arnoldia

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The ARNOLD ARBORETUM of HARVARD UNIVERSITY

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Inside front cover: A showy pink-flowered cultivar of flowering dogwood (*Cornus florida* 'Royal Red', accession 13-61-A) was in full bloom on May 9, 2016. Photo by Kyle Port.

Inside back cover: Its spring burst of yellow flowers is just one of the ornamental attributes of sassafras (*Sassafras albidum*). Photo by Nancy Rose.

Back cover: Extreme drought conditions in 2016 led to plant damage in the collections, including browned leaf margins on this magnolia (*Magnolia* 'Silver Parasol', accession 1144-77-A). Photo by Kyle Port.

The Wardian Case: How a Simple Box Moved the Plant Kingdom

Luke Keogh

In 1873, before a single road was laid at the Arnold Arboretum, founding director Charles Sprague Sargent packed a Wardian case full of ferns from the American West. Wardian cases—wood and glass boxes shaped like small, moveable greenhouses—were used for transporting live plants. They were often more delicate than typical cargo, so to ensure protection Sargent sent the box to England with a friend who also happened to be sailing across the Atlantic. He hoped the ferns, from California and Colorado, might impress his colleagues at the Royal Botanic Gardens, Kew, in particular the director, Joseph Hooker.

Sargent wanted to make sure that Kew's collection of North American ferns was "as complete as possible." In the April 2, 1873, letter that accompanied the Wardian case Sargent wrote to Hooker: "If … you have all you want, will you kindly send them on to the Jardin des

ECONOMIC BOTANY COLLECTION, ROYAL BOTANIC GARDENS, KEW

This Wardian case dates to around 1870.

ARCHIVES OF THE ARNOLD ARBORETUM

A hand-painted lithograph showing *Musa ensete* (now known as *Ensete ventricosum*) growing in Abyssinia (a former kingdom in what is now Ethiopia), from *Curtis's Botanical Magazine,* January 1861.

Plantes at Paris." Sargent hoped that Kew could send at least a few plants on to Paris: "I am sorry to trouble you in this way, but unfortunately we have not as yet any sure way of transporting living plants to Paris and I doubt not you are in constant communication with Dr. Decaisne."

Sargent's letter shows us a number of processes in motion during that time. While moving plants still relied on an important network of botanists, by the 1870s the trade in live plants around the globe had become extensive. This had only become possible because of the invention of the Wardian case. The letter also shows that botanists, arborists, agriculturists, and horticulturists from around the globe needed to remain in constant contact. Indeed, they could use one contact to begin a dialogue with another, in this case using Hooker to re-open contact with Paris. At all times these networks relied on reciprocity—one institution sends some plants and the receiver sends some back. One of the key ways a new contact was smoothed out, or an already established contact was asked for new plants, was to send them some from your own collection.

Sargent concluded his letter to Hooker by sending a list of desiderata—a list of plants that they needed at Harvard. He was not only hoping for plants for the new arboretum in Jamaica Plain but also plants for the botanic garden that then existed in Cambridge. Among the most desired were palms and agaves. "[A]s the Garden is so destitute of them that *anything* you can send will be most acceptable," wrote Sargent.

A few months later Hooker was able to satisfy Sargent's request by sending palm seeds plus some very good seeds of the Abyssinian or Ethiopian banana (*Musa ensete,* now known as *Ensete ventricosum*). This was a very rare plant to have in North America at the time because it did not travel well. In the same consignment Hooker also included a Wardian case full of rhododendrons (*Rhododendron*). In the following months Sargent would go on to return the favor and send another Wardian case of ferns to Hooker. And so the reciprocal relationship continued between them.

The Challenge of Sending Plants

Many common horticultural or agricultural species, for example the Japanese umbrella pine (*Sciadopitys verticillata*) or even tea (*Camellia sinensis*), required the efforts of plant hunters and travelers to discover and introduce them.

CHUCK BARGERON, UNIVERSITY OF GEORGIA, BUGWOOD.ORG

Wardian cases were critical to the movement of economically important plants such as tea (*Camellia sinensis*). A tea plantation in Tanzania is seen here.

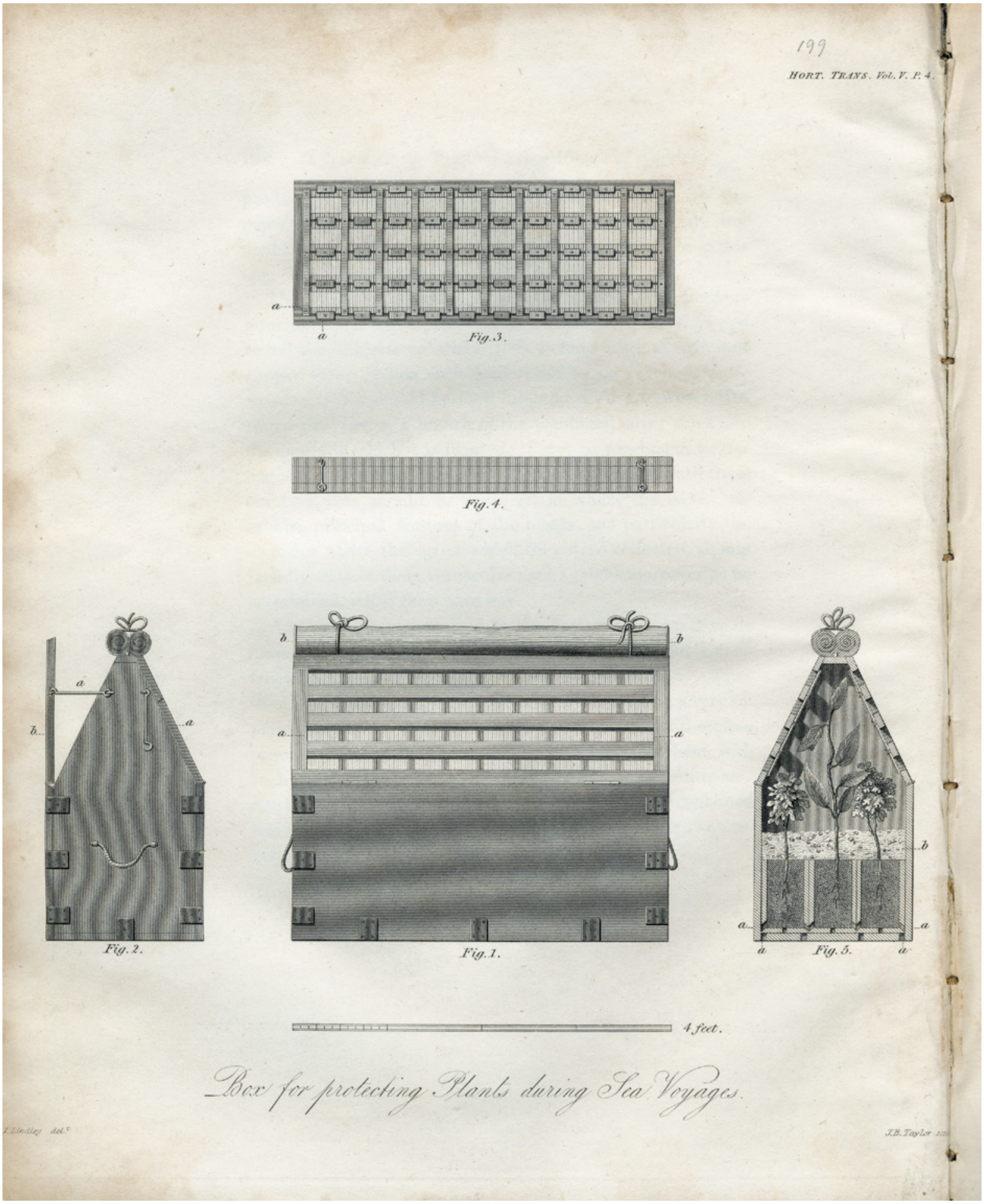
Just keeping plants alive on a long sea voyage was a challenge for early travelers. As early as the seventeenth century plants arrived in Europe from around the globe, to the pleasure of plant enthusiasts. As the centuries wore on, more and more rare and exotic plants steadily made their way to Europe and North America. While some plants were sent as seeds or cuttings, many plants could not be transported in those forms and had to be sent as live specimens. For naturalists this amounted to a great challenge. As shipping increased in the early nineteenth century and the world became increasingly connected through exploration and trade, transporting live plants was still very difficult.

