CHAPTER THREE

Trade and Exploration

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Plant exchange has a long history, accelerating in the fifteenth to eighteenth centuries—the period of the Atlantic world, during which slavery and the cultivation of sugar cane (Saccharum officinarum) in the Americas drove transatlantic exchanges (Bleichmar 2008; Carney 2001; Schiebinger 2004; Schiebinger et al. 2007). However, as this chapter shows, the nineteenth century saw a significant increase in the scale of plant exchange, and in the degree of conscious design applied to it. Colonies of Britain, Germany, France, and the Netherlands became subject to stronger central control, a change in style of government also reflected in the increased capability of federal institutions in the United States. Scientific infrastructure, in the form of museums and botanical gardens, entered its modern form, benefiting too from the widespread use of Linnaean nomenclature for plants, and the development of new analytical techniques in genetics and plant chemistry. Improved transport links, particularly the widespread use of steamships from the 1860s, and the use of the Wardian case to protect plants during transit, meant that few parts of the world were closed to plant explorers. Plant exchange was also affected by wider political changes, above all the abolition of slavery—as early as 1834 in Great Britain’s colonies, though as late as 1888 in Brazil—leading to fundamental changes in the organization of plantation agriculture.

Commerce and industry were the main reasons for plant introduction. Plants formed the basis not only of food and clothing, as they do today, but of materials such as wood, rubber and gutta percha, and medicines (Drayton 2000). While economic historians disagree on the underlying drivers of change—free trade, population increase, increase in consumption, banking, state regulation, technological developments, and transport are among the many factors cited—they agree that the nineteenth century was a period of exceptional growth in industry and trade, and thus of consumption of plant raw materials (Federico and Junguito 2016; Lee 2006). Commerce thus enlarged the market for plantation crops such as rubber or cinchona, often introduced to regions where they were not previously grown, and often for reasons of imperial preference.

In retrospect, global plant-exchange in the nineteenth century can appear to be the result of a well-organized system (Brockway 1979; Hobhouse 1985). However, a more nuanced study of the motivations of those involved, and of the operation of the infrastructure available to them, points instead to the importance of context and contingency. Plant introductions often—perhaps even usually—failed. The history of plant introduction, as written, has tended to focus on the success stories. In this chapter plant exchange is examined in its wider context, largely using examples from Britain and its empire, but drawing attention to comparable developments elsewhere.
INFRASTRUCTURE

Plant exchange depends on infrastructure and logistics: botanical gardens to act as staging posts and places of acclimatization; herbaria and libraries as centers for plant identification, and museums of economic botany to demonstrate the connection between plant raw materials and plant products. Recent research has found complex flows of knowledge and plants between these, emphasizing frequent interactions between commerce, in the form of plant nurseries, or industries based on plant products, and government institutes and departments (Pawson 2008; cf. Coote et al. 2017). Examples such as the transplantation of rubber and cinchona are well documented cases in which much of the necessary science was carried out far away from London, in Singapore and India respectively. Even the great international exhibitions were often preceded by local exhibitions, sometimes very elaborate, of the specimens gathered together for a national display (Modest 2018). Understanding the processes of trade and exploration in the nineteenth century demands looking beyond the metropolitan centers of Europe and North America.

The Botanical Garden

The first botanical gardens arose as medicinal-plant gardens, associated with medical schools, in the sixteenth century. However, as Donal McCracken (1997) argues, the modern form of garden, usually much larger, and acting as a base for plant exploration and research, is an Enlightenment creation, becoming prominent in France and Britain in the early to mid-eighteenth century, at the Jardin du Roi, Paris and the Royal Botanic Gardens, Kew. In the forty years up to 1837, some twenty-two botanical gardens had been founded (and in some cases closed) in the British Empire; by comparison, some one hundred operated there during the Victorian era (1837–1901).

In Britain the Royal Botanic Gardens, Kew (known for most of the nineteenth century simply as the Royal Gardens, Kew) dominated plant exchange involving Britain from the founding of its “Physic Garden” in 1759, but in two very different periods. Georgian Kew was a royal garden, though one run effectively as a national botanical garden from 1782 to 1820 under the control of King George III and Sir Joseph Banks (1743–1820). After their deaths in 1820 the Gardens went into decline, being re-founded as a government botanical garden in 1840, and funded by the Ministry of Works. A large part of the rationale for its new funding was “the promotion of Botanical Science throughout the Empire,” in particular through coordinating the work of colonial gardens (Cornish 2013, 2015; Desmond 2007; Lindley 1840). Large gardens such as those at Kew, in Paris, or Berlin, were closely linked to botanical gardens in overseas parts of the empire, some equally large, such as Calcutta (now Kolkata), many small. These overseas gardens were locally funded, usually by the local legislature or governor, but in the case of those founded by the British, maintained their close relationship to Kew through their staff, usually recruited from there. The overseas garden gained a trained and tested member of staff; Kew gained an excellent conduit for plants. Botanical gardens were nodes in a global system of plant circulation, from the 1840s via the Wardian case, but were also centers of acclimatization, in which newly introduced plants could be tested for their adaptation to local conditions.

