Temperate and Tropical Plant Collections: The changing species concept and other ideas behind their development

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Abstract

The first botanical gardens and collections of preserved plants in the 16th century served didactic purposes and should ensure correct identification of medicinal, ornamental and other useful plants. Collections of preserved plants were nearly all book-herbaria, emulating illustrated books and owned by individual botanists. Curiosity cabinets of nobles and prominent scholars were larger collections, in which all kinds of objects of natural history from remote regions could be incorporated. The Linnaean revolution favoured loose-leaf herbaria over the old book-herbaria: herbaria with loose sheets could be reorganised in agreement with new knowledge or theories and newly accessed specimens could be placed next to earlier ones of the same species. However, the Linnaean collections reflected the essentialist species concept, according to which all species consisted of individuals with similar essence and separated from other species by sharp discontinuities. Therefore only few specimens were accumulated per species. A.P. de Candolle saw the need for the study of variation within species and stressed the importance of many specimens per species. The Darwinian revolution in 1859 further increased that trend, requiring more specimens to allow the study of variation both within and between species. During the 19th and the 20th centuries larger botanical gardens and large public herbaria with tropical plants developed in European countries, particularly in countries with tropical colonies, eventually also in the United States and in some tropical countries, for example in Brazil (Rio) and India (Calcutta). Before and particularly after World War II new botanical gardens and herbaria were established in the tropics and the collections in Europe and North America continued to grow, facilitated by easier travelling and growing interest in exploring the World's biodiversity. New trends in the 21st century included a wider focus than the study of taxonomy and plant geography: for example conservation and climate change. Many factors may influence the future of tropical plant collections: the influence of growing world population and increasing urbanisation on conservation, increasing focus on technologically complex disciplines in the utilisation of collections and an increasingly complex international legislation, such as the Washington Convention, the Convention on Biological Diversity, and the Nagoya Protocol on Access and Benefit-sharing.

Key Words: Convention on Biological Diversity, Darwinian revolution, Linnaean revolution, methodology of plant collecting and herbaria, Nagoya Protocol, origin of herbaria, size of collections, Washington Convention.

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In this, the first presentation at the symposium – *Tropical Plant Collections: Legacies from the Past? Essential Tools for the Future?* – I will outline some of the concepts, ideas, trends and goals that have been behind the creation and maintenance of plant collections. When I started working on my presentation, I realised that it would not be possible to restrict myself to *tropical* plant collections. In many ways the tropical plant collections have developed along the same lines as the temperate collections, but under different conditions and sometimes with a delay of a hundred or more years. Very few tropical plants were accessed to collections in the 17th century, but gradually more and more were added in the 18th, 19th and 20th centuries. I have also found it necessary to refer to the development of certain aspects of taxonomic botany, particularly the species concept. This is necessary because of the ways botanical collections have been created and maintained are very strongly influenced by the needs of the scientific studies, which these collections are to serve.

I will begin with the quote from a summary of the situation just after 1784 by the British botanist James Edward Smith, when the extremely important botanical collection of both temperate and tropical plants in the private herbarium of Linnaeus had been purchased and brought to England from Sweden. In the first pages of his "Introductory discourse on the rise and progress of natural history," which he delivered on the occasion of the foundation of the Linnean Society, J. E. Smith (1789: 1-8) outlined the development of natural history as a science, but also emphasised its deep roots of the study of plants and animals for practical purposes:

> 'In no country hitherto discovered, however barbarous and unenlightened, is the human race found so negligent and helpless as not to have investigated the natural bodies around them, so far at least as from thence to supply their necessary wants, and even to obtain conveniences and luxuries. ... In a very early state of society the sum of human knowledge would become too much for every individual to acquire; of course some must necessarily pursue particular arts or enquiries in preference to the rest; ... Botany was more especially attended to [than zoology] very early, as medicine, which, however it might have been degraded in the ages of barbarism, could never have been totally neglected, stood in immediate need of its assistance. The works of the ancients, and particularly those of Dioscorides, were then studied with the most pertinacious assiduity; remedies which this writer had recommended were deemed infallible, and virtues, which he had attributed to any plant, indisputable. The chief difficulty in almost every case was to find out the plant he meant; and this difficulty becoming at length as great as to be absolutely insurmountable, his commentators were lost in mazes of their own conjectures. It was happy for the credit of Dioscorides that this was the case, and that the world were so occupied by this kind of criticism, as seldom to have examined the truth of his assertions. Of these commentators some few had great original merit in giving figures of the plants of which they treated, and those figures are many of them executed with such perfection as to excite our astonishment; they have rarely been excelled at any following period. ... and ever since the middle of the sixteenth century the press throughout Europe has teemed with similar publications; certainly to the great advancement of botany, although the merit of these works has been very various. For almost two centuries after the revival of letters in Europe the attention of naturalists was chiefly confined to the vegetable creation; and although since that time the animal and mineral kingdoms have received an eminent decree of cultivation, still botany has always kept its ground. ... The institution of public botanic gardens is a memorable era in the history of botany. The first of these was, I believe, at Padua in 1533[1], where

1. Chiarugi (1953) has documented that 1533 was the year when the University of Padua appointed Francesco Bonafede to teach identification of medicinal plants. The world's first botanical garden associated with a university was established by Luca Ghini in Pisa in 1543-1544. However, in Tübingen (Germany) a private garden with medicinal plants was founded in 1535 by the herbalist Leonhart Fuchs (1501-1566) at the Nonnenhaus (House of the Nuns); it has not been maintained, and the following botanical garden in Tübingen was only founded in 1663. The world's oldest still existing botanical garden was established in 1545 in Padua by the above mentioned Francesco Bonafede; the garden in Firenze was established 1548. The following is a list of botanical gardens founded up to ca. 1700: Pavia (1558), Zürich (1560), Bologna and Valencia (both 1567), Leipzig (1580), Jena (1586), Basel (1589), Leiden (1590), Heidelberg and Montpellier

> it still continues to make a tolerable figure, although now surpassed by several others, which have had more powerful protectors. The gardens of Florence, Pisa, Bologna and Leyden were soon after established, and all still exist.'

It is notable that Smith so clearly stressed the importance of the correct interpretation of Dioscorides' works, the teaching of medicinal plants and the illustration of herbals for the early study of botany. The herbals and other botanical books illustrated with woodcuts and the botanical gardens were essential for the correct identification of useful plants, particularly medicinal plants. The gardens were the foremost institutions for botanical education and research up to Smith's own days. He praised for example the excellence of the Kew Gardens, even among the other fine botanical gardens in Britain: "The royal garden at Kew is undoubtedly the first in the world, and we have a number of others, both public and private, each of which may vie with the most celebrated gardens of other countries" (Smith 1789: 52). He did not attribute a similar status to herbaria, collections of preserved plants. Herbaria were tools for individual botanists, as was the case with the herbarium of Linnaeus. Before the time of Linnaeus herbaria mostly consisted of pressed and dried plants glued into books, replacing the woodcuts of the herbals with real pressed and dried plants.[2] From the 16th and 17th century Smith mentions herbaria in the private possession of prominent botanists, the first one being that of Caspar Bauhin (1560-1624)[3]: "I have seen a great part of his herbarium at Basil [Basel] ... This herbarium is inestimable on account of the difficulty of determining many of Bauhin's plants by his descriptions alone ..." (Smith 1789: 14). When describing his own time, Smith still spoke of herbaria as individual collections that had been amalgamated to form part of great scholarly institutions, the natural history cabinets, and singled out the Natural History Museum in London as the most prominent in the world, and : "... the British Museum, which contains among other things the original herbariums of Sloane[4], Plukenet[5], Petiver, Kaempfer[6], Boerhaave[7], of many of the disciples of Ray, and several others, besides innumerable treasures of zoology, claims the first place."

(both 1593), Copenhagen (1600), Oxford (1621), Groningen (1626), Paris (1635), Amsterdam (1638), Uppsala (1655), Hanover (1666), Kiel (1669), Edinburgh (1670), Berlin (1672), Chelsea (London) (1673).