In 1819, John Livingstone, the keen botanist and surgeon posted in Macao for the East India Company, wrote to the Royal Horticultural Society on the challenge of sending live plants from China to London. Livingstone estimated that only one in one thousand plants survived the journey. He proposed a number of plans for the successful movement of plants. One was quite simply to send a gardener with any dispatch of live plants to make sure they were properly cared for on the voyage. But whatever the method was, Livingstone concluded in his November 16 letter to the Society, that it "becomes a matter of importance to attempt some more certain method gratifying the English horticulturist and botanist, with the plants of China." John Lindley, also of the Horticultural Society of London, described the great challenge and care needed in sending live plants across oceans. In 1824, Lindley wrote, "The idea which seems to exist, that to tear a plant from its native soil, to plant it in fresh earth, to fasten it in a wooden case, and to put it on board a vessel under the care of some officer, is sufficient, is of all others the most erroneous, and has led to the most ruinous consequences." Lindley proposed a more controlled and concerned approach to sending plants. Indeed, for many in London it came down to the type of case plants were sent in.

At this time naturalists and gardeners turned their efforts to discovering the best way to send live plants around the globe. Was it in a wooden box? Or were there other ways? Many methods for successfully moving live plants to destinations well beyond their native range were being tried. Accompanying Lindley's paper to the Horticultural Society were designs for a glazed box that had been sent to him by the Governor of Mauritius, Robert Farquhar. One of the more interesting methods proposed was that of Nathaniel Wallich, pioneering botanist and surgeon for the East India Company, based in Calcutta; he sent a box that had a roof made with translucent shell inserts, which allowed light in. These early decades of the nineteenth century were an intense period of experimentation in sending live plants.

Ward's Glass Case

Most inventions do not come about in a vacuum, and so it was with the Wardian case. Many plant transportation containers, some of which were quite successful, paved the way before the actual Wardian case was invented. It was a simple case made of wood and glass and takes its name from its inventor, Nathaniel Bagshaw Ward, a London physician with a keen interest in the natural world. Ward's improvement on



Sketch of the box used by Sir Robert Farquhar to transport plants from Mauritius to London in 1824. This box holds a striking resemblance to the common Wardian case that became widely used in the nineteenth century. From John Lindley, "Instructions for Packing Living Plants in Foreign Countries, Especially within the Tropics; and Directions for Their Treatment during the Voyage to Europe," *Transactions of the Horticultural Society of London* 5 (1824).

the previous attempts was his proposal of an airtight system in which transpiration inside the case provides sufficient moisture to keep plants alive for extended periods. (We would call this system a terrarium today.)

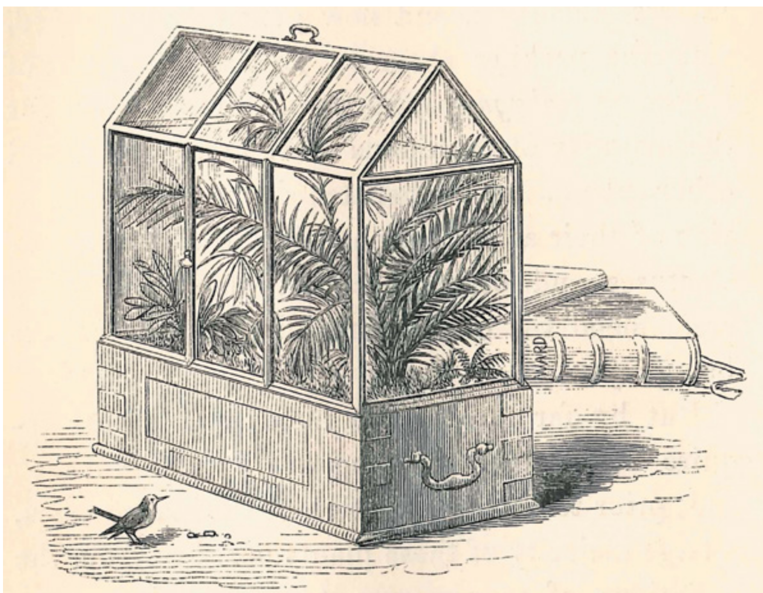
In 1829, in a large sealed bottle partially filled with soil, Ward buried the chrysalis of a sphinx moth, with the hope that it would hatch. The moth never flew, but he observed changes inside the bottle. Sprouts of meadow grass (*Poa annua*) took life, so too did the common fern *Aspidium* (now *Dryopteris*) *filix-mas.* Instead of worrying about the moth, Ward took the sealed bottle and moved it to a window that would get the northern sun. The plants inside survived for three years without water; in the second year he observed the grass inside bloom and the fern grew five fronds. Only after the lid rusted and rain water entered the bottle was the experiment over.

Many other experiments followed. Inside Ward's house was an extravagant display of city gardening under glass. On March 6, 1834, John Claudius Loudon, the well-known garden designer and journalist, visited Ward's house. He described it as "the most extraordinary city garden we have ever beheld." It was also the implications of Ward's gardening in glass cases that was important. Loudon added, "Mr. Ward has no doubt, that by boxes of this kind, with requisite modifications, he could transport plants from any one country in the world to any other country." At the time, Ward was in the process of testing his new glass cases on an overseas voyage.

In 1833, Ward transported a perfectly packed sealed glass case containing a selection of ferns, mosses, and grasses from London to Sydney, Australia. On November 23, 1833, Ward received a letter from Charles Mallard, the ship captain responsible for the two cases: "your experiment for the preservation of plants alive … has fully succeeded." The next challenge was the return journey. In February 1834 the cases were replanted with specimens from Australia. In Sydney the temperature was over 30°C (86°F), rounding Cape Horn temperatures fell to -7°C (19.4°F), at Rio de Janeiro it reached nearly 40°C (104°F), and eight months later when Mallard's ship travelled up the Thames the temperature was below 4°C (39.2°F). When Ward and friend George Loddiges, of the famous Loddiges & Sons nursery in Hackney, went aboard the ship in London they inspected the healthy fronds of a delicate coral fern (*Gleichenia microphylla*), an Australian plant never before seen in Britain.

Following the first successful journey to Australia and back, Ward and his friends commenced moving more plants in the glass cases. In 1835, Ward sent six cases of ornamental plants to the head gardener for the Pasha of Egypt, and later, following this success, coffee plants were sent. George Loddiges was more ambitious. He put into circulation over five hundred cases to all parts of the globe. It is the ingenuity and wide use by Loddiges's nurseries that established the Wardian case as the most compelling tool to use for transporting live plants.

In the nineteenth century, a Wardian case filled with ferns became a feature of many middle to upper class Victorian homes, includ-



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Ward's case for moving plants on long sea voyages. Image from Ward's *On the Growth of Plants in Closely Glazed Cases* (1852; page 71).

COURTESY OF VICTORIA AND ALBERT MUSEUM

The Great Exhibition of the Works of Industry of All Nations was held inside the specially-built Crystal Palace in 1851. Ward's cases appeared just beside the large tree featured in the center of this illustration.

ing many homes along the east coast of North America. This is where the Wardian case has largely been preserved in much historical literature—as occupying a significant place in the natural history crazes of Victorian England. By 1851 a Wardian case full of plants was exhibited at the Great Exhibition. Inside the Crystal Palace, people could view live ornamental ferns brought from far off regions; they could also view one of Ward's glass bottles with a plant in it that had apparently not been watered for 18 years.

Casting our eye wider than the context of the Victorian fern craze, the scale of movement that the Wardian case facilitated is significant. Focusing on the movement of plants we see the extent to which the case was used as a unified transport technology in a time when the world was becoming increasingly connected.

