Welcome to the Museum

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Arboretum

Curated by KATIE SCOTT and TONY KIRKHAM

Royal Botanic Gardens Kew

Welcome to the Museum

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Arboretum

Illustrated by KATIE SCOTT

Written by TONY KIRKHAM

B P P

Entrance

The word *arboretum* means 'a place with trees'. Open this book and you will walk through every tree-filled place as you travel the globe. Discover dense forests, frozen landscapes, tropical jungles and immaculate gardens.

Packed full of fascinating species, every corner of this arboretum has something to discover. Marvel at majestic giants that are hundreds of years old, inhale the sweetest scents of cherry blossom and fresh pine and be amazed by trees like the fever tree, whose bitter bark has been instrumental in the fight against malaria.

Trees have always inspired us and have impacted on every aspect of human life, but, at this time of unprecedented change for our planet, it could not be more important to learn how to live alongside these giants. We cannot protect the natural world until we understand it. Walk through the arboretum gates, and let the journey begin.

What is a Tree?

Trees are beautiful and essential for life. They grow all around us, forming woodlands and forests across many landscapes. From the smallest bonsai to the giant coast redwood, trees are found in a wide variety of shapes and sizes. Their most noticeable feature is a woody stem called a trunk, which increases in height and thickness each year. The trunk supports a network of large branches. These divide into smaller branches extending upwards and outwards, forming the crown of the tree. On the ends of the branches are twigs and shoots that produce buds, leaves, flowers and fruit, taking full advantage of the sunlight in the upper canopy level.

The most important part of the tree, growing underground, is the network of roots. Roots anchor the tree to the ground, keeping it upright and soaking up water and nutrients. The root plate is shallow and found in the upper 60cm of soil, spreading outwards where there is plenty of oxygen, water and nutrients to feed on, rather than downwards where the soil is dry and lacking in nutrients.

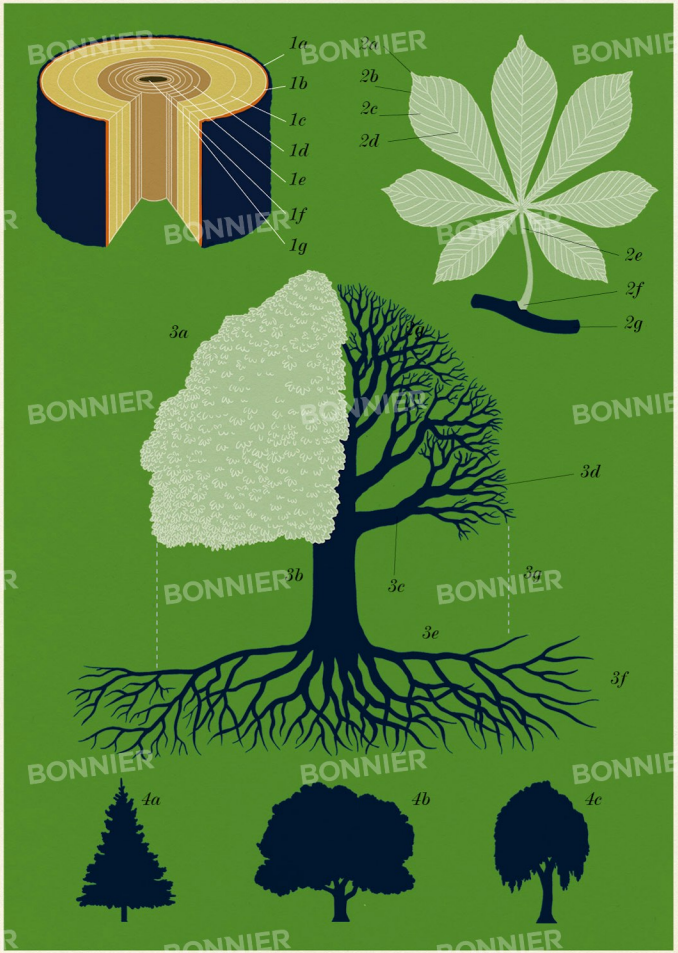
Key to plate

1: **Trunk cross section**
The trunk is made up of annual growth rings. Every ring represents a year's growth.
a) outer bark b) inner bark
c) cambium d) sapwood
e) heartwood f) pith g) growth ring

2: **Leaf**
Leaves are the primary organs for photosynthesis. They are specially adapted to this purpose, with a large, flat surface area.
a) tip b) margin c) vein d) midrib
e) petiole f) axil g) stem

3: **Tree**
a) crown b) trunk c) major branches
d) minor branches e) root plate
f) roots g) dripline
The dripline extends to the edge of the tree canopy. Rain runs from leaf to leaf, finally dripping off its edge.

4: **Tree forms**
Trees naturally grow in a variety of different shapes.
a) pyramidal b) spreading c) weeping



The First Trees

During the Carboniferous period (359 and 299 million years ago), towering fern-like plants covered the land, extending their shallow roots into swampy pools and spongy peat. By the end of this period, these dense forests included giant tree ferns such as Archaeopteris. Considered one of the first true, modern trees, this important species evolved over a period of 100 million years to produce trunks up to 1m thick and establish deep roots.

By the Permian period (290–248 million years ago), trees had evolved to bear seeds and feature branching crowns. Many of them are still recognisable today, including cycads, monkey puzzles and ginkgoes.

With the arrival of the Jurassic period (between 199–145 million years ago), the climate had become warmer and wetter. The wollemi pine and dawn redwood dominated this period, and both still grow today.

Angiosperms were among the last plants to evolve. Broadleaved flowering trees such as magnolias and plane trees appeared during the Cretaceous period. Despite being driven back by at least four ice ages, trees have adapted to every habitat on Earth.

Key to plate

1: **Tree fern**
Psaronius Height: 10m
a) tree b) new unrolling fronds

2: **Sweetbay magnolia**
Magnolia virginiana Height: 30m
Flower

3: **Oriental plane**
Platanus orientalis Height: 30m
a) leaf b) covered bud

4: ***Archaeopteris*** Height: 30m

5: **Maidenhair tree**
Ginkgo biloba Height: 40m
Bi-lobed leaves

6: **Monkey puzzle**
Araucaria araucana Height: 50m
Tree

Habitat: Boreal Forest

The boreal forest, or 'snow forest', is one of the most hostile locations in the world for a tree to grow in. The forest is thick, but because of the harsh conditions, is made up of only a few hardy species – mainly spruces, pines and firs. Covering huge areas of Canada, Alaska, Scandinavia, Russia and Siberia, it is the most northerly forest on the globe and Earth's largest land biome, taking up about 17% of its land surface.