Throughout the world, botanical gardens had similar facilities. Most gardens had ornamental parts, open to the public, and featuring lakes, lawns, and avenues of trees. Glasshouses protected warm-temperate and tropical plants, offering many people their
first and only opportunity to experience tropical nature (Arnold 2006; Driver and Martins 2005). Behind the scenes, plant nurseries raised plants for sale—an important route for newly arrived plants to reach a wider public. A remarkable 174,230 plants were distributed by the botanical gardens in Jamaica in 1884, for example (Taylor, D. 2017). There was often tension between the ambitions of the garden staff, and those of the local government. The annual reports of botanical gardens often give a very frank view of these: for example, in Jamaica funding was inadequate until the imposition of government control by London in 1865 following the Morant Bay rebellion. Plantation owners pressed unsuccessfully for greater support for the sugar estates, ruined by the collapse in sugar prices of the 1820s, while the Botanical Department instead focused on the smallholding class of farmers who had formerly been enslaved. In Jamaica, as elsewhere, staff found themselves torn between their desire to carry out scientific work, such as collecting herbarium specimens and cataloging the wild plants of the country, and the requirement to meet immediate needs for farmers and gardeners (Nesbitt 2018). Botanical gardens also played an important role as a base for visiting plant collectors. It should not be assumed that bioprospecting—the hunt for new plants for practical purposes—was the only or even the main driver for plant collecting in the nineteenth century; botanists’ travels to the tropics and to islands were in part driven by, and had a profound effect on, the understanding of evolution and biogeography, exemplified by the work of Alexander von Humboldt, Robert Brown, Charles Darwin, Alfred Wallace, and Joseph Hooker (Browne 1997; Driver and Martins 2005; Sutter 2014; Wulff 2015).

Toward the end of the nineteenth century, government agricultural departments established specialist seed-storage facilities, the forerunners of today’s seed banks. The two largest were those of the United States Office of Foreign Seed and Plant Introduction founded in Washington, DC, in 1898, and the Bureau of Applied Botany in St. Petersburg,

Russia, founded in 1894. These closely resembled botanical gardens in the range of facilities, including nurseries and herbaria, but focused on crops and their wild relatives, and on distribution of seeds rather than plants (Dierig et al. 2014). They evolved in a different direction from botanical gardens, becoming in the twentieth century the modern germplasm repository with its banks of frozen seeds.

Societies played an important role in representing growers interested in plant exchange, whether of ornamental or economic plants. These included the Horticultural Society of London (founded 1804), the Agricultural and Horticultural Society in Kolkata (1820), the Société Zoologique d’Acclimatation in Paris and Algiers (1854), and the Acclimatisation Society of Victoria in Melbourne, Australia (1861) (Anderson 1992; Gillbank 1986; Osborne 1991, 2000). Such societies worked closely with government, but were able to act independently, often in reaction to what was characterized as colonial government’s insufficient emphasis on applied science. Many ran their own botanical garden, and their publications reached homes and farms.

The Commercial Nursery

In the nineteenth century there was far greater exchange of plants between botanical gardens and commercial nurseries than there is today; now the mission of botanical gardens has moved away from ornamental plants, and the Convention on Biological Diversity imposes restrictions on commercialization of collections (McCork 2016). By contrast, in the nineteenth century Kew exchanged plants with commercial nurseries all over Britain, including the famous ones of Backhouse and Sons (1816–1950) in York, and the Loddiges and Veitch families in London (Alcorn 2020; Gorst 1976). These operated on a substantial scale, sending their own plant collectors overseas, and also following scientific practices, as in the collection of herbarium specimens in Australia by James Backhouse (1794–1869), and economic botany specimens in Japan by John Veitch (1839–70), collections both now deposited at Kew. Similar close relationships continued into the late nineteenth century with plant explorers such as Ernest H. Wilson (1876–1930) collecting plants for the Arnold Arboretum in Massachusetts, while at the same time for commercial nursery firms in Boston and New York.

The Herbarium

Like the botanical garden, the herbarium—a repository for pressed, dried plant specimens—originated in Italy in the sixteenth century. Working herbaria often remained the property of the collector, as in the case of the herbaria of Sir Hans Sloane (1660–1753) and Sir Joseph Banks, both of which collections were deposited in the British Museum only after their owners’ deaths. Sir William Hooker’s herbarium and library remained his private property even after he became director of Kew, only becoming part of Kew’s collection after his death in 1865. During the nineteenth century very large institutional herbaria began to form, requiring purpose-built housing. This was sometimes in botanical gardens, as in Paris (1835) or Kew (1876), sometimes in a city center museum, as at the Natural History Museum, London (1881). Only a proportion of specimens in such a herbarium were collected by its staff; most came by exchange and donation with global networks of collectors. The historian Jim Endersby (2008) has studied the maintenance of these networks during Sir Joseph Hooker’s tenure as Kew’s Director (1865–85). There was a delicate balance between encouraging the inward flow of specimens, while at the same time maintaining control of specimen naming, essential to avoid “splitting” of
local variants into new species. In addition to supplying names for specimens, Hooker carried out many favors for donors, including the supply of books and equipment. Some botanists were paid to collect on Kew's behalf. When Richard Spruce (1817–93) went to the Brazilian Amazon, George Bentham (1800–84) acted as his agent, selling specimens on his behalf to herbaria. Spruce was able to support himself for fourteen years collecting in South America from 1849 to 1864 (Hemming 2015).

**Museums and Exhibitions**

In 1847 Sir William Hooker (1785–1865) opened the Kew Museum of Vegetable Products, in 1852 renamed the Museum of Economic Botany. The museum was distinctive in its emphasis on plant use ("economic" in this mid-nineteenth century context meant practical, or useful), and on the processes that attend transformation from living plant to finished product (Cornish 2013, 2017). It made much use of the "illustrative series" of specimens that started with raw material, showing the tools and half-made object, and ending with the commercial product. The Museum was aimed both at the general public and, more specifically, at British manufacturers seeking advice on plant raw materials. The supply chains from distant lands such as the Andes or the Far East were such that important products such as cinchona bark (Cinchona calisaya) or rice paper pith (Tetrapanax papyrifer) were still of uncertain botanical identity at this time. Kew acted as a source of reliable information, in close collaboration with the brokers of the City of London, who could advise on price and industrial quality.

