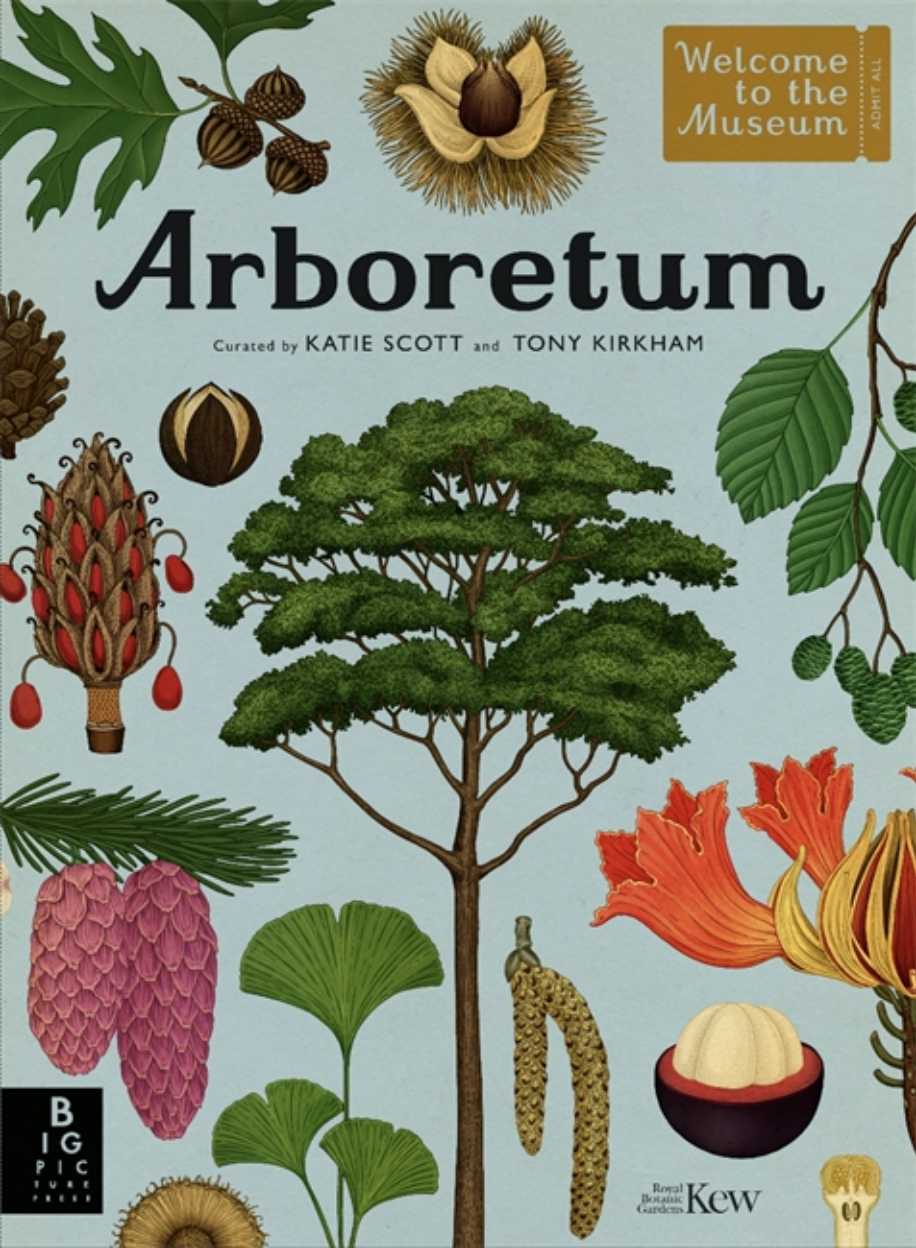
Welcome to the Museum
ADMIT ALL
Arboretum
Curated by KATIE SCOTT and TONY KIRKHAM
BIG PICTURE PRESS
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*Entrance*

# Welcome to Arboretum

The term 'arboretum' translates as 'a place with trees'. This beautiful book allows you to walk every tree-filled place as you travel the globe. Step outside and discover dense forests, frozen landscapes, tropical jungles and meticulous gardens. Enter the arboretum.

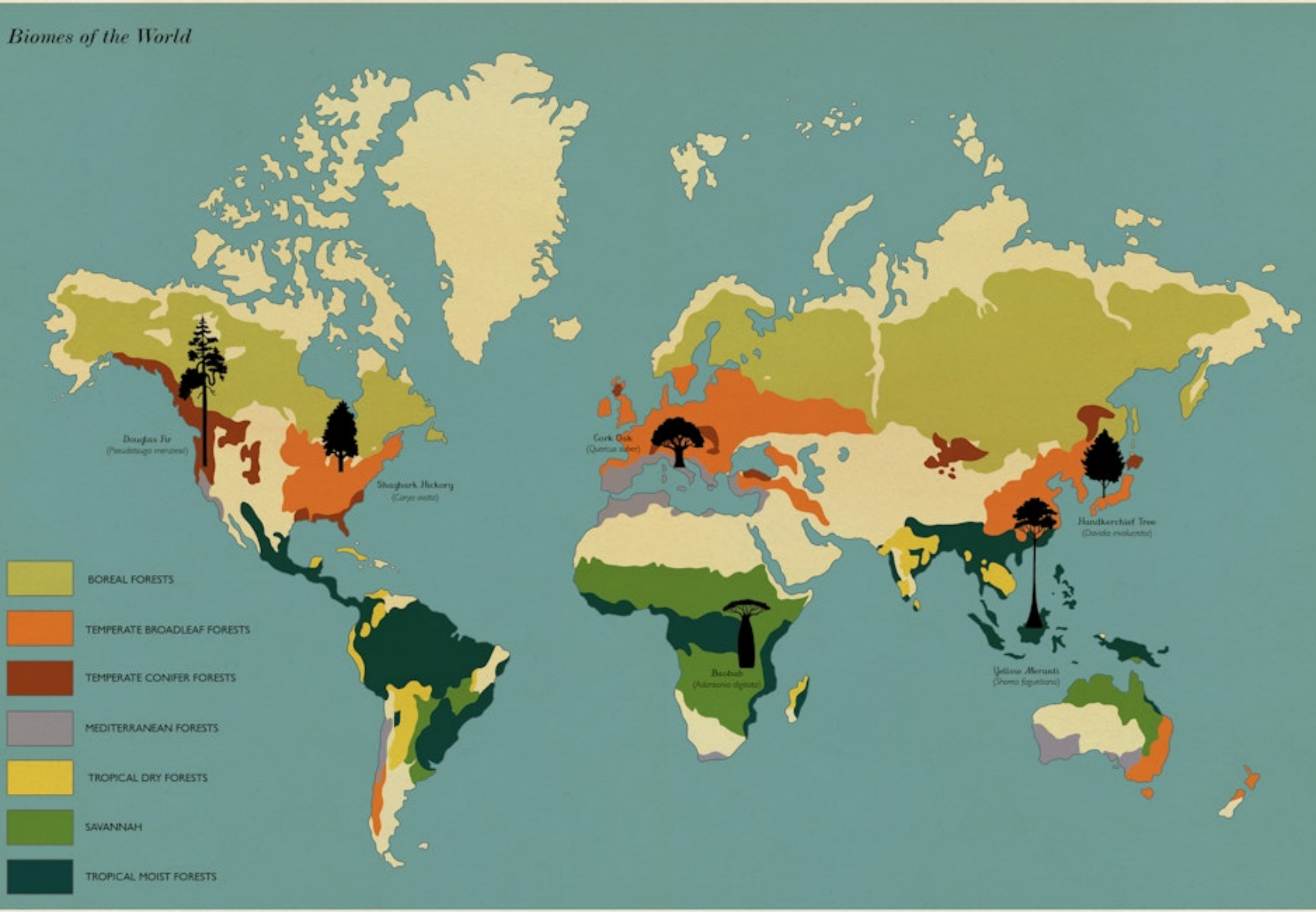
Filled with a collection of over 150 trees, every corner of the arboretum has something to be discovered. You'll marvel at majestic giants that are hundreds of years old, inhale the sweetest scents of cherry blossom and fresh pine, stop to collect delicious mangoes and lemons, and be inspired by trees like the fever tree, whose bitter bark has been instrumental in the fight against malaria.

Your journey begins in the wild and swampy Carboniferous forests where the earliest trees are thought to have evolved millions of years ago. From those first beginnings to their vital place in our world today, trees have always inspired us and have impacted on every aspect of human life, from the air we breathe and the food we eat, to the products we build and the medical treatments we receive.

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.

# *Biomes of the World*



# What is a Tree?

People love trees. They are beautiful, elegant and essential for life. They grow all around us, forming woodland and forests, or sometimes, on their own, across many landscapes, and even in our towns and cities. But have you ever stopped to look hard at a tree? Have you thought about exactly what makes trees different from other plants?

Trees are found in a wide variety of shapes and sizes, from the smallest bonsai to the giant coast redwood, reaching over 115m high. Their most noticeable feature is a woody stem, called a trunk, which increases in height and thickness each year.

The trunk is made up of annual growth rings, making it easy to age a tree. Every ring represents a year's growth. Some trees like the bristlecone pine (*Pinus longaeva*), believed to be the oldest tree on Earth, can have over 4,000 annual rings.

The trunk supports a network of large branches. These divide into smaller branches extending upwards and outwards searching for sunlight, 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 optimum sunlight levels in the upper canopy layer of a woodland, forest or arboretum. A mature oak tree has about 100,000 leaves in its crown.

The most important part of the tree, which we cannot see, is the network of roots growing underground. The main functions of the roots are to anchor the tree to the ground, keeping it upright (especially during high winds), and to soak up water and nutrients, transferring them to the main trunk where they are distributed to the rest of the tree to make food.

Contrary to popular belief, the root plate is very 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 (or bole) contains special types of cells that move water and nutrients around the tree. It is covered in a layer of woody skin called bark, which is made up of dead cells. The bark can be rough or smooth, and protects the tree's vital plumbing works from extreme temperatures, insects, diseases and hungry animals.
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 outer edge of the tree canopy. Rain runs from leaf to leaf, like water on the tiles of a roof, finally dripping off its edge to the ground below.

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

# Arboretum


# How Trees Communicate

Trees naturally grow in woodlands or forests around the world, and very rarely, as solitary specimens. Healthy woodlands are communities of trees that are interconnected by an underground network of fungi called mycorrhizae. Known as the 'wood wide web', this network has been present for around 400 million years and can stretch for hundreds of kilometres. It is how trees exchange important information and nutrients with each other and is vital to the survival of the whole forest.