The forest experiences long, six-month winters, during which the average temperature remains below freezing and there are just a few hours of sunshine. Its growing season is therefore very short: just 50–100 days. Luckily, summers in the forest can see lots of sunshine and rainfall. Shallow bogs form on the forest floors known as 'muskegs'. Although the muskegs are highly acidic and largely infertile, a few small-leaved conifer species can thrive in this special habitat.

The boreal forest is a vitally important carbon sink, which means it absorbs more carbon than it releases. Most of the carbon is found in the permafrost (a frozen underground layer), but, as Earth warms up, the permafrost is in danger of thawing and releasing carbon dioxide into the environment, contributing to climate change.

Key to plate

North American boreal forest

1: **Black spruce**
Picea mariana Height: 15m

2: **Tamarack**
Larix laricina Height: 20m

3: **Lodgepole pine**
Pinus contorta Height: 20m

4: **White birch**
Betula papyrifera Height: 20m

5: **American mountain ash**
Sorbus americana
Height: 12m

6: **Quaking aspen**
Populus tremuloides
Height: 21m

Boreal Broadleaves

Although boreal forests, or 'taiga', are dominated by conifers, there is also a very small but hardy selection of broadleaved trees present, including poplars, willows and birches.

While generally short-lived species, rarely reaching 100 years, these trees have many characteristics that help them survive in the taiga. They can all grow, flower and fruit during the short summer, and then shed their leaves at just the right moment to prepare for the long winter. Their compact leaves have a small surface area, which means they can be produced quickly – ideally suited for a forest with a short growing season – and they are also able to withstand strong winds.

The broadleaved trees grow near water, making the most not only of the available moisture there, but also the light levels around lakes and rivers where there is no competition from the dense-leaved conifers. In the northern tundra, these trees are short and stunted but further south, towards the temperate broadleaved forest, they have straighter trunks and grow taller.

Key to plate

1: **Speckled alder**
Alnus incana subsp. *rugosa* Height: 22m
a) branch b) flower

2: **Large-toothed aspen**
Populus grandidentata Height: 25m
Leaf

3: **American mountain ash**
Sorbus americana Height: 12m
Leaves

4: **Balsam poplar**
Populus balsamifera Height: 30m
Flower

5: **White birch**
Betula papyrifera Height: 20m
a) trunk/bark b) male flower c) leaf

6: **Moosewood**
Acer pensylvanicum Height: 10m
a) leaf b) twig and buds c) trunk/bark

TEMPERATE CONIFER FORESTS

Boreal Conifers

One of the most ancient tree species, conifers are synonymous with boreal forests. Densely packed green firs, spruces and pines all tower high above the dark, damp ground below, while in autumn, the larch brightens up the scene with a warm golden glow.

'Conifer' basically means 'cone-bearing' and, instead of flowers, these trees produce seeds in cones. Conifers are evergreen which means they start producing food as soon as they wake up after the winter and don't have to wait for new needles to grow. The larch is the odd one out. Being a deciduous conifer, it loses its needles each year. However, larches have delicate needles compared to evergreen conifers, so they are quicker and easier to grow.

Although their growth is slow, conifers have adapted to be able to cope with the harsh weather. Their recognisable narrow, conical-shaped canopies are made up of flexible branches that sweep outwards. This design helps to shed heavy snowfall and reduce the potential damage to the branches from snow and strong winds.

Key to plate

1: **Balsam fir**
Abies balsamea Height: 20m
Seed cones and leaves

2: **Black spruce**
Picea mariana Height: 15m
a) seed b) seed cones and leaves

3: **American larch**
Larix laricina Height: 20m
Seed cones on branch

4: **Lodgepole pine**
Pinus contorta Height: 20m
a) female cone cross section
b) male cone c) mature seed cone

Temperate Conifers

There are more than 600 different species of conifers in seven families growing today. As well as the boreal forests, where they are the dominant tree, conifers grow in many other temperate forests in the world.

Pines, spruces and silver firs all belong to the pine family, the largest of the conifer families. They grow in the most diverse habitats in the taiga and other parts of the northern hemisphere. They are evergreen, with needle-like leaves and cone-bearing fruits containing naked, winged seeds. The 54 different types of spruce have branches that radiate in a circle from around the trunk. This makes them perfect for decorating and therefore a very popular Christmas tree.

The Latin name for the fir, *Abies*, means 'to rise', and these trees can grow as high as 80m tall. Tough and resilient, firs can be found growing at the highest levels on mountains. Their young female cones are often brightly coloured blue or purple, and always grow upright off the branches like candles.

Key to plate

1: **Korean pine**
Pinus koraiensis Height: 30m
Leaves

2: **Sitka spruce**
Picea sitchensis Height: 100m
Mature seed cones

3: **Scots pine**
Pinus sylvestris Height: 35m
a) leaves and male pollen cones
b) mature seed cone c) seedling stage

4: **Morinda spruce**
Picea smithiana Height: 50m
Leaves

5: **Single-leaf pinyon**
Pinus monophylla Height: 10m
Leaves and male pollen cones

6: **Santa Lucia fir**
Abies bracteata Height: 35m
Mature seed cone

7: **Gray pine**
Pinus sabiniana Height: 15m
Leaves

Redwoods

The majestic redwoods are record-breaking conifers and include some of the largest and tallest trees on Earth. One impressive coast redwood called 'Hyperion' has reached the dizzying height of just over 115m. The oldest specimen on record is estimated to be 3,500 years old.

The dawn redwood grows in China, while the giant and coast redwoods grow in North America. The North American species are never found together; the coast redwoods grow in the fog belts of the Pacific coastline and the giant redwoods in open groves further inland, on the western slopes of the Sierra Nevada mountains. Both trees have extremely wide trunks, defined by spongy, cinnamon-red bark, growing up to 60cm thick, and their evergreen branches start high up the trunk, which protects them from forest fires.