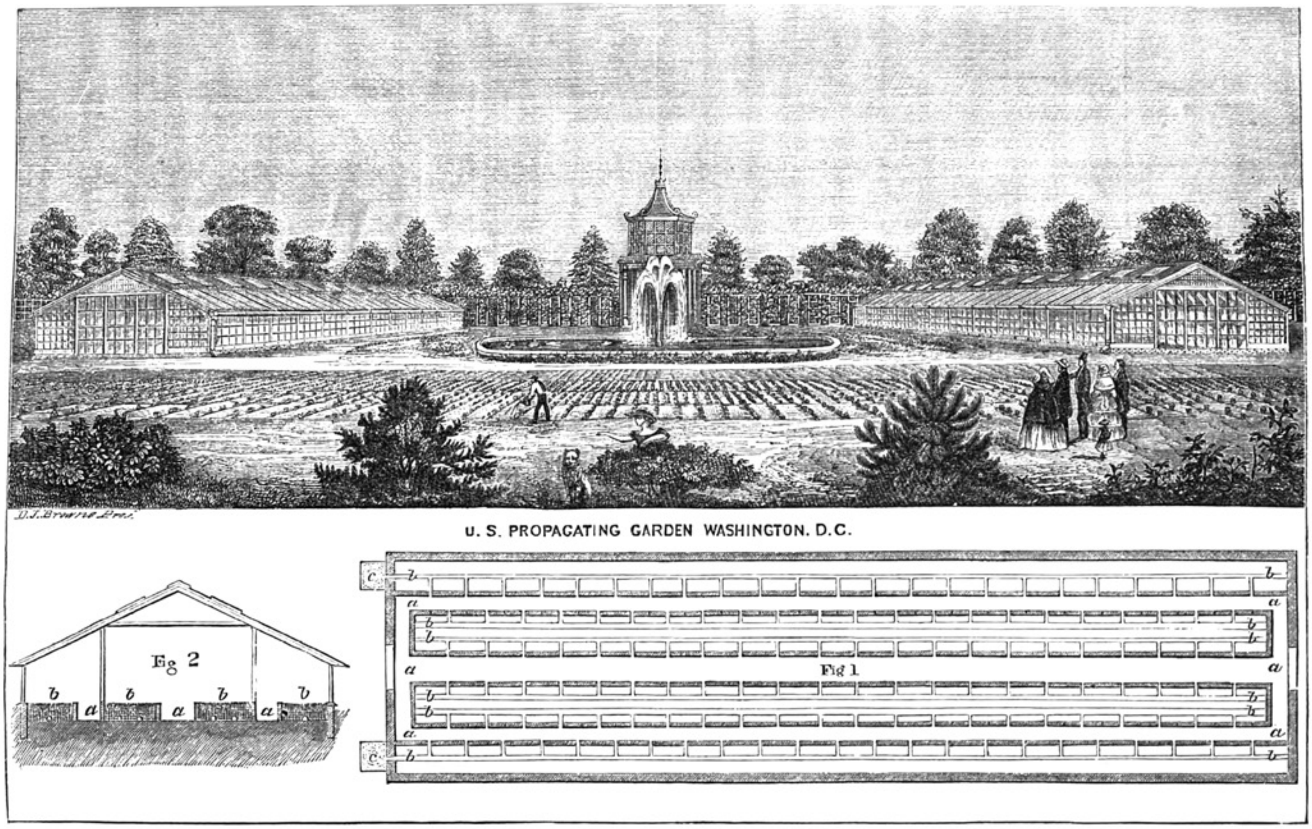
Ward's biggest contribution, building upon the efforts of others before him, was to propose the airtight system for keeping plants alive, as well as putting this technology into practice on many long voyages. Unlike others before him, it was also Ward's promotion of his system for transporting live plants that was important. As well as his short book *On the Growth of Plants in Closely Glazed Cases* (1842, republished with illustrations in 1852), he also published numerous short articles in the popular gardening media promoting his system for transporting plants. And with Ward's promotions the adoption of the case was extensive, not just by well-known nurseries like Loddiges, but by the

British Royal Navy, French government expeditions, the Royal Horticultural Society, and many others.

Travelling the Globe

By 1841, Ward could add many North American ferns to his collection of global plants. He had formed a good relationship with the young Harvard botanist Asa Gray when Gray first travelled to London. Gray helped Ward accumulate an extensive collection, which he kept in glass cases in his home and put in taxonomic order using Gray's textbook. But the Wardian case wasn't just used between botanists on either side of the Atlantic. In the decades following the 1840s, botanical gardens, acclimatization societies (organizations that promoted the introduction of exotic plants and animals to see if they were adaptable), horticultural societies, and nurseries commenced wide use of the Wardian case to transfer plants around the globe.

One of the most well-known uses of the Wardian case was by the Royal Horticultural Society of England. It first experimented with the cases when they sent the plant explorer Theodor Hartweg to California and central America in 1836. Following this in 1848, a member of the Society, Robert Fortune, travelled to China and successfully used Wardian cases to move tea plants from China to India. In total nearly 20,000 tea plants were transplanted in what might be one of the world's largest acts of botanical espionage. These set the foundations of the Assam and Sikkim tea industry in India. Often less known is that a



This illustration of the United States Propagating Garden on the National Mall in Washington, D.C., is from the 1858 *Report of the Commissioner of Patents: Agriculture.* The glass houses pictured on the left and right were built to receive the tea plants that were sent to the United States in Wardian cases by Robert Fortune.

Illustration of the gutta-percha tree (*Palaquium gutta*) from Franz Eugen Köhler's 1887 publication *Köhler's Medizinal-Pflanzen.*

decade later Fortune, this time working for the United States Patent Office, sent 26,000 tea seedlings in Wardian cases to Washington, D.C. This instigated the United States' first experimental plant station in the center of the capital, although it is suggested that not much ever really happened with the tea shrubs.

The Wardian case was used in a range of other botanical appropriations. The cinchona tree, whose bark was used in quinine-based antimalarial drugs, was moved in secret from Bolivia by the Dutch and British to be transplanted to Java and India. The rubber tree (*Hevea brasiliensis*) was taken from its native South America and transplanted, via Kew Gardens, to the Malay and Ceylon regions in Asia. In each of these examples the transplanted regions became leading global producers of the commodity.

Many commercial crops in colonial regions were established with the help of the Wardian case. The dwarf Cavendish banana (a variety of *Musa acuminata*) was moved from China, via the Chatsworth Gardens in England, to the Samoan islands and spread throughout the region as a significant crop. When the French botanist Henri Lecomte was charged with establishing gutta-percha (*Palaquium gutta*, a tree from which a useful latex was extracted) plantations in the French colonies in Indochina in the late 1800s, he took with him plants safely packed in Wardian cases. The establishment of mango (*Mangifera indica*) production in Queensland, Australia, also relied on the case, used as early as the late 1840s to bring grafted mango trees from India.

The first Japanese plants to arrive in New England were carried in Wardian cases and delivered to horticulturists to be distributed in the Jamaica Plain (Massachusetts) area. Japanese umbrella pines, along with dogwoods (*Cornus*), rhododendrons, crabapples (*Malus*), and cypress (*Chamaecyparis obtusa*) survived the seventy-day journey from Yokohama to Boston, tightly and carefully packed into the sealed glass cases. The first package of plants was sent in 1861 by the physician George Rogers Hall and eventually found a home at Francis Parkman's small three-acre summer estate on Jamaica Pond. The following year Hall returned from Japan with six more Wardian cases. These cases were filled with many varieties of plants; among them

NANCY ROSE

Japanese umbrella pine (*Sciadopitys verticillata*) was among the first Japanese plant species imported into New England. Seen here, Arboretum accession 503-70-C grows near the Hunnewell Visitor Center.

was Japanese honeysuckle (*Lonicera japonica*), which was first planted out in a nursery row in Long Island. Many plants that arrived in Wardian cases have swept across North America; some, such as the Japanese umbrella pine, have become beautiful additions to landscapes and gardens, but others, like the honeysuckle, have invaded woodlands across the eastern United States and elsewhere.

Botanical gardens, often with a large focus on economic botany, formed hubs of distribution to move plants around the globe. The significance of Kew Gardens as a global hub of scientific knowledge and a mover of economic plants in the age of empire has been well documented in various sources. However, the significance of the Wardian case has received little specific attention. Following the invention of the case, it is estimated that in just 15 years William Hooker, director of the Gardens at Kew from 1841 to 1865, imported more plants than in the previous century. In the following eras at Kew, when his son Joseph took over as director (from 1865 to 1885), followed by William Thiselton-Dyer (from 1885 to 1905), the Wardian case continued to be used extensively. From the 1860s into the twentieth century, plants were travelling to and from points including Shanghai, Ceylon, Batavia, Yokohama, Calcutta, Hong Kong, Trinidad, Tonga, Venezuela, Dominican Republic, Jamaica, Guyana, Natal, South Australia, and Melbourne. In the cases were everything from Liberian coffee to orchids, tree ferns, sisal, tonka beans (*Dipteryx odorata*), mangoes, and tea. The connections covered the globe and were efficient. In one letter from August 21, 1877, the collector in India, George King, wrote to Thiselton-Dyer that it was quicker to send plants in a Wardian case from Calcutta to Kew than it was to get a case of plants from Sikkim to Calcutta.

With its own imperial interests Germany was not to be left out of the global movement. Estimates from the Berlin Botanical Gardens note that between 1891 and 1907 over 16,000 plants were moved by the Gardens. These included coffee, oil palms, cocoa, rubber, and bananas. They were moved between Berlin and Victo-

COURTESY OF ROYAL BOTANIC GARDENS, KEW

Unpacking a Wardian case at the Royal Botanic Gardens, Kew, around 1890.

ria (now Limbe, Cameroon), Amani (Tanzania), Sokodé (Togo), and Simpson Harbor (today Rabaul, Papua New Guinea). German botanical gardens also played an important intermediary role when the sisal plant (*Agave sisalana*), cultivated for its tough fibers, was transplanted from Central America to colonies in Africa for the German East African Company.