2. The Italian botanist Luca Ghini (1490-1556) is considered the creator of the first herbarium (*hortus siccus*), collected in 1544. His herbarium consisted of pressed and dried plants glued into books. No herbarium collected by Luca Ghini has been preserved (Stearn 1957: 103; Moggi 2012), and it is possible that other botanists had created herbaria before or at the same time as Ghini, but there is no doubt that the herbarium was invented somewhere in northern Italy in the first half of the 16th century, and several book herbaria from the middle of that century still exists in Italy (Moggi 2012; Friis 2017), and one early book herbarium, the En Tibi herbarium, of Italian origin, is kept in Naturalis in Leiden (Welzen & Schollaardt 2017). Only in the 18th century the book herbaria were replaced by loose-leaf herbaria. One of the earliest and still existing big loose-leaf herbaria is that of Adriaan van Royen (1704-1779) and David van Royen (1727-1799) in Leiden with ca. 10,000 loose sheets. The plants in this herbarium are mounted as appearing from vases, as was common in Dutch herbaria in the early 18th century (Thijsse 2003). Wijnands (1983) suggested that the van Royen herbarium may contain as many as 2000-3000 specimens relevant for the typification of Linnaean plant names.

3. Caspar Bauhin (1560-1624), Swiss, collected and pressed numerous plants kept loose in folded sheets of paper; ca. 2400 af these specimens are preserved at the herbarium in Basel (BAS) (Zoller 1966).

4. Hans Sloane (1660-1753), British, collected in 1687-1689 objects of natural history in Jamaica. The botanical specimens are still mounted in seven bound volumes. (Stearn 1957: 119-120; 122; Dandy 1958).

5. Leonard Plukenet (1642-1706) and James Petiver (1658-1718), both British, did not visit the tropics but collected numerous plants preserved in book herbaria; they were later bought by Hans Sloane and incorporated in his collections (Stearn 1957: 122; Dandy 1958).

6. Engelbert Kaempfer (1651-1716), German, travelled in Russia, Persia, India, South-East Asia, and Japan between 1683 and 1693 (Stearn 1957: 120-121; Dandy 1958).

7. Herman Boerhaave (1668-1739), Dutch, collected in 1685-1693 book herbaria in four volumes with dried plants from the Leiden botanical garden and other Dutsch gardens; they are now in the Hans Sloane collections (Dandy 1958).

(Smith 1789: 52). Two terms became common in connection with these kinds of books with collections of dried plants: A 'Hortus siccus' was always a collection of dried plants. A 'Herbarium vivum' was a book with a collection of pressed plants or images. Sometimes the documentation was mixed, so that the illustrations of some text were woodcuts, while other text was illustrated with preserved plants, or even the individual representation could be mixed, so that one part of the representation was an illustration, often the roots, rhizomes or tubers, while a real preserved plant represented the parts above ground. The 'Herbarium vivum' of Hieronymus Harder was prepared in 12 volumes, the earliest from 1562. One volume, from 1576 (Harder 1576), kept at the Bayerische Staatsbibliothek, is particularly rich in mixed 'illustrations' consisting of both preserved plants and drawings.

From Aristotle to Linnaeus: Safe identification of useful plants

From the Antiquity, we have a few works on botany (Mayer 1982): Theophrastos' two large botanical treatises, *Περὶ φυτῶν ἱστορία* ('History of plants' or rather 'Enquiry into Plants'), and *Περὶ φυτῶν αἰτιῶν* ('On the Causes of Plants'). These works contained many theoretical considerations and were important contributions to plant morphology and biology; they also contained information about exotic plants brought by merchants or sailors. Theophrastos adopted a very general method for classification of the plants: trees, shrubs, undershrubs or herbs, presence or absence of spines, etc. Theophrastos used groupings from folklore, which resulted in some groups being quite natural (oaks, willows), while others were not. More important for the immediate development of botany was the work by the Greek physician Dioscorides Pedanius of Anazarbus, *Περὶ ὕλης ἰατρικῆς* ('On the material of medical doctors', better known by its Latin name, *Materia Medica*). The work contained information about and descriptions of ca. 700 species of plants and ca. 1000 drugs that were either of medicinal use or provided oils, spices, resin, fruits or other edible parts. Dioscorides arranged the plants according to their uses, which meant that the sequence in which the plants were listed did not have much to do with their appearance. If you knew the plant under a different name than the one listed by Dioscorides, or if you did not know a name at all, then you would have serious trouble finding the text dealing with it.

From the Antiquity, we have a few illustrated manuscripts that attempted to solve the difficulty of plant identification. *Codex Aninicae Julianae*, the most beautifully illustrated Dioscorides-manuscript from the late Antiquity, was commissioned in Constantinople and delivered in 512 to Princess Anicia Juliana (462–527 or 528), a scholarly and culturally interested daughter of the Western Roman Emperor Anicius Olybrius (?–472). *Codex Aninicae Julianae* and many other subsequent publications or revisions of Dioscorides' work were provided with drawings of the plants, making a reliable identification of the plants relatively easy, just like with the modern illustrated floras.

Better identification of medicinal and other useful plants only became possible when the idea of a hierarchy of taxonomic categories derived from Aristotelian logics was applied to biological classification. Aristotle (384–322 BC) dealt with the classification of all things in one of his six works on logic called *Τοπικά* (*Topics*; Latin: *Topica*) (Balme 1962; Mayr 1982). Aristotle distinguished between the essential and accidental properties of things, including organisms. Essential properties were constant and common denominators for each 'kind' of object. Individual organisms all belonged to one and only one 'kind'. Aristotle referred to a 'kind' as *ειδοσ* (*eidos*, 'form' or 'type'). In order to connect Aristotle's ideas about logic with later biological classification we mostly translate *ειδοσ* as 'species'. Each *ειδοσ* is assigned to a category of higher order with common features, which Aristotle called *γενοσ* (*genos*). Balme (1962) demonstrated that Aristotle did not use these terms consistently in his biological writing[8], and concluded: "The traditional assumption

8. Balme (1962) states that the word *γενοσ* (*genos*) appears 413 times in Aristotle's zoological writing, but in 354 cases it refers to a "kind" of animal, and only in the remaining cases to a

that Aristotle actually classified ... [living organisms] into genera and species ... is not supported by the evidence." Moreover, Aristotle, and indeed Theophrastos, did not recognize the biological integrity of each species, and accepted both frequent hybridisation between species, which we now consider too distantly related for hybridisation, and that mutation of one species into another (heterogony) was possible.

Also medieval herbalists accepted these ideas to be true; Albertus Magnus, for example, described five ways in which one plant could be transformed into another, and there was a widespread belief that species could arise by spontaneous generation. But after the Reformation the fixity of species became a firm dogma, and the species became the unit of creation (Mayr 1982).

The medieval manuscripts about plants nearly all dealt with medicinal and other practical uses, and they – together with the Bible – were among the first books printed after the invention of movable-type printing press by Gutenberg in the 1450s. One of the first was the rather fanciful *Hortus santitatis* (Anonymous 1491). Serious books on medicinal plants were often adaptations of Dioscorides' *Materia Medica*; for example Pierandrea Mattioli's edition of Dioscorides in Italian in 1544 (Mattioli 1544). This edition was provided with woodcuts of the plants and therefore fulfilled the purpose of identifying the plants without a scientific taxonomy. In the countries, north of the Alps there were problems using Dioscorides' work, but the problems were gradually solved during the Renaissance with better plant identification and the discovery of medicinal plants in the temperate floras.

The Aristotelian logic and the terms 'genus' and 'species' survived through the scholastic philosophy in the Middle Ages and became united with the ideas of the unchanging species characterised by constant and common features for each 'kind' or species. During the mediaeval age, the use of a common generic name became a tradition for groups of 'kinds' that could be recognised, and the essentialist species concept developed. The presence of the same essential characters defined the species, in which all individuals were of the same *eidos*, 'kind.' (Mayr 1982). Ray (1686) provided a biological explanation of this:

> 'In order that an inventory of plants may be begun and a classification of them correctly established, we must try to discover criteria of some sort for distinguishing what are called 'species.' ... no surer criterion for determining species has occurred to me than the distinguishing features that perpetuate themselves in propagation from seed. Thus, no matter what variation occur in the individuals or in the species, if they spring from the seed of one and the same plant, they are accidental variation and not such as to distinguish species.'

