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THE WOOD COLLECTION (XYLARIUM) OF THE ROYAL BOTANIC GARDENS, KEW

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SUMMARY

The wood collection of the Royal Botanic Gardens, Kew (United Kingdom) has its origin in the founding of Kew's Museum of Economic Botany in 1847. In the nineteenth century specimens came from explorers and botanists; from imperial institutions such as the Indian Forest Department, and from international exhibitions (world's fairs). Woods were labelled with their names and properties, creating an educational exhibit aimed particularly at forestry students. In the early twentieth century wood specimens from aristocratic estates formed the basis of a new museum of British Forestry. The foundation of the Jodrell Laboratory at Kew in 1876 led to more research in plant anatomy, but sustained research in wood anatomy and the creation of a major collection of plant anatomy slides dates from the 1930s. Since that time, accessions have come from other wood collections (sometimes the transfer of whole collections), from Kew's botanical expeditions in Brazil and Southeast Asia, and often as institutional or personal gifts from wood anatomists in other countries. The woods now number 34,314 and form part of the Economic Botany Collection, kept in a purpose-built research store and with a collection database available online. As well as enabling plant anatomy research, the woods are increasingly used by historians, and for wood isotope studies, biochemistry etc.

***Keywords*:** Empire, exhibitions, forestry, history, museum, plant anatomy, xylotheque.

INTRODUCTION

In this paper, we trace the evolution of Kew's wood collection since 1847, and explore how changes in the pattern of acquisitions can be linked to changes in the scope and practice of wood research at Kew. Such collections come to be through highly diverse routes, both highly structured, *e.g.* through the work of the holding institution, and through chance, *e.g.* unsolicited donations. The data supporting this survey are summarised in a table listing all donors of over 100 wood specimens, together with donor type and approximate date of specimen collecting (Table 2).

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Delving into how a wood collection comes to be, and uncovering the hidden pat-terns of acquisition, are important for three reasons: (1) they lead to better understanding of the provenance and quality of identification of specimens, and are thus of immediate relevance to the wood specialist; (2) wood collections are important sources of information for the history of timber discovery and use, and the history of the collecting institution, and (3) a good understanding of the collection profile is vital in planning future acquisitions.

EARLY HISTORY: 1847 TO 1930

Building the collection

The Royal Botanic Gardens, Kew began its life as a physic garden planted in the grounds of a royal Thames-side estate in 1759 by Princess Augusta, mother of George III. George himself expanded the garden's utilitarian mission by taking on Sir Joseph Banks as botanical advisor. However, after the death of both George and Banks in 1820 the gardens went into a period of decline, to be rescued by the British government in 1840 when ownership of the Kew estate was transferred from the royal family to the state. With the appointment of Sir William Jackson Hooker as director in 1841, the Royal Botanic Gardens went on to become a leading research institute for plant science, a position it continues to hold.

The origins of Kew's wood collection lie in the Museum of Economic Botany, which opened in the grounds of the Royal Botanic Gardens in 1847. The purpose of the Museum was, in the words of its founder William Hooker, to inform 'not only the scientific botanist' but also 'the merchant, the manufacturer, the physician, the chemist, the druggist, the dyer, the carpenter and cabinet-maker, and artisans of every description' of the vast variety of plant raw materials available in British colonies, and to suggest and inspire new applications for them (Hooker WJ 1855: 3).

Kew's wood collection from the second half of the nineteenth century reflects two of its strengths: networks with British territories overseas, and with aristocratic estates in Britain, but they are by no means limited to these. Across colonial networks of government, science, and commerce, the chief sources of woods were world's fairs, voyages of exploration, and institutions of botany and forestry. One of the earliest wood accessions of significant size came from Joseph Hooker's expedition to the Himalaya from 1848 to 1851. Hooker labelled his specimens in the field with details of location and altitude (Fig. 1A), and catalogued them on his return, so they are of great value to researchers. Further details of the species he collected can be found in his *Flora Indica* (Hooker JD 1855).

Kew's Indian wood collection really began to grow, however, with the advent of Indian forestry. Joseph Hooker's conversations and correspondence with the Governor-General of India – the Earl of Dalhousie – are said to have inspired the establishment of the Indian Forest Department in 1864 (Barton 2002: 49–50) and thereafter Kew was actively involved in the development of forestry on the sub-continent. This, of course, had advantageous consequences for its collection. In 1878 Kew received from the Indian Forest Department a duplicate set of a large collection formed for the 1878 Paris International Exhibition. It marks a transition to a more 'complete' representation of Indian

Figure 1. A: *Euonymus grandiflorus* Wall. with Joseph Hooker's original label reading: '353. Euonymus. Khasya. 5000 ft.' EBC 4782. – B: *Stereospermum suaveolens* DC. EBC 13714. – C: *Stereospermum suaveolens* DC. with imprinted figures connoting region of collection and collector (C: Central India Provinces; 1114: specimen number allocated at source by Richard Thompson, who collected them in the Chanda forests). EBC 13714.