Originating from two Greek words meaning 'fungus' (myco) and 'roots' (rhiza), mycorrhizae are the meeting point between the roots and the soil. The tree plays host to the fungi, providing it with up to 30% of the sugars it produces through photosynthesis (the process in which plants use sunlight to make their own food). In exchange, the fungi provide the tree with carbon, nitrogen and other nutrients, and increased water uptake. This is especially useful during periods of drought, and for small, young trees growing in shady areas that cannot adequately photosynthesise.

But research suggests that mycorrhizal networks can go much further. Similar to fibre-optic cables, trees can use fungal threads to communicate. From sending distress signals about insect and disease attack, allowing neighbouring trees to produce chemicals to protect themselves, to donating extra nutrients to dying trees in the forest. Studies on Douglas fir trees even show that mother trees can identify their saplings and provide them with additional nutrients and information, giving them the best chance of survival.



Because this activity happens at microscopic level, deep underground, there is very little evidence on the surface of the interaction going on below. But every year, signs of a healthy mycorrhizal network flourish: toadstools and mushrooms are the sporing bodies of this network, and they grow out of the forest leaf litter to reproduce. Fungi can always be found growing near the tree species it has formed a symbiotic relationship with, for example conifers (Pinaceae) are frequently seen alongside edible penny buns and chanterelles, while black and white truffles are associated with oaks (*Quercus* spp.) and beeches (*Fagus* spp.). Some fungi are poisonous, however, such as fly agaric mushrooms, which can be found in birch and pine woodlands.

## *Key to plate*

*1:* **Silver birch**
*Betula pendula*
Height: 25m
A successful pioneer species, the silver birch can form a mycorrhizal association with a wide range of fungi. It will share them with neighbouring oaks and pines, as well as having its own dedicated species, making birch woodlands very rich in fungi.

*2:* **Scots pine**
*Pinus sylvestris*
Height: 35m
One of only three native conifers in the British Isles, the Scots pine has a special mycorrhizal association with over 200 different species of fungi. These include the chanterelle and the penny bun.

*3:* **Pedunculate oak**
*Quercus robur*
Height: 40m
With the ability to live for over 1,000 years, the oak tree is rich in biodiversity and can support over 2,300 different species of algae, lichens and mosses, fungi, mammals, birds and insects. More than 350 are obligate species, which means they will only live on the oak.

*4:* **Fly agaric**
*Amanita muscaria*
A poisonous fungus found in deciduous and coniferous woodlands, these often appear in circles, known as fairy rings.

*5:* **Penny bun**
*Boletus edulis*
This fungus is found with over 15 different genera of conifers including pines, spruces and Douglas fir.

*6:* **Black truffle**
*Tuber melanosporum*
Truffles have been cultivated on oak trees since 1808. A delicious delicacy, truffles are very expensive due to how difficult they are to grow, store and harvest.

*To Sally, Jennifer and Robert*
*for understanding my passion for trees – T.K.*

*For Willow and Maya,*
*endlessly distracting me during the making of this book – K.S.*

BIG PICTURE PRESS

First published in the UK in 2022 by Big Picture Press,
an imprint of Bonnier Books UK,
4th Floor, Victoria House
Bloomsbury Square, London WC1B 4DA
Owned by Bonnier Books
Sveavägen 56, Stockholm, Sweden
www.bonnierbooks.co.uk



1 3 5 7 9 10 8 6 4 2



ISBN 978 1 80078 137 5

This book was typeset in Gill Sans, Mrs Green and Modern20 BT.
The illustrations were created in pen and ink and coloured digitally.

Edited by Joanna McInerney and Victoria Garrard
Designed by Nathalie Eyraud
Produced by Neil Randles

Printed in China

This book was produced in association with the Royal Botanic Gardens, Kew.

With special thanks to Gina Fullerlove and Lydia White at Kew Publishing,
and Tim Utteridge, David Goyder, Harry Baldwin, Tony Hall, Xander van der Burgt,
Iain Darbyshire and Sharon Willoughby for their support and expert advice.

Welcome to the Museum

ENTER HERE

# Arboretum

Illustrated by KATIE SCOTT

Written by TONY KIRKHAM

B P P

# The First Trees

Between 359 and 299 million years ago, in a time known as the Carboniferous period, Earth was covered in dense forest – but not the kind we'd recognise today. 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.

Of these giants, *Archaeopteris* emerged. Considered one of the first true, modern trees, and thought to be an ancestor of all seed plants, this important species evolved over a period of 100 million years to produce trunks up to 1m thick. *Archaeopteris* established deep roots to support the increasing height and weight of its crown, and developed vascular tissue, enabling it to take water and nutrients up through the trunk to the leaves and outer branches. It became the dominant species.

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 (*Araucaria araucana*) and ginkgoes. Although just one species of ginkgo remains – *Ginkgo biloba* – it is remarkably similar to its ancestors, with fan-shaped leaves identical in size and shape to 250-million-year-old fossil records.

With the arrival of the Jurassic period (between 199–145 million years ago), the climate had become warmer and wetter, providing perfect conditions for life to flourish. New dinosaur species emerged, including *Stegosaurus*, *Brachiosaurus* and *Allosaurus*, who prowled, stomped and chewed their way through the lush vegetation. The wollemi pine (*Wollemia nobilis*) and dawn redwood (*Metasequoia glyptostroboides*) dominated this period, and both still grow today in our temperate forests.

Angiosperms were among the last plants to evolve. These included broadleaved flowering trees such as magnolias (*Magnolia* spp.), figs (*Ficus* spp.) and plane trees (*Platanus* spp.), which appeared during the Cretaceous period and went on to dominate the planet's ecosystem by the Tertiary period, around 66 million years ago. Despite being driven back by at least four ice ages, trees have maintained their ecological niches and have adapted to every habitat on Earth, in an enormous variety of shapes and sizes.

*Key to plate*

*1:* **Tree fern**
*Psaronius*
Height: 10m
a) tree b) new unrolling fronds
This tree fern did not have a true tree trunk, but something known as a 'mantle'. Made up of hundreds of rootlets, the mantle could reach over 1m in diameter.

*2:* **Sweetbay magnolia**
*Magnolia virginiana*
Height: 30m
Flower
Magnolias are one of the most primitive angiosperms, with fossil records showing that they existed over 95 million years ago.

*3:* **Oriental plane**
*Platanus orientalis*
Height: 30m
a) leaf b) covered bud
The end of the leaf stalk shrouds the bud like a glove, only exposing it in autumn when the leaves fall, protecting the bud from pests and fungal diseases.

*4:* **Archaeopteris**
Height: 30m
Looking like a Christmas tree, this earliest known and now extinct tree is very close to the seed-bearing trees that we know today.

*5:* **Maidenhair tree**
*Ginkgo biloba*
Height: 40m
8-lobed leaves
The ripe, fleshy outer parts of the seeds smell strongly of vomit, which was once attractive to now-extinct carrion-eating dinosaurs and large mammals that would feed on the fruits and disperse the seeds.

*6:* **Monkey puzzle**
*Araucaria araucana*
Height: 50m
Tree
The monkey puzzle tree was so named because the congested branches and spiralling prickly leaves would be puzzling for any monkey attempting to climb it! These leaves would have discouraged hungry herbivorous dinosaurs from feeding on the foliage 200 million years ago.



# Preface

Walking into a natural forest and standing under a giant like the coast redwood or a baobab can be a breathtaking and awe-inspiring experience, leaving wonderful memories that remain with us forever.

Forests are found on every continent in the world except Antarctica, and are home to over 58,000 different tree species (58,497 to be exact). Despite looking the same to many people, every tree has its own needs, character and stories, making each one very special. Trees are the lungs of the planet, providing the oxygen that we breathe, whilst at the same time improving air quality. They also preserve soil by reducing erosion from storms, and store carbon in their roots and trunk, protecting us from both natural and human disasters.

Trees have been central to human existence for millennia. Objects of worship in many cultures, they also provide materials essential for our survival, from the timber we use in construction and transport, to the fruits, nuts and spices that we eat every day. Forest bathing – an ancient Japanese tradition – can even reduce stress levels, boost our mood and combat illness.

Trees have helped to shape the world that we live in, but sadly, we often take them for granted. Today, 30% of species are now threatened with extinction, with at least 142 species already extinct in the wild. We cannot afford to lose any more. As we go about our daily lives, we must think about the trees that we have growing in our gardens, parks and urban landscapes, as well as forests around the world, and remember that without them, the planet will be a poorer place for us all. Not only will a large number of other diverse species – including plants, fungi, insects, mammals and birds – lose their homes, driving mass extinction, but the very structure of our magnificent world will be lost.

As many habitats become increasingly fragile, we urgently need to protect the forests that remain. Doing so will heal our world, protecting all life on Earth and guaranteeing that future generations can enjoy the wonder of trees as we do now.

Royal Botanic Gardens Kew

**Tony Kirkham MBE, VMH**
Royal Botanic Gardens, Kew



*Gallery 1*

# Temperate Conifer Forests

*Habitat: Boreal Forest*
*Boreal Broadleaves*
*Boreal Conifers*
*Temperate Conifers*
*Redwoods*
*Cypresses*
*Unusual Conifers*
*Douglas Fir*

# Habitat: Boreal Forest

The boreal forest, or 'snow forest', is one of the most hostile locations in the world for a tree to live and grow in. The forest is thick, but because of the harsh conditions, is made up of only a few hardy species, mainly spruces (*Picea* spp.), pines (*Pinus* spp.) and firs (*Abies* spp.). Found only in the northern hemisphere, between the freezing Arctic tundra to the north and the temperate broadleaved forests to the south, this is the most northerly forest on the globe, covering huge areas of Canada, Alaska, Scandinavia, Russia and Siberia. It's Earth's largest land biome, taking up about 17% of its land surface and representing around a third of its forest area.

The forest experiences long, six-month winters, during which the average temperature remains below freezing and there are just a few hours of sunshine meaning the nights are longer than the days. The forest is covered in a blanket of snow for up to eight months of the year. Its growing season – the period when plants can grow successfully – is therefore very short: just 50–100 days. Summers in the forest can see up to 20 hours of sunshine a day and a good amount of rainfall. This gathers and creates shallow bogs on the forest floors known as 'muskegs'. Muskegs are wet, largely infertile and highly acidic, and so only a limited number of small-leaved conifer species can thrive in this special habitat.

Despite the freezing conditions, boreal forests are still full of life. Rodents such as muskrats and beavers live in the muskeg, while moose, reindeer and brown bears graze on young shoots and berries, and wolves and lynx prowl. Boreal forests are also a very important resource for the survival of indigenous communities who hunt and fish there.

