latter is a curious case, where Jacquin the father received the plant from his son (“a filio”), integrated it into his herbarium (marked in red ink), and later his son inherited it back. For herbaria integrated later, stamps were added (Fig. 1D: W0000960, Herbarium Wulfen). What has been impossible from the beginning was to keep record of changing identifications for the specimens/species included in the individual batches. As a consequence, W has no coherent taxonomic catalogue to this date.

Systematic numbering of newly acquired specimens started in 1879 (Fig. 1F) during Reichardt's term of office and is continued until today. This series was only interrupted during the years 1944–1946, towards the end of World War II and shortly thereafter (Table 3). Before 1879, specimens had been accessioned, but not formally acquisitioned, for they did not have a stamped acquisition number (the equivalent of an inventory number/accession number referencing the year during which the specimen was officially integrated into W) as formal proof of ownership by the museum. Since their introduction, acquisition numbers of specimens consisted of the year the specimen was acquired and a running number (handwritten until 1889, stamped in and after that year). In the accession books, these acquisition numbers were assigned to the original batches the individual specimens were part of (which originally were labelled with “year/Roman numerical”, cf. Fig. 4D). The accession books therefore were the official register for specimens kept at and owned by W. The stamps used to mark the specimens with the acquisition numbers changed over time, especially with respect to arrangement of the component elements and naming of the institution (see Figs 1–4 and Table 3 for overview and numbering of figures). Running numbers for each year were unique until 1889, when the Reichenbach herbarium was acquired and its sheer size along with special regulations required by Reichenbach's last will made it necessary to number both his general and orchid herbarium separately, as well as marking them with special stamps (“HERB. MUS. PALAT. VINDOB. Collectio Reichenbach fil. Acqu. 1889 No. [stamped running number]” (Fig. 2A) and “HERB. MUS. PALAT. VINDOB. Reichenbach: Herb. Orchid. Nr. [stamped running number]” (Fig. 2B)). While the other acquisitions in 1889 were stamped “HERB. MUS. PALAT. VINDOB. Acqu. 1889 No.” plus handwritten running



Fig. 1 A–D: Different ways larger herbaria integrated into W were marked; E–L: stamps used for acquisition of specimens at W from 1879 to 1889 with range of years used and additional notes; E: 1879–1882; F: 1883–1884; G: 1885; H: 1885, Herbarium Host; I: 1885–1886; J: 1886; K: 1887; L: 1888–1889



Fig. 2: stamps used for acquisition of specimens at W from 1889 to 1957; A: 1889; B: 1914; C: 1890–1893; D: 1893–1921; E: 1922–1938; F: 1939; G: 1940–1941 (“H.-M.” is one of the stamps used to mark the specimens received from Handel-Mazzetti); H: 1942; I: 1943; J: 1947–1949; K: 1950; L: 1951–1957



Fig. 3: stamps used for acquisitioning of specimens at W from 1958 to 2019; A: 1958–1961; B: 1962; C: 1963; D: 1964–1987; E: 1981; F: 1981 (cryptogams); G: 1987–1992; H: 1992–1997; I: 1997; J: 1996 (cryptogams); K: 1997; L: 1997



Fig. 4: stamps used for acquisition of specimens at W from 1992 to 2020; A: 1997–2019; B: 1992; C–D: c. 2000–2019; E: c. 2000–2019, stamp almost illegible, original batch number included; F: 2009 (original stamp illegible; cryptogams); G–H: 1999 (cryptogams); I: 2020–, QR-code (<https://w.jacq.org/W0102487>)

numbers (analogous to Fig. 1L), both Reichenbach collections have stamped numbers, with the orchid herbarium not opened, mounted, and acquisitioned before 1914, as instructed in his will (Zahlbruckner 1914, Keissler & Rechner 1916, Rechner 1916).