Pre-Linnaean Plant Collections: Book-herbaria and Curiosity Cabinets

The quotation from J. E. Smith's lecture described the state of botanical collections as they were just after the Linnaean revolution, and he discussed public and private botanical gardens, privately owned collections of preserved plants and natural history cabinets, for example as represented by the British Museum in London. The tropical plant collections mentioned previously had been collected by a single traveller or travelling scholar like Hans Sloane in Jamaica or Engelbert Kaempfer in temperate Asia, mostly Japan. We have mentioned that illustrated herbals were produced as manuscripts before the invention of the printing press, later as printed books with woodcuts and finally with engravings, and that book-herbaria in some ways imitated the herbals by gluing pressed plants into book. But almost until the time of Linnaeus such book-herbaria remained the private property of the people that had produced them. The Flemish medical doctor, herbalist and pioneering botanist Carolus Clusius (1526–1609) was called to Leiden in 1593 and became director of the new botanical garden. He initiated systematic collections of tropical plants by urging the staff of the

category we can accept as a genus. In the 96 cases where *eidos* is used, only 24 refer to a kind of animal, in all other cases to a category of higher rank.

Fig. 1. Bound book herbarium, the Marcgrave herbarium, collected by Georg Marcgrave in the Dutch colony in Pernambuco, Brazil, in 1637–1644 and brought to the Netherlands, where it was used by Jan de Laet for editing *Historia Naturalis Brasiliensis* (Piso & Marcgrave 1648). After Jan de Laet's death 1649 the Marcgrave herbarium was purchased by Willum Worm, the son of the Danish scholar Ole Worm, who was in Leiden to arrange the publication of his father's *Museum Wormianum* (Worm 1655). The herbarium was brought to Copenhagen and incorporated in Worm's collections. After Worm's death it was acquired by King Frederic 3, who included it in his collections. The herbarium was studied by N. Wallich during his time as a student of botany in Copenhagen, and later by Eugen Warming in connection with his studies of Brazilian plants (Andrade-Lima *et al.* 1977). More recently the herbarium has been studied by a number of visiting botanists. Now in the Natural History Museum of Denmark (photograph by Jørgen Andersen).

Dutch East India Company[9] to collect seeds and living plants and dried plant specimens for the botanical collections in Leiden (Baas 2002, 2017); this seems to be one of the earliest attempts of producing public or university-owned collections of tropical plants.

Early colonisation of the tropics resulted in book herbaria (Fig. 1). An example will illustrate this. In the middle of the 17th century, the Netherlands invaded Brazil, which was otherwise being colonised by Portugal (Andrade-Lima *et al.* 1977; Wagner 2008). After an unsuccessful attack on Bahia (Salvador) the Dutch West India Company attacked Pernambuco, and in 1636 Count (later Prince) Johan Maurits van Nassau-Siegen was appointed governor-General of the Dutch colonies in Brazil. He called scientists and artists to his newly established colony, including the German scientist Georg Marcgrave (1610–1644), who arrived in 1638 and made a collection of Brazilian plants. After Marcgrave's death in Angola, Jan de Laet (1581–1649) received his herbarium in Leiden and used it for editing a posthumous edition of Marcgrave's work (in Piso & Marcgrave 1648).

Appearing during the Renaissance was also the idea of a 'Kunstkammer', collected by royalty or scholars. There were two kinds of 'Kunstkammer':

(1) The Royal or Princely 'Kunstkammer', which mainly contained works of art or crafts, but sometimes also objects of natural history. The earliest

9. The company mostly referred to by the British as the 'Dutch East India Company' had many slightly varying names: 'the United East India Company', 'the United East Indian Company', 'the United East Indies Company', or, in Dutch, 'Vereenigde Oost-Indische Compagnie' or 'Verenigde Oostindische Compagnie', and was often just known as 'VOC'.

Fig. 2. A piece of stem of *Clusia rosea* Jacq. (Clusiaceae) from the West Indies (48 cm long). Adventitious roots have grown around the trunk of a host so it resembles a giant hand. This specimen was in the 'Kunstkammer' of the King Christian V of Denmark in 1674 (Gundestrup 1991 (vol. 1): 71). Now in the Natural History Museum of Denmark. (photograph by Jørgen Andersen).

Princely 'Kunstkammer' was established in Vienna in 1553 and has formed the basis of two major museums in Vienna, the Kunsthistorisches Museum and the Naturhistorisches Museum (Haag & Kirchweger 2012). Founded only a few years later, in 1560, was a 'Kunstkammer' in Munich, belonging to Albrecht V, Duke of Bavaria (ruled 1550–1579). This soon became one of the largest in Central Europe and among the first princely collections explicitly conceived as a site for storage and production of universal knowledge, although plants were scarcely represented in the collection (Pilaski 2007).[10] Also the Danish King Frederic 3 established a 'Kunstkammer' at his palace in 1650, but that also contained an element of 'curious' objects of natural history, such as a natural 'hand' formed by the roots of a climbing *Clusia rosea* Jacq. (Fig. 2; Gundestrup 1991).

(2) The private scholarly collections were usually less spectacular than the Royal or Princely 'Kunstkammer', and might contain everything the professor wanted to study or use for teaching his students. It was in Italy that such collections were first assembled. One of the earliest and most spectacular was Ulisses Aldrovandi's vast collection in Bologna from ca. 1550 (Findlen 1994). His collections were supposed to contain 18,000 objects of natural history and 7000 pressed plants in fifteen volumes. Presently the University of Bologna exhibits much of what is left of this vast collection.[11]

The Danish *Museum Wormianum*, gathered from 1621 and onwards by professor Ole Worm in his residence

10. Pilaski's statment does not take note of the fact that this 'Kunstkammer' for some time contained the important book-herbarium of the Oriental traveller Leonhart Rauwolf (1535–1596). Upon his return to Europe, Rauwolf prepared a book herbarium in four folio volumes with 834 European and Near Eastern plants. The herbarium was sold to Duke William of Bavaria and placed in the 'Kunstkammer' in Munich, but was taken to Sweden during the Thirty Year' War. About 1650 Queen Christina presented the herbarium to her teacher Isaac Vossius. In 1680 the University of Leiden purchased the volumes, and it is now at L.

11. With regard to plants, only parts of the Aldrovandi collection is now on public view (Biblioteca Universitaria di Bologna 2017). Numerous woodblocks of plant illustrations are on show, not Aldrovandi's 7000 dried plants in 15 volumes, which are kept with the *Erbario di Università di Bologna* (BOLO), where the volumes represent one of the world's oldest still existing book-herbaria with tropical plants. Aldrovandi's plants are mostly wild plants collected in Italy, but a few are exotic species.

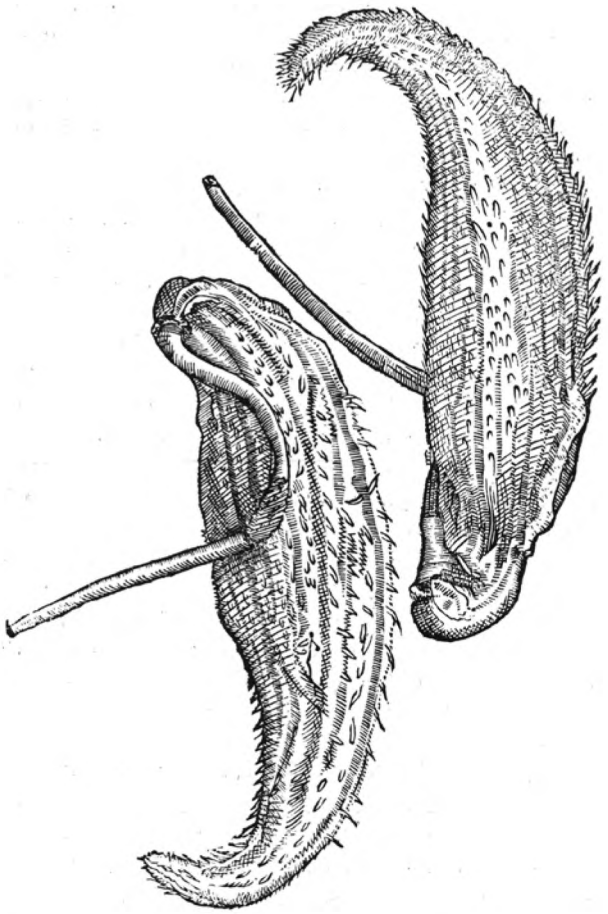

Fig. 3. Fruits of *Asclepias syriaca* L. from Ole Worm's 'Kunstkammer', illustrated in his *Museum Wormianum* (Worm 1655: 188). Worm's original material has not been traced; the fruits were received from the mayor of Copenhagen, Hans Nielsen, who had grown the plant from seeds in his garden. According to Worm this plant was identical with 'Beid el Ossar', a plant from Egypt, which was described and illustrated by Alpino (1592). Alpino's plant is *Calotropis procera* (Aiton) W.T. Aiton, widespread in drier parts of tropical Africa, Arabia and south Asia, and naturalised elsewhere, whereas *Asclepias syriaca* is indigenous in the warmer parts of North America and introduced early to the Mediterranean and the warm parts of Europe. This is an example of the many misidentifications in the pre-Linnaean literature, which were most frequent when the new material was not compared to authentic material.

at the University of Copenhagen (Worm 1655). The identification of the objects in these scholarly collections was sometimes far from correct, at other times the owner of the collection was tempted to identify the object simply by comparing it with descriptions and illustrations in published works, as can be seen in the example from Worm's museum in Fig. 3. It is not certain if Worm considered the previously mentioned Marcgrave-herbarium part of his *Museum*; in *Museum Wormianum* (Worm 1655) only the *Historia Naturalis Brasiliae* (Piso & Marcgrave 1648) is mentioned, not the herbarium.