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. Logging – and specifically clear-cutting (removing all trees) – also releases carbon and destroys habitats. Around a third of the world's timber and 25% of its paper is exported from these valuable ecological forest regions.

*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 (*Populus* spp.), willows (*Salix* spp.) and birches (*Betula* spp.).

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. Position is important too. 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.

Boreal broadleaves are pioneer species which means they are the first to appear in disrupted environments, such as a fire-ravaged forest. While a forest fire might kill off conifers, broadleaves can resprout from their trunks or regrow new trees from their underground roots, which are not damaged by fire. Their lightweight seeds are easily spread, either by a breeze or by birds and other animals, which means the broadleaves can establish themselves in an area before the conifers have even begun to recolonise.

## *Key to plate*

*1:* **Speckled alder**
*Alnus incana* subsp. *rugosa*
Height: 22m
a) branch b) flower
Both male and female flowers are called catkins but they look very different. They bloom in early spring before the leaves arrive.

*2:* **Large-toothed aspen**
*Populus grandidentata*
Height: 25m
Leaf
The leaf stalks (petioles) of the aspen are flattened from side to side along the entire length, which makes them tremble when the wind catches them. This gives them the common name of quaking or trembling aspens. *Populus tremuloides* (see page 12) has a similar trembling leaf effect, giving rise to this species' scientific name.

*3:* **American mountain ash**
*Sorbus americana*
Height: 12m
Leaves
This tree is a food source for lots of forest creatures. Moose and white-tailed deer (*Odocoileus virginianus*) feed on the leaves, twigs and branches.

*4:* **Balsam poplar**
*Populus balsamifera*
Height: 30m
Flower
The sticky pointed leaf buds of this poplar are covered with a resinous sap that has a strong turpentine aroma. It is the source of 'balm of Gilead', an ointment traditionally used to treat chest infections.

*5:* **White birch**
*Betula papyrifera*
Height: 20m
a) trunk/bark b) male flower c) leaf
The paper-thin bark has a high oil content and is extremely waterproof. In fact, native Americans and early fur trappers used the bark as paper to write messages on and to make lightweight canoes.

*6:* **Moosewood**
*Acer pensylvanicum*
Height: 10m
a) leaf b) twig and buds c) trunk/bark
The moosewood is so-named because its bark is consumed by moose in winter. The tree is also known as 'goosefoot maple', because its leaves are shaped like the foot of a goose, and 'striped maple', due to its distinctive stripy bark.



# Boreal Conifers

One of the most ancient species of trees, conifers are synonymous with boreal forests. Densely packed green firs (*Abies* spp.), spruces (*Picea* spp.) and pines (*Pinus* spp.) 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. One of the reasons conifers are dominant in the boreal forest is that they are evergreen. This means they start producing food as soon as they wake up after the winter, without having to wait for new needles to grow.

Their growth is slow, but 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.

Dark green needles are a defining feature of most conifers. These leaves have a low sap content to prevent them from freezing, a thick waxy outer covering (cuticle) and deeply sunken pores (stomata) to prevent them drying out and losing valuable moisture in the cold winter winds. The needles are mostly triangular to provide the greatest surface area for absorbing maximum light. This also gives them a head start over the broadleaved trees in spring, as they can be quick to start producing food for the tree without having to wait for new leaves to develop. The larch (*Larix* spp.) however, is the odd one out. Being a deciduous conifer, it loses its needles each year. Larches have delicate needles compared to evergreen conifers, however, so they are quicker and easier to grow.



## *Key to plate*

*1:* **Balsam fir**
*Abies balsamea*
Height: 20m
Seed cones and leaves
This evergreen loves cold winters and moist forests, so is well adapted to the lowland swamps and muskegs in its native northeastern North America.

*2:* **Black spruce**
*Picea mariana*
Height: 15m
a) seed b) seed cones and leaves
An important species for local biodiversity, the caterpillars of the bog elfin butterfly (*Callophrys lanoraieensis*) feed on the needles of this black spruce before pupation.

*3:* **American larch**
*Larix laricina*
Height: 20m
Seed cones on branch
The alternative common name of this species is 'tamarack' – the Algonquian name for the tree, meaning 'wood used for snowshoes'.

*4:* **Lodgepole pine**
*Pinus contorta*
Height: 20m
a) female cone cross section
b) male cone c) mature seed cone
This tree is fire dependant, which means it needs forest fires to maintain its population. The bark is thin, offering no protection from fire, but the seed cones are serotinous meaning they protect the seeds inside the cone from fire. The heat opens the cones, releasing the seeds for germination on the forest floor, allowing the species to regenerate.

# Temperate Conifers

There are more than 600 different species of conifers in seven families growing on our planet. 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 (*Pinaceae*), 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. All three of these conifers are commercially important – their timber, known as softwood, is often used in construction.

There are 176 different types of pines found growing in temperate regions, from scrubby dwarf trees growing at high elevations in mountains, to the tallest firs reaching heights of 80m in the conifer forests of California. Pine trees (*Pinus* spp.) are typically long-lived, and the oldest in the world is a bristlecone pine called 'Methuselah' which is around 4,800 years old. Some species of pines produce large edible seeds called pine nuts or 'piñon', which are used as an essential ingredient in the Italian green sauce pesto.

The 54 different types of spruce (*Picea* spp.) 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 impressive trees can grow as high as 80m tall. There are almost 90 species, which are tough and resilient, and can be found growing at the highest levels on mountains. Their young female cones are instantly recognisable, 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
The needles of this pine are in bundles of five.

*2:* **Sitka spruce**
*Picea sitchensis*
Height: 100m
Mature seed cones
'Tonewoods' such as spruce and red cedar, play an important part in the sound quality of acoustic instruments.

*3:* **Scots pine**
*Pinus sylvestris*
Height: 35m
a) leaves and male pollen cones
b) mature seed cone
c) seedling stage
This tree once formed much of the ancient Caledonian Forest in Scotland.

*4:* **Morinda spruce**
*Picea smithiana*
Height: 50m
Leaves
Native to the western Himalayas, 'Morinda' means 'honey of flowers' in Nepalese: the tree's large cones are covered in pearls of resin or nectar.

*5:* **Single-leaf pinyon**
*Pinus monophylla*
Height: 10m
Leaves and male pollen cones
The needles of the pines are arranged in bundles of two, three and five, but this pine is unique in being the only pine that has a single needle.

*6:* **Santa Lucia fir**
*Abies bracteata*
Height: 35m
Mature seed cone
The thin, resinous bark and cones of this tree are highly susceptible to fire damage. Endemic to the Santa Lucia Mountains in California, the Santa Lucia fir grows on steep, rocky terrain, avoiding forest fire by settling on sparse ground.

*7:* **Gray pine**
*Pinus sabiniana*
Height: 15m
Leaves
The needles of this pine are in bundles of three, and are distinctively grey-green.

# 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, while the giant redwood 'General Sherman' has the largest volume of trunk, with a circumference of 31m and a height of 84m. The oldest specimen on record is estimated to be 3,500 years old.

There are three redwoods with 'sequoia' in their scientific name – the giant redwood (*Sequoiadendron giganteum*), the coast redwood (*Sequoia sempervirens*) and the dawn redwood (*Metasequoia glyptostroboides*). Sequoia is believed to have been used in honour of a Native American named Sequoyah, who invented the Cherokee syllabary (written characters), between 1810 and 1820.

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 dense stands 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. Fires however, play an important role in creating seedbeds for germination. The fires burn off the ground leaf litter on the forest floor, exposing soil that contains vital minerals needed for the seeds to grow.

Unlike the two North American redwoods, the Chinese dawn redwood is a deciduous conifer with flat, feathery needle-like leaves. Its reddish-brown, fibrous bark resembles a redwood, hence its generic name *Metasequoia*, meaning 'like a sequoia'. 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
These giants rely on the summer fogs for moisture, as they would be unable to transport water from the roots to the very top of the tree owing to gravity. The leaves and bark have adapted to be able to absorb the fog moisture, allowing the coast redwood to reach incredible heights.

*2:* **Dawn redwood**
*Metasequoia glyptostroboides*
Height: 50m
a) leaves b) mature seed cone
At 47km long, the longest tree avenue in the world is the Pishou Dawn Redwood Avenue in Jiangsu Province, China. It was planted with more than one million individual trees making it a world record-breaker.

*3:* **Giant redwood**
*Sequoiadendron giganteum*
Height: 115m
a) tree b) leaves and female cones c) seed d) cross section of trunk
Despite their impressive size and legacy, the giant redwood is under threat. Rising temperatures mean droughts and less moisture available for the trees, and dry conditions mean more extreme wildfires. Just one redwood can absorb as much carbon as 250 regular trees so they are a crucial part of combating climate change and must be protected.

# Cypresses

Trees in the cypress family (Cupressaceae), 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 (*Cupressus* spp.), junipers (*Juniperus* spp.), swamp cypresses (*Taxodium* spp.), incense cedars (*Calocedrus* spp.) and arborvitaes (*Thuja* spp.), and they are found in all northern temperate regions of the world.

These trees have many different forms, from stunted junipers that hug mountainsides, to the mammoth, cathedral-like Western red cedars (*Thuja plicata*) 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 and, because the leaves are sweetly scented when crushed, they are used as incense on altars in Buddhist temples in China.

There are many varieties of evergreen trees cultivated for their ornamental attributes, including the ever-popular Leyland cypress (*Cupressus* x *leylandi*) 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 (*Cupressus sempervirens*). 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. It is believed that because of its resistance to decay and the aromatic oil it contained, the Italian cypress was the 'gopher wood' that Noah used to build his Ark.

## *Key to plate*

*1:* **Italian cypress**
*Cupressus sempervirens*
Height: 35m
a) spray of foliage with seed cones b) mature seed cone
Captured in artworks by masters Leonardo da Vinci and Vincent van Gogh, the species name translates as 'everlasting cypress', and since ancient times it has been seen as a symbol of eternal life. For this reason, it is often planted in cemeteries.

*2:* **Western red cedar**
*Thuja plicata*
Height: 70m
a) mature seed cone b) male cone c) spray of foliage
Native to the Pacific Northwest of North America, the huge trunks of the Western red cedar are rot-resistant. For this reason, they were used by the First Nations and indigenous people of the Pacific Northwest coast to carve monumental totem poles.

*3:* **Hiba arborvitae**
*Thujopsis dolobrata*
Height: 40m
Spray of foliage
Endemic to central and southern Japan, this tree was one of the 'five sacred trees of Kiso'. The slowly-grown, aromatic and durable wood was used historically to build temples and notable buildings throughout Japan. During feudal times commoners were not allowed to cut the trees – the penalty being death!