The year 1993 marks a major discord in stamp usage and numbering systems in the department of botany, with a new stamp introduced for the phanerogams in 1992 (Fig. 3H), whereas the older one continued to be used in the cryptogam section (Fig. 3J, 4B). Number ranges were initially matched between cryptogams and phanerogams so not to generate duplicates in the running year. In 1993, the workflow for cryptogams was separated and consequently acquisitions were recorded in a separate accession book. Numbering started from 1 in both cryptogams and phanerogams, therefore creating duplicate numbers. Since the cryptogams had no dedicated curator from time to time, specimens frequently were simply filed in the general collection, but without assigning acquisition numbers. From 1995 onwards, those were gradually added to these specimens with the standard “year – running number” stamp (Fig. 4G, H; as opposed to the one used for phanerogams for such cases, see Fig. 4D), irrespective of when they actually had been acquired. While these specimens were at least differentiated from the newly acquisitioned ones in the accession books, it remained obscure when dealing with the specimens themselves.

After about 8,000 phanerogam specimens had been acquisitioned in 1997, yet another stamp was introduced, including the “W” as internationally recognized herbarium acronym in front of the acquisition number (Fig. 4A). This aimed at ending the ambiguity in the varying institution names and to help clarify citation of specimens. Since the institution name and seal had been stamped on herbarium sheets before mounting plants and before adding numbers, some “hybrid” specimens ended up with the old name and seal, but also the new stamp with the “W” (Fig. 3L). Unfortunately, the new stamp was used in the phanerogam section only, so parallel numbering with regard to the cryptogams continued. Since the internal separation of the cryptogams was not officially announced and no separate acronym registered, citation of specimens from W, that should follow the standard scheme of “acronym + acquisition number”, was not unambiguously possible anymore without adding extra information, such as “W Krypto” for cryptogams to distinguish the duplicate numbers.

Table 3: Overview of the types of stamps used for acquisition of specimens since 1879. “Years” indicates the period during which the respective stamp was used. The “Stamp” column shows the structure of individual stamps with changes towards the one above highlighted in gray. The “Notes, Figure” column contains noteworthy points for a given stamp or time period. The range of acquisition numbers for each stamp is provided as precisely as possible. In some cases, stamps were changed between two more or less distant acquisition numbers within one year, but due to low extent of digitization we currently do not have evidence when exactly. In those cases, the min[imum]/max[imum] possible end/start number is given.

Years	Stamp with institution/collection abbreviation and acquisition number (mostly year + running number)	Notes, Figure
1879–1882	MUS. PALAT. VINDOB. [year, stamped] Nr. [running number, handwritten]	Fig. 1E
1883–1884	Mus. Palat. Vindob. [year, stamped] Nr. [running number, handwritten]	Fig. 1F
1885	Mus. Palat. Vindob. 1885 Nr. [running number, handwritten]	running numbers 1–1926, Fig. 1G
1885	Mus. Palat. Vindob. 1885 Herb. Host Nr. [running number, handwritten]	running numbers 1927–5569, Fig. 1H