Like the herbarium, the museum played a vital role in naming and authenticating plant material. It also acted as a center of circulation in its own right: the museum at Kew had accumulated about seventy-five thousand specimens by 1914, but had also distributed fifty thousand specimens to other museums, receiving many in exchange (Cornish and Driver 2019). The Kew Museum was much imitated, and over forty galleries or free-standing museums of economic botany have been identified in Great Britain alone; among the many surviving international museums were those in Adelaide (1864), Berlin (1878), Harvard (1838), New York (1891), and Missouri Botanical Garden (1860), mostly founded in the period 1850–90 (Cornish and Nesbitt 2014). It was Sir William Hooker's view that a botanical garden should comprise gardens, a herbarium, and a museum, the latter showing "all kinds of useful and curious Vegetable Products, which neither the living plants of the Garden, nor the specimens in the Herbarium could exhibit" (1855).

Museums of economic botany (Mackenzie 2009; Sheets-Pyenson 1988) were connected to a much wider museum network, including natural history museums, newly established museums in the colonies, and international exhibitions (World's Fairs). Although each of the last was shortlived, the sequence of international exhibitions that begins with London's Great Exhibition of 1851 and perhaps ends (in terms of significant botanical exhibits) with the British Empire Exhibition (1924–5) was important in disseminating knowledge of plant products in trade. Such exhibitions usually featured large-scale displays of plant products, acting as both a trade fair connecting exporters and importers, and promoting products direct to the public (Hoffenberg 2001). Visitor numbers were large: London's Colonial and Indian Exhibition of 1886 was attended by 5.5 million people. The impact of such exhibitions was increased by the dispersal of their exhibits to museums and, thus, permanent display after the exhibition closed: for example, the founding economic botany collections of the Field Museum in Chicago derive from the World's Columbian Exposition of 1893.
TRANSPORT

Improvements in transport played a crucial role in expanding geographical reach. Sea travel became more reliable after the end of the Napoleonic Wars (Daws et al. 2007), and an extensive network of ships regularly sailed directly to British ports, for example from Manaus on the Amazon to Liverpool. Steamships came into use in the 1830s on mail routes, and were widespread by the 1860s. Previously, the sea journey from England to India took five to eight months by the Cape route; from the 1850s a combination of rail and steamship, crossing Egypt, took a month, reduced still further after the Suez Canal opened in 1869. As well as speeding the transport of living plants, steamships had a major impact on the cost of plant products (Headrick 1981). From the 1860s cheap cereals from Russia, eastern Europe, and the United States reached Britain, leading to a halving of wheat prices over a thirty-year period, with severe effects on British agriculture (Cain and Hopkins 2016; Offer 1999). Building of railways often went hand in hand with the development of new agricultural areas, but these routes were usually less useful to the plant explorer.

Fieldwork continued to rely on the hire of porters and horses or mules. Plant collecting still took botanists into extremely difficult terrain, often only accessible with assistance from local guides. Once fresh plant material had been collected, it needed to be transported to a botanical garden for cultivation and propagation. In the case of seeds that retain viability after drying, this was relatively straightforward. However,
the seeds of many species, especially those from the tropics, are “recalcitrant,” a term used by seed scientists to describe seeds that die when dried. And in any case, the newly encountered plant might not be bearing mature fruits. However, transport of living plants by sea is far more challenging, with death through salt-water spray, lack of fresh water, extremes of weather, and the depredations of animals onboard ship. Many plants—and sometimes entire collections—were lost in the eighteenth century (Keogh 2017; Parsons and Murphy 2012; Rigby 1998). Only well-funded journeys, such as those sponsored by Sir Joseph Banks, could afford a greenhouse on deck. These problems were resolved in the 1830s, when Dr Nathaniel Ward (1791–1868), a physician and naturalist in London, developed the Wardian case, a highly portable wood and glass greenhouse (Keogh 2019, 2020; McCook 2016). It was designed in collaboration with the commercial nursery of Loddis and Sons, and was first tested by sending two cases of Loddis’ plants to Australia in 1833, and bringing Australian plants back in 1834. The Wardian case was rapidly adopted, for example in the successful transfer of the Dwarf Cavendish banana (a cultivar of Musa acuminata) from the Duke of Devonshire’s garden at Chatsworth, England to Samoa in 1838. The plants survived the seven-month journey, and their cultivation spread widely through the Pacific (Simmonds 1959).

GOVERNMENT AND EMPIRE

In broad terms, nineteenth-century trade in plants was driven by the requirement of large-scale industry, in developed countries, for cheap, reliable supplies of raw materials (Drayton 2000). These could be made into more expensive manufactured goods and be exported to world markets (Johnson 2003). However, then, as now, the creation and maintenance of the necessary worldwide networks was not straightforward. Two factors helped: the easy availability of capital after about 1800 in the financial center of London, which funded many of the global developments in transport and agriculture, and the large-scale migration of Europeans, to be farmers themselves, or to supervise plantation agriculture. Over six hundred thousand people left Great Britain between 1815 and 1850 (Cain 1999).