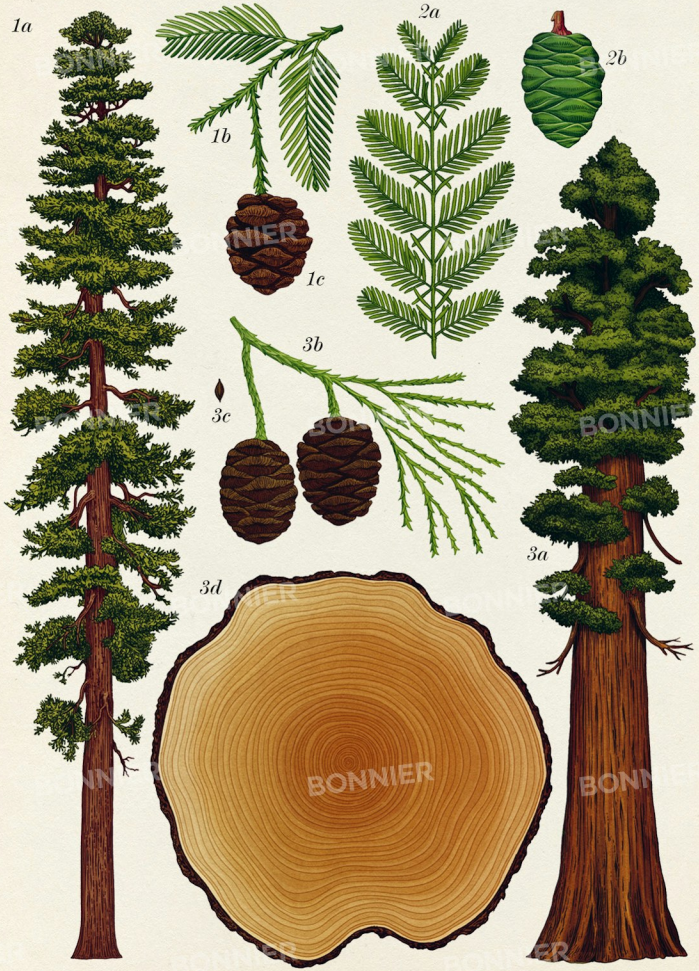
Unlike the two North American redwoods, the Chinese dawn redwood is a deciduous conifer with flat, feathery needle-like leaves and reddish-brown, fibrous bark. Incredibly, it was first discovered in 1941 as a 150-million-year-old fossil tree dating from the Mesozoic Era. A few years later, a living species was found in Central China. Seeds were collected and distributed to arboreta around the world, where they grow today.

Key to plate

1: **Coast redwood**
Sequoia sempervirens Height: 115m
a) tree b) leaves c) mature female seed cone

2: **Dawn redwood**
Metasequoia glyptostroboides Height: 50m
a) leaves b) mature seed cone

3: **Giant redwood**
Sequoiadendron giganteum Height: 115m
a) tree b) leaves and female cones
c) seed d) cross section of trunk



Cypresses

Trees in the cypress family are easily recognisable by their scale-like leaves which appear as flattened sprays on the branchlets that hang from the main branches. These evergreens include cypresses, junipers, swamp cypresses, incense cedars and arborvitaes. They are found in all northern temperate areas.

These trees have many different forms, from stunted junipers that hug mountainsides, to the mammoth, cathedral-like Western red cedars growing on the west coast of North America. Regarded as trees of good fortune, the branches and foliage of the Asian species of arborvitae and juniper are used as good luck charms.

There are many varieties of evergreen trees cultivated for their ornamental attributes, including the ever-popular Leyland cypress which is often used as a hedging plant in small gardens. The one tree that epitomizes all the true cypresses, however, is the Italian cypress. Easily recognisable by its erect, flame-like conical pillars, these rich-green trees can be found growing in Mediterranean regions. Slim, beautiful and easy to grow, they are often used as decorative features, and are particularly synonymous with grand, Renaissance-style gardens.

Key to plate

1: **Italian cypress**
Cupressus sempervirens Height: 35m
a) spray of foliage with seed cones
b) mature seed cone

2: **Western red cedar**
Thuja plicata Height: 70m
a) mature seed cone b) male cone
c) spray of foliage

3: **Hiba arborvitae**
Thujopsis dolabrata Height: 40m
Spray of foliage

4: **Incense cedar**
Calocedrus decurrens Height: 60m
a) spray of foliage b) close-up of scale-like leaves c) male cone d) mature seed cone

Habitat: Temperate Broadleaf Forest

Temperate deciduous forests make up some of the world's most dramatic biomes. These forests produce dainty buds at the start of the growing season, transforming to lush greens, then bursting into blazing reds, oranges, yellows and browns before their leaves drop, leaving bare, skeletal structures to face the cold months ahead.

These magnificent forests occur mainly in the mid-latitude parts of the globe, encompassing parts of the United States, Canada, Europe, China, Korea, Japan and Russia and South America. All of these regions have four seasons, with no season getting too hot or too cold.

Remarkably, all these forests share similar genera of tree species, which include oaks, maples, beeches and ashes, but also have their own native species in each region. Beneath these forest giants, smaller, shade-tolerant species such as dogwoods and sourwood fill the understorey and shrub layers, mingling with ferns and mosses to create perfect hidden habitats for birds and small mammals. The forest floor itself is full of insects and fungi, who enjoy the rich, fertile soil created by falling leaves and deadwood.

Key to plate

North American broadleaf forest

1: **Red oak**
Quercus rubra Height: 40m

2: **American beech**
Fagus grandiflora Height: 35m

3: **Pecan**
Carya illinoinensis Height: 40m

4: **Flowering dogwood**
Cornus florida Height: 9m

5: **Osage orange**
Maclura pomifera
Height: 15m

6: **White sassafras**
Sassafras albidum
Height: 20m

North America

This temperate ecosystem, also known as the Central Hardwood Forests of North America, takes in more than 26 eastern US states. Despite being severely deforested by the mid 1800s for agricultural land, these forests are still the largest of their kind on the globe. They include some of the world's most picturesque provinces, including the Appalachian and Ozark plateaus, Great Smoky and Blue Ridge mountains.

These forests feature various overstorey species, including the pin oak, American elm, American sycamore, hickories and basswoods or limes. Perhaps two of the most well known are the black tupelo and the sweetgum – trees renowned for their tantalising yellow, orange and scarlet autumn colours as they prepare for winter.

The American chestnut was once the largest and most dominant tree, but sadly succumbed to the fungal disease chestnut blight which was introduced into North America from Asia in 1906. It is now all but extinct.

Key to plate

1: **Pin oak**
Quercus palustris Height: 25m
Leaves and seeds: acorns

2: **Flowering dogwood**
Cornus florida Height: 9m
Flowers

3: **Osage orange**
Maclura pomifera Height: 15m
Cut open fruit

4: **Kentucky coffee**
Gymnocladus dioicus
Height: 30m
Fruit

5: **American chestnut**
Castanea dentata Height: 30m
Fruit

6: **American elm**
Ulmus americana
Height: 30m
Leaves and fruit

7: **American sycamore**
Platanus occidentalis
Height: 50m
Fruit

8: **White sassafras**
Sassafras albidum Height: 20m
Leaves
a) simple
b) mitten-shaped
c) trident-shaped

9: **Persimmon**
Diospyros virginiana
Height: 20m
Fruit

Asia

The temperate deciduous forests of eastern Asia are some of the richest in terms of plant diversity. This biome stretches from the boreal forests in the north and south to the tropical rainforests above the Tropic of Cancer, and as far east as the Pacific coast of Japan.