Years	Stamp with institution/collection abbreviation and acquisition number (mostly year + running number)	Notes, Figure
1885–1886	Mus. <u>Pal.</u> Vindob. 1885 Nr. [running number, handwritten]	in 1885 running numbers from 5570, in 1886 up to 2715 (min) or 2731 (max), Fig. 1I
1886	Musei Palat. Vindob. 1886 N ^o . [running number, handwritten]	in 1886 from 2716 (min) or 2732 (max), Fig. 1J
1887	HERB. MUS. <u>PAL.</u> VINDOB. 1887 N ^o . [running number, handwritten]	Fig. 1K
1888–1889	<u>HERB. MUS. PALAT. VINDOB.</u> Acqu. [year] N ^o [running number, handwritten on dotted line]	Fig. 1L
1889	<u>HERB. MUS. PALAT. VINDOB.</u> Collectio Reichenbach fil. Acqu. 1889 N ^o . [running number, stamped]	separate numbering from 1 in parallel to other acquisitions in 1889, Fig. 2A
[1889/1914]	<u>HERB. MUS. PALAT. VINDOB.</u> <u>Reichenbach:</u> Herb. Orchid. Nr. [running number, stamped]	received in 1889, but officially acquisitioned in 1914 without year stamp, Fig. 2B
1890–1893	HERB. MUS. <u>PALAT. VINDOB.</u> Acqu. [year] N ^o [running number, stamped on dotted line]	in 1893 up to 2444 (min) or 2875 (max), Fig. 2C
1893–1921	<u>HERB. MUS. PALAT. VINDOB.</u> Acqu. [year] N ^o . [running number, stamped]	in 1893 from 2445 (min) or 2876 (max), Fig. 2D
1922–1938	<u>HERB. MUS. HIST. NATUR. VINDOB.</u> Acqu. [year] No. [running number, stamped]	from 1922 up to 1986 only slightly modified, Fig. 2E
1939	<u>HERB. MUS. HIST. NATUR. VINDOB.</u> Acqu. [year] No. [running number, stamped]	spatial arrangement changed, Fig. 2F
1940–1941	<u>HERB. MUS. HIST. NATUR. VINDOB.</u> Acqu. [year] No. [running number, stamped]	spatial arrangement changed, Fig. 2G
1942	<u>HERB. MUS. HIST. NATUR. VINDOB.</u> Acqu. [year] Nr. [running number, stamped]	Fig. 2H
1943	<u>HERB. MUS. HIST. NATUR. VINDOB.</u> Acqu. [year] No. [running number, stamped]	Fig. 2I
1944–1946		no acquisitions
1947–1949	<u>HERB. MUS. HIST. NATUR. VINDOB.</u> Acqu. [year] No. [running number, stamped]	Fig. 2J
1950	<u>HERR. MUS. HIST. NATUR. VINDOB.</u> Acqu. [year] No. [running number, stamped]	two typos, Fig. 2K
1951–1957	<u>HERB. MUS. HIST. NATUR. VINDOB.</u> Acqu. [year] No. [running number]	one typo corrected compared to above, Fig. 2L
1958–1961	<u>HERB. MUS. HIST. NATUR. VINDOB.</u> Acqu. [year] No. [running number]	font/spatial arrangement changed as well, Fig. 3A
1962		spatial arrangement changed, Fig. 3B
1963		spatial arrangement changed, Fig. 3C
1964–1987		font/spatial arrangement changed; in 1987 up to 2856 (min) or 3378 (max), Fig. 3D
1981	year originally stamped as 1980, “1” stamped over “0”	wrong stamp for year used and corrected, Fig. 3E

Years	Stamp with institution/collection abbreviation and acquisition number (mostly year + running number)	Notes, Figure
1981	[preprinted in green on cryptogams capsules:] NATURHISTORISCHES MUSEUM WIEN BOTANISCHE ABTEILUNG [handwritten: year – running number]	in the cryptogams section, sometimes both the card and the capsule have the acquisition number, one stamped, one handwritten, Fig. 3F
1987–1992	[preprinted on card: coat of arms eagle “Republic”] NATURHISTORISCHES MUSEUM WIEN BOTANISCHE ABTEILUNG [stamped: year] – [running number]	up to 4287 (min) or 8001 (max), Fig. 3G
1992–1997	[preprinted on specimen: coat of arms eagle “Republic”] NATURHISTORISCHES MUSEUM WIEN BOTANISCHE ABTEILUNG [stamped: year] [running number]	change of font in running numbers; in 1992 starting from 4288 (min) or 8002 (max); in 1997 coat of arms eagle “Republic” up to 8017 (min) or 8120 (max), with exceptions, Fig. 3H; in some cases, coat of arms stamped (Fig. 3I), not printed, in some cases left out
1992–2019	[stamped: year] – [running number]	old acquisition number stamp 1987–1992 was in continued to be used in the cryptogams section, Fig. 3J, 4B
1992–2019	Original stamp (1964–1987) illegible, restamped with standard stamp for cryptogams	Fig. 4F
1992–2019	Herbarium W. Brunnbauer, originally accessioned and stamped prior to 1879, but retroactively stamped with an acquisition number in 1999	Fig. 4G, H
1997	[preprinted on specimen: coat of arms eagle “Republic”] NATURHISTORISCHES MUSEUM WIEN BOTANISCHE ABTEILUNG COLLECTIO REICHENBACH fil. [stamped: year] [running number]	some of Reichenbach’s ferns were not officially accessioned with the rest in 1914, Fig. 3K
1997	[preprinted on specimen: coat of arms eagle “Republic”] NATURHISTORISCHES MUSEUM WIEN BOTANISCHE ABTEILUNG [combined with:] HERBARIUM W [year] – [running number] NATURHISTORISCHES MUSEUM WIEN	mix of the 1987–1997 preprint on card and new W stamp (see below), Fig. 3L
1997–2019	HERBARIUM W [year] – [running number] NATURHISTORISCHES MUSEUM WIEN	new single stamp introduced in the phanerogams section, running numbers from 8018 (min) 8121 (max), Fig. 4A
c. 2000–2019	NATURHISTORISCHES MUSEUM WIEN W – [running number] [e. g. combined with:] [stamped on specimen: coat of arms eagle “Habsburg”] K.K. NATURHISTORISCHES HOFMUSEUM WIEN BOTANISCHE ABTEILUNG	“new” stamp to provide specimens acquired before 1879 with acquisition numbers, Fig. 4C, D; combined also with the “Reichenbach” stamps 1889/1914
c. 2000–2019	“new” stamp to provide specimens acquired before 1879 with acquisition numbers (see above) almost illegible, original batch number from 1836 included	Fig. 4E