The mutual influence of trade and empire is complex and much debated by historians (Cain and Hopkins 2016; Porter, A. 1999). Globally, the Spanish empire was in decline, but the British, Dutch, and French maintained substantial colonies, joined by Belgium and Germany after the Treaty of Berlin of 1884–5 divided up Africa between the European powers. In Britain the nineteenth century saw the expansion of empire despite the loss of the American colonies in 1776, with a reorientation from the West Indies to Africa, Southeast Asia, and India. The same period also saw increasingly centralized control of empire; in Britain the first ministry for War and the Colonies was established in 1801, in 1854 divided into the Colonial Office and the War Office. British India had been administered by a commercial enterprise, the East India Company, but from 1858 by the British government’s India Office. The large volume of correspondence with these departments in the archives of the Royal Botanic Gardens, Kew, shows how closely botany and empire were sometimes connected. In the cases of tea, cinchona, and rubber, the East India Company or India Office played crucial roles in their transfer and introduction.

However, empire was not an exclusive frame for plant trade and introduction. Throughout the nineteenth century the empire accounted for about a third of overall exports from Britain, and just under a quarter of imports of primary products such as grain, cotton, timber, sugar, tea, and indigo (Cain 1999). From the 1840s onwards, a
strong impetus for free trade in Britain led to reduced tariffs and freedom to choose the cheapest supplier. This reduced sugar imports from the West Indies and timber imports from Canada. In large parts of the world—China, Thailand, Latin America—British trade and influence, often backed up by the threat of military force, was so extensive that historians have termed them "informal empire" (Lynn 1999; Osterhammel 1999). Although the concept of informal empire is much debated, these regions often had similar advantages to the formal empire in terms of contacts and access for the traveler and trader.

While the commercial impetus was predominant, humanitarian concerns were increasingly visible and sometimes effective (Porter, A. 1999). Britain abolished the slave trade in 1807 and emancipated its enslaved in 1834, with a severe impact on the profitability of the West Indian sugar plantations, as freemen left plantations for their own small-holdings. However, Britain replaced West Indian sugar with imports from Cuba and Brazil, both of which still depended on slavery. "Legitimate commerce" sought to replace slavery, where it survived, by trade. David Livingstone's Zambezi expedition (1858–64) to modern-day Mozambique was unsuccessful in this aim, but other missionary and commercial endeavors, in West Africa, led to the establishment of a thriving oil palm (Elaeis guineensis) industry by the 1850s (Dritsas 2006, 2010; Olabintan 2013).

Plantation agriculture of rubber, coffee, tea, and cinchona in Southeast Asia depended on slavery's replacement, indentured labor (Johnson 2003). Concerns for the rights of workers and indigenous peoples were strongly expressed in European countries, and sometimes supported by colonial governments, but had limited effect in remote rural areas. Two notorious examples are associated with rubber: Julio César Arana's Peruvian Amazon Company, responsible for the deaths of some thirty thousand rubber collectors on the Putumayo river of the Amazon region between 1908 and 1913, and King Leopold II's Congo Free State, in central Africa, which saw the death of well over a million rubber collectors in central Africa between 1885 and 1908 (Loadman 2005; Stanfield 1998; Tully 2011). In both cases prolonged pressure in Europe was necessary to end these practices.

GARDEN PLANTS

The nineteenth century saw major changes that increased the consumption of introduced ornamentals: technological changes such as easily available plate glass for greenhouses, and social and economic changes, which meant there were more of the rich and middle class who could afford exotic plants. Furthermore, there was simply more space for garden plants, with ambitious planting schemes in public parks, cemeteries, and hospitals as well as homes (Billston 2008; Elliott 1986; Wimmer, Chapter 7 of this volume). An increasingly professional class of gardeners had excellent access to information through journals such as the Gardeners' Chronicle. Two groups of plants illuminate the story of ornamentals. First, orchids for their extraordinary and much publicized stories and, second, trees for their visual impact. Both illustrate the importance of commercial nurseries in trade and introduction of garden plants.

Orchidmania

More than every other plant, orchids exemplify the intersection of infrastructure, commerce, and desire that drove—and drives—the acquisition of new garden plants. Although the competitive acquisition of large numbers of exotic plants was well established in eighteenth-century gardens, such as that of the Marquess of Bute at Whitton, orchids
FIGURE 3.3 Flowers of Cattleya labiata gaskelliana. Illustration from Reichenbachia: Orchids illustrated and described, by the nurseryman Frederick Sander (1888–94). Courtesy of New York Public Library.

came late to the scene. The first tropical orchid flowered in Britain in 1728 and, as Jim Endersby has argued, orchids could only become popular with the wide availability of greenhouses after 1800, aided by advances in shipping, and—crucially—in the numbers of very wealthy patrons (Endersby 2016; Reinikka 1995). Successful cultivation also depended on improved scientific knowledge of the orchid’s original environment, and on horticultural experimentation to replicate these. By the 1840s both the technology and knowledge was in place for successful imports by the Wardian case, and successful cultivation of tropical orchids outside the tropics.