Up to the beginning of the 19th century, the essentialist species concept was generally accepted, and all species in genera were given names beginning with the name of the genus and followed by phrase-names, consisting of one to many words, giving the essential or diagnostic characters of the species, This should enable the botanist to distinguish the species from all other known species by its name alone (Stearn 1957: 81–88). Mayer (1982: 260) has summarised the consequences of the essentialist species concept in four postulated characteristics:

1. Species consist of similar individuals sharing in the same essence.
2. Each species is separated from all others by a sharp discontinuity.
3. Each species is constant through time.
4. There are severe limitations to the possible variation of any one species.

These ideas culminated in the work of Linnaeus, who – as we will see in the next section – began to introduce changes, and his students an followers continued this trend until the next major shift in ideas, the Darwinian revolution.

The Linnaean Revolution: A new nomenclature

The two main changes in botany caused by the Linnaean Revolution were (1) the establishment of a simple system for classification of genera (the sexual system), (2) the binary nomenclature that reduced the

phrase name to two words, a generic name and a specific epithet, which Linnaeus called 'nomen triviale'. Not less important was the consistent use of these two innovations in works covering the entire plant kingdom, primarily the *Species Plantarum* (Linnaeus 1753). Of these two innovations, only the binary nomenclature has survived to the present.

Linnaeus and his pupils continued to use the essentialist ideas about genera and species; the number of species now in existence is identical with the number of forms that were created in the beginning. "We maintain that, in the beginning of things, a single sexual pair of every species of living [being] was created" (from S. Freer's translation of Aphorism 132 of *Philosophia botanica*; Linnaeus 1751: 86). "That new species can come into existence in vegetables [plants] is disproved by continued generation, propagation, daily observations and the cotyledons."[12] (from Aphorism 157; Linnaeus 1751: 99). Linnaeus did not deny the existence of variation, but in aphorism 158 of *Philosophia botanica* Linnaeus (1751: 100) he stated: "A variety is a plant that is changed by accidental cause: climate, soil, heat, wind, etc., and likewise it is restored by a change of soil." In Aphorism 162 (Linnaeus 1751: 101), he stated: "The species are very constant, since their generation is actual continuation. ... That varieties are the work of cultivation is clearly shown by horticulture, which frequently produces and modifies them." This had consequences for collections: one single complete specimen with root, stems, leaves, flowers, and fruits, could stand for the entire species with its essential characters. What mattered was to have as many species as possible represented in the collection, not many specimens of each species.

In Aphorism 11 in *Philosophia botanica* Linnaeus (1751: 6) made the famous remark: "A herbarium is better than any picture, and is necessary for every botanist." This indicated that a herbarium was an individualistic

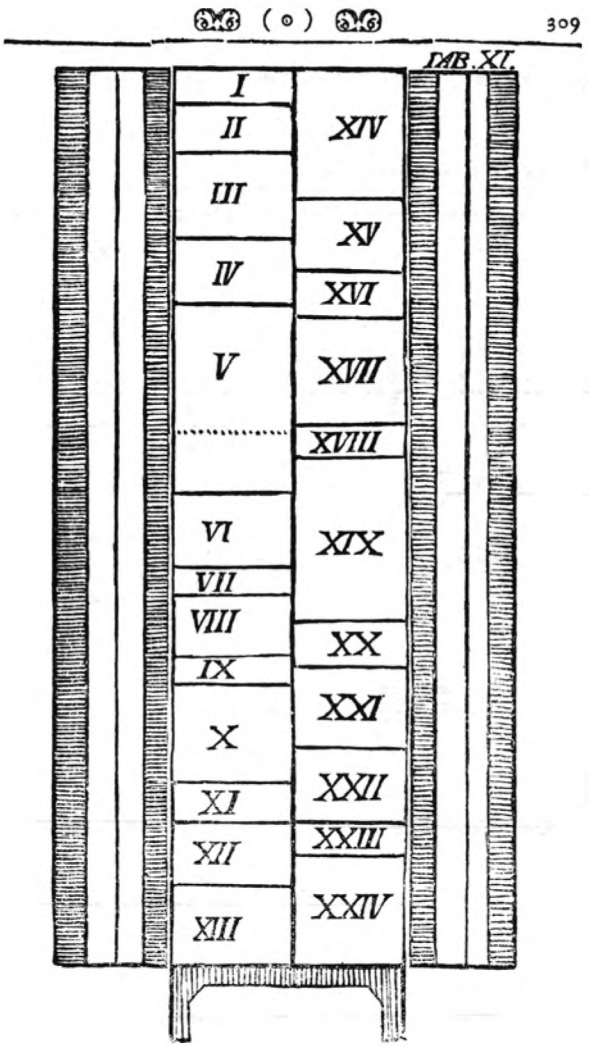

Fig. 4. A cupboard with two doors and two rows of shelves for a herbarium with specimens mounted on loose sheets of paper. The Roman numerals indicate the shelf-space to be allocated to each Linnaean class in the sexual system (Linnaeus 1751: Plate XI). In the legend to this plate Linnaeus stated that this was a herbarium arranged according to his sexual system with two long folding doors, nicely corresponding to a vertical partition. The cupboard would hold ca. 6000 specimens, which was almost the number of species known in 1751. The dimensions should be accurate: 7 ½ Paris feet from top to bottom, 16 inches wide, excluding the partition. Then the space to be allotted to each class is accurately indicated in inches.

12. This is the translation by S. Freer in his English edition of Linnaeus (1751). The reference to cotyledons in this context is not clear to the author. The original Latin text is: "Novas species dari in vegetabilibus negat generatio continuata, propagatio, observationes quotidianae, Cotyledones."