*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
The sweet, spicy aroma of the wood gives this tree its common name and it is used to make the best wooden pencils. Sharpen a pencil and smell the shavings and you will see why it gets the name incense cedar. A large cedar tree can be made into 300,000 pencils. More than 14 billion pencils are made every year – that's enough to circle our planet 62 times!



# Unusual Conifers

The conifers, also known as gymnosperms (meaning 'naked seed' in Greek), occur on every continent except Antarctica and make up roughly 30% of the world's forests. They are represented by seven different families and number about 615 different species. Despite growing on our planet for millennia with a rich fossil record, they have retreated, and are now a highly specialised group of trees capable of growing in a variety of severe conditions, from waterlogged swamps to the frozen boreal forests in restricted parts of the world.

Some of these conifers have remained so well-hidden in these forests, they have only recently been discovered. The dawn redwood (*Metasequoia glyptostroboides*) for example, was found in the mid-twentieth century by a Chinese forester. So, are there still new conifer species out there waiting to be identified? Evidence would certainly suggest so. In the 1950s, scientists found and described a new member of the pine family, the Chinese silver fir, *Cathaya argyropylla*, from the mountains of western China. Most surprisingly of all, a new species of conifer thought to have become extinct two million years ago was discovered in 1994, deep in the gorges of the Blue Mountains, 150km northwest of Sydney, Australia. This new living conifer, closely related to the monkey puzzle, was named *Wollemia*. Conveniently, 'wollemi' means 'look around you' in the Aboriginal languages, suggesting we must never stop looking.

Most conifers have woody cones, and rely on the wind to disperse their seeds, but some have adapted to imitate flowering plants – for example, the willow-leaf podocarp. Instead of cones it has brightly coloured fruit-like structures to attract birds, which swallow them, fly away, and, once digested, disperse the seeds ready for germination.

## *Key to plate*

*1:* **Californian nutmeg**
*Torreya californica*
Height: 25m
a) fruit cross section showing seed
b) leaves and fruit
Although not related to the true nutmeg tree, the Californian nutmeg seeds are edible, and were eaten by native peoples. The tree is also known as 'stinking nutmeg' because of the strong smell of its leaves, branches and wood.

*2:* **Umbrella pine**
*Sciadopitys verticillata*
Height: 25m
a) emerging leaves b) mature leaves
While not actually a pine, this tree species is endemic to Japan and very rare in the wild. What appear to be needle-like leaves are in fact cladodes, dwarf shoots in tight upward spirals that resemble the spokes of an umbrella and function as a leaf.

*3:* **Golden larch**
*Pseudolarix amabilis*
Height: 40m
a) male pollen cones
b) twig with leaves
Introduced from China to the west by plant collector Robert Fortune in 1853, this is a deciduous conifer like the larch. Its needles turn a stunning golden yellow colour in autumn.

*4:* **Wollemi pine**
*Wollemia nobilis*
Height: 40m
a) tree b) female seed cone
c) male pollen cone
The female cone is always positioned above the male pollen cones to prevent self-pollination.

*5:* **Taiwanese China fir**
*Cunninghamia konishii*
Leaves and female seed cone
Height: 50m
The 'Tiklu Sacred Tree' is estimated to be 3,000 years old and 50m tall, with a girth of 3.5m.

*6:* **Chinese silver fir**
*Cathaya argyrophylla*
Height: 20m
Twig with immature female cones
The species name *argyrophylla* means silver leaves, and the underside of the 5cm-long leaves are silvery-white.

*7:* **Willow-leaf podocarp**
*Podocarpus salignus*
Height: 20m
a) leaves b) fruit
Each fruit bears two seeds, which develop at the end of a brightly coloured receptacle following fertilisation. Birds are attracted to the receptacle, swallow the entire thing, fly away and disperse the seeds after a period in their gut.



# Douglas Fir

The Douglas fir (*Pseudotsuga menziesii*) is an easy conifer to identify, with a magnificent upright trunk and dark brown, deeply furrowed, rugged bark, up to 36cm thick. The fine, needle-like leaves on the drooping branches are bright green and the cones have three-pointed structures called bracts protruding from between each of the cone scales. According to legend, the three parts represent the rear legs and tail of a mouse that hid in the cone to escape a huge forest fire.

The Douglas fir shares its name with two intrepid explorers and plant collectors of the eighteenth and nineteenth centuries. Its scientific name honours Archibald Menzies, a physician and naturalist on Captain George Vancouver's voyage to the Pacific Northwest in 1791. Its common name honours the Scottish botanist and plant collector David Douglas, who 36 years later, in 1827, introduced the tree into cultivation in the British Isles, where it is now grown as an ornamental specimen tree in large gardens, parks and arboreta. It is an important forestry plantation tree grown for its timber, which is used worldwide in construction.

The mature, old growth forest that this tree creates over thousands of years is a very important habitat for animal and plant biodiversity, including the red tree vole (*Arborimus longicaudus*) and the rare spotted owl (*Strix occidentalis*). Another example is the Douglas fir dwarf mistletoe (*Arceuthobium douglasii*), a small parasitic shrub that uses the Douglas fir as a host tree, taking water and nutrients from the tree without harming it.

## *Key to plate*

**Douglas fir**
*Pseudotsuga menziesii*
Height: 100m

*1:* **Mature seed cone**
After pollination, the female cones take a year to mature. They become woody, with the three-pointed bracts protruding from the cone scales, before the seeds are released and dispersed by the wind.

*2:* **Leaves**
These are short, soft-pointed needle-like leaves, 30mm long, which resemble those of a fir (*Abies* spp.). When crushed, they give off a delicious citrus-pineapple aroma.

*3:* **Tree**
This specimen is 'Big Lonely Doug', a 70m-tall Douglas fir. Over 1,000 years old, it was saved from the clear-cut of old growth forest on Vancouver Island in British Columbia, Canada in 2011, and is now a noted celebrity of the tree world. With a trunk over 4m in diameter, it would take 12 adults holding hands to reach around the base of it.

*4:* **Cross section of trunk**
The knot-free timber is light brown with hints of reds and yellows running through the grain. It is resistant to decay and used extensively for the construction industries.

*5a:* **Immature female seed cone**
The young female cones are pink when young. They turn from pink to pale green as they mature, and then light brown when fully ripe.

*5b:* **Maturing female seed cone**
After fertilisation in late spring/early summer, the young, fleshy female cones develop, gradually extending to the mature length of 6-10cm long.



*Gallery 2*

# Temperate Broadleaf Forests

*Habitat: Temperate Broadleaf Forest*
*North America*
*Asia*
*Europe*
*Autumn Colour*
*Evergreen Broadleaves*
*Shagbark Hickory*

# Habitat: Temperate Broadleaf Forest

Temperate deciduous forests make up some of the world's most dramatic biomes, impressing with their growth and stunning colours during the changing seasons. 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 between the tropics and the Arctic polar regions in the northern hemisphere, encompassing parts of the United States, Canada, Europe, China, Korea, Japan and Russia. Small pockets can also be found in South America. All of these regions are subjected to warm and cold air masses, creating the four seasons, with no season getting too hot or too cold.

The term 'deciduous' is derived from the Latin *decidere*, meaning to fall off and die. Unlike evergreen 'needle-leaf' species such as conifers, broadleaf trees (angiosperms) stop producing the green pigment chlorophyll in their large leaves as the daylight hours decrease during the autumn, slowly shutting down and dropping their leaves in preparation for a long-earned rest in winter months.

Remarkably, all these forests share similar genera of tree species, which include oaks (*Quercus* spp.), maples (*Acer* spp.), beeches (*Fagus* spp.) and ashes (*Fraxinus* spp.), but also have their own native species in each region. Beneath these forest giants, smaller, shade-tolerant species such as dogwoods (*Cornus florida* and *Cornus nuttallii*) and sourwood (*Oxydendrum arboreum*) fill the understorey and shrub layers, mingling with ferns and mosses to create perfect hidden habitats for birds and mammals, such as mice, rabbits and foxes. The forest floor itself is teeming with insects and fungi, who enjoy the rich, fertile soil created by falling leaves and deadwood, supporting the diverse food web of the whole forest.

*Key to plate*

**North American broadleaf forest**

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

*2:* **American beech**
*Fagus grandifolia*
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, is a geographic region taking in more than 26 states, from Florida in the south, to New England and parts of south-eastern Canada in the north, and from the Atlantic coast in the east to Texas and Minnesota in the west.

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 – so called because of the distinctive blue haze seen on the treeline from a distance, caused by its unique atmosphere.

These eastern North American forests feature various overstorey species, including oaks, like the pin oak (*Quercus palustris*), American elm (*Ulmus americana*), American sycamore (*Platanus occidentalis*), hickories (*Carya* spp.) and basswoods or limes (*Tilia* spp.). Perhaps two of the most well known are the black tupelo (*Nyssa sylvatica*) and the sweetgum (*Liquidambar styraciflua*), trees renowned for their tantalising yellow, orange and scarlet autumn colours as they prepare for winter, which is a seasonal spectacle of this special ecosystem. Some common subcanopy trees include the white sassafras (*Sassafras albidum*), the Osage orange (*Maclura pomifera*) and the beautiful flowering dogwood (*Cornus florida*), with flowers that light up the forests in the spring.

The landscape of the forests has however, dramatically changed in appearance since the early 1900s. The American chestnut (*Castanea dentata*) was once the largest and most dominant tree, but sadly succumbed to the fungal disease chestnut blight (*Cryphonectria parasitica*), which was introduced into North America from Asia in 1906. This chestnut 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
These strange-looking fruits resemble a yellowy-green brain. When damaged they exude a milky sap, making them inedible to any animal. For seed dispersal they rely on rivers and floods.

*4:* **Kentucky coffee**
*Gymnocladus dioicus*
Height: 30m
Fruit: 25cm long

*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
The female flowers develop into green, fuzzy, long-stalked spherical balls, which ripen to brown in autumn and stay on the tree into winter.

*8:* **White sassafras**
*Sassafras albidum*
Height: 20m
Leaves
The leaves of this tree give off a spicy scent when crushed and come in three different shapes: a) simple, b) mitten-shaped, c) trident-shaped.

*9:* **Persimmon**
*Diospyros virginiana*
Height: 20m
Fruit
These fruits contain tannin and are astringent when immature, but turn very sweet, tasting of dates when ripe.



# Asia

The temperate deciduous forests of eastern Asia are some of the richest in terms of plant diversity, with a greater number of tree species than most other temperate forests in the world. This biome stretches from the boreal forests in the north and south to the tropical rainforests north of the Tropic of Cancer, and as far east as the Pacific coast of Japan, and includes the Korean peninsula and the forests of the Russian Far East.