Years	Stamp with institution/collection abbreviation and acquisition number (mostly year + running number)	Notes, Figure
2020	Naturhistorisches Museum Wien Herbarium W W[running number] [QR code pictorial]	Standardized globally unique identifiers (CETAF) W QR codes (cryptogams & phanerogams), Fig. 4I; for small objects such as microscope slides the lines “Naturhistorisches Museum Wien” and “Herbarium W” are omitted

Numbering systems, the beginning of systematic databasing, and transition to QR-codes and a unique stable identifier system

Digital cataloguing and systematic databasing of the collections at W were triggered by the activities of GBIF Austria (GÖTZL et al. 2003), which also lead to novel approaches for the online presentation of W objects. As an important subsequent stimulus, the African Plants Initiative with financial support by the Andrew W. Mellon foundation started in Vienna in March 2005. It was focused on type specimens of African origin, but was soon extended to a global scale leading to the Global Plants Initiative (see <https://plants.jstor.org/>). The botanical objects were recorded in JACQ (2004 ff.), a continuously developing consortial platform, which at that stage also included herbarium specimens from other Austrian institutions such as the Styrian Museum Joanneum (GJO), the University of Graz (GZU), and the University of Vienna (WU). As a preemptive consideration for the cataloguing efforts at W, the acquisition routines in place at that time were maintained, as they were considered unambiguous and thus suitable for identifying and citing specific specimens. Barcodes were not introduced, since they were considered merely as representations of the stamps with no additional information and, maybe more importantly, the reliability of available glues used to attach these barcodes permanently was not convincing. For phanerogams, specimens that were integrated in the main collections without acquisition numbers (usually those accessioned before 1879) another new stamp was introduced (analogous to the new 1997 phanerogams stamp) having “NATURHISTORISCHES MUSEUM WIEN”, the “W” and a seven-digit running number starting from “0000001” (Fig. 4D). The acquisition numbers field for JACQ (2004 ff.) was therefore designed to accommodate either eleven or seven digits (either with or without year), to allow entry of any numbers occurring on specimens. Digits not present on the physical specimen were therefore filled with “0”. If not on the specimen already, a “W” prefix was added separated by a blank. While the entry in JACQ would be clear for Fig. 4D (W 0058301), Fig. 3H would read W 1992-**001**5446 (with those numbers, i.e., “virtual” digits, not on the specimen shown in bold) in the database. Placement of “virtual” digits, blanks and dashes are a challenge for both citation of specimens and searching a particular number in the database. For example, as outlined above, formal processing of the substantial general herbarium of Reichenbach started in 1889 (orchids acquisitioned separately in 1914) in parallel to the regular annual sequence of acquisitions. When the Reichenbach