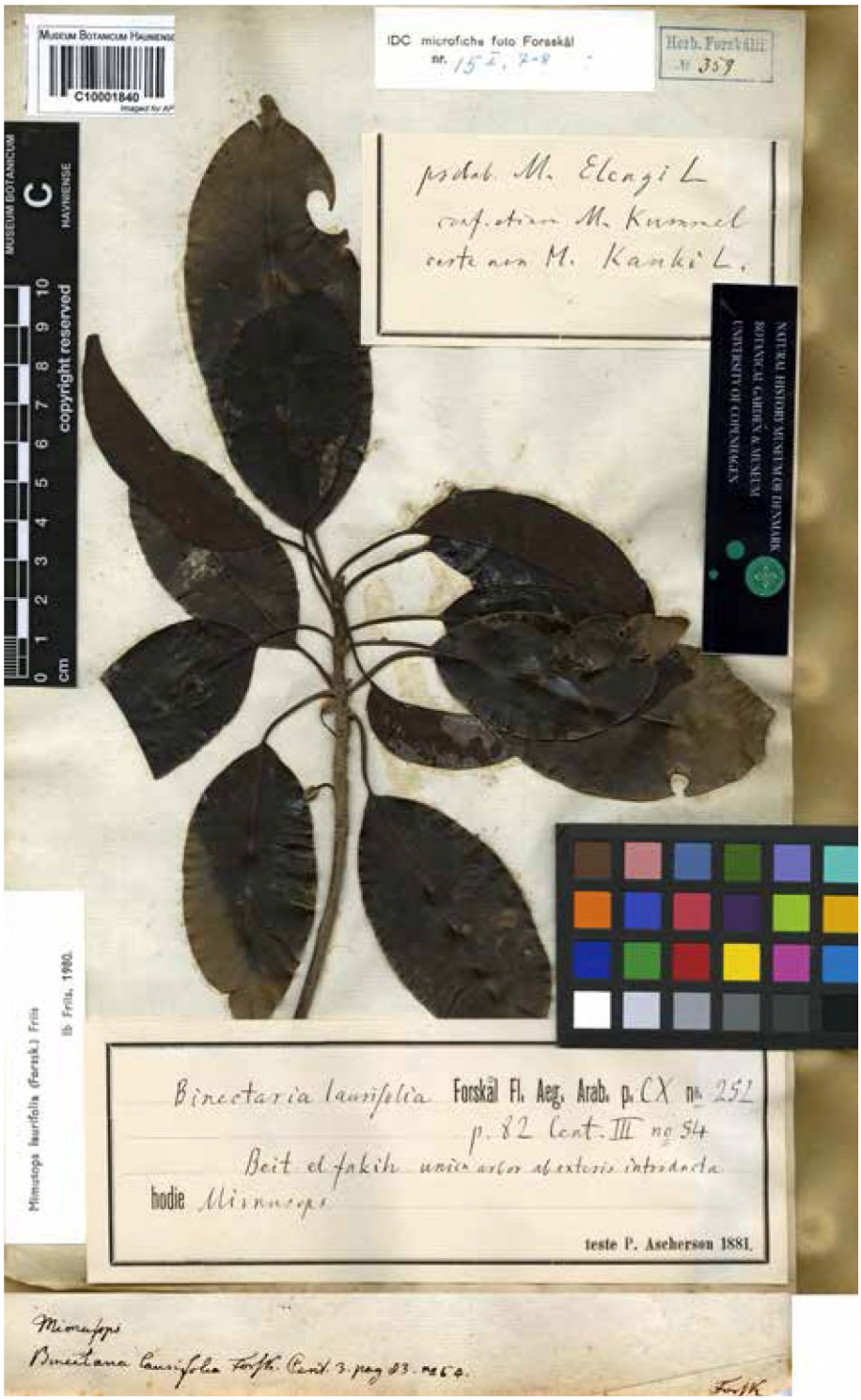

Fig. 5. Specimen of *Mimusops laurifolia* (Forssk.) Friis (Sapotaceae), collected by P. Forsskål at the town of Beit el Fakih in Yemen. This is one of two preserved specimens and type of the species name. Forsskål stated in his information about the plant that there was only one tree of this species at Beit el Fakih, and that it was introduced from elsewhere. In fact the tree occurs in a few localities with evergreen forest on the slopes of the Yemen escarpment, but is more widespread on the escarpments facing the Red Sea and the Gulf of Aden in Ethiopia and northern Somalia. There is no original Forsskål-label on this collection. The oldest annotations are the ones by Martin Vahl on the back of the sheet (inserted here at the bottom of the image). Vahl organised Forsskål's specimens to be mounted on paper and identified with his notes. The stamp in the upper right corner is an early attempt at numbering the Forsskål-collections, made in the second half of the 19th century. The large label at the bottom of the sheet was added by the German botanist P. Ascherson, who studied Forsskål's herbarium around 1880 (Hepper & Friis 1994: 50). The small labels are all from the last quarter of the 20th century. Now in the Natural History Museum of Denmark and digitised as C10001840.

and private collection; everyone should have one, as we have seen exemplified above. Linnaeus then goes on to give some simple advice on how to press plants and make a herbarium, and recommend that the pressed and dried plants should be glued to a loose sheet of paper, only one plant to a sheet, and not

bound, as in book herbaria. In the same work, Linnaeus strongly recommended the herbarium of loose sheets that could easily be reorganized in agreement with new knowledge.[13] At the end of *Philosophia botanica,* Linnaeus (1751: 311, "Tabula XI") gave detailed direction for the size of cabinets needed to hold a complete herbarium, and how much shelf-space were needed for each of his classes in such a collection (Fig. 4). This clearly indicated that he did not see a herbarium as an ever-expanding collection. The number of specimens in Linnaeus' own herbarium changed, as he gave away specimens when he received new and more complete ones. It is estimated that about 16,000 specimens have at one time been in the Linnaean herbarium (Stearn 1957: 103). When J.E. Smith purchased the Linnaean herbarium it included ca. 13,800 specimens (Jackson 1922; "some 14,600 specimens", according to Jarvis 2007), only a slightly higher number than the number of species he accepted during his lifetime. The number of tropical plants in the Linnaean herbarium has not been counted, but it was probably less than 1/3 of the total. However, the number of specimens from the tropics was still limited in spite of the journeys to tropical countries undertaken by the students of Linnaeus.[14] P. Forsskål's visit to Yemen as part of his participation to the Royal Danish expedition to Arabia, 1761-1763, resulted in ca. 1850 specimens, representing ca. 1000 species, of which probably only half the number came from the tropics (Fig. 5; Hepper & Friis 1994).

13. As we have seen, already Carpar Bauhin (1560-1624) kept pressed plants loose in folded sheets of paper in his herbarium, a method which, with modifications, was used 200 years later in the development of the herbarium of A.P. de Candolle in Geneva, and which is still used at the Conservatoire et Jardin botaniques de la Ville de Geneve (G). And, as mentioned elsewhere in this paper, the loose-leaf herbaria were well known in the Netherlands during Linnaeus' visits to that country in 1735-1738.

14. A map of the journeys by the students of Linnaeus was published at the end of Fries (1950). The tropical countries most visited were in South-East Asia and along the north coast of South America. The Cape of Good Hope (not tropical) was also frequently visited, and two students took part in Captain Cooks voyages: Daniel Solander in the first and Anders Sparrman in the second voyage.

After the Linnaean Revolution: Variation becomes a subject of study

Augustin Pyramus de Candolle (1778-1841) changed the principles for developing herbaria. The first sentence in in book 3, chapter 2 in his *Théorie elementaire,* (in both editions of the book; A.P. de Candolle 1813: 157; 1819: 193), deals with the species concept and variation within the species. The ideas behind this are basic to the representativeness of specimens (my own translation and paraphrasing): "Nature only shows us individuals. This fact is true, but often the wrong consequences are drawn from it. Is it not necessary to realise that although all the oaks in a forest and all the pigeons in a dovecot are individuals, they are more similar to each other than they are to other creatures? Is it necessary to use science to realise that the acorns of the oaks and the eggs of the pigeons produce offspring that is more similar to the creatures that generated them than to the offspring of any other creature? From these two commonly accepted observations has the idea of species arisen." After a few more examples he concludes, somewhat like John Ray in an earlier quotation in this paper, that a species is a group of individuals that resemble each other more than they resemble any other individuals, and that they can produce through generations other individual specimens that look more like their ancestors than any other individuals. All this is in good agreement with the essentialist species concept.

However, A.P. de Candolle (1813: 160-182, 1819: 196-215) also discussed the concepts of varieties and hybrids, classifying them into categories and – mildly – criticizing Linnaeus for too rigid and superficial views on variation. Thus, he concluded, it is necessary to have enough specimens of each species to represent both the accidental variation of the species and the variation represented by hybridisation and real 'varieties', a concept not yet fully understood. According to other parts of *Theorie elémentaire*, particularly where the author promoted natural classification rather than the sexual system of Linnaeus, it is necessary to have representative observations of all the possible characters that can be used for such a natural classification.

The two editions of the *Theorie elémentaire* also dealt with practicalities of herbaria in a full chapter (in both editions of the book as part 2, chapter 6), stating that even the best description or illustration could not replace material of the plant itself. Because of A.P. de Candolle's emphasis on variation, he concluded that it was necessary to conserve significant material for comparison, the variation of the different parts of plants. This was best done in a herbarium, rather than in a botanical garden, because in a herbarium at any time one could study the organs one needed. This is discussed in detail in the second edition of *Theorie elémentaire* (A.P. de Candolle 1819: 323)[15].