The main source of tropical orchids in Britain was commercial nurseries, such as the Royal Exotic Nurseries, run by the Veitch family, and those of Conrad Loddiges, and Benjamin Samuel Williams of the Victoria and Paradise Nurseries, all in London, and Frederick Sander of St Albans, Hertfordshire. Arrangements for collecting orchids in tropical America and Asia, and then ensuring their transport to Europe was complicated. Some collectors were employed directly by nurseries, while consignments of orchids were also imported on a speculative basis for auction, often at Messrs Stevens of King Street, Covent Garden in London. Orchids could be extremely expensive at first importation: a single orchid is said to have been sold at auction for 650 guineas. Endersby notes that the first example of the Indian orchid, Cyripediump (i.e. Paphiopedilum) spicarium sold in London in the 1870s for over £250; within a year plants were selling for two shillings (ten pence), a tiny fraction of the original price. Other notable introductions included Cattleya labiata, first sent to Britain in 1818 by William Swainson (1789–1855),
who had found it in northeastern Brazil, and reintroduced (after some confusion over its area of origin) by Sander in 1891, and *Dendrobium phalaenopsis* (i.e. *D. bigibbum*), also collected in 1891, in New Guinea by the prolific commercial collector Wilhelm Micholitz (1854–1932). While plants could now be grown in Europe, propagation was much more difficult, and very large numbers of orchids were therefore collected from the wild to supply the sizeable middle-class market. Benedict Roezl (1823–85), a Czech plant hunter, collected many thousands of orchids in the Americas for Sander, and “discovered” eight hundred new species in a forty-year career. One Roezl shipment alone, in 1873, was of a hundred thousand orchids; another was of 10 tons of cacti. However, as the nineteenth century came to an end, there were fewer new territories to explore for new orchids, and nursery cultivation became more advanced, leading to a decline in the mass harvesting of wild orchids.

**Trees and Shrubs**

The idea of the arboretum arose in the eighteenth century but became most popular from the 1830s, inspired in part by Loudon’s *Arboretum et Fruticetum Britannicum* (1838) and the garden designs of Humphry Repton (1752–1818). Well-known arboreta in Britain, such as Derby Arboretum (1840) and Westonbirt (1828), existed alongside ambitious arboreta overseas, such as the Segrez Arboretum near Paris (1856), with 4,267 species of tree, the Spath Arboretum near Berlin (1876), and the Arnold Arboretum near Boston, Massachusetts (1872). Arboreta were also established in many colonial gardens. Often arranged taxonomically, with the trees of the same genus or family planted in proximity, the scientific organization of many arboreta in the British Isles sat within planting that reflected the “cultural status of trees in British myth, culture and society, estate economy and changing fashions in landscape gardening” (Elliott et al. 2007, 2011).

As with orchids, commercial nurseries were the most important source of trees for planting. This is reflected in the presence of an arboretum at Loddiges’ nursery in north London, begun in about 1820. Display specimens could be seen alongside young plants for sale. The range of plants and reliability of identification made Loddiges the most important supplier of garden trees in nineteenth-century Britain. The rise of the arboretum in the nineteenth century was based on the huge increase in the number of new species, and selected cultivars, available. In the eighteenth century about three hundred new trees and shrubs were introduced to the British Isles, giving a total of 733 woody species in cultivation; by 1900 the figure was 1,911 species (Bean and Taylor 1970; Jarvis 1979). For climatic reasons few new introductions came from the tropics. North America had been the main source in the preceding two centuries, and in the nineteenth it remained important, as new territories were opened up by colonization in the west. The best-known collector in western North America was David Douglas (1798–1834), sent there in 1814 by the Horticultural Society of London; among many trees sent back was the Douglas fir, *Pseudotsuga menziesii*. Douglas’ death—fatally gored in a wild bull trap in Hawaii in 1834—is a reminder of the dangers facing plant collectors at the time. Chile was also an important source of conifers, with the most notable collector being William Lobb (1809–64), sent by Veitch in 1840 (Noble 2009). Lobb was the first to collect the monkey-puzzle tree (*Araucaria araucana*) in quantity; later he also collected for Veitch in California and Oregon, introducing the Wellingtonia (*Sequoia sempervirens*). However, a distinctive feature of nineteenth-century plant collecting is the eastwards turn to Asia. In the case of trees and shrubs, China and Japan were the most similar in
climate to Europe and North America, but access for foreigners had long been restricted to coastal traders. Wider access to China was the result of the Opium Wars. Notoriously, the East India Company encouraged the production of opium (the morphine-rich latex of *Papaver somniferum*) in India, exchanging it for Chinese tea via intermediary traders so as to reduce loss of silver currency (Emdad-ul 2000; Trocki 1999). By 1830 illegal exports of Indian opium to China were 2.5 million lbs (1,133 tonnes). In 1839, further efforts by the Chinese Imperial government to control opium importation led to the destruction of large stocks of imported opium at Guangzhou, but military action by British forces in the Opium Wars of 1840–2 ended with the Treaty of Nanking, ceding Hong Kong and giving trading rights in five ports including Guangzhou and Shanghai; the second Opium War of 1856–60 further opened the country, allowing the work of French missionaries such as Père Armand David (1826–1900), who introduced *Davidia involucrata*, the handkerchief or dove tree, via the Jardin des plantes, Paris (Fan 2004; Kilpatrick 2014; Mueggler 2011). British trade with China never met expectations, and opium imports peaked in 1879, thereafter being replaced by cultivation of opium poppy within China itself.

**USEFUL PLANTS**

Those plants that dominate international trade are but a tiny proportion of those used by humans. The nineteenth century saw a well-developed scientific infrastructure applied to the commercial development of thousands of locally used plants, with varying degrees of success. The appropriation and transformation of indigenous knowledge is under-investigated; Abena Dove Osseo-Asare’s work on the arrow poison and heart medicine, from *Strophanthus* species, has demonstrated that careful reading of sources can expand on both indigenous uses and the process of transfer (Osseo-Asare 2008, 2014).

Many plants were commercialized, but with limited impact; for example, New Zealand flax or harakeke (*Phormium tenax*) was introduced to St. Helena and formed the basis of an export industry, but this only survived from 1907–66. The New Zealand flax industry in New Zealand itself began in the 1860s and lasted to the 1980s, but with government subsidies for the last fifty years of its production (Cruthers et al. 2009). Here are examined in some detail three groups of plants, each with complex histories, and two of which—tea and rubber—with histories that have attracted much mythology.