woods in the Kew collection. This 'magnificent collection of forest produce' comprised over one thousand specimens of timber as well as 'a number of large rounds, planks, bark pieces, specimens of trees grown in plantations, bamboos, canes and other palms, gums, fibres, fruit, and other miscellaneous forest produce' (Hooker 1880: 56). The value of the collection lay then, as now, in its breadth and presentation: each specimen was labelled with its botanical name (according to Kew's own Bentham-Hooker system and with reference to Joseph Hooker's *Flora Indica*), vernacular name, geographical provenance, and details of uses; in short, they had been 'accurately determined by its scientific officers' (Hooker 1880: 59) (Fig. 1B). The numbers and letters stamped into the woods (Fig. 1C) can be understood using Gamble's *Manual of Indian Timbers* (1881), thus allowing the wood anatomist to pinpoint individual collectors and precise locations.

International exhibitions

As the case of the 1878 Indian woods indicates, world's fairs in the nineteenth and early twentieth century have played a vital role in the development of Kew's wood

collection. The woods acquired from the 1862 London International Exhibition were so extensive that they prompted the opening of a new museum at Kew in the former Orangery – Museum No. 3, otherwise known as the Timber Museum (Fig. 2A). Although woods from exhibitions were initially intended for a commercial market, their scientific value was assured by the involvement of scientists such as William and Joseph Hooker as commissioners, setting standards and conventions for the objects to be submitted, or as jurors, judging exhibits against those same standards and conventions. In this way they managed to ensure that wood specimens were labelled scientifically and could therefore enjoy an afterlife in the Kew Museum.

The Kew xylarium also includes woods from other international exhibitions: the Great Exhibition in London 1851 and its successor of 1862; Paris 1855, 1867 and 1900; Vienna 1873; Philadelphia 1876; the Forestry Exhibition in Edinburgh 1884; the Colonial and Indian Exhibition London 1886; St. Louis 1904; the Japan-British Exhibition 1910 and the Empire Timber Exhibition held in London in 1920. The last world's fair to contribute to Kew's collection was the British Empire Exhibition at Wembley, London 1924–25, with 380+ specimens. From the 1940s, world's fairs took on the character of entertainments and no longer showed large numbers of botanical specimens.

Institutions

During this early period of the collection, woods were as likely to come from fellow institutions of science as from exhibitions; this is particularly true for Kew's European and American woods. Sizeable exchanges occurred between Kew and the US Department of Agriculture in the 1870s, for example, as they did with Charles Sprague Sargent at the Arnold Arboretum, Harvard in the 1880s. At the same time Kew's European networks were highly active. Over the first years of the twentieth century Kew received around 300 woods from Adriano Fiori's *Xylotomotheca italica* at the Portici Botanical Garden near Naples, Italy. These were duplicates which the Italian botanist had collected in the regions of Italy for his magnum opus *Flora analitica d'Italia* (Fiori 1896–1909).

The network of colonial botanic gardens was particularly valuable in expanding the wood collection; from the 1880s, for example, tropical woods at Kew were augmented by accessions from Henry Ridley at the Singapore Botanic Gardens. However, not only British botanic gardens were involved; so were those of other nations' colonies. During the 1870s and '80s Rudolph Scheffer of the Bogor Botanic Gardens presented Kew with rich collections from the Indonesian archipelago, showing that scientific loyalties can outweigh political ones.

Aristocratic woods

Kew Gardens began as a royal estate, and after it passed to state ownership in 1840 successive Kew directors revived and expanded exchange networks with aristocratic landowners in order to accumulate British timbers. As early as 1850 a donation of woods came from the estate of the Duke of Northumberland, a neighbour of Kew at Syon Park immediately across the River Thames.

Figure 2. A: Museum No. 3 (Orangery), opened 1863. – B: Case 67 in Museum No. 2 with plant specimens on the top shelf and manufactured objects (walking sticks) on the lower shelf. Photograph by Johannes Lotsy, 1902. – C: Iron galleries in Museum No. 3. – D: Museum No. 4, opened 1910.

Museum No. 4, or, the Museum of British Forestry, opened in 1910 in the former residence of the Duke of Cambridge, in response to government moves to render British forests more 'remunerative' (Report from the Select Committee on Forestry 1884–85). Parliamentary Reports in 1885 and 1902 emphasised the need for better forestry training facilities and Kew anticipated the demand for a national collection of British timbers by rapidly building up its collection. In Britain at that time, the largest owners of trees were the landed gentry, and by 1910 Kew's donor base amongst these had broadened to include the Earls of Wharncliffe, Darnley, Derby, and Yarborough, and King George V, who donated a wood specimen from the Sandringham Estate. Currently the largest 'aristocratic' legacy in the collection is that donated in 1910 by the Sixth Earl of Yarborough from his Brocklesby estate in Lincolnshire. Brocklesby is a fine example

of early twentieth-century sustainable forest management and record-keeping. By 1932 the Earl had planted over 12 million trees on his estate, with each planting and felling logged (Havelock 1932).