At this place it is relevant to mention the Danish (Norwegian born) botanist Martin Vahl (1749-1804). Generally, Vahl was a strict follower of Linnaeus, but he also realised the need to see original material used by other botanists when they had established new species (Vahl 1790: Latin unpaginated Praefatio, translated into English in facsimile, p. viii-ix). Vahl realised the danger of identifying plants only with the aid of diagnoses, descriptions, and illustrations, a danger illustrated in this paper on Ole Worm's identification of *Asclepias syriaca* L. with *Calotropis procera* (Aiton) W.T. Aiton (legend to Fig. 3). Throughout his life Vahl wanted to revise the – in his opinion – far too uncritical new editions that appeared of Linnaeus's *Species plantarum*, and he criticized the compilers of these new editions for not seeing enough material when describing or accepting a new species. Vahl therefore made two long journeys through Europe, visiting most major plant collections, in order to see both new herbarium material and material studied by previous authors. Vahl does not seem to have questioned the sharp discontinuity between species or that species are constant through time. A.P. de Candolle shared Vahl's views on the importance of seeing enough, and particularly *original* material, and *Théorie élementaire* contains a section on the importance of this material, thus Vahl and A. P. de Candolle foreshadowed the modern type concept. A.P. de Candolle (1813: 280) pointed out that Vahl in his *Enumeratio plantarum* (Vahl 1804-1805) indicated if and where he had seen a dried specimen.

From the early decades of the 19th century the amount of plants that arrived in Europe from the tropics increased dramatically. One example will illustrate this: the *Prodromus*-herbarium, on which A.P. de Candolle founded his enumeration of all vascular plants except ferns and monocotyledons (A.P. de Candolle *et al.* 1825-1874), began at the beginning of the 19th century its existence with very few specimens, when A.P. de Candolle died in 1841 it contained 161,748 specimens, when A. de Candolle died in 1893 it had grown to 324,376 specimens, and when the accession to the herbarium ceased at the completion of the *Prodromus* and its supplements at the beginning of the 20th century the number of collections was 399,646 specimens (Conservatoire et Jardin botaniques de la Ville de Genève, undated).

A few important collectors, some of which also contributed to the *Prodromus* herbarium, can be mentioned: Indian and South Asian collections were provided by Nathaniel Wallich (1786-1854; ca. 20,500 collections, including those made by others, main set at K-W) (Vegter 1988: 1110); Wallich lived and travelled in India, Nepal (Fig. 6), Burma, and Singapore from 1807 to 1835 and moved to London, where he organised the vast herbarium of the British East India Company to be listed and numbered, and duplicates to be distributed to most of the important herbaria in Europe. Carl Ludwig von Blume (1796-1882) made numerous collections in the Dutch East Indies (present Indonesia), mainly on Java in 1822-1826; his main

15. As a further example of A.P. de Candolle's ideas about the variation to be studied in herbaria, one can cite these lines (A.P. de Candolle 1819: 323-324): "Il serait éminemment précieux pour la connaissance des lois réelles de la Taxonomie, de réunir d'une manière analogue des exemples variés de soudures plus ou moins complètes, d'avortements, de transformations ou d'aberration d'organes; il serait précieux pour l'étude des lois générales de la végétation, d'avoir des- herbiers où l'on trouverait des échantillons comparatifs des mêmes organes et des mêmes plantes crues dans un sol sec ou humide, découvert ou ombragé, au pied, sur le flanc ou an sommet des montagnes, dans les pays chauds ou froids, etc."

Fig. 6. Specimen of the grass *Isachne albens* Trin., collected in 1821 in Nepal by N. Wallich, sent to J.W. Hornemann in Copenhagen and now in the General Herbarium of the Danish Natural History Museum. Wallich was born in Copenhagen in 1785 and originally sent to India as surgeon at the Danish trading post Frederiksnagore (Serampore) north of Calcutta. In 1814 Wallich was appointed assistant surgeon in the East India Company's service, temporary superintendent of East India Company's botanical garden at Calcutta in 1815 and finally superintendent of that garden in 1817. In 1820–1821 Wallich made an 18-month expedition to Nepal. This and another specimen, stated to be collected at Sanko in Nepal, are almost certainly early distributed duplicates of the collections from Nepal, which were later incorporated in the Wallich Herbarium at Kew (K-W), and in the Wallich catalogue as No. 8658. Now in the Natural History Museum of Denmark and digitised as C10021700.

set is at L, but also at more than 20 other herbaria, including G-DC (Lanjouw & Stafleu 1954: 80), and Franz Wilhelm Junghuhn (1809–1864) followed this tradition with many collections from Java 1837–1839 and 1855–1864; elsewhere in the Dutch East Indies, particularly the Malay Archipelago (1837–1848, 1851–1855) and on Sumatra (1840–1842), the main set of these collections are at L (Chaudhri *et al.* 1972). Alexander von Humboldt (1769–1859; ca. 6000 collections, main set now at P, many duplicates) (Lanjouw

Fig. 7. *Dioon edule* Lindl. (1843), collected in 1842 by Frederik Michael Liebmann at Conchiquitla (Consoquitla) in the low mountains between Mt. Orizaba and the coastal town of Veracruz in southern Mexico. The originally collected plants are still in cultivation in the Botanical Garden, Natural History Museum of Denmark. On herbarium sheets and on watercolours Liebmann named the plants *Macrozamia littoralis* and *Macrozamia pectinata*, but the names were not taken up or validly published. Lindley described his new genus *Dioon* Lindl. [as 'Dion'] on a cone and a live plant brought to England at almost the same time as Liebmann made his collections (photographed by Ib Friis).

& Stafleu 1957: 292), Carl Friederich Phillip von Martius (1794-1868; ca. 7200 own collections, 63,000 including other collectors, main set BR, many duplicates) (Vegter 1976: 509) and Richard Spruce (1817-1893; ca. 10,000, main set K, many duplicates) (Vegter 1986: 938) are famous collectors in South America from that period. F. M. Liebmann (1813-1856) collected more than 95,000 specimens in southern Mexico, Cuba and the West Indies (Chaudri *et al.* 1972: 441), but his collections were only numbered after his return and the figure reflects sheets, not number of collections (Fig. 7, 8). From tropical Africa and warm temperate South Africa came the collections made by William John Burchell (1782-1863; ca. 5000 collections, main set at K) (Lanjouw & Stafleu 1954: 106), Friedrich Martin Josef Welwitsch (1808-1872; > 3000 collections, many duplicates, main sets at COI, LISU and BM) (Vegter 1988: 1136) and Georg Heinrich Wilhelm Schimper (1804-1878; probably ca. 4000 collections, widely distributed) (Vegter 1986: 840).

In the first part of the 18th century, European botanical gardens developed better heated greenhouses, allowing the cultivation of an increasing number of plants collected in the tropics (Fig. 7). At the same time, botanical gardens and herbaria started developing in the tropics, particularly in colonies of European countries, for example in Brazil (Rio) and India (Calcutta).

The Darwinian Revolution and After: The delimitation of species in focus

When Charles Darwin (1809-1882) published his 'Origin of Species' (Darwin 1859) he was not the first to suggest the evolution of species as a fundamental theory in biology. That had been suggested already by Jean Baptiste Lamarck and others in the early 19th century, and it seems gradually to be realized that this would put an end to the essentialist species concept. Lamarck's new theories about the modifications of species were first seen in his manuscript lecture notes from May 1800 (Mayr 1982: 344-345) and elaborated in his book *Philosophie zoologique* (Lamarck 1809). The need for larger collections with more specimens had already been suggested by A.P. de Candolle because of the need to understand variation. After Lamarck and Darwin, it became essential to study as much material as possible in order to circumscribe species, define their natural variation and delimit species against similar species. The growth of one of the largest her-

Fig. 8. Specimen of *Urtica chamedryoides* Pursh. (1814), collected in September 1841 by F.M. Liebmann near the top of Mt. Orizaba (Pico de Orizaba) in southern Mexico at 10,000 ft. (ca. 3100 m). Liebmann (1851: 292) described it as a new species, *Urtica orizabae* Liebm. He sorted and annotated his own collections, but did not provide them with labels. His notes about localities and dates of collecting were written directly on the sheets on which the plants were mounted, just as Linnaeus, Forsskål, and Vahl had done. When later incorporated in *Museum botanicum Hauniense*, all Liebmann's specimens were numbered and provided with printed labels. Now in the Natural History Museum of Denmark and digitised as C10013025.