Unlike other parts of the temperate world, this region was left largely untouched by glaciation during the Pleistocene epoch (1.6 million to 10,000 years ago). These forests therefore include very ancient types of trees such as the ginkgo and the dawn redwood which date back to the days of the dinosaurs. Today, despite the extent of human activities over at least 4,000 years, many areas of remote wild forest remain intact in the mountains.

There are several ancient genera of trees that can only be found growing in these forests. These include the only two species of tulip tree; *Liriodendron tulipifera*, a tall hardwood of Eastern North America, and *Liriodendron chinense* in China and Vietnam.

Key to plate

1: **Campbell's magnolia**
Magnolia campbellii Height: 30m
Flower

2: **Cone nut**
Platycarya strobilacea Height: 10m
Fruit

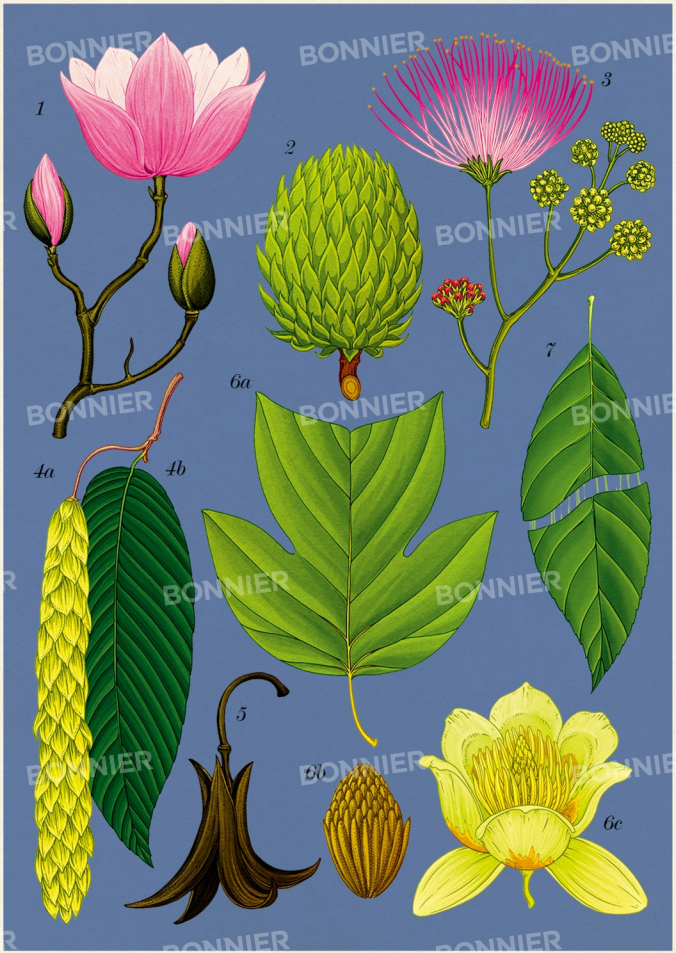
3: **Persian silk**
Albizia julibrissin Height: 15m
Flower

4: **Monkey tail hornbeam**
Carpinus fangiana
Height: 20m
a) fruit b) leaf

5: **Goat horn**
Carrierea calycina Height: 10m
Fruit

6: **Chinese tulip**
Liriodendron chinense Height: 40m
a) leaf b) fruit c) flower

7: **Chinese rubber**
Eucommia ulmoides Height: 15m
Torn leaf



Europe

At the end of the last Ice Age (around 10,000 years ago), the ice masses melted and retreated northwards, exposing tree seeds that had stayed dormant under the ice sheets in a natural seed bank. These quickly germinated and began to reforest the European continent, helped by the movement of wind, and animals such as birds and small mammals. Today, the dominant canopy tree species of western Europe include the beech, the pedunculate oak and the sessile oak as well as elms, limes, ash and sycamore.

In the early twentieth century, these forests endured yet more hardship. Dutch elm disease had been around for centuries, but in the 1960s a more virulent strain of the disease spread across the continent. Carried by elm bark beetles, particularly *Scolytus scolytus*, it would prove to be lethal to the European elm population, causing near extinction.

Today, one of the last and largest remaining middle European forests is the Białowieża Forest on the Poland–Belarus border covering an area of 1,419 km². A place of exceptional biodiversity, it is home to the largest population of European Bison and a wealth of protected species including 59 mammals, 250 birds and more than 12,000 invertebrates.

Key to plate

1: **Small-leaved lime**
Tilia cordata Height: 40m
a.) leaf with immature flowers
b.) close-up of flower

2: **Horse chestnut**
Aesculus hippocastanumb Height: 35m
a) seed: conker b) fruit c) leaf
d) twig with terminal bud

3: **Caucasian wingnut**
Pterocarya fraxinifolia Height: 30m
a) seed b) fruit

4: **Turkish hazel**
Corylus colurna Height: 25m
Fruit

Autumn Colour

Autumn colour is one of the seasonal spectacles of the northern hemisphere temperate forests. As the days shorten and temperatures begin to fall, the deciduous trees stop photosynthesising and get ready to shed their leaves in preparation for winter dormancy. The forests become an explosion of colour.

The green pigment in leaves is called chlorophyll, and is an important ingredient in photosynthesis. As the production of chlorophyll halts for another year, and any useful chemical components are reabsorbed back into the tree, the green tints gradually disappear. This allows the weaker pigments which have been hidden throughout the year to shine through. Carotenoid pigments produce yellow and orange colours, while anthocyanins provide red and purple.

Key to plate

1: **Tulip**
Liriodendron tulipifera Height: 50m
Native to Eastern North America.

2: **Northern red oak**
Quercus rubra Height: 30m
Native to Eastern North America.

3: **Red maple**
Acer rubrum Height: 30m
Native to Eastern North America.

4: **Black tupelo**
Nyssa sylvatica Height: 25m
Native to Eastern North America.

5: **Katsura**
Cercidiphyllum japonicum Height: 45m
Native to China and Japan.

6: **Quaking aspen**
Populus tremuloides Height: 25m
Native to North America.

7: **American ash**
Fraxinus americana Height: 30m
Native to Eastern and Central North Asian

8: **Sweetgum**
Liquidambar styraciflua Height: 45m
Native to Eastern North America

9: **Persian ironwood**
Parrotia persica Height: 20m
Native to North Iran and the Caucasus region.