Other botanical gardens played major roles in moving plants around the globe whether it was for acclimatization, commercial, or ornamental reasons. The world renowned *Jardin d'agronomie tropicale,* Paris, was a major hub for acclimatization and agricultural research for the French colonies. In the first decade of the twentieth century the garden sent more than 40,000 live plants to the colonies. At Dutch gardens, including the Amsterdam Botanical Gardens and Leiden Gardens, many plants passed through on their way to Asian colonies including cinnamon, clove, mango, and ginger. For the Dutch the gardens at Buitenzorg (Bogor), Java, was the central hub for plant movement. At Russia's most prominent gardens in St. Petersburg, the German-born Carl Maximowicz became head of the botanical gardens, which

COURTESY OF THE COLLECTION NATIONAAL MUSEUM VAN WERELDCULTUREN. TM-10010760

Specially crafted Wardian cases made by local Indonesian workers were used to send plants from the Buitenzorg Botanic Gardens, Java, in 1904.

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Workers at the *Jardin d'Agronomie Tropicale* [Garden of Tropical Agronomy] in Paris prepare to send live plants in Wardian cases to the French Colonies, circa 1910.

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With an interior botanical style inspired by the Wardian case, a rectangular terrarium sits near a New York apartment window in this photograph by Jessie Tarbox Beals, circa 1910 to 1930.

allowed him to develop an extraordinary array of Japanese plants. In each of these places the Wardian case proved an important technology for building collections and disseminating plants to other regions.

The United States became one of the most important users of the case in the early twentieth century (although there were many uses in the late nineteenth century, some of these noted above) because of the extensive usage by the United States Department of Agriculture. The Wardian case was used on many expeditions by American plant explorers importing everything from orchids to avocados and even insects. However, by the 1920s the Wardian case had become an expensive method of transport. There was also a change in the air as scientists, primarily entomologists, started to see the dangers of importing foreign plant material and biological matter. In a 1924 circular to the USDA, Beverley Galloway, the chief of the Bureau of Plant Industry, noted: "The Wardian case, a sort of small portable greenhouse, has probably been the means of scattering more dangerous insects, nematodes, and other pests over the earth than almost any other form of carrier; hence its use is not advised except under special instructions." As quarantine became the order of the day, protecting the natural biota of a country became a much more significant goal of plant industries and scientists. In the eyes of gardeners, exotics still held value but they now had to compete with a greater value placed on native flora.

A Century of Exchange

The Wardian case is a persuasive and wide-reaching example of how a simple technology for moving plants had a major impact on the ecosystems we know and value today. It was a prime mover for botanical enterprises for over a century. But by the 1940s it was largely phased out, with the last journeys carrying ornamental plants occurring in the 1960s. The case was superseded by the use of polyethylene bags and temperature controlled air transport.

The Wardian case was extensively used by many different groups of people from across the globe to move many different plants; from scientists to gardeners, from ferns to bananas, from Australia to Boston, the case was put to good use. Collectively in the nineteenth and early twentieth century the use of Wardian cases facilitated a major plant migration across the globe. These plant distribution networks, established with the introduction of the Wardian case, are still in use today.

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Luke Keogh is an environmental historian and was a Sargent Award recipient at the Arnold Arboretum in 2015–2016.

2016 Weather Summary

Sue A. Pfeiffer

Winter (December 1, 2015, to February 29, 2016)

This meteorological winter was the third mildest winter on record (since 1872) for Boston, yet it also brought the lowest temperatures recorded at the Arboretum in nearly 30 years and subsequent damage to a number of plants in the collections.

Precipitation was above normal every month during this period for a total of 12.12 inches compared to the average of 10.40 inches. While snow typically accounts for much of winter precipitation (melted snow is measured as liquid precipitation), this year we received only 25.4 inches of snow. The snow-to-liquid ratio varies with temperature and other conditions, but assuming a rough range of 20:1 to 10:1, the snow accounted for just 1.3 to 2.5 inches of the total precipitation. This above average precipitation reduced the abnormally dry conditions of late 2015 and we entered spring under no drought conditions.

An extraordinarily warm December 2015 (temperatures were 10°F above normal) led into a mild January, with only 1.5 inches of snow falling during the latter part of the month. February began with above normal temperatures—highs from the upper 50s to mid 60s—before returning to normal. Most of the snow for the month (14.7 inches total) came during two snowfall events on the 5th–6th and the 8th. During the first storm a combination of wet, heavy snow and soft, unfrozen ground led to the toppling of a number of trees, including a large 85-year-old hemlock cultivar (*Tsuga canadensis* 'Compacta', accession 21278-A) on Hemlock Hill. By the 11th, an arctic front moved in, bringing frigid temperatures to the area. Low temperatures were below zero February 13th through 15th; the low of -11°F on Valentine's Day was the coldest ever recorded at the Arboretum for February 14th. Unseasonably warm temperatures returned for the latter half of the month. February was notable for dramatic temperature fluctuations, with a difference of 76.3 degrees between the highest (65.3°F) and lowest (-11°F) recorded temperatures. The mild temperatures throughout early winter meant buds had started to swell far earlier than usual; the mid-February freeze resulted in damaged buds on some species as well as stem dieback and complete death of some marginally hardy specimens.

Spring (March 1 to May 31)

Precipitation was below normal during this period, with a total of 9.52 inches compared to the average 11.57 inches. This slight decrease in precipitation lead to abnormally dry conditions as we entered summer.

March saw temperature fluctuations fairly typical for spring weather. A record high was set on March 9th when the temperature soared to 78°F, breaking the old record by 6°F. This made an 89 degree temperature range within 24 days from the -11°F record on February 14th. Overall, March was warmer than average and had less precipitation than normal (2.96 inches versus 4.33 inches) despite consistent and regular rain events throughout the month. On March 31st a storm brought wind gusts in the high 30s mph.

KYLE PORT

Cornelian cherry (*Cornus mas*) and forsythia were in bloom on March 30th, a few days before a cold front brought sub-freezing temperatures that damaged many flowers and buds.

An arctic system caused erratic temperature fluctuations in early April (1st to the 8th) along with 5.5 inches of snow and windy conditions. Several nights with below freezing temperatures, including a low of 18.5°F on April 4th, resulted in damage to emerging foliage, buds, and open flowers. Spring flowering ended for many magnolias, whose tepals turned to brown mush, as well as forsythias and some spring bulbs. These conditions resulted in reduced flowering on other early blooming trees and shrubs and slowed foliage expansion. Significant temperature fluctuations occurred in April and the

KYLE PORT

A newly accessioned Carolina jessamine (*Gelsemium sempervirens* 'Margarita', accession 520-2016-A) was in bloom on May 3. This cultivar, 'Margarita', is reported to be somewhat more cold hardy than the species typically is.


KYLE PORT

Visitors enjoying a beautiful day at the Arboretum on May 20th passed by a blooming weigela (*Weigela praecox* 'Gracieux', accession 164-2000-B).

monthly high of 80.5°F was recorded on April 22nd, though the month overall was cooler than average. Precipitation was normal, with most falling during the first half of the month.

May began with unseasonably cool temperatures and rain each day of the first week. These conditions further delayed plant development but did extend bloom time for early spring plants and late flowering bulbs. Unfortunately the flower bud damage from the extreme cold in February and the early April freeze resulted in a less colorful spring than usual.

Lilac Sunday on May 8th started cloudy and dreary with light showers, though the afternoon was sunny and warmed up into the 60s. Lilacs were also delayed in their flowering and did not peak until the following week when temperatures warmed and sunny conditions returned. Temperatures heated up during the last week of the month, hitting 95°F on the 28th, Memorial Day, which set a new record and helped to advance plant growth. A storm at the end of the month soaked the ground and brought the strongest winds of the year; fortunately there was minimal damage in the collection.

Summer (June 1 to August 31)

Summer 2016 was very hot and very dry. Precipitation was well below normal, only 4.05 inches compared to the average 10.44 inches, and led to moderate, severe, and eventually extreme drought conditions as we entered autumn.

June was warmer than usual and precipitation was far below normal. By mid-June, the effect of winter damage was evident and it became clear which plants would not leaf out and stood dead in the landscape. Unirrigated turf began to go dormant, making the landscape look more like August than June, and supplemental watering started in the collections. Cloudy conditions prevailed on only three days in June and solar radiation for the month was very high.