Fig. 9. The Herbarium of the Royal Botanic Gardens, Kew, interior of what is now Wing C. Built in 1876–1877 for storage and work with herbarium specimens over three floors, the upper two galleried on iron columns. The design maximised admission of natural light as gas-light presented a serious fire hazard. In 1903 the building was stripped of its elaborate ironwork and wooden panelling, fire-proof concrete floors laid, and the galleries widened. The original interior can be seen in an early photograph reproduced in R. Desmond's history of Kew (Desmond 1995: 248). The building was added to the oldest part of the present herbarium complex, the Hunter House, to hold the rapidly growing collections. At the appointment in 1841 of the first director of the Royal Botanic Gardens, William Hooker, there was no official herbarium at the gardens. Hooker made his own collections available to staff and visitors on the ground floor of the Hunter House; the collections grew so quickly that this pupose-built wing was added in 1876–1877. The next wing, currently Wing B, also with three floors, was added in 1902. Wing A, with four floors, was added in 1932. A fourth Wing D closed the quadrangular courtyard in 1969. A basement with compactors was added under the quadrangle in 1990, and a fifth Wing E was added in 2009. Photo and information kindly provided by David Goyder, Kew.

baria focussing on tropical plants, the Herbarium of the Royal Botanic Gardens, Kew (Fig. 9), but similar stories can be told about the growth of the other big herbaria with tropical plants in for example Berlin (B; growth interrupted by destruction of most of the herbarium in a fire during World War 2), Bruxelles (BR), Geneva (G), Leiden (L, now incorporating the herbaria from Wageningen (WAG) and Utrecht (U), see Welzen & Schollaardt 2017), Missouri (MO), New York (NY), and Paris (P).

This change in collection-based plant taxonomy was well reflected in the work of Alphonse de Candolle, son of A. P. de Candolle. In *La phytographie* (A. de Candolle 1880), he presented his general review of analytical and descriptive plant taxonomy. He stated that testing species descriptions against specimens in good herbaria with much material is the best way to achieve accuracy in taxonomy, or at least in descriptions. Unfortunately, tropical plants were often only known from few specimens, and if described as new species and given a name, it was necessary to test the taxonomy when more material became available, and possibly establish synonymy if the studies revealed that the variation of two or more previously accepted species overlapped. A. de Candolle listed three important uses of herbarium material:

> (1) It helped to fix the names of plants with preserved material that could be studied for verification;
> (2) It provided material allowing the botanist to study the variation of plant species and describe this variation;
> (3) It made accessible material of previous botanists, and thus made it possible to test and understand previously published descriptions and taxonomic conclusions.

A great and well-equipped herbarium would make much more widely sampled material available than for example a botanical garden, would contain specimens from a wide range of habitats, altitudes, geographical range, of different age, and from collections made at different times of the year. Living collections, on the other hand, would allow better anatomical studies and better information about colour, fragrance, etc., if the living material was tested against good and ample herbarium material. A. de Candolle criticized earlier botanists who published only descriptions and illustrations without documenting these with herbarium material. Making good collections in remote countries was a challenge and that some eminent botanists had provided more service to science as field collectors than as herbarium taxonomists. Phillibert Commerson (1727-1773), Carl Friedrich Drège (1791-1867) and Richard Spruce (1817-1893) were singled out for praise as collectors, in spite of their having published nothing or very little.

In his advice to collectors A. de Candolle emphasized well-known virtues: to select good and representative material and to preserve it well by careful pressing and drying of the specimens, but he added that the new requirements of botany made it necessary also to collect as much material as possible for many duplicates from the same locality and to number this material carefully, so that the various duplicates of the same collections could be identified, even when in separate herbaria.

De Candolle praised two botanical collectors for innovation and consistent practice in making their collections: (1) Phillibert Commerson, global collector, was praised for being the first to follow the first of these recommendations, and his duplicates from remote parts of the tropics were deposited in up to twenty herbaria in different towns. However, de Candolle mentioned that it might be difficult to identify which specimens in different herbaria were actually duplicates of the same collection, for Commerson did not number his collections. (2) William John Burchell, collecting in South Africa, was one of the first to number his collections, and the idea of numbering collections spread quickly to other collectors when authors started citing them in the *Prodromus*. It was most likely because of this that Wallich and his collaborators made such efforts to number the duplicates from the British East India Company which they distributed from 1830 and onwards with reference to the published catalogue of the collections. With the idea of carefully numbering the collections followed the absolute requirement that the collector, collecting locality and year of collecting should be clearly indicated. This information was more important than a precise name, for it would always remain with the specimen, while the scientific identification might change.

Because it required special knowledge to understand some old herbaria, and these were closely associated with classical botanical works, it could – according to A. de Candolle – be advantageous to keep them as separate, special herbaria that reflected par-

ticular traditions or practices of their original private owners, such as the Tournefort herbarium in Paris, the Bauhin herbarium at Basel, the Linnaean herbarium in London, the Willdenow herbarium in Berlin and the *Prodromus* herbarium at Geneva.

In Demark, I may add, this should also continue to apply to the previously mentioned herbarium of Peter Forsskål (1732-1763) from Egypt and Yemen. But mostly it would be advantageous to integrate the work of many collectors in one large *herbarium generale,* where the botanists could with ease compare many specimens from many parts of the world.

The post-Darwinian period saw a vast increase in the number of collections from the tropics, particularly in herbaria in European countries with colonies (Great Britain, France, the Netherlands and Belgium). This was due to improved transportation of both material and scientists and progress with the understanding of health-hazards in the tropics, improved medication, such as vaccination programmes and malaria prophylaxis.

The International Trend after the First World War: Collaboration and standardisation

After the First World War there was a strong move towards internationalism in botany, reflected in the renewed discussions about a unified nomenclature on both sides of the Atlantic, including making an end to the special 'Kew Rule"[16] with a united set of rules for priority in botanical nomenclature and rules for types, but only after ca. 1950 the collaboration became successful. Nicolson (1991), taking a pessimistic view, called the period from the beginning of the First World war up to ca. 1950 the 'dark age', emphasising the many unsuccessful attempts at agreements and progress at Botanical Congresses. After the Second World War there was also a strong urge for more collaboration between herbaria, a movement which to a large extent originated in the Netherlands and resulted in the creation of the International Association for Plant Taxonomy (IAPT) (founded on the seventh international botanical congress in Stockholm, 1950), the journal *Taxon* and the monograph series *Regnum Vegetabile*, of which the first volume, appearing in 1953, was a report from the very same botanical congress in Stockholm in 1950. Dutch botanists had important roles in all this, not least the energetic and productive Franz Stafleu (1921-1997), who, while attending to many other tasks, brought order in more than two hundred years of botanical literature and wrote a monograph on the spread of the Linnaean ideas (Stafleu 1971). A biographic obituary of Franz Stafleu was published by Werner Greuter (1998).

It is not surprising that ideas and results of these efforts were exemplified in a major Dutch botanical publication, the general parts of the *Flora Malesiana*, especially in parts of vol. I, mainly due to Cornelis Gijsbert Gerrit Jan van Steenis and his wife, Mrs. M.J. van Steenis-Kruseman (Steenis 1949-1958; Steenis-Kruseman 1950). The general chapters in this part of the flora contain detailed lists and reviews of the available taxonomic literature for the area covered by the flora, information about collectors and their collecting localities, chapters about where and how to collect, how to incorporate material in herbaria, dates of publication of important works, general considerations about taxonomy, delimitation of species and infraspecific taxa, etc. These texts largely follow the ideas and examples of A. de Candolle, who was also a pioneer of rules for botanical nomenclature in *Lois de la nomenclature botanique* (A. de Candolle 1867). In a way the introductions to the *Flora Malesiana* can be seen as a 200 years younger parallel to Linnaeus's *Philosophia botanica*

16. The so-called 'Kew Rule' was followed by botanists at the Royal Botanic Gardens, Kew, and by some other British botanical authors, to determine the choice and application of names in botanical nomenclature. *Index Kewensis*, used the Kew Rule until its *Supplement IV* (published in 1913). The Kew Rule applied the rules of priority for specific epithets only within genera, so that when transferring a species to a new genus, there was no requirement to retain the epithet of the original species name, and the priority of species names was counted from the time the species was established in or transferred to the new genus. This was contrary to the international rules that required, and still require, priority for epithets when species are moved from one genus to another.