**Rubber**

There are many parallels between the transplantation of rubber and cinchona (discussed with other medicinal plants by Simmonds in Chapter 5 of this volume), including South American origin, obstacles to introduction, and continuing controversy over ethical and legal aspects. However, in contrast to cinchona—the only significant source of quinine alkaloids—many different plants produce latex with the long-chain polymers that give it the elasticity and strength of rubber. These include the rubber plant of ornamental horticulture (*Ficus elastica*) in India, *Castilla* species in Central and South America, and *Landolphia* species in the Congo basin. However, it was the Brazilian rubber tree or “Pará,” *Hevea brasiliensis*, that entered plantation agriculture in the 1870s and has dominated world production of natural rubber up until today. Its successful transfer from the Amazon rainforest, where it is native, to Malaysia, depended on careful planning. It is likely that lessons were learnt from the introduction of cinchona a decade before.
The impetus for transplantation came from Clements Markham (1830–1916), by 1870 the leading figure in the Geographical Department of the India Office. He had recognized that both Amazonian and Indian rubber trees were threatened by overharvesting. In addition, rubber was in high demand by industry since Charles Goodyear’s invention of vulcanization in 1839, which led to a material with more controllable properties. A survey of rubber species identified Pará both as the source of high-quality rubber, and suitable

FIGURE 3.4 The Amazonian rubber tree (*Hevea brasiliensis*), its flower and fruit segments bordered by six scenes illustrating its use by humans. Colored lithograph, c. 1840. Courtesy of Hamza Khan/Alamy Photo.
for cultivation in Britain’s colonies in the wet tropics of Asia. Robert Cross (1836–1911) was dispatched by Kew to collect seeds in the Brazilian Amazon, while Henry Wickham (1846–1928), a British trader in Santarém on the Amazon, was also commissioned to collect them (Dean 1987; Loadman 2005; Nugent 2017).

Rubber seeds are “recalcitrant”; in other words, they die if allowed to dry out. This had already put paid to two earlier batches of seeds sent to Markham. Without using Wardian cases, Wickham sent seventy thousand seeds which arrived at Kew in June 1876. Of these, for which he was paid £70 per hundred, only 2,397 germinated. In November 1876, Cross returned to Kew with a further 1,080 seedlings. About 2,200 seedlings were sent to Sri Lanka, and in 1877 twenty-two of these were sent to Singapore, and nine or ten of these to Perak in Malaysia. Although a large rubber industry developed in Sri Lanka in the early twentieth century, production in Malaysia came to dominate. However, this was a slow process, depending on innovations in rubber-tapping and cultivation by Henry Ridley (1855–1956) at Singapore’s botanical garden. As fungal rust affected Malaysian coffee plantations in the 1890s, planters switched to Pará rubber, and production increased from 2,000 acres in 1898 to 540,000 acres in 1910.

Although the export of rubber seeds from Brazil remained legal until 1914, it is often cited as an early example of biopiracy. However, the reality is more complex, and complicated by the unreliability of the principal witness, Henry Wickham. Those details that can be checked of the shipment of Wickham’s rubber seeds from Santarém to Liverpool undermine his romanticized account of chartering a boat. Wickham’s subsequent knighthood and generous pension from the rubber industry are testimony to his ability for self-promotion, but it remains unclear whether it was Wickham’s seeds, or those of the little-known Robert Cross, that were sent to Malaysia. Looking at the bigger picture, the collapse of the Brazilian rubber industry from about 1920 led to the ending of the associated system of slavery required to harvest wild rubber from far-scattered trees; however, even plantation rubber harvesting and processing is labor intensive, leading British planters to bring in indentured laborers from China, and Tamils from southern India, to Malaysia. Both in its cultivation and in its manufacturing, rubber has a worldwide association with poor labor practices (Tully 2011).

**Fiber Plants**

In the era before artificial (oil-based) fibers, and the full suite of techniques for modifying natural fibers, there was a strong demand from industry for novel fibers, particularly those with the strength and sheen of silk (Lane 2007). Fibers were also popular with farmers and colonial botanists looking for new export crops that had the potential to be high value, yet also easy to ship on long voyages. Many fiber plants were circulated for trials, but typically failed against one of two criteria. Either the fibers were too difficult to extract to a high standard, particularly from the tough leaves of plants such as sisal (*Agave sisalana*), or prices were too low on the European market to cover production costs and long-distance travel. Nathaniel Wilson (1809–74), superintendent of the botanical garden in Jamaica from 1846 to 1872, experimented with a wide range of fiber plants, and sent many specimens of extracted fiber to international exhibitions (Wilson 1855). Renewed efforts in the 1880s, under Daniel Morris (1844–1933), failed for the lack of the correct machinery for fiber extraction (Morris 1884). Local fiber plants such as lace-bark (*Lagetta lagetto*) were the basis of an important souvenir industry but resisted commercialization (Brennan et al. 2013).
Historians have naturally concentrated on those fibers that were economically dominant, such as sisal, ramie (*Boehmeria nivea*), and jute (*Corchorus* spp.). In some cases the plant did not travel, but its manufacture did. Jute cultivation remained concentrated in Bengal throughout the nineteenth century, initially encouraged by the East India Company as an export crop, but mechanized manufacturing was developed in Dundee, Scotland, which became jute capital of the world—"Juteopolis"—between the 1830s and 1880s. Cotton was by far the most important of these fibers (Beckett 2014; Riello 2013). The early years of the nineteenth century saw New World cotton production shift from the Caribbean, where soils had become exhausted, to the south of the United States. Here production depended on slavery until its abolition in 1865. Concerns over continuity of supply—amply justified in the American Civil War—led British mills to look to India for their supplies. The East India Company introduced long-staple American Upland cotton (*Gossypium hirsutum*) to India, as its longer fibers were better suited to machine spinning. American cotton farmers were even persuaded to settle in the Bombay presidency although they did not stay long. There were substantial obstacles to the initial introduction of American cottons, including resistance from local farmers who found New Orleans cotton poorly adapted to local soils, and the long fibers difficult to separate from the seeds (Hazareesingh 2012). The outbreak of the American Civil War in 1861 spurred on British companies to provide suitable machinery for processing, and to create purchasing arrangements through agents that made the crop worthwhile for farmers.