Wooden artefacts

The Kew xylarium is unusual in forming an integral part of a larger collection – now known as the Economic Botany Collection – that also includes many hundreds of wooden objects. As described below, the adjacent display of raw material and product was an important feature of the Museums. The collection is extremely varied; highlights include Tunbridge Ware, pulleys, and brush-making from Britain; some fine drinking mugs from Germany, Russia and Sweden; a wooden drum and cassava grater from the Amazon; a remarkable writing desk constructed in Sydney, Australia in 1805 (George 2006); a painted xylotheque from Japan (Nagata *et al*. 2013); a house portal ('totem pole') from British Columbia (Cornish 2012) and household items (including several hundred walking sticks) from around the world. These objects offer a rare opportunity to see timber samples next to objects made from the same wood.

Housing and using the collection

By 1910 the Museum of Economic Botany had grown to encompass four separate museum buildings, two of which – Museums 3 and 4 – were dedicated to woods. Museums 1 and 2 were arranged taxonomically, according to de Candolle's 'natural' system, with Museum 1 given over to dicotyledons and gymnosperms, and Museum 2 to monocotyledons and cryptogams.[1] To walk through the two museums in the prescribed order was to perform de Candolle's system. There were woods in these two museums, as representations of particular families, genera, and species of the Plant Kingdom. However, they were generally small specimens which could fit the scale of the Museums' display cases. In the very first Museum Guide, Hooker outlined the display principle adopted in the Museum: 'the *raw material* (and, to a certain extent, also the *manufactured* or *prepared article*) … correctly named, and accompanied by some account of its origin, history, native country, etc., either attached to the specimens or recorded in a popular catalogue' (Hooker WJ 1855: 3). So plant or wood specimens would usually be accompanied by examples of products illustrating possible uses, as can be seen with the walking sticks displayed in Case 67 (Fig. 2B).

Museum No. 3 opened in 1863 in Princess Augusta's Orangery, a building designed by William Chambers and dating from 1761 (Fig. 2C). The building offered the space for larger 'show' specimens; as the museum guide boasted, 'Here, their full diameter is shown, and the magnitude of many of our Colonial trees becomes the more striking' (Oliver 1866: 78). In Museum No. 3 Hooker chose to reflect the geographic principle employed in the 1862 Exhibition from which the majority of the exhibits were acquired. This catered better to the needs of the commercial visitor whose systematic botanical knowledge may have been slight, and who was more interested in geographical provenance. The collection grew such that by the 1880s Museum No. 3 had become

[1]) They were later re-arranged to reflect Bentham & Hooker's *Genera Plantarum*.

'inconveniently crowded, and the contents difficult of inspection and confused' (Royal Botanic Gardens, Kew 1886: 4). In 1883 'two light iron galleries with spiral communicating staircases' were erected, effectively creating a spatial separation of display and research specimens (Fig. 2C). Those involved in the timber trade and researchers – referred to as 'special students' – were allowed to view this reserve collection by appointment beyond public visiting times. This idea of spatial zoning was further developed with the opening of Museum No. 4 (British Forestry) in 1910 (Fig. 2D). The suite of rooms which constituted Cambridge Cottage – the space allocated for the new Museum – lent itself to a series of themed displays aimed at specific audiences. The 1902 Report on British Forestry had identified three discrete groups with varying training needs: 'working foresters', would-be land agents, and students of forestry on the newly-formed courses at Oxford, Cambridge, and Edinburgh – the future cadre of forestry experts (Committee on British Forestry 1902). The Museum reflected this by separating out displays of applied botany from more theoretical ones: Rooms 1 and 2 contained timbers, broadly separated into conifers and deciduous species, dried specimens of tree foliage and flowers, and 'photographs of isolated trees, woodland scenery, and the planting of sand dunes' (Royal Botanic Gardens, Kew 1919: 5); Room 3 was arranged according to the *Genera Plantarum* (Bentham & Hooker 1862–83), 'to assist the *student* rather than the worker of timber' (Royal Botanic Gardens, Kew 1919: 6); Room 4 was dedicated to burrs and other abnormalities, plant and animal pests, and examples of good and bad grafting; and Room 5 featured the uses of British timbers. Finally, Room 6 consisted of models of machines, photographs of forestry practices, and tools, for 'persons engaged in forest work' (Royal Botanic Gardens, Kew 1919: 129).

By 1987, however, all four museums had closed to the public. The remaining museum collection – including all the woods - was databased and rehoused in the Sir Joseph Banks Centre for Economic Botany which opened in 1990. From this point onwards, the collection became known as the Economic Botany Collection. Since 2010 the Collection has been managed by the Herbarium at Kew.

The Jodrell Laboratory

From early in Kew's history the Kew Museums held many wood specimens. As discussed above, these were used both for public display and teaching, focusing on external appearance. What of research use by Kew staff, especially in the Jodrell Laboratory? The Laboratory was established in 1876 through a benefaction from T.J. Phillips-Jodrell, as a centre for laboratory botany (Metcalfe 1976a, 1976b). Research on plant anatomy, alongside work on plant physiology and pathology, was a regular feature from the beginning of the Laboratory, commencing with D.H. Scott, the first keeper of the Jodrell Laboratory (from 1892 to 1906), who was a pioneer in the science of palaeobotany, including fossil woods. In the years 1876–1929, 400 papers and books were published by Jodrell staff, but only seven specifically concerned wood anatomy (Gregory 1976).