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 (*Ginkgo biloba*) and the dawn redwood (*Metasequoia glyptostroboides*), which date back to the days of the dinosaurs. Today, despite the extent of human activities over at least 4,000 years (including large-scale clearance of natural vegetation for intensive agriculture, and the harvesting of trees for timber and fuel), many expanses of wild forest remain intact in the remote mountainous areas.

There are several ancient genera of trees that can only be found growing wild 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. The white sassafras (*Sassafras albidum*) grows in the forests of Eastern North America, while *Sassafras tzumu* and *Sassafras randaiense* are found in Asia.

## *Key to plate*

*1:* **Campbell's magnolia**
*Magnolia campbellii*
Height: 30m
Flower
This tree can be found in sheltered valleys in the Himalayan region, Southwest China and North India. Its pretty pink flowers bloom from late winter to early spring.

*2:* **Cone nut**
*Platycarya strobilacea*
Height: 10m
Fruit
Looking similar to the cone of a conifer, the fruit opens to release black, winged seeds, which are wind dispersed, unlike the other members of the walnut family, which are dispersed by animals.

*3:* **Persian silk**
*Albizia julibrissin*
Height: 15m
Flower
This tree goes to sleep at night by folding its leaves with the onset of darkness to reduce water loss, prevent nighttime herbivores from eating it, and to protect the fluffy flowers from rainfall. This is known as nyctinasty.

*4:* **Monkey tail hornbeam**
*Carpinus fangiana*
Height: 20m
a) fruit b) leaf
A rare hornbeam from western China. Its long female catkins – up to 30cm-long – give it the common name.

*5:* **Goat horn**
*Camptotheca acuminata*
Height: 10m
Fruit
The woody capsule splits and curls at the tips, resembling goat horns.

*6:* **Chinese tulip**
*Liriodendron chinense*
Height: 40m
a) leaf b) fruit c) flower
The yellow-green, tulip-shaped flower gives this species its common name.

*7:* **Chinese rubber**
*Eucommia ulmoides*
Height: 15m
Torn leaf
'Eucommia' means 'good gum', and this tree lives up to its name, producing rubber that is revealed when the leaf is gently torn in half, the two parts held together by fine strands of latex. Native to China, it is thought to be extinct in the wild but is cultivated for its bark, which is used in Chinese herbal medicine and known as 'Du Zhong'.



# Europe

The temperate broadleaf deciduous forests of Europe have the lowest diversity of broadleaf trees of any other temperate biome in the world. This is due to the mass extinction of plants during the Pleistocene Ice Ages, as the huge glacial ice sheets and cold air killed many of the forest areas. As plants were forced to spread southwards with glaciation, they were stopped in their tracks by a huge barrier – the mountains of the Alps, which run west to east – with many species being made extinct.

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 (*Fagus sylvatica*), pedunculate oak (*Quercus robur*) and the sessile oak (*Quercus petraea*), as well as elms (*Ulmus* spp.), limes (*Tilia* spp.), ash (*Fraxinus excelsior*) and sycamore (*Acer pseudoplatanus*).

In the early twentieth century, these forests endured yet more hardship. A tree disease was introduced to Europe from Asia, changing the tree make-up in the landscape and affecting native elm populations across the continent. Dutch elm disease had been around for centuries, but in the 1960s a more virulent strain of the disease (*Ophiostoma novo-ulmi*) had 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. An area of exceptional biodiversity, it is home to the largest population of European Bison (*Bison bonasus*) 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
A large tree with heart-shaped leaves, which can be found in ancient woodlands. The small flowers are a very important food source for bees and are also used to make a herbal tea (known as linden tea), which is believed to improve digestion and reduce anxiety.

*2:* **Horse chestnut**
*Aesculus hippocastanum*
Height: 35m
a) seed conker b) fruit c) leaf
d) twig with terminal bud
This tall, broad tree is often found in woodlands and parks, and is famous for providing conkers – shiny brown seeds encased in a spiky shell. Conkers have been used as medicine for both horses and humans in the past, despite being mildly poisonous if consumed in excessive quantities.

*3:* **Caucasian wingnut**
*Pterocarya fraxinifolia*
Height: 30m
a) seed b) fruit
In the summer, this large tree produces impressive catkin-like necklaces up to 40cm long. The seeds take the form of winged nutlets and are dispersed by the wind.

*4:* **Turkish hazel**
*Corylus colurna*
Height: 25m
Fruit
This tree often lines city streets, where it thrives and isn't affected by air pollution. While its nuts and catkins are similar to the common hazel, the fruit is very different as the nut sits in a prickly mass of leafy bracts.

# Autumn Colour

Autumn colour, or fall colour, is one of the seasonal spectacles of the northern hemisphere temperate forests. As the day length decreases and temperatures begin to fall, the deciduous trees stop photosynthesising and get ready to shed their leaves in preparation for winter dormancy. And so the show begins – the forests become an explosion of colour, with leaves turning every shade of yellow, orange, red and even purple.

The green pigment in leaves is called chlorophyll, and is an important ingredient in photosynthesis, the chemical process of producing energy. 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 within the leaf throughout the year, to shine through. Carotenoid pigments produce yellow and orange colours, while anthocyanins provide red and purple, giving us autumn colour. Some tree species, for example maples (*Acer* spp.), oaks (*Quercus* spp.) and tupelos (*Nyssa* spp.), have higher levels of carotenoids and anthocyanins in their leaves than others, and therefore provide more spectacular displays during autumn.

Autumn colour varies from year to year and depends on the varying climatic conditions. The brightest and more brilliant colour displays require a good supply of moisture in the soil from late summer rains, frost-free cooler nights, and warmer daytime temperatures with brighter sunshine. These conditions are synonymous with Eastern North America and Japan, which often display the best autumn colour.

As the winter months draw closer, most deciduous trees lose their leaves entirely as they no longer serve a purpose. A layer of cork is formed at the end of the petiole (leaf stalk) where it attaches to the tree, allowing the leaf to detach and fall. As layer upon layer of leaves begin to break down and decompose, they eventually form the top layer of soil, adding to its fertility and providing a rich source of food for worms and other soil-dwelling invertebrates.

## *Key to plate*

*1:* **Tulip**
*Liriodendron tulipifera*
Height: 50m
Native to Eastern North America. The tulip tree has a distinctive four-lobed green leaf, which turns yellow in autumn.

*2:* **Northern red oak**
*Quercus rubra*
Height: 30m
Native to Eastern North America. This tree is fast-growing and long-living. It is known for its beautiful red autumn colour, and is of great value to wildlife, with both its acorns and twigs providing food for raccoons and deer.

*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, the leaves give off a scent of caramel or burnt sugar during leaf fall.

*6:* **Quaking aspen**
*Populus tremuloides*
Height: 25m
Native to North America. This aspen creates large clonal colonies, with each tree changing colour at the same time.

*7:* **American ash**
*Fraxinus americana*
Height: 30m
Native to Eastern and Central North America. This tree is under threat from an Asian beetle, the emerald ash borer (*Agrilus planipennis*), which has killed an estimated 30 million trees since 2002.

*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. Many selected ornamental varieties are planted in gardens.



# Evergreen Broadleaves

Not all evergreen trees are needle-bearing conifers. In fact, many are also broadleaves, including the vibrant red robins (*Photinia* spp.) and decorative holly (*Ilex aquifolium*) 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, with felty undersides and a darker green hue. 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 also begin to photosynthesise early in spring, before the other trees in the woodlands produce their leaves, giving them a head start on their competitors before a surge of new growth causes the canopy to close in. Their thick leaves have another advantage – they are less palatable to herbivores and feeding insects than their deciduous counterparts. Some trees have even adapted their leaves with prickly edges, like holly, or they taste unsavoury and bitter with high tannin levels, like the Californian headache tree (*Umbellularia californica*).

Unlike the leaves of deciduous trees, when they fall, evergreen broadleaf leaves are not easily broken down and have a low nutrient value, so most evergreen species are able to grow in poor, low nutrient soils.

## *Key to plate*

*1:* **Japanese chinquapin**
*Castanopsis cuspidata*
Height: 30m
a) leaf b) fruit
The dead wood from this tree is used as a host to cultivate edible shitake mushrooms in Japan.

*2:* **Bull bay**
*Magnolia grandiflora*
Height: 25m
a) fruit b) flower
The black seeds are wrapped in a fleshy orange coat and attached to the fruit by a very thin stalk called a funiculi.

*3:* **Holly**
*Ilex aquifolium*
Height: 10m
a) leaves b) fruit
The leaves of the lower branches are shiny, with between three and five sharp spines on either side of the leaf. The leaves on high branches, however, cannot be reached by hungry herbivores so they do not require the same prickly protection.

*4:* **Californian headache**
*Umbellularia californica*
Height: 30m
a) leaf b) fruit
The leaves of this large hardwood tree contain a chemical called umbellulone, which induces headaches when the leaves are crushed and inhaled.

*5:* **Loquat**
*Eriobotrya japonica*
Height: up to 10m
a) leaf b) fruit
This tree was introduced to Japan from China during the Tang Dynasty, where it has been cultivated for over a thousand years.

*6:* **Strawberry**
*Arbutus unedo*
Height: 10m
Fruits
This tree's common name comes from the fact its fruit resemble strawberries. The species name unedo originates from Pliny the Elder, and means 'I eat one only', which suggests that the fruit isn't particularly tasty.

*7:* **Winter's bark**
*Drimys winteri*
Height: 20m
Flowers
This tree is famous for its vitamin C-rich bark. Sir Francis Drake's commander, Vice-Admiral Sir John Winter, noticed that natives in Patagonia ate the bark of the trees, and for centuries it was used to cure scurvy in sailors.

*8:* **Ulmo**
*Eucryphia cordifolia*
Height: 12m
Flower
This tree originates from the forests of Chile.



# Shagbark Hickory

This handsome, temperate deciduous tree is the shagbark hickory (*Carya ovata*). It's easy to see how it got its name – mature trees have long peeling strips of bark curling away from the trunk. Young trees, however, have smooth bark. 'Hickory' comes from a Native American Algonquian word, 'pockerchicory' or 'pocohicora', which is the name for the tree's nut, and the milky drink made from the nuts. Hickories are members of the walnut family, and the fruit of the shagbark hickory is highly prized by both humans and wildlife. Many birds and mammals feast on hickory nuts every autumn, including black bears, foxes, mice, chipmunks, squirrels and rabbits.