**Tea**

By the mid-eighteenth century tea was a popular drink in Europe and North America, appreciated for its flavor and for the stimulant effect of caffeine (Mair and Hoh 2009). Tea was imported from China, by the British East India Company and other European traders, and a steep reduction in tax on tea in 1784 made it a mass-market product in Britain (Moxham 2003). By 1860 tea was widely cultivated in northeast India, then Sri Lanka, and, eventually Kenya, and tea had become widely affordable in Europe. This transformation was a complex process, still incompletely understood, and an example of the transfer of knowledge being arguably more important than the transfer of plants.

Tea plants from China had been traveling the world since the seventeenth century, including to the botanical garden in Kolkata, but there was little incentive for the East India Company to find another source for tea: it had a monopoly on British trade with China, and from the mid-eighteenth century onwards, a system of exchanging Indian opium for Chinese tea that made the trade even more profitable. However, in 1834 the Company lost its monopoly on trade with China, making cultivation in India a more attractive possibility. It established a Tea Committee, which took on the joint roles of procuring seeds and expertise from China, and investigating claims that tea was native to India. Assam tea had first been encountered in 1815, but it was only in the 1830s that Assam became easily accessible to British officials. In 1834 tea, in the form of *Camellia sinensis* var. *assamica*, was recognized by the Tea Committee as indigenous to the Assam region in northeastern India, where its leaves were chewed as a stimulant. Experts were divided as to whether Assam tea (var. *assamica*) or Chinese tea (var. *sinensis*) would grow best, and over the next decade both were tried. George James Gordon, Secretary of the Tea Committee, sent eighty thousand seeds from China to a botanical garden in Kolkata in 1834, with many more seeds later. In 1839, the first auction of Assam tea took place in London, but with only a few Chinese artisans taking up the opportunity to work in India, expertise in the harvesting and processing of tea was scarce (Mair and Hoh 2009).
TRADE AND EXPLORATION

The need for know-how is demonstrated by the fact that in the 1830s Western botanists were still unsure whether black tea and green tea were different species of *Camellia*, rather than the actuality, a single species processed in different ways. Access to tea plants was relatively easy; access to Chinese tea planters was difficult because Europeans were forbidden to travel to China's interior, and in particular to the Bohea Hills (Wuyishan), which produced the finest black teas. The bold travels of Robert Fortune (1812–80), a Scottish-born plant collector, were to change this. Taking advantage of the improved access for Europeans to China after the First Opium War, Fortune was commissioned by the Horticultural Society in London to collect ornamental plants. On this first trip, in 1843–5, eighteen Wardian cases of garden plants were sent back to Britain from Hong Kong. On this and a further four journeys to China and Japan, Fortune collected over 250 different kinds of garden plant, mostly already grown by the Chinese, including the windmill palm (*Trachycarpus fortunei*) and tree peonies (*Paeonia* spp.). Fortune's second expedition, from 1848 to 1851, was commissioned by the East India Company, at a generous annual salary of £500. By disguising himself in Chinese dress, and traveling with Chinese servants, Fortune was able to circumvent the ban on inland travel, reaching the Bohea Hills in 1849.

Fortune had no difficulty collecting large numbers of tea seeds, which were sown in soil at the bottom of Wardian cases and sent to India in several shipments during the expedition. Most of these went to the province of Uttarakhand in northern India, where

FIGURE 3.5 Nine scenes showing tea cultivation and preparation on an Indian plantation. Engraving by T. Brown, c. 1850, after J. L. Williams. Courtesy of the Wellcome Collection, London.
the East India Company was promoting plantations that were to prove unsuccessful in the long run; however, it is likely that Fortune's teas contributed to the Chinese stock that still forms the basis of tea cultivation in Darjeeling today. The explosion in tea cultivation of the 1860s was based on var. assamica, cultivated in Assam. Fortune's most important contribution was in being one of several botanists to show in the 1840s that the difference between green and black tea was in the processing, with black teas allowed a much fuller fermentation. On his third expedition (1853–6) Fortune was able to recruit seventeen specialist workers from China, with their equipment, to come to India and train the staff of the new plantations. As Fortune's biographer Alistair Watt (2017) suggests, this, and similar initiatives by others, may have enabled the breakthrough in tea production, rather than the movement of plants.

Fortune's fourth expedition to China, in 1858–9, was on behalf of the American government, and resulted in thirty-five thousand plants being grown in a glasshouse in Washington, DC (Gardner 1971). Much delayed by the American Civil War, subsequent attempts at cultivation foundered on the high labor costs of harvesting, an issue resolved in Sri Lanka through the employment of Tamil laborers from South India. The British had established a successful coffee industry in the hills around Kandy in the 1820s, but in the decade from 1869 the coffee rust disease destroyed the plantations. Cinchona at first appeared a savior, but prices collapsed in the mid-1880s. In 1867 tea plants were ordered from the botanical garden in Kolkata, and by 1885 there were over 100,000 acres of tea, of both Indian and Chinese varieties.