C.R. Metcalfe joined the Jodrell Laboratory in 1930 as a plant anatomist. Recollections of his early years confirm that wood anatomy was not well-established at Kew: there was little equipment and few chemicals; fresh sections were made, mounted and

then discarded every time wood was examined, and there was opposition from the Museum's Keeper to the cutting of woods for sections. Although Leonard Boodle, Assistant Keeper of the Jodrell Laboratory 1906–1930, was a very skilled plant anatomist, there was little emphasis on wood, or on the development of long-term projects. Overall, there was not a close relationship between the wood collection in the Museum of Economic Botany and the anatomical research carried out in the Jodrell Laboratory.

WOOD ANATOMY BECOMES ESTABLISHED 1930–1969

Metcalfe's arrival in 1930 marks the beginning of a programme of sustained research into systematic wood anatomy that continues at Kew to the present day (Fig. 3A). In his first decade (1930–1939) Metcalfe published six papers on wood anatomy, nearly as many as published in the previous five decades. Despite the pressure of war work on subjects such as medicinal plants and nettle fibres, in 1950 Metcalfe published a two-volume, 1500-page survey entitled *Anatomy of the Dicotyledons*, co-authored by Lawrence Chalk, of the Imperial Forestry Institute at the University of Oxford (Metcalfe & Chalk 1950). In this work Metcalfe focussed on leaf and young stem anatomy whilst Chalk wrote the substantial wood anatomy descriptions. Although Metcalfe's research then shifted to the anatomy of monocotyledons, wood anatomy continued to be an important tool for answering the many routine queries received by Kew.

This period saw an increase in the number of large collections received from field botanists. Notable accessions include woods from Suriname collected by Gerold Stahel of the Department of Agriculture, Arius Jacobs of the Bogor Herbarium, Java, and African woods from Edgar W.B. Milne-Redhead. Forestry institutes were another important source. Senior technicians F.R. Richardson at Kew and G.L. Franklin at the Forest Products Research Laboratory, Princes Risborough, were on good terms (Baas 2013, pers. comm.), as were anatomists Chalk and Metcalfe with Bernard Rendle and John Brazier at Princes Risborough. This facilitated exchanges of large numbers of specimens, including 400 woods from the Imperial Forestry Institute in Oxford and 267 from Princes Risborough. Networks of exchange extended beyond Britain. Under Metcalfe the fertile relationship between Kew and Harvard, which had begun with Sargent and Joseph Hooker in the nineteenth century, was further developed, and new global connections were established with S.J. Record at Yale and Herbert Dadswell at the Council for Scientific and Industrial Research (CSIR) in Australia.[2] The legacy of these relationships can be seen in Kew's xylarium today (see Table 2 below).

Metcalfe's most significant innovation in collections was the creation of a collection of microscope slides (Fig. 3B, C, D). These covered not only woods, but other vegetative and floral plant parts. Slides were, and still are prepared in the Jodrell Laboratory and also exchanged with other institutions, and therefore the slide collection draws on far wider wood collections than those represented in Kew's own collection. The microscope slide collection now numbers around 120,000, and is currently being databased by volunteers. A high proportion of the wood microscope slides have been made from Kew's xylarium samples.

[2]) Later the Commonwealth Scientific and Industrial Research Organization (CSIRO).

Figure 3. A: C.R. Metcalfe in his office in the old Jodrell Laboratory building, demolished in 1963. Portrait of D.H. Scott on the wall. – B: F.R. Richardson, who prepared most of the anatomical slides in the Jodrell Laboratory between 1934–1975; the microtome is still in use at Kew. – C: The main laboratory in the old Jodrell Laboratory, c. 1960; the wooden cases in the foreground contain the slide collection. – D: Part of the slide collection in its current fire-proof housing. – E: Compactor unit drawers housing the W2 size woods. – F: Wood anatomist Peter Gasson amidst the wood collection in the Sir Joseph Banks Building at Kew.

The shift in acquisition from exhibitions to field botanists and specialist forestry institutes is clearly reflected in a greater proportion of wood specimens being vouchered by herbarium specimens. Most older wood specimens bear no indication of whether they are vouchered, making systematic matching of woods to herbarium specimens a l arge task. It is only since the establishment of the Economic Botany Collection database in the late 1980s that the existence of a voucher specimen is recorded as a matter of routine. Metcalfe (1976a: 15–16) addressed the question of reliability of unvouchered specimens. Forty years of experience with the Kew collection led him to conclude that there were few serious errors of naming in the earlier, unvouchered collections, and this has been repeatedly confirmed by subsequent work. A case where the identification proved to be incorrect shows the importance of referring to original records of provenance. A large table top in the Kew Collection labelled as *Dalbergia nigra* (Brazilian rosewood) was examined by chemical analysis and found to be lacking dalnigrin, a marker for that species (Kite *et al* 2010). Reference to the Museum Entry Books showed that the wood was purchased in 1896 at a public auction and received tentatively at Kew as 'Bahia rosewood'. Subsequent labelling disguised the uncertain basis and ambiguity of that identification. Anatomical examination by Gasson showed the table top to be a good match for *Hymenaea*.