Fig. 10. Specimen collected in the late 20th century in Uganda by Axel D. Poulsen, D. Nkuutu, and H. Dumba as no. 975. The collection was numbered when the plant was collected and the number is the same for all duplicate specimens. Holotype of *Chlorophytum occultum* A.D. Poulsen & Nordal (Asparagaceae, formerly Anthericaceae). Modern labels for herbarium specimens include information about collectors, their institutional affiliation, detailed information about the locality where the specimen has been collected, including geographical coordinates and altitude, collecting date and year, phytosociological information about the habitat, and such information about the plant which is not available from direct inspection of the specimen. Original determination and later redeterminations also appear from labels, as well as type status. Now in the Natural History Museum of Denmark and digitised as C10000932.

and a 75 years younger parallel to parts of Alphose de Candolle's *La Phytographie,* in which clear identification of authors and collectors, clear identification of herbaria, etc., were also promoted. The methodologies proscribed in the introductory chapters in *Flora Malesiana* are therefore also to large extent analogous with the recommendations of A. de Candolle, and I will not repeat them here. The virtues with regard to taxonomy praised by A. de Candolle and *Flora Malesiana* were indeed the virtues I was taught to respect when I first

came in contact with tropical botany in the 1960s and still respect as the basis for sound taxonomic work, not least in the tropics.

Tropical Plant Collections Now and in the Future

But in the 1960s and 1970s a new revolution started; phylogenetics was introduced as the testable method for the study of evolutionary relationships among groups of organisms, proposed first through mathematical analyses of morphological data-matrices and later through matrices of data obtained from sequencing of macromolecules (DNA, RNA). The English translation in 1966 of Willi Hennig's *Grundzüge einer Theorie der phylogenetischen Systematik* (Hennig 1950, 1966) could be taken as a starting point for this new revolution, which continued with the development of molecular techniques during the following decades. In the same decades computer technology developed fast, allowing handling of large amounts of data and electronic storing and transmission of images. Up to now, this has had two important consequences for botanical collections: digitization of plant material and the gathering and analyses of large-scale data.

The preserved collections are basically still pressed and dried plants mounted on paper, but now provided with much more detailed labels (Fig. 10) and supplemented with DNA collections and all the traditional collections (plant parts in alcohol, carpological collections, wood collections, anatomical slide collections, pollen collections, etc.).

Nowadays herbaria have a problem with their reputation, as everyone in the present symposium was aware of. It is almost too easy to assume that a methodology developed through more than 250 years ago is outdated, a burdensome legacy from the past. Herbaria with good coverage of the world's flora, as recommended by A.P. and A. de Candolle, are big, take up a lot of space and need permanent curation. If they are not well curated, they will gradually be more and more difficult to use, not follow the latest nomenclature and taxonomy and cease to reflect our knowledge of the plant world.

The same applies to botanical gardens. It is not easy to justify what it takes in expenses and manpower to maintain comprehensive plant collections to politicians, university managers and others, who do not work with herbaria and botanical gardens themselves, and it becomes even more complicated if we deal with tropical herbaria and tropical botanical gardens maintained in temperate countries. Examples of this are presented in papers in this volume by Sanjappa and Venu (2017) and Blackmore (2017). For botanists is seems self-evident that the relatively biodiversity-poor temperate countries have the tradition, financial and academic capacity to look after at least the collections that have already been gathered from the tropical and more biodiversity-rich countries, and perhaps to supplement them somehow, so they are still useful in international scientific collaboration.

However, it is obvious that the old idea of collections being representative samples of nature will come under further pressure in the future. Since the end of the 18th century a culture has developed among botanists granting free access to scientific information and material in plant collections, private or public, provided that this was for *bona fide* academic studies. This was a necessity for the writing of monographic studies covering plants with wide distribution areas which therefore had to be looked for in many herbaria in different countries. Specimens and other material was freely sent on loan or exchanged over country borders, at least in long periods during the last two hundred years.

The first step towards restrictions on sending specimens across borders was taken at a meeting in 1963 between members of the International Union for Conservation of Nature (IUCN), a membership international membership union created in 1948 and composed of both governments and civil society organisations with an interest in nature conservation (IUCN 2017)[17]. A draft resolution to control the exchange of

17. In Denmark, the Danish Ministry for Food and Environment, Agency for Water and Nature Management, and eight non-governments organisations are members of the IUCN.

threatened species was adopted. The final *Convention on International Trade in Endangered Species of Wild Fauna and Flora* (CITES 2017) was opened in 1973 for signing by countries that agreed to be bound by the Convention, and it entered into full force in July 1975. The basic aim of the convention is to ensure that international trade in specimens of wild animals and plants does not threaten the survival of the species in the wild, but any transfer from country to country of scientific material, such as loan and free exchange herbarium specimens, seeds and other propagules between botanical gardens are covered by the convention, and the customs authorities of countries that have signed the convention are instructed to confiscate any material of endangered species, which occur on the appendices of the convention and are sent across borders without the necessary permissions and documentation. This applies to more than 35,000 species of animals and plants, mainly plants, for example, all species of the genus *Aloe* and all species of orchids. Today, almost all countries in the world have signed this convention, and bureaucratic control has become relatively firmly established for legal exchange under CITES of scientific material between established academic institutions such as national herbaria and botanical gardens.

More wide-ranging is the *Convention on Biological Diversity* (CBD 2017). The United Nations Conference on Environment and Development (UNCED), also known as the Rio Summit, was held in Rio de Janeiro in June 1992 (UNCED 1992) and endorsed the *Convention on Biological Diversity*, largely a product of the preparations for the Rio Summit. This convention recognized for the first time in international law that biological diversity should be "a common concern of humankind", that policy for the country's biodiversity was an integral part of the development process in all countries, also those in the tropics, even if the biodiversity of these countries was not sufficiently known, and that the convention changed the fundamental concept of ownership of biodiversity from the "common heritage of humankind" (as opposed to "common concern of humankind") to the "sovereign right" of each country. This is being interpreted in such a way that national law under the umbrella of the convention regulates the movement of living or preserved specimens across boundaries. Thus the convention has made each of the more than 170 nations responsible for regulating access to their own biodiversity. In spite of all its virtues the CBD has opened up new and partly as yet unresolved questions on a global scale about the opportunity to study biodiversity represented to any sample of plants and animals in other countries than that of its origin, and to move specimens of biodiversity beyond national jurisdictions.

It is not yet clear what the exact consequences of the international legislation under the CBD will be for herbaria and botanical gardens which hold material from other than their own country. In 2010 a protocol was signed in Nagoya, Japan, by a range of the signature countries of the CBD. The intention behind the Nagoya protocol (2017) is to further access to biological diversity, including genetic resources, and a fair and equitable sharing of benefits arising from utilisation of biodiversity between the home country and the countries where biodiversity is utilised. Unlike with the CITES convention, an internationally accepted practise has not yet developed with regard to the consequences of the Nagoya protocol for herbaria and botanical gardens. The critical procedures are referred to in the Article 17 of the protocol; according to which each signature country is obliged to monitor the use of genetic resources by establishing one or more checkpoints. All access to genetic resources, which is taken to cover living and preserved specimens of animals and plants, is to be governed by prior informed consent between the original owner of the biodiversity and the user, for which mutual terms have to be established. If enforced down to single specimens, this will require a formidable bureaucracy at herbaria and botanical gardens with thousands or millions of specimens. International agreements between consortia of institutions housing natural history collections may smoothe the bureaucracy of the Nagoya protocol, as it has to some extent been possible with the transactions between institutions under the CITES convention. In October 2016, the Consortium of European Taxonomic Facilities (CETAF), a

European network of large natural history museums, botanical gardens and biodiversity research centres, signed a Memorandum of Understanding with the Botanic Gardens Conservation International (BGCI), standardising procedures under, for example, the Nagoya protocol, and CETAF has drafted a set of standard documents for exchange of material between its member institutions, but still it seems that this may be a challenge for institutions with dwindeling staff.

Possibly, digitisation of specimens and increasing use of DNA-sequence data for characterization of taxonomic units or clades may reduce the need for actual movement of specimens or other forms of biological material across boundaries, but according to the Annex of the Nagoya protocol, it is intended to cover not only material of biodiversity, but also intellectual property rights. The good intentions of the CBD and the Nagoya protocol must be put into a workable practice that will further, rather than hinder, basic research utilising plant specimens in the future. Herbaria and botanic gardens have a proud tradition of serving science world wide; it is to be hoped that this can and will be carried on.

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