July was much warmer than usual; we had 14 days with high temperatures in the 90s, including an eight-day heat wave from July 21st to 28th. The hottest temperature of the year, 97.5°F, was recorded on the 25th. Precipitation was far below normal for the month. A fast moving thunderstorm on July 18 brought strong winds, storm damage, and washouts. We received almost half an inch (0.47 inches) of rain that day, but most of this was lost as runoff because the entire amount fell within a 15-minute period. Signs of drought stress became evident throughout the landscape and irrigation continued.

August did not offer much reprieve. After a few pleasant days in the mid 70s, the summer heat returned with high temperatures in the 80s and 90s for the remainder of the month. On August 16, this high heat and lack of precipitation upgraded the drought from severe to extreme for the first time here since national drought monitoring began in 2000 (US Drought Monitor – National Drought Mitigation Center). On the 22nd, an overnight front brought 0.76 inch of rain, more than half the monthly total. In the end, this was the warmest August ever recorded in Boston, with below average temperature on only four days. By the end of summer the compounding effects of defoliating insects (winter moth, gypsy moth, etc.), drought conditions, and unusually warm weather left many plants showing signs of extreme stress (green leaf drop, premature fall color, wilting, browning along leaf margins). Irrigation continued but could not make up for the lack of rainfall.

KYLE PORT

Conditions had progressed to extreme drought by August 17 when Arboretum Plant Records Manager Kyle Port documented the dry slope of Peters Hill, looking toward Hemlock Hill and the Boston skyline.

How Hot and Dry Was It in 2016?

Number of days with temperatures in the 90s: 24

May: 1 day
June: 1 day
July: 14 days
August: 7 days
September: 1 day

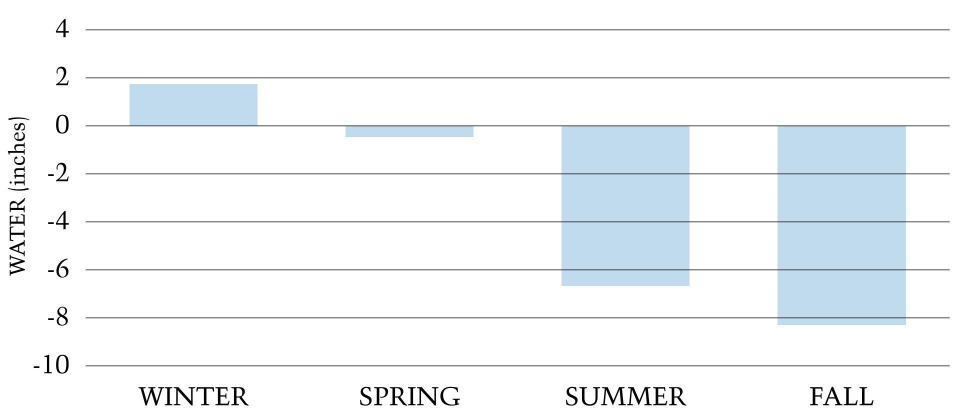
The average number of days per year with temperatures in the 90s is 13 (for Boston). The last year with more than 20 days in the 90s was 2010 (25 days).

Summer 2016 (June 1 to August 31) was the second driest on record at the Arnold Arboretum. We received 4.05 inches of rain; the record is 3.97 inches set in 1957. (The official Boston weather station received only 3.92 inches, which did beat the record, making 2016 the driest summer ever recorded for the City.)

PRECIPITATION SURPLUS/DEFICIT BY SEASON

Winter 2015–2016	12.12 inches	average is 10.40 inches	surplus of 1.72 inches
Spring 2016	9.52 inches	average is 11.57 inches	deficit of 2.05 inches
Summer 2016	4.05 inches	average is 10.44 inches	deficit of 6.39 inches
Autumn 2016	9.92 inches	average is 11.35 inches	deficit of 1.43 inches

2016 CUMULATIVE PRECIPITATION DEFICIT



2016 Drought Conditions at the Arnold Arboretum

FROM THE UNITED STATES DROUGHT MONITOR, THE NATIONAL DROUGHT MITIGATION CENTER

Scale

D0 .... (Abnormally Dry)
D1 .... (Moderate Drought)
D2 .... (Severe Drought)
D3 .... (Extreme Drought)
D4 .... (Exceptional Drought)

Arnold Arboretum conditions (dates of status change)

January 1, 2016 .... D0 (Abnormally Dry)
March 1, 2016 .... Normal conditions
June 7, 2016 .... D0 (Abnormally Dry)
June 14, 2016 .... D1 (Moderate Drought)
July 26, 2016 .... D2 (Severe Drought)
August 16, 2016 .... D3 (Extreme Drought)
November 1, 2016 .... D2 (Severe Drought)

In 2016, we had 14 weeks with normal conditions (no drought) and 38 weeks with drought conditions

14 weeks .... Normal Conditions
10 weeks .... D0 (Abnormally Dry)
6 weeks .... D1 (Moderate Drought)
11 weeks .... D2 (Severe Drought)
11 weeks .... D3 (Extreme Drought)

In 2015, we had 28 weeks with normal conditions (no drought) and 24 weeks with drought conditions

28 weeks .... Normal Conditions
21 weeks .... D0 (Abnormally Dry)
3 weeks .... D1 (Moderate Drought)

Previous years reaching Severe Drought Conditions (records began in 2000)

2012—2 weeks .... D2 (Severe Drought)
2002—5 weeks .... D2 (Severe Drought)

From 2000 through 2015 there were no instances of Extreme Drought at the Arnold Arboretum.

Autumn (September 1 to November 30)

Rainfall was again below average for this period, with 9.92 inches compared to the average 11.35 inches, and we entered autumn in extreme drought conditions. September's total was far below average; some relief arrived in October when a total of 5.81 inches of rain fell, which was more than the combined rainfall from June through September (5.48 inches).

September was another warmer than usual month with minimal precipitation. The remains of Hurricane Hermine offered hope to alleviate drought conditions, but ultimately produced less than half an inch of rain as it passed by on the 8th. Temperatures warmed to above normal for most of the rest of the month before finally cooling down to the 50s at the end of the month.

October was a very wet month, bringing soaking rains on five occasions. Torrential downpours occurred on the evening of the 21st, bringing half an inch of rain within a 15-minute period and an inch of rain over a one-hour period. This left low areas flooded and there was significant erosion on gravel paths and washouts in mulched beds. Three storms in October each delivered between 1.25 and 2 inches of rain. Despite this much-needed precipitation, extreme drought conditions persisted and much of the rainfall was lost as runoff. October temperatures were normal with pleasant fall days and cooler nights. Sourwood (*Oxydendrum arboreum*), ginkgo (*Ginkgo biloba*), red maple (*Acer rubrum*), sugar maple (*A. saccharum*), and hickories (*Carya* spp.) produced a great show of fall foliage color, but the leaves of many other trees desiccated or dropped off prior to color change because of the drought.

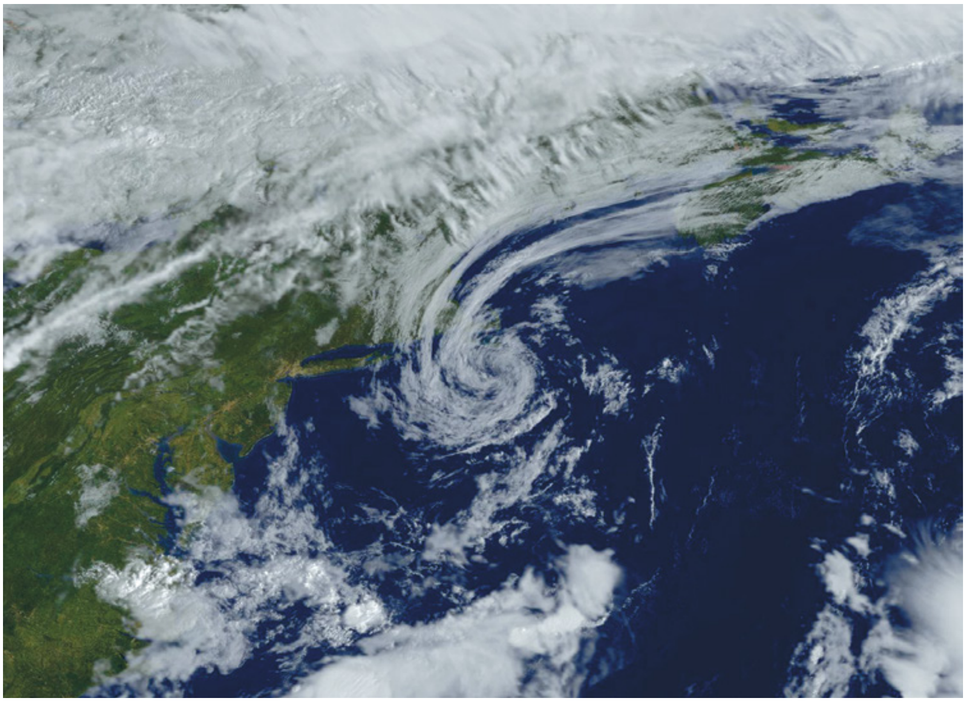


IMAGE COURTESY OF NASA

Anticipated rain from a dwindling Hurricane Hermine didn't materialize. This satellite image shows a swirl of clouds with no rainfall off the coast of southeastern Massachusetts on September 8th.