10: **Japanese maple**
Acer japonicum Height: 10m
Native to Japan.

Evergreen Broadleaves

Not all evergreen trees are needle-bearing conifers. Many are also broadleaves, including the vibrant red robins and decorative holly we associate with Christmas. Despite the name, few evergreen broadleaves are able to tolerate the severe cold, and do in fact shed their leaves when temperatures drop to freezing. This happens very gradually and the leaves are replaced as they fall, so evergreen broadleaves never appear 'naked' as deciduous species do during winter.

The leaves of evergreen broadleaves are thicker, tougher and glossier than deciduous leaves too. They are specially adapted to cope with the harsh conditions of winter – less water, low temperatures and lower light levels – so they can continue to function when deciduous trees cannot. Evergreen broadleaves can begin to photosynthesise early in spring, before the other trees in the woodland produce their leaves, giving them a head start on their competitors before a surge of new growth causes the canopy to close in.

Key to plate

1: **Japanese chinquapin**
Castanopsis cuspidata
Height: 30m
a) leaf b) fruit

2: **Bull bay**
Magnolia grandiflora
Height: 25m
a) fruit b) flower

3: **Holly**
Ilex aquifolium
Height: 10m
a) leaves b) fruit

4: **Californian headache**
Umbellularia californica
Height: 30m
a) leaf b) fruit

5: **Loquat**
Eriobotrya japonica
Height: up to10m
a) leaf b) fruit

6: **Strawberry**
Arbutus unedo
Height: 10m
Fruits

7: **Winter's bark**
Drimys winteri
Height: 20m
Flowers

8: **Ulmo**
Eucryphia cordifolia
Height: 12m Flower

Habitat: Mediterranean Forest

The Mediterranean is a term used to define a unique two-season climatic zone that is home to a specialised group of shrubby plants.

The largest of the Mediterranean regions takes its name from the sea that surrounds it – the European Mediterranean Basin. The other three Mediterranean climatic zones are spread across the southern hemisphere. Found in three different continents, they are the Chilean matorral, the South African fynbos and the Australian mallee.

All the trees that grow in these Mediterranean forests and woodlands are well adapted to the climate; long, dry, hot summers and mild, wet winters and springs. They grow during the cool spring, taking full advantage of the available moisture, and then rest during summer periods of drought. Known as 'sclerophyllous', which is Greek for 'hard leaf', their small, stiff, leathery leaves can tolerate dry heat and prevent water loss, and also tend to be evergreen, like the cork oak and the stone pine. Another example is the European olive, a quintessential Mediterranean tree. Its popular fruit, the olive – and its oil – is a staple of the healthy Mediterranean diet.

Key to plate

Mediterranean Basin

1: **Aleppo pine**
Pinus halepensis
Height: 25m

2: **Stone pine**
Pinus pinea
Height: 25m

3: **Italian cypress**
Cupressus sempervirens
Height: 30m

4: **European olive**
Olea europaea
Height: 15m

5: **Cork oak**
Quercus suber
Height: 15m

Mediterranean Basin

The Mediterranean Basin has been classed as one of the world's 36 biodiversity hotspots, meaning it is a biologically rich area that is also at risk from land clearance caused by human habitation. When area such as this are cleared, important natural habitats are lost. Shockingly, these regions have lost 70% of their original vegetation.

The Mediterranean Basin covers three continents: Europe, Africa and Asia. It is made up of evergreen mixed woodlands and dense maquis shrubland, and is dominated by a variety of sclerophyllous broadleaved trees of varying heights, including three evergreen oaks – the kermes oak, the cork oak and the holm oak.

Plenty of non-sclerophyllous species like maples, hornbeams and hackberries can also be found growing in the Mediterranean Basin. Trees like the Judas tree, for example – a plant heavily steeped in myth. All these trees provide the perfect habitat for the rich mixture of aromatic plants that are used in Mediterranean gardens and kitchens such as rosemary, lavender and rock rose as well as delicious fruits, including figs and pomegranates.

Key to plate

1: **Holm oak**
Quercus ilex Height: 30m
a) leaf b) fruit: acorns

2: **Fig**
Ficus carica Height: 10m
Twig with leaves and fruits

3: **Pomegranate**
Punica granatum Height: 6m
a) leaves b) fruit

4: **Montpellier maple**
Acer monspessulanum Height: 15m
a) leaves b) fruit

5: **Hackberry**
Celtis australis Height: 25m
Fruit

Mediterranean Conifers

The sound of popping and cracking can sometimes be heard in a Mediterranean forest on a hot summer's day. This noise comes from the crowns of the conifers as the female pine cones mature and ripen. The scales of the woody cones are forced open by the heat, releasing the small-winged seeds. Carried by the wind, the seeds eventually find their way to the woodland floor. The smaller seeds from trees like the Aleppo pine and black pine can travel distances up to 1km to their new home. The drier and warmer the conditions, the further the seeds will travel to recolonise soil that is often left exposed by fire. The cone's scales reclose during wet weather and will reopen again when temperatures rise. This process continues until all the seeds are released and the cones fall to the ground.

There are other ways that seeds can be dispersed in these dense forests. The stone pine produces large unwinged seeds that fall directly to the ground as the cones break. This provides a feast for all manner of hungry animals, including small rodents and birds.

Key to plate

1: **Aleppo pine**
Pinus halepensis Height: 25m
a) leaves b) mature seed cones

2: **Black pine**
Pinus nigra Height: 50m
a) young female cone
b) cross section of young female cone
c) mature seed cone
d) leaves with male cones

3: **Cedar of Lebanon**
Cedrus libani Height: 40m
Spray of leaves with mature seed cone

4: **Prickly juniper**
Juniperus oxycedrus Height: 15m
a) spray of leaves with mature seed cones
b) young female cone
c) cross section of young female cone

Australian Mallee

The Australian mallee is made up of a variety of small trees and woody shrubs, but is dominated by Eucalyptus species – there are over 700 endemic to Australia, but fewer than 30 species grow in the mallee.

Eucalyptus trees produce eucalyptol; a toxic substance found in their leaves and bark, it is a natural insect repellent and makes them inedible to almost all animals. Because of this, the trees cannot be pollinated by insects, and are instead 'self-pollinating'. This results in breathtaking displays, as each season the trees burst with red, yellow or white tassel-like flowers. The flowers have no petals, but hundreds of fluffy, pollen-bearing stamens instead. These are required to ensure there is enough pollen for self-pollination, as there is no way to transport it.