The housing of the wood collection in the four Museum buildings was unchanged for much of Metcalfe's time, and he recounts searching for the smaller specimens of wood, stored amongst other specimens in the glass cabinets of Museum No. 2, with doors with defective locks, and no electric light.

1969 TO THE PRESENT

Research and acquisitions

The year 1969 marked the retirement of Metcalfe, by then the Keeper of the Jodrell Laboratory. Many of the retired staff who have worked on wood anatomy since that time are still active at Kew as honorary research fellows. These include David Cutler (who joined in 1962 and was Head of Anatomy, subsequently Micromorphology, from 1969 to 1999), Hazel Wilkinson (1973–1992) and Mary Gregory (1961–1992). These three former staff and Paula Rudall (1979 onwards, Head of Micromorphology from 1999) have all contributed to one or both of the major works of synthesis that followed the original *Anatomy of the Dicotyledons*: *Anatomy of the Monocotyledons* (vols. 1–9, 1960–2003) and the Second Edition of *Anatomy of the Dicotyledons* (vols. 1–4). Kew's anatomists continue to undertake many identification enquiries, led by Peter Gasson (1979 onwards).

Collaborations, contacts and even natural disasters have helped to increase the scope of Kew's xylarium in recent years. Juliet Prior's interest in southern African charcoals led to collaborations with David Cutler on fuelwood projects and over 400 of her wood samples were added to the collection (Prior & Gasson 1990; Prior & Price Williams 1985). Peter Gasson has developed Kew's interest in woods of Brazil, and particularly concentrated on the wood anatomy of legumes (Gasson 1994, 1996, 1997; Gasson *et al*. 2003, 2004; Evans *et al*. 2006). He has also focussed on endangered timbers, especially

Table 1. Collection provenance of Kew wood collection, by TDWG World Geographical Scheme for Recording Plant Distributions region, at February 2013.

	n	%
Europe	2291	7
Africa	5670	17
Asia-Temperate	1149	3
Asia-Tropical	11332	33
Australasia	1990	6
Pacific	935	3
Northern America	2622	8
Southern America	5145	15
Region not assigned	3172	9
Total	34306	100

those listed by CITES (Gasson 2011; Gasson *et al*. 2011), such as mahogany (*Swietenia* spp.) (White & Gasson 2008) and rosewoods (*Dalbergia* spp.) (Gasson *et al*. 2010; Kite *et al*. 2010). Woods from South America make up a relatively small proportion of the collection, at 15% (Table 1), but dominate recent field collections. Gwilym Lewis and the Kew legume team have been particularly active collectors.

Since its beginnings in 1876, the Jodrell Laboratory has welcomed many guest researchers. In view of the decline in teaching of plant anatomy in UK universities, this role is increasingly important. A strong tradition of collaboration is also visible in Kew's role as contributor to international projects such as *InsideWood* and *PROTA* (Plant Resources of Tropical Africa), and as the current home of *Index Xylariorum* (Lynch & Gasson 2010), an online listing of all major wood collections worldwide. These close links to researchers in other institutions have been a major factor in significant donations of specimens from other wood anatomists, including Ken Ogata in Japan (woods of Brunei) and Luis Garcia Esteban and Paloma de Palacios in Madrid (woods of the Canary Islands).

There is a large community of amateur wood collectors, often building collections to a very high standard (rarely listed, but see for the Netherlands, van der Dussen & Miedema 2008, and the website of the International Wood Collectors Society). Donations from amateur collectors (amateur only in the sense that they were not professional wood scientists or foresters) include Sri Lankan woods collected by J.B. Worthington, a British tea planter, and world woods collected by the well-known typographer, F.H. Pierpont, and the wood technologist at Imperial College, London, L.G. Booth. The 1933 donation of 280 woods by George Bowes Loddiges added interesting eighteenth century specimens, some from Brazil and some from the Duchess of Portland's collection, originally housed at Bulstrode Hall in Buckinghamshire.

A notable feature of the last decade is that users of the wood collection are no longer exclusively anatomists. Increasingly refined analytical techniques for wood are making good progress with chemistry (Kite *et al*. 2010), DNA (Lowe & Cross 2011), spectros-

Table 2. Donations totalling over 100 woods to the Kew collection, by donor type.

Specimen numbers and collection dates are approximate. Number of specimens refers to those present in the Economic Botany Collection now; original numbers given may have been larger but some specimens were discarded prior to the 1980s, and some have lost the labelling that links them to the original donor.