A grand North American tree, it grows in the eastern United States and south-east Canada and can live for as long as 350 years. The average height of shagbark hickories is 18–24m but they can grow as tall as 36m!

The stunning yellow colour of its autumn leaves make the shagbark hickory one of the most valued specimens to grow in any arboretum, but it is also prized for the excellent timber it produces. Said to be some of the toughest, strongest wood there is, it is used today to make tool handles, shafts for sports equipment and baseball bats.



The shagbark hickory is in fact seen as a symbol of the American pioneer age, and settlers used the wood for almost every aspect of their life: rifles, fences, furniture and wagon wheels. The wood also makes excellent firewood and is one of the best types for barbecues, and smoking meat and fish.

## *Key to plate*

**Shagbark hickory**
*Carya ovata*
Height: 36m

*1:* **Terminal bud**
This is the main bud and is covered in loose scales that give way to the new growth.

*2:* **Female flowers**
Usually produced in clusters of up to three, and on short spikes.

*3:* **Male flowers**
The catkins sprout from the base of the terminal bud, along with the new leaves.

*4:* **Fruit**
The thin, green husk of the fruits ripen in autumn, turning brown, and split into four husks revealing a single nut.

*5:* **Seed**
This seed is a nut and is very similar to a pecan or a walnut. They can be eaten raw or they can be toasted to bring out the flavour and crunch.

*6:* **Leaf**
The pale-green pinnate leaves have a total of five leaflets, the top three being larger than the two at the base. The entire leaf turns a bright butter-yellow in autumn.

*7:* **Trunk and bark**
Mature tree trunks have a shaggy appearance, with the grey fissured bark peeling away in long strips.

*Gallery 3*

# Mediterranean Forests

*Habitat: Mediterranean Forest*
*Mediterranean Basin*
*Mediterranean Conifers*
*Australian Mallee*
*Cork Oak*

# Habitat: Mediterranean Forest

When we think of the Mediterranean, we immediately imagine beautiful beaches and azure seas, but it is also a term used to define a unique two-season climatic zone that is home to a specialised group of plants. These shrubby plants and trees thrive in climates with long, dry, hot summers and mild, wet winters and springs, and grow in five distinct regions of the world. Despite only covering a small percentage of the globe, around 10% of Earth's plants can be found in these regions, including many native species.

The largest of the Mediterranean regions takes its name from the sea that surrounds it – the European Mediterranean Basin. It makes up more than two thirds of the total Mediterranean landscape, and joins the Californian chaparral and woodlands in the northern hemisphere. 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 dry soils and unique climate. 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 are able to tolerate dry heat and prevent water loss, and also tend to be evergreen, like the cork oak (*Quercus suber*) and stone pine (*Pinus pinea*). Another example is the European olive (*Olea europaea*), a quintessential Mediterranean tree. It's popular fruit, the olive, and its oil, is a staple of the healthy Mediterranean diet.

*Key to plate*

**Mediterranean Basin habitat**

*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. This means when areas 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 (see page 46) broadleaved trees of varying heights, including three evergreen oaks – the kermes oak (*Quercus coccifera*), the cork oak (*Quercus suber*) and the holm oak (*Quercus ilex*). The latter is a typical Mediterranean tree and the dominant species in woodlands across the Iberian Peninsula, especially Spain. The leaves of this tree vary in shape and size, with smooth or spiny margins, depending on the habitat that it lives in. The harsher the environment, the smaller and thicker the leaves. Despite being an evergreen tree, every two or three years it will shed all of its leaves and start again with a new set of 'clothes' to rid itself of any dust, insects or damaged leaves that interfere with maintaining its health.

Plenty of non-sclerophyllous species like maples (*Acer* spp.), hornbeams (*Carpinus* spp.) and hackberries (*Celtis* spp.) can also be found growing in the Mediterranean Basin. Trees like the Judas tree (*Cercis siliquastrum*), 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 (*Salvia rosmarinus*), lavender (*Lavandula* spp.) and rock rose (*Cistus* spp.), as well as delicious fruits, including figs (*Ficus carica*) and pomegranates (*Punica granatum*).

## *Key to plate*

*1:* **Holm oak**
*Quercus ilex*
Height: 30m
a) leaf b) fruit: acorns
This tree takes its name from the ancient name of the holly. Its leaves resemble holly, with some having prickles along their margins.

*2:* **Fig**
*Ficus carica*
Height: 10m
Twig with leaves and fruits
There is a wonderful plant/animal interaction between the fig and the fig wasp. The fig fruit is actually a cluster of flowers hidden inside a bulbous stem and requires a specialist pollinator. The fig wasp knows the secret way into the enclosed flower is through a small opening called an 'ostiole'. On entering the fig, the wasp lays her eggs and deposits pollen on the female parts, fertilising the fig.

*3:* **Pomegranate**
*Punica granatum*
Height: 6m
a) leaves b) fruit
The pomegranate is the jewel of the fruit world. Its name means 'apple with many seeds' and botanically its fruit is classed as a berry. Considered a superfood, recent research suggests pomegranate seeds can help prevent conditions such a heart disease, diabetes and cancer.

*4:* **Montpellier maple**
*Acer monspessulanum*
Height: 15m
a) leaves b) fruit
Native to the Mediterranean Basin from Portugal to Lebanon, this tree was first found in the south of France. *Mons pessulanus* is the Latin name for the French city of Montpelier.

*5:* **Hackberry**
*Celtis australis*
Height: 25m
Fruit
Hackberries are edible and highly nutritious. Sometimes referred to as 'nature's candy', they have a crunchy shell with a sweet and tasty pulp inside.



# Mediterranean Conifers

If you ever find yourself standing in a Mediterranean forest that includes conifers on a hot summer's day, you might be treated to the sound of popping and cracking – this means nature is working its magic right above your head!

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 high air temperatures or heat from wild fires, 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 (*Pinus halepensis*) and black pine (*Pinus nigra*) 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 will reclose during wet weather to secure any seeds left inside. Then, when the temperature increases, the cones will reopen again. 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 (*Pinus pinea*) 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.

Perhaps one of the most iconic trees of this region is the cedar of Lebanon (*Cedrus libani*). This huge, upright conifer is native to the mountains of the eastern Mediterranean Basin and is steeped in history. Popular in ancient woodworking, its cones and timber once provided a source of resin, which was used by the Egyptians for the mummification process. Its timber is also very durable, strong and aromatic, making it resistant to insect infestation. It was widely used in the construction of ancient temples, palaces and ships – perhaps most famously by King Solomon, to build his temple in Jerusalem.

### *Key to plate*

*1:* **Aleppo pine**
*Pinus halepensis*
Height: 25m
a) leaves b) mature seed cones
The resin of the Aleppo pine was used to seal wine vessels in ancient times. It prevented oxidisation and also infused the wine with an aroma of resin. Today, the Greek white wine, retsina, is still flavoured with small pieces of pine resin during the fermentation process.

*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
This handsome pine has stiff needles that occur in pairs. Reproductive cones open in May – the females are red while the males are yellow and full of pollen.

*3:* **Cedar of Lebanon**
*Cedrus libani*
Height: 40m
Spray of leaves with mature seed cone
The cedar of Lebanon is the symbol of the Maronite Christians and is positioned in the middle of the national flag of Lebanon.

*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
The wood from the trunk and branches of this tree is steam-distilled to make juniper tar, or an essential oil called cade oil. It is used to treat many types of skin irritations.



# Australian Mallee

The Australian mallee is the second most diverse Mediterranean region of the five Mediterranean biomes (see page 46). It is made up of a variety of small trees and woody shrubs, but is dominated by *Eucalyptus* species (Myrtaceae family) – 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's 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 instead hundreds of fluffy, pollen-bearing stamens. 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. These trees each have a 'lignotuber' – an underground, swollen part of the tree, where resprouting occurs. This 'swelling' contains buds from which new shoots grow. The lignotuber also contains starch that feeds the shoots, especially important when tree foliage is damaged by frequent wildfires that occur in the area.

Other small tree species that can be found growing in the understorey are wattles (*Acacia* spp.) and tea trees (*Melaleuca* spp.). Like eucalypts, they are able to grow and survive the arid conditions of the mallee.

## *Key to plate*

*1:* **Red mallee**
*Eucalyptus oleosa*
Height: 12m
a) young seed pods b) flower
c) leaves
Called 'gumnuts', the fruits of the red mallee are non-edible. They have valves at the end that are opened by heat from wildfire or hot weather, which release the small wavy seeds en masse.

*2:* **Bell-fruited mallee**
*Eucalyptus preissiana*
Height: 5m
Flower
This tree produces stunning bright yellow flowers up to 3cm across. The flowers are followed by bell-shaped fruits that appear in October.

*3:* **Red-flowered mallee**
*Eucalyptus erythronema*
Height: 6m
a) flower b) flower bud
c) breaking bud
The word 'eucalyptus' comes from a combination of Latin *eu*, meaning 'f', and Greek *kolyptos*, meaning 'covered', which describes the cap-like structure (operculum) that covers the flower buds, retaining the fluffy stamens.

*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
This is a very tough plant. Often found overlooking the ocean, it is subject to salt-laden winds and extreme heat, but thrives in these conditions. The nectar-rich flowers are popular with honey-eating birds and honeybees.

# Cork Oak

The cork oak (*Quercus suber*) 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. They play an important role in preserving the habitat of some critically endangered animal species, including the Iberian lynx (*Lynx pardinus*) and the Iberian Imperial eagle (*Aquila adalberti*).

Cork is made up of many dead cells of cellulose and a waterproof substance called suberin, which are filled with air 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. In 1981, cork harvested from 225 trees was used to insulate the huge fuel tank on the space shuttle *Columbia*.

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, some 15 times during its lifetime. 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**
Before maturity the acorns are shorter and green in colour. As they ripen they expand in length and turn a nutty brown.

***1b:*** **Mature acorns**
Not many acorns produced by oak trees are edible, but cork oak acorns are! The acorns are boiled before eating, like chestnuts.

*2:* **Tree with the corky bark harvested from the main trunk and branches**
As you walk through a mature cork oak forest you'll notice different types and colours of bark. The bark of an unharvested tree is very pale, almost grey, compared to a freshly harvested tree, which is bright red. A tree whose bark was harvested several years ago is a darker brown and can be almost black in colour. This can be a way of determining when the bark was last harvested.

*3:* **Trunk cross section showing the thick spongy bark layer**
Just 1cm³ of bark contains up to 40 million air cells. When the cells are cut and shaped into bottle corks, the suction-cup effect makes them stick to a bottleneck.

*4:* **Flower**
The flowers are monoecious (see page 84), with both male and female growing on one tree. The male flowers are 4–7cm in length, and grow as yellow pendant catkins, which are wind-pollinated.