The word 'mallee' is Aboriginal in origin and refers to the way eucalyptus trees resprout from root crowns and develop into new trees with multiple stems or trunks. The nutrient-poor, sandy soil, creates arid conditions that few trees can survive. Eucalypts have, however, adapted to this harsh environment well.

Key to plate

1: **Red mallee**
Eucalyptus oleosa Height: 12m
a) young seed pods b) flower c) leaves

2: **Bell-fruited mallee**
Eucalyptus preissiana Height: 5m
Flower

3: **Red-flowered mallee**
Eucalyptus erythronema Height: 6m
a) flower b) flower bud c) breaking bud

4: **Mallee wattle**
Acacia montana Height: 3m
a) leaves b) flowers c) flower buds

5: **Soap mallee**
Eucalyptus diversifolia Height: 6m
a) leaves b) flower c) fruit

6: **Western black tea**
Melaleuca lanceolata Height: 10m
Flowers

Cork Oak

The cork oak is famous for its bark – a hugely versatile natural product. An evergreen tree, it is one of more than 500 species of oak found in temperate and tropical regions of the Northern Hemisphere. The unique forests where these trees are found are known as *montado* in Portuguese and *dehesa* in Spanish.

Cork is made up of many dead cells of cellulose filled with air and a waterproof substance called suberin, making it light in weight, impermeable and buoyant. Its thermal and fire-retardant properties mean it is used by a wide range of manufacturers, including the space industry.

Despite more recent usage in shoes, flooring and yoga mats, harvesting the thick bark from this special oak tree is an ancient and sustainable practice; it has been carried out by skilled professionals using only an axe for thousands of years. Harvesting the bark doesn't harm the tree – in fact the bark regenerates, growing back annually in rings. However, re-harvesting must take place at a minimum of 9-year intervals. An average-sized cork oak lives for about 150 to 200 years and can produce approximately one tonne of raw cork in its lifetime, making more than 65,000 bottle corks.

Key to plate

Cork oak
Quercus suber
Height: 15m

1a: **Immature acorns**

1b: **Mature acorns**

2: **Tree with the corky bark harvested from the main trunk and branches**

3: **Trunk cross section showing the thick spongy bark layer**

4: **Flower**

Habitat: Tropical Moist Forest

Hot, moist and densely packed with towering trees that disappear into the mist, the rainforest is crammed with life at every level – large insects scuttle on the jungle floor, flamboyant hornbills, parrots and toucans flash their feathers between the trees, while exotic big cats prowl in the dense undergrowth.

These rainforests can be found on the continents of South America, Africa, Asia and northeast Australia, and include the Amazon and Congo River Basin. Together, they are known as the tropics. Characterised by having the same daylight hours all year round, with average constant temperatures between 26°–27°C, there is also an abundance of moisture in these regions, with between 250–450cm of rainfall annually.

Rainforests are rich in biodiversity and hold the highest number of tree species in any forest habitat. The forest is divided into five layers: the overstorey, where the tallest trees reach over 30m; the densely packed canopy, which receives plenty of sunlight and rainfall; the dark and damp understorey, crammed with plants competing for precious sunlight; and the lowest levels, the shrub layers, reached by just 2% of sunlight.

Key to plate

Malaysian rainforest

1: **Strangler fig**
Ficus virens
Height: 40m

2: **Dipterocarp**
Dipterocarpus retusus
Height: 60m

3: **Malay padauk**
Pterocarpus indicus
Height: 40m

4: **Mangosteen**
Garcinia mangostana
Height: 10m

African and Asian Rainforests

Spanning six African countries, the Congo River Basin is the second largest tropical rainforest on Earth. It is home to more than 600 trees which provide shelter to the many endangered animals that live here, including the lowland and mountain gorilla.

Unlike the Amazon, the trees in these forests typically have thin, smooth bark to discourage climbing vines, or in the case of the kapok tree, bark with thorns to prevent animals from feeding on them. The wood is also extremely hard and dense as protection from wood-feeding insects such as termites, but sadly this adaptation has been to their detriment, as these features also make their timber a valuable resource. West Africa has suffered from heavy deforestation and today less than 20% of its moist rainforests remain intact.

Southeast Asian rainforests, known as *malesia* are some of the oldest on Earth, existing for more than 100 million years. The vegetation in these ancient forests is rich and diverse, and many of the trees are evergreen. They are dominated by trees of a single family, Dipterocarpaceae (meaning two-winged fruits).

Key to plate

1: **Red silk cotton**
Bombax ceiba Height: 25m
a) flower b) fruit

2: **Rambai**
Baccaurea motleyana Height: 12m
a) fruit b) cross section through fruit

3: **Dipterocarp**
Dipterocarpus retusus Height: 60m
a) leaf b) flower c) fruit d) floral parts

4: **Kola nut**
Cola acuminata Height: 20m
Flowers

Americas Moist Rainforest

Also known as the Neotropical rainforest, these forests can be found in the Caribbean Islands, Central America and South America. The largest rainforest is the Amazon, which includes an incredible 45% of the total tropical rainforest biome of the world, and is home to an estimated 390 billion individual trees.

Trees in these forests have massive, broad buttressed trunks to help with anchorage and stop them falling over in the strong winds. The leaves are thick and waxy, and tend to be oval-shaped with sharp drip tips to shed rainfall. The widely spaced emergent trees that stick out of the canopy, such as the Brazilian rosewood, reach an average height of 30–50m, but in the lowland tropical forest, some have reached heady heights of up to 90m, and thrive despite being subjected to strong, drying winds.

Sadly, much of the rainforest is fast disappearing, with deforestation and fires making way for cattle ranching, mining and illegal logging. A rainforest fire will kill most of the trees and seedlings. This is because forest fires are recent and human-made so the trees have no natural resistance to fire.

Key to plate

1: **Mahogany**
Swietenia mahagoni Height: 25m
a) fruit b) flower c) ripening fruit
d) section through fruit

2: **Diesel**
Copaifera langsdorffii Height: 35m
Seed pod

3: **Brazilian rosewood**
Dalbergia nigra Height: 40m
Timber transection

4: **Lignum vitae**
Guaiacum officinale Height: 9m
a) flowers b) leaves
c) fruit d) open seed pod

Habitat: Tropical Dry Forest

Not all tropical forests feature lush evergreen vegetation and steamy jungle climates. Dry forests, also known as tropical deciduous forests or monsoon forests, are found in the tropics of South America, Africa and Asia. The average temperature all year round is always above 20°C, with a long dry season. These two seasons separate dry forests from rainforests, which don't have a dry or wet season, but a constant climate throughout the year.