Donor (Index Xylariorum code)	Number of specimens	Region	Collection dates
Institution / Expedition			
Natural History Museum, London (BMw)	2573	World	19th/20th century
Indian Forestry Department (DDw)	2305	India	19th century
Forest Department, Malaya	1007	Malaysia	1950s
Smithsonian, USA (USw)	791	North & South America	1960s
CSIR / CSIRO, Australia (FPAw)	723	Australia & Pacific	1960s–1970s
Yale Firestone Expedition	448	Liberia	1931
Imperial Forestry Institute, Oxford (FHOw)	400	World	1950s–1960s
Burma Forestry Department (ARw)	376	Burma	1920s, 1930s
Fairchild Tropical Botanic Garden, USA	334	South America	1990s
Xylotomotheca Italica	298	Italy	1900s
Victoria & Albert Museum, London	278	India	
Imperial Institute, London	276	World	1920s
Forest Products Research Laboratory, Princes Risborough (FPRLw)	267	World	1920s–1950s
North Borneo Forestry Department	236	Borneo	1950s
Naturalis, Nationaal Herbarium Nederland, Leiden (Lw)	217	Indonesia	1960s
Departments of Agriculture & Interior, Washington, DC	158	United States	1870s
CEPEC, Bahia, Brazil (CEPECw)	136	Brazil	1960s–1980s
Forest Products Laboratory, Madison (MADw)	134	World	1970s
Forest Herbarium Ibadan, Nigeria (FHIw)	125	Nigeria	1950s
India Museum, Calcutta / Kolkata	125	India	to 1885
Royal Botanic Garden, Calcutta	118	India	1867
Field Museum of Natural History	107	South America	1970s–1980s
Kribi Herbarium	106	Cameroon	1990s
Technical Museum, Sydney	104	Australia	1890s
Exhibition			
Paris Exhibitions	501	World	1855–1900
1862 International Exhibition, London	398	World	1862
1924 British Empire Exhibition, London	381	World	1924
Japan-British Exhibition, London	164	Japan	1910
1886 Colonial and Indian Exhibition, London	154	World	1886
Commercial			
American Colony Store, Jerusalem	198	Near East	1920s
Earl of Yarborough	111	United Kingdom	1900s

(continued on next page)

Botanists (Professional)			
Gerold Stahel, Surinam	688	Suriname	1942–1945
Ken Ogata	512	Brunei	
Lionel G. Booth, Imperial College	474	World	1960s–1980s
Juliet A. B. Prior, London	445	Swaziland	1980s
Phyto Chemical Survey Malaya	275	Malaysia	1960s–1970s
Oxford University Tanganyika Expedition	246	Tanzania	1958
Marius Jacobs, Leiden	244	Malaysia	1950s
Henry Nicholas Ridley, Singapore	239	Malaysia, Singapore	1880s–1890s
John Carrick, Singapore	233	Malaysia	1950s–1960s
André J. G. H. Kostermans, Bogor	220	Indonesia	1970s
Charles Sprague Sargent, Harvard	167	United States	1880s
Raulino Reitz, Santa Catarina, Brazil	151	Brazil	1940s–1970s
Allen Hiram Curtiss	125	United States	1880s
W. E. Broadway	110	Caribbean	1920s
Rudolph H. C. C. Scheffer, Bogor	109	Indonesia	1870s
Luis García Esteban & Paloma de Palacios de Palacios, Madrid (UPMAw)	102	Canary Isles	2000s
M. T. Dawe, Angola	101	Africa	1920s
Botanists (Amateur)			
Thomas Berkeley Worthington, Sri Lanka	668	Sri Lanka	1938–1956
Frank Hinman Pierpont, Redhill, UK	392	World	
George Bowes Loddiges, London	280	Jamaica, Brazil	18th / early 19th century
Botanists (Kew)			
Mark J. E. Coode	219	Brunei	1970s–1990s
Edgar W. B. Milne-Redhead	186	Africa	1930s
Gwilym P. Lewis	182	South America	1980s–1990s
Joseph Dalton Hooker	148	Himalayas	1850s
1987 Storm, Royal Botanic Gardens, Kew	104	United Kingdom	1987

copy (Braga *et al*. 2011) and stable isotope analysis (Kagawa & Leavitt 2009). The wood collection is available to external researchers both through an active programme of exchange of wood anatomy slides (and to lesser extent of wood specimens), and through supply of wood for destructive methods of analysis.

The wood specimens are also used by researchers in the arts and humanities; for example, in the history of wood, whether archaeological (Gale & Cutler 2000) or nineteenth century (Bowett 2012). Caroline Cornish's PhD thesis (2013) takes the wood collection as a case study for the broader history of Kew's museums. Wood samples can be highly attractive and are regularly lent for display in exhibitions.