acquisitions were simply combined with acronym “W” that would result in duplicated numbers for a part of that year’s acquisitions (>5835 numbers). In principle, all those numbers could be entered in JACQ (2004 ff.), since there is an option to add a particular collection specifier to the acquisition number (here “W-Rchb.”). However, the collection specifier was not a viable solution, because “W-Rchb.” is neither an officially recognized acronym, nor included as such on the specimen (see Fig. 2A). Hence, a workaround was implemented by stamping those specimens with a separate “W” stamp including a seven-digit running number without year. When we discovered that – only considering the numbering – since 1993 more than 100,000 cryptogams and phanerogams had been stamped with parallel numbers, it was clear that it would not be an option to handle them the same way. Since the internal collection specifier “W Krypto” could neither be used for the same reasons as “W-Rchb.” (e.g., Fig.4B), we decided to shift to a different numbering system retroactively.

The availability of CETAF stable identifiers (GROOM et al. 2017, GÜNTSCH et al. 2017, GÜNTSCH et al. 2018) finally triggered the introduction of printed QR codes. This system now is applied to all botanical objects in the department across all collections: herbarium specimens in both phanerogams and cryptogams, as well as the ancillary wood, spirit, and fruit collections, bulky specimens, microscope slides, and other samples. It allows an unequivocal, straight forward citation of individual objects, and printing of the labels also guarantees easy readability of both text, numbers (“W” and a seven-digit running number without blank), and QR codes. The codes in turn include the stable identifier URL enabling handling of the material for administrative purposes. QR codes also allow any user to find the corresponding record online, given the specimen has been catalogued digitally (e.g. <https://w.jacq.org/W0102487>). While stamps were illegible in a considerable number of specimens (Fig. 4E, F), the QR codes (Fig. 4I) are even machine readable. For all specimens stamped with an acquisition number (i.e., year plus running number) and all those previously without acquisition number, QR codes are assigned randomly as running numbers starting from W0100000. Specimens without acquisition number and stamped as e.g., “W 0058301” (Fig. 4D), receive the same number as QR code, but without the blank (W0058301).

The Nagoya Protocol and sampling for molecular research at W

The NHMW in general and W in particular are dedicated to the objectives of the Convention on Biological Diversity (CBD, <https://www.cbd.int/convention/text/>), to comply with the Nagoya protocol (NP, <https://www.cbd.int/abs/text/>), and our workflows and policies are in accordance with them. This means that as a rule, we seek all necessary permissions before collecting any material and we reserve the right not to accept material from third parties failing to clarify the legal status of their material (including donations and exchange). Being a research infrastructure with an almost global geographic and rather comprehensive taxonomic coverage, we aim to support taxonomic and evolutionary research worldwide. Primarily, this is done by making our specimens available for investigation physically and digitally, but we may also contribute samples to molecular studies, where the material allows. As a rule, types are excluded, and sampling by third parties or material sent on loan is not permitted. Sampling of our objects depends on staff

availability, with a priority on collaborative projects. Requesters have to prove that the intended methodology was successfully applied to samples from the same taxonomic group and of similar age (e. g., by providing a relevant publication from their lab group). Samples are exclusively provided for noncommercial use. When passing material on to third parties, we ensure the NP is respected by using written material transfer agreements (MTAs). Material originating from countries that ratified the NP and collected on or after 12.10.2014 (date by which the NP officially entered into force), is not provided for the purpose of destructive sampling unless Prior Informed Consent (PIC) and Mutually Agreed Terms (MAT) have been obtained, where applicable. The majority of parties to the protocol understand utilization currently to include DNA or RNA sequencing for any purpose (i. e., including basic taxonomic and systematic research). In case none of these have been sought for the concerned specimens before, or where documentation for this has not been submitted to W at the time of material transfer (i. e., older specimens), it is the duty of the requester to seek it. For any material collected before that date, we encourage requesters to make a reasonable effort to share benefits with the country of origin according to the NP where possible. A request form and guidelines for this will be made available on the department's website (<https://www.nhm-wien.ac.at/forschung/botanik>) within the next months. Ownership of the material provided for molecular studies usually remains with the NHMW.