Many of the tree species that inhabit these unique forests are deciduous, losing their leaves at the start of the dry season to reduce water loss. When the leaves fall to the forest floor, their decomposition starts quickly, undertaken by various insects and bacteria that turn the old foliage into nutrients for the trees. Specialised fungi also facilitate the uptake of these nutrients by forming symbiotic relationships with the fine tree roots that spread extensively through the upper surface of the soil.

Despite being called a dry forest, these regions can receive large amounts of rainfall in the wet season, receiving as much as 1–2m during the summer months. In Asia and some parts of Africa, this is greatly influenced by monsoons, which bring intense torrential bursts, delivering as much as 700mm of rain in one day. All this rain is needed to bring the trees back into leaf and begin another growing and flowering season.

Key to plate

Savannahs of equatorial East Africa

1: **Whistling thorn**
Vachellia drepanolobium
Height: 6m

2: **Fever tree**
Acacia xanthophloea
Height: 25m

3: **Baobab**
Adansonia digitata
Height: 20m

Tropical Savannah

Found in locations near the equator, the savannah is a vast, rolling tropical grassland scattered with trees and shrubs. The most well-known of these is the Serengeti in Tanzania, Africa, covering around 30,000km^2. It is famous for its unique wildlife including lions, giraffes, elephants and zebras.

Savannahs occur where there isn't enough rain to support a tropical rainforest, but there is enough to keep it from becoming a desert. It is a carefully balanced ecosystem with two distinct seasons – a rainy season, and a dry season with high air temperatures all year round. The lack of water, hot temperatures and strong winds make it very difficult for tall trees to grow, but many species have adapted to these harsh conditions. Some trees only produce leaves during the rainy season and have deep tap roots that can reach far down to ground that is water-saturated, storing excess water in their roots and trunks.

The trees found in these regions need clever defence mechanisms against threats such as wildfires, insects and animals. Iconic acacias release poisonous alkaloids into the leaves when an animal such as a giraffe first takes a bite. The bitter taste stops the giraffe feeding, while neighbouring acacias will emit a pheromone from their leaves to warn off other animals.

Key to plate

1: **Flame tree**
Delonix regia Height: 12m
a) flower b) leaf

2: **Fever tree**
Acacia xanthophloea Height: 25m
a) leaves b) flower

3: **Whistling thorn**
Vachellia drepanolobium Height: 6m
a) swollen thorn b) leaves

4: **Frankincense**
Boswellia sacra Height: 8m
a) resin b) cross section of trunk with papery bark

Baobab

Often called the upside-down tree, as the stubby-branched crown resembles a root system in the air, the iconic baobab tree is widespread throughout the African savannahs. It can live for over a thousand years, making it the oldest known flowering tree, or angiosperm, in the world. The generic name, *Adansonia*, commemorates the French explorer and botanist Michel Adanson, who saw a specimen in 1749 on his travels through Senegal, and this species is the only one found growing on the African continent.

The baobabs' short, disproportionately stumpy, barrel-like trunks are known as 'pachycauls', and are one of the trees' most defining features. The trunks are incredilby large – up to 10m in diameter. During the long dry season, the trees can appear dead and lifeless, but beneath the grey twisted bark, a baobab can store up to 100,000 litres of rainwater – more than enough to get them through the dry season.

Known as the 'tree of life', the baobab is of great social and economic importance, capable of providing shelter, clothing, food, water and wood for local people. It is an important indigenous fruit tree – the pulp of the fruit is rich in vitamin C and the calcium-rich leaves are eaten as a vegetable. The roots, bark, leaves and seeds are used medicinally, and fibres from the bark are used to make rope and string for basketry.

Key to plate

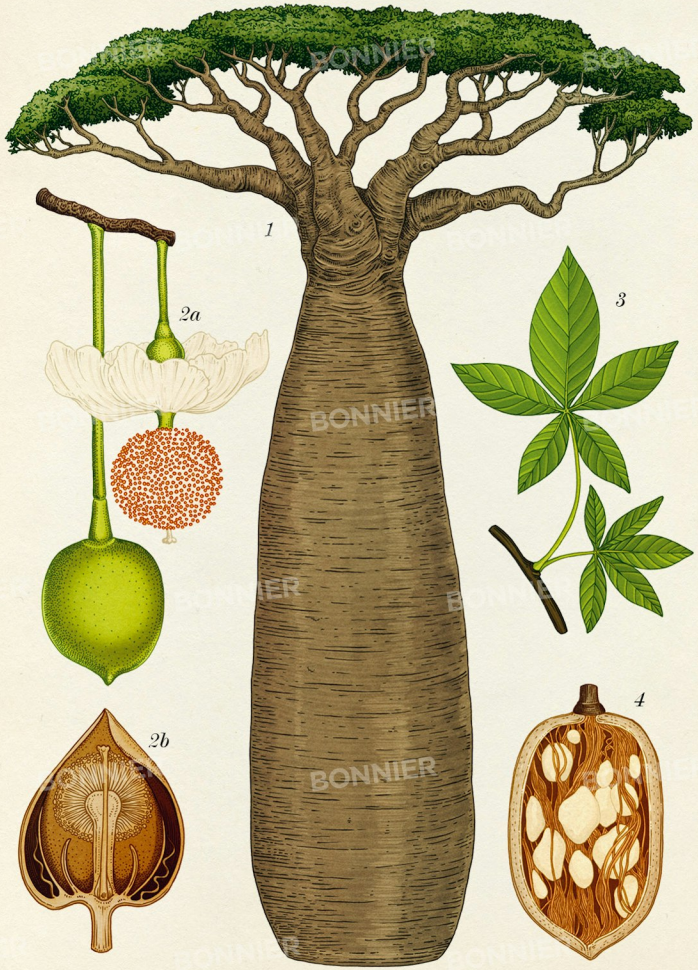
Baobab *Adansonia digitata*
Height: 20m

1: **Tree**

2: **Flowers**
a) flowers
b) cross section through flower bud

3: **Leaves**

4: **Cross section of fruit capsule**



Tropical Nuts and Spices

We may not realise it, but we rely on tropical regions to form many parts of our diet – from our morning coffee to the spices we use in everyday cooking.

Nuts are one of our most nutritious foods, and needed as part of a well-balanced diet. Nuts and spices are often encased in tough shells and grow in dense tropical rainforests with hard-to-reach treetops. With its three-sided shell, the brazil nut is extremely difficult to crack, and in fact only two species have been able to achieve this – humans (with the help of tools) and the agouti, a rodent with razor-sharp teeth.