Storm woods

'Every cloud has a silver lining': on 16 October 1987 Kew and Wakehurst were among the arboreta and gardens in southeast England that were damaged by the 'Great Storm'. This storm was only a month after the publication of an identification manual for tree roots (Cutler *et al*. 1987), which was written in response to the need to identify

tree roots implicated in damaging building foundations, especially on the shrinkable London Clay. If the roots from a neighbour's tree were damaging the foundations of a house, and it could be proven, then they were responsible for the cost of repairs. The 'Great Storm' provided Kew's anatomists with the opportunity to collect wood and root samples from the many trees felled in the storm, to undertake a windblown tree survey (Cutler & Gasson 1988; Cutler *et al* 1989), dendrochronological work (Cutler *et al*. 1993; Bridge *et al*. 1996) and to add knowledge of the roots of another 16 genera not covered by the root book (Gasson & Cutler 1990a, 1990b). Another storm in January 1990 added further material, and in September 1992, following Hurricane Andrew in southern Florida, Peter Gasson collected many wood and root samples at the Fairchild Tropical Garden in Miami as part of the process of clearing up the garden (Gasson 1993; Gasson & Cutler 1996).

Institutional transfers

The largest single accession of woods into the Economic Botany Collection came to Kew from London's Natural History Museum in 1983 (at the time it was still known as the Natural History Department of the British Museum, abbreviated to BM (NH)). The Museum was closing down its Acton store, and offered Kew first option on the woods. The Kew accession register records that 'hundreds of wood specimens' were selected by Kew Museum staff from the British Museum's stores ; in fact the total was closer to 2,500 specimens, with the remainder going to Liverpool's World Museum (Edmondson *et al*. 1989).

The specimens, mostly of standard reference collection size, are well-provenanced and presented. They cover most regions of the world and two date from Sir Hans Sloane's collection which led to the foundation of the British Museum. Other early specimens include Robert Brown's woods collected in Australia on the Flinders Expedition of 1801–1803; at the other end of the chronological spectrum are those from botanical fieldtrips of the twentieth century, such as Iltis and Koeppen's Mexican expedition of the early 1960s. This acquisition enabled Kew to expand its geographical range – particularly of North and South American woods - and to extend its chronological range back in time to the seventeenth century.

Kew has recently received a large number of wood specimens – not yet accessioned – from the closure of the Forensic Science Service laboratory in London, and it is likely that institutional reorganisations will continue to be a source of specimens.

Housing and curation

In the context of the British Empire, Kew's Museums of Economic Botany were considered to be at the forefront of utilitarian science. However, by the Commonwealth era of the 1950s the Museums were seen as old-fashioned and Kew's Director, Sir George Taylor, wished to take the Orangery (Museum No. 3) back to its original purpose in time for Kew's bicentennial celebrations in 1959. The closure in 1958 of Museum 3, which contained the tropical woods, including many massive specimens, led to a space crisis. In response, about 2000 ethnographic artefacts were given to the British Museum, the Horniman Museum and the Pitt-Rivers Museum. A large number

of timber specimens was despatched to the Forest Products Research Laboratory at Princes Risborough, including a spectacular block of Douglas Fir wood weighing about five tons which was subsequently cut down at the Laboratory and used in special testing work.[3] Some of the specimens previously in the galleries of Museum No. 3, mainly those approximately 1 metre in length, remained initially in the annexe of the building as a reference collection, along with the conifer collection. The smaller woods were transferred to the top floor of Museum No. 1, with this floor now closed to the public and used as a store. Some of the colonial woods, principally planks around 2 metres in length, were moved to Museum No. 4, which now became known simply as the Wood Museum. They were accommodated by 'modifying and reducing' the collection of British timbers there (Royal Botanic Gardens, Kew 1960: 14). The decision was made to concentrate on commercial woods – those imported or used in the woodworking industries. They were now arranged geographically, 'with some emphasis on the Commonwealth countries' (Royal Botanic Gardens, Kew 1960: 14), an arrangement thought to best suit the most frequent group of visitors to the Museum, 'carpentry or wood-work instructors with their classes of boys'. The specimens were all uniformly re-labelled to emphasise the properties of the various species, and the Museum continued to enlarge this part of the collection in the post-war period.

In 1960 Museum No. 2, containing monocotyledons (and thus the 'wood' of monocots such as palms) was also closed to the public, but it remained intact as a museum store. Following the closure of Museum No. 2, a plan had been put in action to catalogue and order the wood collection and this progressed steadily. In 1968 the reference wood collections were re-united when those in the annexe of the Orangery and those stored in Museum No. 1 were all re-housed in Museum 2, often referred to at this time as the 'Reference Museum'. A second round of closures took place in the 1980s, in response to the need to extensively restore the buildings and use them for other purposes. A purpose-built research store was constructed as part of the Sir Joseph Banks Building, with an internal area of 500 m^2, and in the late 1980s the specimens in Museum No. 2 and the Wood Museum (No. 4) were moved in and databased (Fig. 3E, F).