Arnold Arboretum Weather Station Data • 2016

	Avg. Max. (°F)	Avg. Min. (°F)	Avg. Temp. (°F)	Max. Temp. (°F)	Min. Temp. (°F)	Precipitation (inches)	Snowfall (inches)
JAN	30.4	22.9	30.7	59.4	6.7	3.38	8.8
FEB	44.3	23.5	33.9	65.3	-11.0	4.24	15.1
MAR	50.8	33.6	42.2	78.1	18.9	2.96	2.6
APR	56.1	37.1	46.6	80.5	18.5	3.62	5.3
MAY	67.8	48.9	58.3	94.9	39.7	2.94	
JUN	78.7	57.1	67.9	89.8	49.5	1.22	
JUL	85.6	64.0	74.8	97.5	55.3	1.34	
AUG	86.7	64.3	75.5	97.0	52.4	1.49	
SEP	75.6	57.8	66.7	93.5	38.8	1.43	
OCT	63.2	44.5	53.8	79.8	27.8	5.81	
NOV	54.0	36.4	45.2	70.2	28.1	2.69	
DEC	41.1	25.7	33.4	57.4	3.1	2.92	6.2

Average Maximum Temperature . . . . 61.9°F
Average Minimum Temperature . . . . 43.0°F
Average Temperature . . . . 52.4°F
Total Precipitation . . . . 34.04 inches
Total Snowfall in 2016 . . . . 38.0 inches
Snowfall During Winter 2015–2016 . . . . 33.3 inches
Warmest Temperature . . . . 97.5°F on July 25
Coldest Temperature . . . . -11.0°F on February 14
Strongest Wind Gust . . . . 38.2 mph on March 31
Last Frost Date . . . . 32.0°F on April 27
First Frost Date . . . . 27.8°F on October 27
Growing Season . . . . 183 days
Growing Degree Days . . . . 3165 days
Number of Days at 90°F or above . . . . 24 days

WILLIAM (NED) FRIEDMAN

Despite the drought, some trees in the collections still displayed spectacular fall color including this black oak (*Quercus velutina,* accession 127-2016-A) photographed on November 19th.

November was slightly warmer than normal with below average precipitation. On November 1st, drought conditions were downgraded from extreme to severe but supplemental irrigation continued to be necessary. We received regular precipitation throughout the month with fewer intense storms and a light dusting of snow on the 21st. The first half of November was unseasonably mild but more normal conditions returned mid-month and cooled further during the last week. Red oak (*Quercus rubra*) foliage was a beautiful red despite the ongoing drought conditions. By the end of autumn, we were 8.15 inches below normal rainfall for the year.

Early Winter 2016–2017

December brought the beginning of meteorological winter. We finished the year (January 1 to December 31) with a deficit of 8.6 inches of precipitation and entered 2017 still in severe drought conditions.

2016 Recap

It was a tough year for the Arboretum's living collections. Cold temperature events in February and April led to much damage and even the death of some plants. Summer brought hot and humid conditions and little precipitation, leaving soils extremely dry. Autumn saw some relief with cooler temperatures and more rain than summer, but drought conditions still prevailed. We are concerned about the long term effects of drought on the health of our collection and expect to see the effects of the 2016 water deficit on plant survival and growth in 2017.

Sue A. Pfeiffer is an Arboretum Horticulturist at the Arnold Arboretum.

Witness Tree: What a Single, 100-Year-Old Oak Tells Us About Climate Change

Lynda V. Mapes

Environmental reporter Lynda V. Mapes spent a year at Harvard University's Harvard Forest in Petersham, Massachusetts. There, she got up close and personal with a special red oak (*Quercus rubra*) that provided great insights on forest life and the growing effects of climate change on the natural world. This article is adapted from her recently published book, *Witness Tree: Seasons of Change with a Century-Old Oak,* which chronicles her experience.

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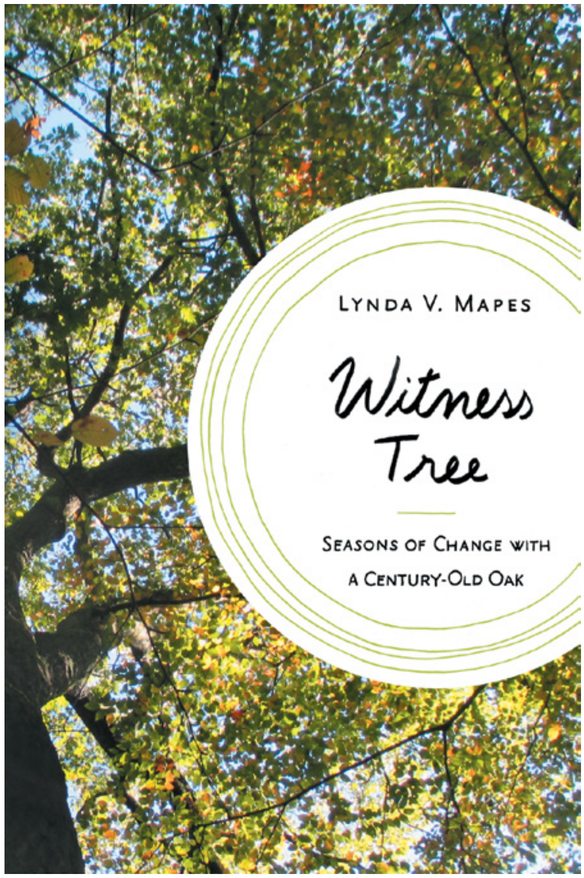

I first met the oak in the fall of 2013, walking the Harvard Forest with John O'Keefe. A biologist given to wearing the same two sweaters all winter—that's a long time in Massachusetts—and a slouchy rag wool hat, John has walked the same circuit of 50 trees in the Forest for more than 25 years.

John likes to say he started his long term survey of the timing of the seasons in the Forest, revealed in the budding, leaf out, leaf color, and leaf drop on the trees, as a way to get outside at least one day every week, then just never stopped. By now, he has compiled a valuable and unique record. Seasonal changes in nature are among the most readily observable clues to the biological effects of our changing climate, as warming temperatures reset the seasonal clock. In forests, water use, the growth rate of trees, the length of the growing season, and temperature all are connected. So John's work, documenting the seasonal gyre of the woods, was a look, told through the language of leaves, at our changing world.

His foot survey is literally the ground truth for images of the tree canopy that are beamed over the Internet, continually recorded in daylight hours by surveillance cameras, watching these trees' every move, from 120 feet overhead. With John's tree-by-tree observations, the forest-level view from the cameras and other devices on observation towers, and even a drone used to fly regular photographic missions, these must be among the most closely-monitored trees in the world.

For while the Harvard Forest is a natural wood, reminders that it is also an outdoor laboratory and classroom are never long out of sight. Spread over nearly 4,000 acres, the Harvard Forest, founded in 1907 and with more than 100 years of research in the archives, has one of the longest records of some types of data anywhere.

Trees bristle with tags and flagging, and the Forest floor is studded with equipment. There are light sensors, and laundry baskets gathering leaf litter. Often, amid the birdsong, came sounds of science, from the buzz of a drone flying a photographic mission overhead, to the hum of motors, and fans. The reality is this forest is under a microscope. It's the full-time, year-round focus of a staff of about 40 to 45 biologists, modelers, GIS specialists, historians, ecologists, dendrologists, paleo-ecologists, information and communication specialists, policy experts, atmospheric chemists, research assistants, lab technicians, and administrative staff at the Harvard Forest with an operating budget from $4.5 to $6 million a year, and a larger cadre of visiting researchers from around the world.

On his weekly survey walks, John measured little but the occasional snow depth or length of an unfurling leaf. But what he does do is look closely at a set number of tracked trees, chosen to represent a range of species, heights in the canopy, and forest environments—dry, wet, open, and shaded. He makes systematic notes of his observations on data sheets he created for the purpose, filled out the same way each week, year by year.