Spices are the aromatic parts of tropical plants and have been used for more than 5,000 years to flavour food. During the medieval period, spices were considered as valuable as gold in Europe. Cloves, cinnamon and nutmeg are harvested from the bark, seeds, buds and roots of tropical trees while sumac and star anise come from berries, seeds or dried fruits.

Key to plate

1: **Cinnamon**
Cinnamomum verum Height: 17m
a) twig with leaves and flowers
b) cross section through flower
c) bark quill

2: **Brazil nut**
Bertholletia excelsa Height: 50m
a) cross section through flower
b) twig with leaves, flowers and fruit
c) cross section through fruit showing three-sided nutshells
d) nutshell

3: **Clove**
Syzygium aromaticum Height: 20m
a) cross section through flower bud
b) twig with leaves and flower buds

4: **Nutmeg**
Myristica fragrans Height: 23m
a) cross section through the seed
b) seed c) cross section through the outer husk, showing the seed

Tropical Fruits

For most of human history, we have been hunter-gatherers of wild plants, scouring the landscape for fruits which provided a much-needed burst of sweetness after a day of energy-sapping foraging.

Fruits are the fleshy, or dry, ripened parts that hang from flowering trees. Most can be eaten raw, straight from the tree. Some fruits, including mangoes, avocados, passion fruits and citrus fruits, enclose the seeds, or seed, in a fleshy pulp, which when ripe emits delicious smells. The skins also turn a bright colour, enticing the many animals which feast on them. These animals are known as frugivores, and most are found living in tropical rainforests.

Not only does the juicy pulp provide the seed with protection, it also helps with dispersal. When birds such as the Australian cassowary, or mammals, ingest raw fruits, the seeds pass through their digestive systems unharmed, and are deposited in faeces over a kilometre away from the parent tree, ready for germination. By spreading the tree's seeds over greater distances, instead of directly under the canopy of the parent tree, fruit eaters ensure a greater chance of survival for the offspring.

Key to plate

1: **Breadfruit**
Artocarpus altilis Height: 20m

2: **Lychee**
Litchi chinensis Height: 10m

3: **Lemon**
Citrus x *limon* Height: 12m

4: **Mango**
Mangifera indica Height: 30m

5: **Mangosteen**
Garcinia mangostana Height: 10m

6: **Star fruit**
Averrhoa carambola Height: 10m

Habitat: Gardens

The first use of trees in Western gardens was in the form of clipped hedges and pleached fruit trees, entwined to form a hedge. Dating back to the sixteenth and seventeenth centuries, these garden trees were originally used to provide shelter, shade and fruit production. It wasn't until the late seventeenth and eighteenth centuries that trees were used purely for decorative purposes.

As well as looking beautiful, there are great environmental benefits to planting trees in gardens. They reduce air pollution by absorbing harmful greenhouse gas into their foliage and bark, and also reduce the risk of flooding after heavy rainfall. Trees are natural air conditioners; their shade can lower summer air temperatures by at least 8°C during the day and night, reducing energy use.

Urban gardens with at least one flowering tree provide a rich habitat and food source for a diverse range of wildlife, including birds and pollinating insects. Planting the right tree in the right place can also create microclimates by reducing wind speeds and noise pollution created by traffic.

Key to plate

Typical European Garden

1: **Purple Japanese maple**
Acer palmatum
'Atropurpureum' Height: 4m

2: **Himalayan birch**
Betula utilis var. *jacquemontii*
Height: 15m

3: **Japanese flowering cherry**
Prunus 'Kanzan' Height: 5m

4: **Yew topiary (cloud pruned)**
Taxus baccata
Height: 20m (if left to grow naturally)

5: **Box topiary (ball pruned)**
Buxus sempervirens
Height: 9m (if left to grow naturally)

6: **Chinese flowering dogwood**
Cornus kousa var. *chinensis*
Height: 7m

Handkerchief Tree

Of all the ornamental trees that are planted in gardens and arboreta, the handkerchief tree is one of the most outstanding for the beautiful showy flowers it produces in spring. A rare and very special tree, it can be found in parks and large gardens in Europe and is also popular in Australia.

The handkerchief tree's standout feature – its flowers – resemble small, purple-red pom-poms attached to a pair of large white bracts (specialised leaves), which dangle from the branches and flutter in the breeze like handkerchiefs.

The handkerchief tree was first seen in the temperate forests of Western China's mountains in 1869 by the French missionary and botanist, Père David. Almost 30 years later, a botanical race began as to who would introduce it to western gardens. In 1899, plant hunter Ernest Henry Wilson was sent to China from Kew Gardens to find the tree and collect as many seeds as possible. The journey was perilous and Wilson's boat capsized in rapids on the mighty Yangtze River, but eventually Wilson managed to collect some seeds. The journey home was also eventful, and Wilson's boat was wrecked during the return to England. Many of his specimens were lost, but not the precious handkerchief seeds, and eventually over 13,000 seedlings were raised.

Key to plate

Handkerchief tree
Davidia involucrata
Height: 15m

1: **Leaves**

2: **Flowers with bracts**

3: **Fruits**

4: **Twig with winter buds**

5: **Bark**

Ornamental Trees

Whether its their delicate flowers, abundant fruit, interesting leaf shape, fragrance, or even overall shape and height, ornamental trees all have highly sought-after features that make them outstanding specimens for gardens.

Gardeners have spent decades looking for the ideal ornamental tree – a breathtaking specimen that can be propagated, sold by nurseries and planted in gardens around the world. The ancient Egyptians uprooted and replanted for aesthetic purposes, but it wasn't until the Victorian era that more exotic specimens were introduced via trade routes. Plant collectors such as George Forrest and William Lobb sailed to faraway lands to find and gather new exotic plants. These expeditions were often dangerous but with plants quickly becoming a status symbol, plant collectors were happy to risk the perils of long boat journeys. The discovery of new ornamental trees prompted wealthy landowners to plant arboreta, or to build glasshouses, hoping to be the first to get a new tree species to flower in cultivation.

Cultivating trees to show consistent features is not an easy task. The tree must be propagated and reproduced asexually by taking a cutting from the parent tree and rooting it in a nursery, or by joining a branch from the parent onto the root system of another tree of the same genus (known as grafting). Japanese flowering cherries are an excellent example of asexual propagation – they are identical the world over.

Key to plate

1: **Yoshino cherry**
Prunus × *yedoensis* Height: 12m

2: **Contorted willow tree**
Salix babylonica var. *pekinensis 'Tortuosa'*
Height: 15m

3: **Flowering crab apple**
Malus 'Evereste' Height: 5m

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