IMPACT

The scale of plant introductions to the Europe was huge; British historian Keith Thomas has estimated that in 1500 there were two hundred species of cultivated plants in England; by 1839, about eighteen thousand (Jarvis 1979). We do not have equally precise figures for tropical countries, but there is good evidence for massive shifts in production; for example, the virtual cessation of wild rubber harvesting in Brazil, and its replacement by the planting of 433,000 acres (175,228 ha) of rubber trees in Malaysia by 1920. This nineteenth-century combination of plant transplantation and large-scale plantation, combined with advances in transport, meant that correspondingly large populations in Europe could be supplied with food and industrial raw materials from around the world. In the years 1834–6 the British cotton industry imported £14.5 million worth of cotton, most of it from the United States—by far Britain's most valuable import. The impact of this easy access to raw materials on European economies then, and subsequently, is much debated by economic historians (Cain 1999; Peers 2004).

Transoceanic plant introductions had a major impact on the environment soon after Columbus' voyages of the late fifteenth century. What Alfred Crosby (1986) termed “ecological imperialism” saw crops and animals such as wheat and sheep spread from Europe into the temperate regions of North and South America, southern Africa, and Australia and New Zealand, while crops such as maize and potatoes moved in the other direction. However, the nineteenth century saw a step-change in the ability of transport to take plantation crops to market, and to bring labor forces to crops. Forests were extensively cleared for plantations of cinchona, rubber, and oil palm, although those sometimes replaced other crops. It is estimated that about 1.5 million square km of tropical forests were converted to crops or grasslands between 1850 and 1920 (Ross 2017; Williams 2003). Large-scale felling of trees occurred in North America and
Australia, but in other cases trees were introduced to treeless lands, as in the case of naturalized cinchona in the Galapagos Islands (Macdonald et al. 1988), or eucalyptus trees planted in Italian marshes (Doughty 2000). These cases are a reminder that plant introduction is often complex in its effects (Brock 2014). Similar impacts occurred in other ecosystems including grasslands, with wheat cultivation in the Argentinian pampas growing from 12,000 square kilometers (4,600 square miles) to 62,000 square kilometers (24,000 square miles) between 1890 and 1914, and the cultivated area of the Russian steppe increasing fivefold to 340,000 square kilometers (131,000 square miles) during the eighteenth and nineteenth centuries: it was not only the tropics that were affected by the expansion in crop monocultures (Isenberg 2014). Many of these regions were to become dustbowls in the twentieth century.

Richard Grove’s pioneering study _Green Imperialism_ traces the origins of modern environmentalism to the colonial world, initially in the eighteenth century in islands such as St. Helena and Mauritius, in which the effects of deforestation on climate and soils were worked out, and then in the nineteenth century, to a more structured body of knowledge that saw large-scale application to forests in India (Grove 1995; Ross 2017). Although initially marked by a purely pragmatic approach to maintaining timber supplies and climatic stability, by the 1840s some were also raising concerns about the extinction of plants and animals. Tensions between the economic and environmental roles of protected areas, and the rights of local communities within protected areas, arose early on and continue to trouble nature conservation today. By the late nineteenth century orchid collectors were becoming concerned at the effects of the plunder of tropical orchids, all the more foolish as so many plants died en route to their eventual markets (Endersby 2016).

Plant invasions were another consequence of plant introductions. The greatest impact of these has been in island ecosystems, where the effects of introduced animals such as rats and goats on native vegetation paved the way for introduced plants. For example, in the South Atlantic island of St. Helena, first visited by Europeans in 1502, goats browsed the saplings of trees such as gumwood (Commidendrum robustum), leading to the replacement of forest by imported grasses such as Bermuda grass (Cynodon dactylon). The effects were compounded by the nineteenth-century introduction of New Zealand flax as a crop; although no longer cultivated, it is widely naturalized and forms an “impenetrable monoculture” (Cronk 1989). Ornamental horticulture was an important source of invasive plants too. The best-known example in Britain is _Rhododendron ponticum_, introduced in about 1763 from Spain, selected for hardiness, and proving to grow fast and set abundant seed, allowing naturalization (Dehnen-Schmutz and Williamson 2006). Invasive in woodland since the nineteenth century, it was not recognized as a problem until the mid-twentieth century. Other nineteenth-century introductions of problematic ornamentals to Europe include Japanese knotweed (*Reynoutria japonica*), giant hogweed (*Heracleum mantegazzianum*) from the Caucasus, and Himalayan balsam (*Impatiens glandulifera*). About a quarter of ornamental plants for sale in nineteenth-century Britain escaped into the wild; of these about a third became established there (Dehnen-Schmutz et al. 2007a, 2007b). Although the historical ecology of invasive plants is not yet well resolved on a global scale, these examples show that the nineteenth century was a period of exceptional impact.

Plant trade and introductions have had a long legacy in human affairs. Viewed from the West, new plants brightened homes and gardens as ornamentals, enabled the importation of cheap food, and provided raw materials for major industries that employed
and supplied many. Viewed from the perspective of source communities, the impact of nineteenth-century extraction of natural resources, migration, and forced labor remains deeply felt, and is visible in contemporary inequalities (Ross 2017). Past practices of plant translocation, although at the time often legal and in the context of global exchange of plants, took place within highly unequal power structures of which indigenous peoples remain keenly aware (Mt. Pleasant 2014). Unpicking the motives and practices behind nineteenth-century plant exchange is an enterprise of high contemporary relevance.
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OF PLANTS

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CENTURY

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