*Gallery 4*

# Tropical Moist Forests

*Habitat: Tropical Moist Forest*
*African and Asian Rainforests*
*Americas Moist Rainforest*
*Yellow Meranti*

# 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. In fact, more than 1,000 evergreen or semi-evergreen tree species grow in a square kilometre. 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. Trees are small at the lower levels, but have larger leaves to make the most of the limited sunlight that filters through the canopy.

Unfortunately, these majestic rainforests are disappearing fast. Over 81,000 hectares of rainforest is burned every day to make way for farming plantations. Logging is also a major contributor, and over half of the world's tropical rainforests have disappeared in the last 50 years. It is more important than ever to protect these special places.

*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 10,000 plant species, including more than 600 trees, which provide shelter to the many endangered animals that live here, including the lowland (*Gorilla gorilla*) and mountain gorilla (*Gorilla beringei*).

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 (*Ceiba pentandra*), bark with thorns to prevent animals from feeding on them. The wood is also extremely hard and dense as protection from termites and other wood-feeding insects, 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% its moist rainforests remain intact.

Southeast Asian rainforests are some of the oldest on Earth, existing for more than 100 million years. They can be found in mainland countries such as Sri Lanka, Vietnam and Thailand, the Malay Peninsula and Archipelago including the islands of Sumatra, Java and Bali, and on the Pacific islands, including Borneo, and are known as *malesia*.

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), such as the huge dipterocarp (*Dipterocarpus retusus*). These immense trees can exceed 60m in height with smooth, straight trunks that tower into the emergent canopy.

## *Key to plate*

*1:* **Red silk cotton**
*Bombax ceiba*
Height: 25m
a) flower b) fruit
The bright red flowers appear in spring before the leaves develop and hold a reservoir of sweet, intoxicating nectar that is irresistible to the birds, squirrels and bees that pollinate them.

*2:* **Rambai**
*Baccaurea motleyana*
Height: 12m
a) fruit b) cross section through fruit
Most trees produce their flowers from new growth or young shoots, but some, such as the rambai, flower and fruit on their trunks and main branches. This botanical peculiarity is called 'cauliflory' and may occur because the large fruit produced is too heavy to be supported by branches alone. Another reason is to help with seed dispersal by large animals such as primates, which would not be able to reach the fruit if it grew high up in the canopy.

*3:* **Dipterocarp**
*Dipterocarpus retusus*
Height: 60m
a) leaf b) flower c) fruit d) floral parts
Dipterocarps produce an oily resin on the trunk, which builds up wherever the bark is bruised. It helps defend against bacteria, fungi and animals.

*4:* **Kola nut**
*Cola acuminata*
Height: 20m
Flowers
Kola nuts contain 2% caffeine, theobromine and kolanin, and were used in the early production of many tonics and carbonated soft drinks, including Coca-Cola™.

# Americas Moist Rainforest

Also known as the Neotropical rainforest, these forests can be found in three parts of the world: 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 and help with transpiration.

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 here have had no reason to develop a natural resistance to fire. The widely spaced emergent trees that stick out of the canopy 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. Emergent trees such as the Brazilian rosewood (*Dalbergia nigra*) and the Brazil nut (*Bertholletia excelsa*), have flattened, spreading crowns resembling a large umbrella, to provide the tree with the maximum surface area exposed to the sun, while at the same time reducing the amount of shade from the tree's leaves to the lower parts of the tree.

These forests have a high diversity of other flowering plants, including more climbing vines than in all the rainforests of Africa and Asia, and epiphytic plants (plants that grow on the trunks and branches of trees). Some individual trees have been found to contain as many as 200 orchids (Orchidaceae) and 1,500 other epiphytic plants.

### *Key to plate*

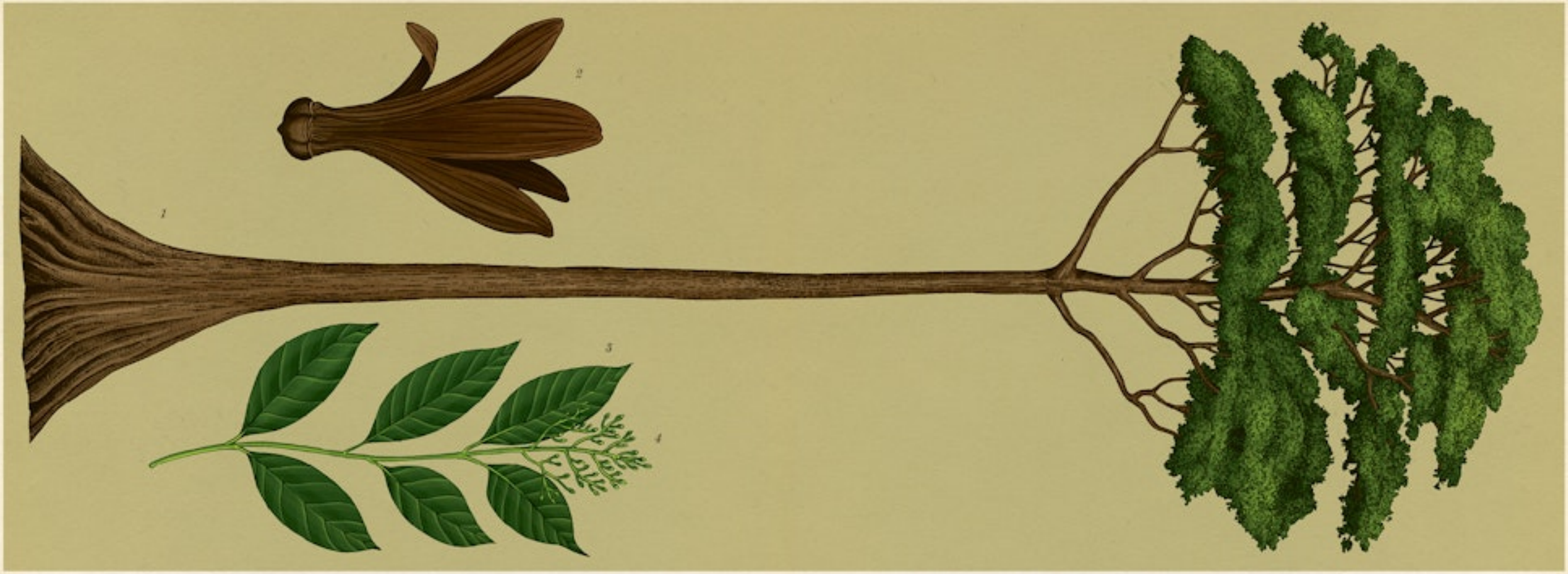
*1:* **Mahogany**
*Swietenia mahogani*
Height: 25m
a) fruit b) flower c) ripening fruit
d) section through fruit
The wood of the mahogany is a heavy, dark reddish-brown and is prized by carpenters for making high quality furniture, pianos and other musical instruments, boat building and fine veneers.

*2:* **Diesel**
*Copaifera langsdorffii*
Height: 35m
Seed pod
The trunk of this tree can be tapped to produce a hydrocarbon-rich sap that can be used as a replacement for diesel fuel without the need for refining, hence the common name.

*3:* **Brazilian rosewood**
*Dalbergia nigra*
Height: 40m
Timber transection
This tree has dark chocolate-brown coloured wood with dark contrasting streaks, often referred to as 'spider webbing'. The Brazilian rosewood can grow quickly in very poor, infertile soils as it produces microorganisms on its roots that can take nitrogen from the atmosphere and convert it into fixed nitrogen, which it uses for growth.

*4:* **Lignum vitae**
*Guaiacum officinale*
Height: 9m
a) flowers b) leaves
c) fruit d) open seed pod
'Lignum vitae' is Latin for the 'Tree of Life', so called because of its medicinal uses. It is used to treat a variety of conditions including coughs, tonsilitis and arthritis. The wood of this tree is the hardest and heaviest in the world, making it ideal for engineering bearings, shafts and pulleys.








# Yellow Meranti

At almost 101m tall, the extraordinary yellow meranti (*Shorea faguetiana*) is the tallest tropical tree in the world. Fittingly, the team that found it in 2019 named it 'Menara' – Malaysian for 'tower'. It soars above the canopy on the island of Borneo, where it grows deep in the Danum Valley Conservation Area. But despite its record-breaking height, scientists believe that even taller yellow merantis could still be uncovered in the region.

The valley that Menara calls home is one of Southeast Asia's best-protected areas. Aside from providing shelter to some of the world's most endangered animals, including the orangutan (*Pongo pygmaeus*) and elusive clouded leopard (*Neofelis diardi*), the Danum Valley is a refuge for these rainforest giants, and is proving to be a hotspot for this species. In 2016, an entire grove of yellow meranti was found, with each specimen measuring over 90m. At these phenomenal heights, scientists believe Menara may be close to achieving the tallest height possible for any tree on Earth. Much taller, and it would be impossible for the tree to pump essential sugars and water up to its crown.

In order to stand and be resilient to the strong seasonal winds that blow through the valley, the yellow meranti has adapted to produce enormous, flared buttresses at the base of the trunk – they weigh an estimated 81,000kg, without taking into account the roots. This is heavier than a fully loaded Boeing aeroplane. It has also evolved to grow particularly straight, with a beautiful pale yellow-brown timber. Sadly, these qualities make it a highly sought-after specimen for logging, and as such it is critically endangered.



## *Key to plate*

**Yellow meranti**
*Shorea faguetiana*
Height: 100.8m

*1:* **Tree**
The genus *Shorea* is named after Sir John Shore, the governor general of the British East India Company between 1793 and 1798.

*2:* **Fruit**
The yellow meranti is in the dipterocarp family. Single nut-like seeds of most dipterocarps have two wings, but *Shorea* species are three-winged, resembling a badminton shuttlecock, which helps with seed dispersal to the forest floor by the wind. An individual yellow meranti can produce as many as 120,000 energy-rich seeds in one season.

*3:* **Leaves**
The leaves of the yellow meranti are long and arranged alternately along the twig. They have a very shiny surface, allowing any rainwater to run off quickly.

*4:* **Flowers in bud**
Very large numbers of flowers are produced at irregular intervals of between three to ten years. The tree goes on to produce lots of seeds, which helps to ensure survival in times of drought and protect against seed-eating predators.

*Gallery 5*

# Tropical Dry Forests

*Habitat: Tropical Dry Forest*
*Dry Tropics*
*Tropical Savannah*
*Baobab*
*Tropical Nuts and Spices*
*Tropical Fruits*

# Habitat: Tropical Dry Forest

When most people think of tropical forests, they imagine lush evergreen vegetation and steamy jungle climates, but this is not entirely accurate. 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 that can last for months. These two seasons separate dry forests from rainforests, which don't have a dry or wet season, but a constant climate throughout the year.