The wood specimens are arranged in four size classes: W1 (smallest, height <7 cm, width <10 cm, 7,037 specimens), W2 (book-sized, height <25 cm, width <12 cm, 25,498 specimens), W3 (medium-sized, maximum dimension 30 cm, 917 specimens) and W4 (large exhibition pieces up to 200 cm tall, 862 specimens). Within each size class, the specimens are arranged by family in the same taxonomic order as used in the former Kew Museum, the Bentham and Hooker system. Within each family, the genus and species are arranged alphabetically. The smallest specimens (W1) are stored in nine-drawer Bisley cabinets; the largest (W4) are propped upright in wire cages on compactor units. The intermediate specimens (W2, W3) are kept in drawers in compactor units (Fig. 3E). The 34,314 specimens classified as woods (at March 2013) are robust and further packaging or support is not required. There are a further 3,299 specimens

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[3]) In 1988 the Forest Research Products Laboratory and its wood collections were taken over by the Building Research Establishment (BRE) at Garston where they can currently be consulted.

made of wood that are housed in the main run of the Collection. These comprise artefacts made from wood or wood specimens that are spiny, fragile or otherwise in need of packaging, typically in acid-free boxes. Thus, searches for wood specimens must be made across the whole collection, not only the part designated as wood specimens.

Wood specimens are vulnerable to insects and mould. All the woods transferred to the Banks Building in the 1980s were frozen first, and new accessions are frozen at -30 °C for a week. In practice, the Kew woods show almost no evidence of past or recent infestation. The other portion of the Economic Botany Collection – medicines, foods, baskets etc. – was not frozen, as an economy measure, and was immediately infested with the biscuit beetle, *Stegobium*. While this has been brought under control, by lowering the temperature of the store (initially to 11 °C, now 14 °C), all specimens (including woods) are frozen before exit from and re-entry to the Collection, to minimise the (already low) risk of any spread. Mould has caused more damage, during two short periods when the air-conditioning unit broke down over summer weekends, and relative humidity exceeded 70 %. A few woods now show signs of mould on their end grain. Relative humidity is usually maintained at 45–55 % and there have been no further problems with mould.

There are two accession records for each specimen. The earliest, implemented as a continuous series since 1847, is the Museum Entry Book. This series of books records acquisition events each year; for example, 12.1859 is the twelfth group of specimens to be accessioned in 1859. Museum labels usually bore this number, thus connecting specimens back to museum registers. In many cases this has been lost, but can usually be retrieved if the specimen bears year or donor data. The second series of accession records is the Economic Botany Collection database (Royal Botanic Gardens, Kew 2011). In this, each specimen (not only woods) is allocated a unique running number (starting with 1, currently at 92000). We agree with those who have argued that the collector name and number of the herbarium voucher specimen is the most desirable unique identifier of a wood specimen (Baas 1980; Barker 2008), and this information is indeed recorded in the Kew database when available. Nonetheless, many older wood specimens have no voucher specimen or incomplete collection data, and thus require a unique identifier to be allocated. In addition, the Kew catalogue number is an unambiguous identifier for collection management. Best practice in citing Kew specimens is to give both the Kew catalogue number (in the format EBC 00000) *and* the collector name and number, where available. Genus and family names are standardised against Brummitt (1992) but only incomplete efforts have been made to update botanical names when they are changed for nomenclatural or taxonomic reasons. It is therefore essential to search the database for specimens by synonyms as well as accepted name.

In addition to Museum Entry Books and the Collection database, further information about specimens can be found in lists held in the curation office, and in letters and papers held in Kew's Archives. Although these are as yet largely uncatalogued, good progress has been made in finding relevant files. Kew's Library has good holdings for forest botany, plant anatomy and forestry, including many books directly related to wood specimens held at Kew.

CONCLUSIONS

Kew's history shows that there is an intimate link between the activity of a wood collection, as measured by acquisition of specimens and enhancement of collection records, and its use by researchers. Kew is one of the few 19th century collections to have a continuous history of growth and use. Kew has employed one or more plant anatomists since 1906, and some of them have specialised in systematic wood anatomy, for which comprehensive wood collections are vital. The presence of specialist anatomists is visible in their influence on collecting by Kew botanists, and the role of their research connections outside Kew in bringing visiting researchers, and donations of woods to Kew.

Long-term staffing patterns are hard to predict, but the future of two aspects of curation is more within grasp.

Firstly, there is the development of a proactive acquisitions policy. It is clear that, while Kew's work over the last 50 years in Brazil is well represented in the wood collection (and in wood anatomy research), this is not the case for equally active fieldwork carried out in Africa, southeast Asia or Madagascar. Whereas woods from the first two regions are at least well-represented in Kew's historic collection, they are not for Madagascar. Of course woods from these regions are held elsewhere, for example Tervuren, Belgium (Africa), Montpellier, France (Madagascar) and Leiden, The Netherlands (Suriname, Indonesia), but a major strength of Kew's botanical holdings is that they are global in scope. Filling the gaps will require closer liaison with field botanists in these regions. At the same time, Kew will continue to incorporate other wood collections as the trend to greater consolidation of collections in Europe and North America continues.

Secondly, there is the question of closer integration with other collections, by digital means. In part this relies on digitisation of other collections, such as herbaria containing voucher specimens, or wood collections from which Kew holds duplicates. However, although Kew's wood collection is catalogued and online, many woods are catalogued under synonyms. Updating these to accepted names is important both for improved searching, but also because it is an essential precondition of any rearrangement of the Collection. Kew's herbarium, like many others, is being reorganised into the DNA-based family sequence proposed by the Angiosperm Phylogeny Group; at some point in the future the wood collection may be rearranged too.

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