Best practice guideline for requests and use of our collections

The situation at W illustrated in detail above results in some things that should be considered when requesting and using material kept in our collections. To facilitate this process for external researchers, we sum up the most important points as a best practice guideline here:

- The best option for most purposes is usually a physical visit to W (upon prior appointment via botanik@nhm-wien.ac.at). Where this is not possible, requests can be sent electronically or by post.
- When preparing a request, the list of families destroyed should be consulted (Table 2). Although specimens of those families sometimes did survive, the probability is low.
- A full list of all relevant taxonomic names (including family), under which the required material could be stored, must be provided. Please indicate the basionym, alphabetize your list, and include the authorities.
- Requests for types should be made only with a strong background in nomenclature. Please check and provide the protologue and all further text passages (possibly also from other publications) providing information relevant for typification. Be aware that staff at W has limited resources for access to primary literature.
- W has neither a taxonomic catalogue nor a complete inventory, hence we cannot tell you what we actually have in our collections (e. g., how many specimens are present for a particular collector and under which names those may actually be stored) without considerable effort.
- Only a small fraction of our collections has been digitized, so if a particular specimen is not in JACQ, that does not mean it is not in the collection.

- W is not geographically arranged, and particular collectors are not kept separate (except for some cases in the cryptogamic collection). Requests for all specimens from a certain region or collector can therefore not be accommodated easily. This needs additional resources that could be applied for through joint research proposals, but the requester needs to take the lead on that.
- Physical loans of specimens are only granted in well justified cases and requesters should carefully consider whether digital images may suffice. Moderate numbers of these can be generated upon request.
- Facilities and equipment for preparation and imaging of microscopic details are available, but this is done only in very well justified cases and/or in collaboration on publications.
- Destructive sampling for molecular studies may be provided under the objectives of the Convention on Biological Diversity (CBD) and regulations of the Nagoya Protocol (NP) with the following preconditions: 1) the material allows for removal of a sample, 2) proof for the previous successful application of the proposed methodology is provided, 3) collaboration with W staff and/or scientists from the country of origin (e. g., on grant applications or publications) is considered.
- Specimens must be cited by standardized globally unique identifiers, i. e., the W QR code (Fig. 4I) and no longer W + acquisition number. When citing images that have already been included in the JACQ platform with the old acquisition numbers, please contact W staff to have a QR code assigned.

Volunteers and Citizen Science at W

An overview of W would not be complete without mentioning the considerable contribution of volunteers. As long established practice in institutions such as the NHMW, we always have had the help of volunteers – either professionals, retired curators, or interested citizens, often teachers with a special interest in plants and fungi. In the early years of the Naturalien-Cabinet, it was even mandatory to work as a volunteer for several years and prove one's qualification to stand a chance of being employed. Even the later directors Endlicher, Zahlbruckner, von Keißler, and Rechinger started as volunteers in the Botany Department. In the 1990ies, policy changed and non-scientific volunteers were recruited for part of the technical work. At present, their contributions are manifold and are integrated in regular W workflows: mounting, restoring and repairing specimens, transliterating and in some cases translating labels of various characters such as Cyrillic, Gothic script (Kurrent), and Hanzi. More experienced volunteers take on the sophisticated tasks of identification and revision of material. Recently, databasing of specimens, as well as transcription of field notebooks, especially recording itineraries of collection trips, and digitizing of catalogues has been aided by volunteers. At peak times, the number of volunteers increased to 70+, translating to approximately six full-time position equivalents. The current COVID-19 pandemic is a serious threat to these well-established workflows. In consequence, we aim at establishing a multi-lingual citizen science platform to increase outreach and minimize the risk of disruption of volunteers' contributions during times in which the museum building and the collections may not be accessible.

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