Professor Andrew Richardson of Harvard University was among the first of many researchers to use John's records in influential scientific papers about the effects of climate change on forests. I met Andrew in August 2013, when I first arrived in Cambridge as a Knight Fellow in Science Journalism at MIT. I wanted to explore new ways to tell the story of our changing climate—a yawner of a story for too many, if told as a distant debate about treaties, dueling politics, and doomsday scenarios. The stakes are high: species extinction, the function of natural processes, and viability of habitats. But the facts won't matter if we can't get anyone to pay attention.

I wanted to tell the story through the charisma of living things, and the compelling but largely overlooked drama of the delicate seasonal timing of the natural world and how it was being disrupted. So when Andrew took me up on my request to sit in with his lab, and John let me join his walks, I decided to dive deep. "John," I wrote in an email not long after our first survey walk together, "I need a tree."

We picked it not long after—a single, glorious, nearly 100-year-old red oak in his survey that I could use as a narrative frame for my own inquiry into the Richardson lab's work. What where they learning? Could I see climate change at work in this forest, and even in this one tree? Just as settlers used notable trees, known as witness trees, to mark the metes and bounds of changing landscapes, could the big oak reveal the changing climate?

John's walks were enthralling. He noticed everything, and with all five senses, creating in his field notes a portrait of the forest in Pointillist detail: how firm the tree's buds were, or whether they had softened and were getting ready to crack open. The sound of the first call of wood frogs, the scent of mineral soil as the frost melted from the ground. The sight of the leaves' first emergence; the filling and draining of puddles; the flow of the streams, and first unfolding of woodland flowers. The autumn colors of the leaves, the thunk of falling acorns; frost flowers and ice on the puddles, and the wintergreen taste of birch bark. Here was a place richly and closely observed, right down to the mud and black flies. With nothing more than a pair of binoculars, six-inch ruler, and clipboard, John, by walking the Forest again and again, amassed a detailed calendar of the seasonal year, his tiny handwriting

ALL PHOTOGRAPHS BY THE AUTHOR UNLESS OTHERWISE INDICATED

A spectacular luna moth rests on a building in early June.

in Number 2.5 pencil recording local events with planetary implications. His findings over the decades were clear. On average, spring is coming earlier. Fall is coming later. And winter is being squeezed on both ends.

Everything in the woods reflected these changes, from the level of water in the vernal pools and springs to when the black flies were biting, the ground frozen, or leaves budding out or finally coming off the trees. It wasn't a matter of conjecture or political argument; the discussions of who does and doesn't "believe" in climate change in editorial pages, news reports, and Congressional debates frames this all wrong. The changing climate, trees, streams, puddles, birds, bugs, and frogs attest, is not a matter of opinion or belief. It is an observable fact. Leaves don't lie; frost isn't running for office, frogs don't fundraise, pollinators don't put out press releases. What John compiles, while taking all these walks, is the testimony of an unimpeachable witness: the natural world.

Studying Phenology

Discerning the workings of the natural world in seasonal timing has a long history. The roots of the word are the Greek words *phaino,* meaning to show or appear, and *logos,* to study. It's from *phaino,* too, that we get phenomenon, and traditionally phenology has consisted of the study of the timing of biological phenomena in nature and the relationship of these phenomena with Earth's environment, particularly the climate. The Belgian botanist Charles Morren argued that like meteorology, botany, zoology, physiology, and anthropology, this merited being a scientific discipline unto itself: phenology. He is credited with the first use of the term at a public lecture at the Belgian Royal Academy of Sciences at Brussels in 1849.

Biologist John O'Keefe has recorded phenological details about trees at Harvard Forest for decades.

Mushrooms, moss, and fallen leaves color the forest floor.

Newly expanded foliage provides a bright green crown for the witness tree.

MELISSA LEVANGIE

Author Lynda V. Mapes takes notes aloft in the century-old red oak.

Phenology's roots are in old-style, hands-on observation like John's, practiced long before the term phenology was invented. The longest continuous written phenological record is probably marking the first flowering of cherry trees at the royal court of Kyoto, Japan, dating back to AD 705. In Europe, French records of grape harvest dates in Burgundy stretch back to 1370, and have been used by scientists to reconstruct spring-summer temperatures back into the Middle Ages.

In England, Robert Marsham in 1736 began recording what he called his "Twenty One Indications of Spring" at his country estate in Norfolk. He tracked the seasonal stirrings of animal life: croaking frogs and toads, singing nightjars, pigeons and nightingales, arriving swallows and cuckoos, rooks building nests, and all manner of plant activity, from flowering snowdrops, wood anemones, and hawthorns to leafing birches, elms, oaks, beech, and horse chestnut. The recording duty passed from one generation of Marsham's descendants to another until the death of Mary Marsham in 1958.

Mainstream science left phenology aside long ago. But it's being rediscovered, as researchers look for evidence of climate change in the seasonal calendar of living things. Old photographs, records of birding and garden clubs, even art and literature reveal changes subtle in the moment but visible over time.

The daffodil of Shakespeare has advanced its bloom time so drastically as to no longer fit its literary frame: "Daffodils, That come before the swallow dares, and take The winds of March with beauty," Shakespeare wrote in *The Winter's Tale.* March. Not in January. And certainly not at Christmas, as happened in 2015 when the United Kingdom witnessed its warmest start to December in 50 years, *The Guardian* reported. At this rate, Britain's native daffodil, the Lent lily [*Narcissus pseudonarcissus*]—named for its expected February–March bloom time—is going to need a new name. Of course this just confirms what the gardeners, the hikers, the outdoorsmen and women of every sort already know from their own sense of a fraying natural order. Reliable patterns of nature's pageant are slipping their chronology.

Phenology Plus Technology

For Andrew Richardson, John O'Keefe's records offer valuable data he uses to explore the effects of climate change on tree physiology and seasonal timing of the forest canopy. The object is to probe the forest at a variety of scales, from individual trees to the forest, region, and biosphere. The data from John's weekly walks has also helped Andrew deploy phenology as a lens on the workings of the forest in a whole new way—and brought new relevance to John's work.

It all got started when Andrew was at the University of New Hampshire, working with his colleagues making measurements of the daily and seasonal rhythms of carbon dioxide exchange between the trees and the atmosphere—the breathing of the forest. He was using instruments at the top of a 90-foot-tall tower in the Bartlett Experimental Forest in the White Mountains of New Hampshire. Then he had a hunch there were a lot of other things he could also be measuring to get a better idea of how the ecosystem worked. Which, in a project meeting one day, led to a conversation with one of Andrew's collaborators. What, they wondered, about putting a camera on the tower, with the thought that at the very least they would get cool pictures of the forest canopy through the seasons for presentations at science talks?

Professor Andrew Richardson examines a core extracted from a tree in Harvard Forest.

They figured they would also probably be able to tell when the leaves came out and when they fell off, which would also be useful for estimating growing season length, key information for scientists studying how much carbon forests pack away. Within a few weeks they installed what was then a state of the art camera, beaming its images over a wireless connection back to a server on campus. When the first images came in over the Internet to their computers, they were delighted that, dinky as it was, the camera was performing just as they hoped. Suddenly, they could monitor their remote field site from their desks. That got Andrew thinking.

The next summer, Andrew asked a PhD student, Julian Jenkins, whether he thought he could use computer analysis to spot the beginning of spring green-up in the images. In just days, Julian created a computer program that converted the red, blue, and green pixels in the camera image to numeric values. He then could count the amount of greenness in an image. Voila: spring, pinpointed from the pixel mix. Now the team could track the development of the canopy all the way into summer, with every day's incremental growth in the leaves showing up as increasing numbers of green pixels. And come fall, the camera's pixilated signals of leaf coloring and drop were just as clear. Suddenly, big swaths of landscape could be remotely monitored for seasonal development, over the Web, from anywhere.

It was a breakthrough. Here was the possibility of creating a whole new kind of observatory: a remote, digital observatory, with a network of cameras that could monitor the rhythm of the seasons as they transformed the land, over as large an area as the cameras could be placed, with the information streamed to a central server where the data could be shared, archived, and analyzed. Andrew dubbed it the PhenoCam network. There had never been anything like it.

In less than a year, Andrew found funding to start a small PhenoCam network to observe forest phenology across northern New England and adjacent Canada. That was in 2007. Then the National Science Foundation (NSF) in 2011 provided money that allowed the team to expand the monitoring network. Next, in 2013, NSF kicked in more money that the team

Observation towers in Harvard Forest hold cameras and other devices for research studies.

used to involve volunteers in interpreting and analyzing more than 5 million images streaming into a network by then grown to some 250 sites across North America, uploading images at least once an hour, seven days a week, during daylight hours. The cameras were all over the place, from instrument towers such as those in the Harvard Forest to weather stations and building tops, from forests to tundra to Hawaiian grasslands and the desert southwest. The PhenoCam network brought the phenological tradition of Robert Marsham, Thomas Jefferson, Henry David Thoreau, and Aldo Leopold into the digital age. What would Jefferson have given for a PhenoCam on his beloved gardens, instead of having to wait for letters from Monticello to fill him in on what was in leaf and in flower. We even put a camera for the network under my red oak. Visit it at http://harvardforest.fas.harvard.edu/webcams/witness-tree

Here was the ability to see the forest not only up close, from tree to tree, as John does, but at scale. The proverbial forest for the trees. Researchers are no longer limited only to what can be seen on foot, or the occasional imagery of a satellite, available only intermittently and from a great distance. Not surprisingly, Andrew and his collaborators are still figuring out what to do with so young a method. Their work keeps turning up surprises.

New Insights on Climate Change

Trevor Keenan, now at the Lawrence Berkeley National Lab, with Andrew published a paper in 2015 showing that the timing of spring and fall are connected, but not in the way widely

The witness tree red oak stands leafless in late autumn.

supposed. Conventional wisdom—and many climate models—held that the warmer temperatures that brought on an earlier spring would also mean a later fall, and a longer and longer growing season. But Trevor and Andrew found out that the timing of autumn correlates more closely with the onset of spring than with temperature or day length. Spring, it turned out, exerted a strong control on the timing of fall, somewhat offsetting the effect of warming. The findings do not imply a growing season of fixed length, as the relationship between spring onset and autumn senescence they discovered was not one to one. Rather their results suggested that current models don't include the effects of spring on autumn, leading to an over-prediction of the extension of the growing seasons by as much as 50 percent under future warming scenarios. "It was a eureka moment," Trevor said. Struck by the importance of their initial findings, Trevor scaled up to investigate seasonal trends on the entire east coast. The same pattern still held true.

There are several possible explanations. "Plants know from the history of their ancestors how long their timeline is," Trevor said. "So it makes sense they would have some mechanism built into their optimum function, to have a pre-programmed senescence … The question is how quickly can they learn to change and detect that the environment around them has changed?" Another theory is that once trees have filled up their carbon stores they are finished with their work for the year, even though the weather is still fine. "They have been as productive as they need to be for the year," Trevor said. "They are done."

For me the idea of seasons lasting longer than the leaves could stay on the trees was a lot to take in. There is something unnatural about it—because of course, it is unnatural. It's a human-caused forcing of the climate system, imposed on a natural physiological cycle with its own timing. There are two seasons now: the seasons of living things, and the seasons made by us. Trevor expected that in time the trees would catch up, using their ability to adapt to take advantage of longer growing seasons, as trees do further south. The question is how fast.

Long term carbon sequestration measurements at the Harvard Forest also show that trees at the Forest, dominated by red oak, have been growing faster since the 1990s, as global average temperatures and carbon dioxide levels began their most rapid rise. By now, red oak is putting on more mass than any other tree species in the Forest, and faster. True, that is partly just red oak's nature. The relatively young age of the forest, still recovering from the deforestation of the nineteenth century, also makes for this strong growth. But the red oak's surge is also the result of climate change, manifest in warmer temperatures on average in winter, increased rainfall, and growing seasons lasting longer than at any point in the last two decades.

With the millions of microscopic openings on their leaves, called stomata (from the Greek *stoma,* for mouth), trees also are speaking truth about the effects of the changing atmosphere. Water vapor, carbon dioxide, and oxygen all move in and out of leaves through these openings, creating a survival challenge. But Andrew and Trevor documented in another widely-read published paper that at higher carbon dioxide levels trees, including red oak at the Harvard Forest, are working more efficiently. They don't open their stomata as much or as often to take in the carbon dioxide they need. That means they can make as much and even more food while using less water. It also suggests a shift in the physiology of trees, with profound implications for everything from water cycling to climate. Trees like my big oak are changing their inner workings, using less water even as they put on more growth as temperatures warm and carbon dioxide levels rise.

From the sky and its atmosphere to the seasonal timing and growth rate of trees and, deeper still, all the way into the photosynthetic process of individual leaves, human fingerprints are now on the most grand to the most intimate scales of our planet. You could see all this even within one tree. The big oak's witness was clear: Our world is already changing.

Acknowledgements

The author is grateful to the Knight Program in Science Journalism at MIT for the purchase of the PhenoCam under the witness tree at the Harvard Forest and to the Harvard Forest for keeping it online. To learn more about the witness tree project see http://harvardforest.fas.harvard.edu/witness-tree

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Lynda V. Mapes is the environment reporter at the *Seattle Times* and the author of *Witness Tree.* Her research was supported by a Knight Fellowship in Science Journalism at MIT and a Bullard Fellowship in Forest Research at the Harvard Forest. For more on Lynda's experience and the book visit http://lyndavmapes.com.

Through the Seasons with Sassafras

Nancy Rose

Sassafras (*Sassafras albidum*) is an admirable tree any time of the year. Native to most of the eastern United States as well as far southern Ontario, sassafras is a medium-sized (typically 30 to 60 feet [9 to 18 meters] tall) deciduous tree with an attractive tiered branching habit. It may form dense, shrubby thickets as suckers arise from its shallow, wide-spreading, lateral root system, especially in sites like old farm fields where it has room to spread.

Sassafras is primarily dioecious, bearing staminate (male) and pistillate (female) flowers on separate plants. Blooming in early to mid spring, the fragrant yellow flowers are borne in clusters that, en masse, put on quite a show despite the relatively small size (about 1/3 inch [8 millimeters] in diameter) of individual flowers. Sassafras fruits are rather striking: ovoid, deep blue drupes cupped in fleshy, cherry red pedicels that often persist after the fruit has dropped or been eaten.

Sassafras albidum has unusual foliage—its leaves may display three distinct morphologies, all of which may be present on the same tree. The three leaf shapes are 1) an unlobed oval, 2) a two-lobed "mitten," with one large lobe and a smaller "thumb" lobe, and 3) a three-lobed, trident-like form. Sassafras foliage is a pleasant-enough light green in summer, but its autumn coloration in shades of yellow, orange, and red is truly spectacular. The foliage also has a culinary aspect; filé powder, a flavoring and thickening agent used in Creole gumbo, is made of young sassafras leaves, dried and finely ground. Sassafras is also a food plant for caterpillars of spicebush swallowtail and tiger swallowtail butterflies.

Young sassafras twigs are olive green and, when scratched, emit a lemony, slightly medicinal odor. Mature bark on trunks is orangish brown and deeply furrowed. The yellowish wood is light and somewhat brittle, however, it is fairly rot resistant and so has been used to make barrels, fence posts, and other items. Oil of sassafras is extracted primarily from the bark of sassafras roots and has been used for medicines, fragrances, and flavorings, including for root beer.

Sassafras is a member of the laurel family (Lauraceae), a group of mostly tropical trees and shrubs. There are just three species in the genus *Sassafras.* In addition to the North American *S. albidum* there are two similar looking species in Asia, *S. tzumu* from China and *S. randaiense,* endemic to Taiwan. Another familiar temperate region genus in the family is *Lindera,* the spicebushes. Scratch the stem of the native North American spicebush (*Lindera benzoin*) and you'll smell a lemony-medicinal fragrance similar to sassafras.

For all its ornamental attributes you'd think sassafras would be more widely planted. Perhaps the main reason it's not on every street corner is that it's a bit difficult to propagate and transplant. Stem cuttings do not root readily, so propagation is done from seeds, which require stratification, or from root cuttings. Fortunately, container-grown sassafras can be found at some nurseries, especially those specializing in native plants. Sassafras grows best in moist, well-drained sandy loam but also tolerates other soils as long as they're well drained. It is generally cold hardy through USDA Plant Hardiness Zone 5 (average annual minimum temperature -10 to -20°F [-23.3 to -28.9°C]).

There are currently ten specimens of *Sassafras albidum* growing in the Arboretum. The most prominent of these is a group (22915-A, B, C, and E) growing right along Bussey Hill Road across from the lilac collection. This is a a great-looking grove of sassafras, but unfortunately their exact provenance is unknown (they were accessioned in 1950 as "existing plants"). We do have several accessions of known provenance, including one (968-A) collected from a woods near the Arboretum in 1884, but we also hope to add more wild-collected accessions of this beautiful native tree as part of our ongoing Campaign for the Living Collections.

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The ARNOLD ARBORETUM of HARVARD UNIVERSITY