Although these forests are less biodiverse than the moist rainforests, they are still very important habitats for a variety of wildlife, much of which is endemic to these regions. Animals like monkeys, large cats, including tigers, rodents, ground-dwelling birds and bats live on varied seasonal diets and store fat to survive in this difficult climate.

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 (see pages 6–7). It is because of this nutrient-rich soil that dry rainforests are ideal for deforestation to create agricultural land, making them among the most threatened of all the tropical rainforests.

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 short, 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



# Dry Tropics

At the start of the dry season, some trees in the tropical deciduous forests of Africa burst into life. Flowering trees like the African tulip (*Spathodea campanulata*), light up the forest with displays of flamboyant flowers, and stand out among the other neighbouring trees, who shed their leaves during this period to conserve water. But bare trees have purpose, too. They open up the canopy layer, enabling sunlight to reach the forest floor, and facilitate a dense undergrowth which many wildlife species depend on to survive.

The trees of these forests have also developed numerous methods to cope with the extreme seasons. In Mexico and tropical America, where the dry forests meet the rainforests, the kapok (*Ceiba pentandra*) stores excess water captured during the rainy season in its trunk, a feature that the baobabs of Africa also share (see page 74). This precious reserve keeps the tree nourished during the dry months, as do its shallow roots, which absorb water from the surface. To protect itself from any animals that might steal this water, the kapok tree has another trick up its sleeve – it produces remarkable sharp spines on its branches and main trunk, similar to thorns on a rose bush. These spines are also an aid for climbing vines or lianas, which grip the otherwise smooth trunk and ascend towards the light.

Many trees in these regions are reliant on different types of seed dispersal, including wind and dispersal by animals. Seeds may become attached to birds and bats, while animals including elephants disperse the seeds through their droppings. Insects such as ants and dung beetles also play a role in moving seeds away from the parent tree to a suitable seed bed.

## *Key to plate*

*1:* **African tulip**
*Spathodea campanulata*
Height: 23m
Flower
Gathering in large clusters about the size of a football, the vibrant flowers open wide like saucers, holding copious amounts of sweet nectar that attract flocks of pollinating hummingbirds.

*2:* **Cocobolo**
*Dalbergia retusa*
Height: 20m
a) seed pod b) timber transection
The heartwood of this tree is hard, heavy, strong and very dark red, with streaks of black through the grain. It is used for a wide range of items, including cutlery and tool handles, musical and scientific instruments, and for this reason it has been widely exploited.

*3:* **Kapok**
*Ceiba pentandra*
Height: 70m
a) tree stem with spines b) seed pod
This tree is the source of kapok, a cotton-like, water resistant fibre harvested from the seed pods in which the seeds are embedded. This down-like material was used to fill mattresses, life jackets, pillows and upholstery, and as insulation. It has now been replaced by synthetic materials.



# 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 30,000km². It is famous for its unique wildlife including lions, giraffes, elephants and zebras, as well as herds of grazing herbivores, which feast on the grasses.

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. They have 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.

Not only do trees need to be hardy enough to survive the unfavourable weather conditions, but hazards such as wildfire and voracious insects and animals pose significant threats to their survival. Fortunately, the trees found in these regions have some clever defence mechanisms. Iconic acacias, which are a familiar sight on the savannah, release poisonous alkaloids into the leaves when an animal such as a giraffe first takes a bite. Not only is the bitter taste unpalatable to the giraffe, who will stop feeding, the tree will also warn neighbouring acacias of the danger by emitting a pheromone into the air, which in turn triggers their leaves to emit the same chemicals.

## *Key to plate*

*1:* **Flame tree**
*Delonix regia*
Height: 12m
a) flower b) leaf
The appearance of these spectacular flowers is what the genus name is derived from – the Greek words *delos* meaning 'conspicuous' and *onyx* meaning 'claw'. Due to the destruction of its habitat in Madagascar, this beautiful flowering tree is under increasing threat.

*2:* **Fever tree**
*Acacia xanthophloea*
Height: 25m
a) leaves b) flower
The fever tree gets its common name from early European settlers who believed that the tree caused malarial fever. We now know that it was the mosquito that spread the fever, and the bark contains properties that were used in traditional medicines for treating the disease.

*3:* **Whistling thorn**
*Vachellia drepanolobium*
Height: 6m
a) swollen thorn b) leaves
This tree has developed a symbiotic relationship with stinging ants which feed on the tree's nectar and live in the hollow, swollen thorns. When grazing animals eat the leaves and thorns, they receive a sting from the ants that are nestled inside. A whistling sound is made as the wind passes through the ant holes in the swollen thorns.

*4:* **Frankincense**
*Boswellia sacra*
Height: 8m
a) resin b) cross section of trunk with papery bark
This small, deciduous tree is the main source of the resin frankincense. Harvested once the tree reaches 10 years old, a small incision is made through the papery bark of the trunk to allow the milky resin to seep out and be collected. The Egyptians used the resin to embalm their dead and called it the 'sweat of the gods'.

# Baobab

Often called the upside-down tree, as the stubby-branched crown resembles a root system in the air, the iconic baobab tree (*Adansonia digitata*) 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 so large (up to 10m in diameter), that some hollow trees having been used for shelter by local people, holding up to 35 adults! 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 leaves, which contain 50% more calcium than spinach, are eaten as a vegetable. The roots, bark, leaves and seeds are used medicinally for a variety of ailments, and fibres from the bark are used to make rope and string for basketry.

## *Key to plate*

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

*1:* **Tree**
Remarkably, the bark of the baobab is fire-resistant.

*2:* **Flowers**
a) flowers
b) cross section through flower bud
The showy, white flowers bear as many as 1,000 stamens. At night, they release a fragrance to attract fruit bats, which pollinate the tree.

*3:* **Leaves**
The leaves are divided into 5–7 leaflets resembling the digits of a hand. This gives the species the specific name, *digitata*.

*4:* **Cross section of fruit capsule**
The woody, egg-shaped fruits, called 'monkey bread', are up to 30cm long. The powdery pulp is highly nutritious and is often eaten raw, or used in porridge. Some cultures believe that a decoction made from the seeds holds magical powers that will protect against crocodile attacks.

# Tropical Nuts and Spices

The protection of rainforests around the world is not only essential for a healthy planet. We may not realise it, but we rely on tropical regions to form many parts of our diet – from the vanilla pods we use in ice cream, the chocolate we have as a treat, the coffee we have with our breakfast to the spices we use in everyday cooking.

From Brazil nuts to macadamias and cashews, 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, making harvesting a challenge.

The Brazil nut is a prime example of this. Its three-sided shell 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 (*Dasyprocta* spp.), a rodent native to Brazil, with razor-sharp teeth. The magnificent Brazil nut tree grows naturally in the Amazon River Basin, where it reaches towering heights of 50m. The nuts are collected by local people known as *castañeros*, who gather the fruits that have fallen to the forest floor during the wet season. The fruits are so heavy, and fall from such heights, that they are often driven into the earth.

Spices are the aromatic parts of tropical plants and have been used for more than 5,000 years to flavour food. Their use has been documented as far back as 3,500BCE, when the ancient Egyptians used them for cooking food and embalming their dead. So prized were spices during the medieval period, that they were considered as valuable as gold in Europe. The movement of spices around the world played an important role in exploration and colonization of Southeast Asia, and caused fierce competition across Europe for control of the spice trade in the sixteenth century.

Today, some of the most common spices include cloves, cinnamon and nutmeg, and these are harvested from the bark, seeds, buds and roots of tropical trees. Other spices, including 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
The bark is harvested from only half the circumference of the trunk so as not to kill it. The outer skin of the bark is removed, and the spicy inner bark is cut into short lengths, which are dried in the sun. The process curls them into cylindrical 'quills', which are sold as cinnamon sticks.

*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
The fruits of the Brazil nut tree are hard, spherical pods, like a woody cannonball, measuring up to 20cm in diameter and containing up to 24 nuts.

*3:* **Clove**
*Syzygium aromaticum*
Height: 20m
a) cross section through a flower bud
b) twig with leaves and flower buds
Cloves are the quintessential aroma of Christmas, used in mince pies and puddings, but also added to chutneys and curries. As the flower buds mature, they turn bright red and are hand-picked before the flowers open.

*4:* **Nutmeg**
*Myristica fragrans*
Height: 23m
a) cross section through the seed
b) seed c) cross section through the outer husk, showing the seed
The nut is dried over 6 to 8 weeks and the seed is ground into a powdery spice known as nutmeg, used mainly for sweet cooking.



# 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. Remarkably, archaeologists have found 4,500-year-old remains of bananas preserved in human settlements in Africa, and 4,000-year-old cherry stones have been found in Bronze Age settlements in the United Kingdom, showing just how far back our relationship with fruit stretches.

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, and the skins 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 (*Casuarius casuarius*), 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
Breadfruit trees are one of the highest yielding food plants known, with a single tree producing up to 150 fruits per year, each weighing as much as 5kg.

*2:* **Lychee**
*Litchi chinensis*
Height: 10m
Native to Southern China, where it has been cultivated and eaten for more than 4,000 years, when peeled the lychee exposes a translucent white flesh with a floral-scented smell and a sweet taste.

*3:* **Lemon**
*Citrus x limon*
Height: 12m
The origin of the lemon is unknown, but it is believed to be a hybrid made by crossing bitter oranges with citron. True bergamot oil also arises from this crossing, and the fragrant oil from the rind is used to flavour Earl Grey tea.

*4:* **Mango**
*Mangifera indica*
Height: 30m
A mango is a drupe – a fruit with an outer fleshy part containing a single, hard seed. Drupe fruits, including plums and peaches, are also known as stone fruits.

*5:* **Mangosteen**
*Garcinia mangostana*
Height: 10m
Mangosteen are apomictic, which means that the female trees produce fruit without pollination. The mature fruits have a thick, dark purple rind containing up to four seeds.

*6:* **Star fruit**
*Averrhoa carambola*
Height: 10m
Also known as 'five fingers', every part of the star fruit is edible, including the slightly waxy outer skin. The deep-yellow-coloured fruit has five distinctive ridges running down the sides and looks like a star when cut in half horizontally.



*Gallery 6*

# Gardens

*Habitat: Gardens*
*Flower Types*
*Pollination Types*
*Handkerchief Tree*
*Ornamental Trees*

# Habitat: Gardens

Whether pretty, rustic cottage gardens, a peaceful, balanced Japanese landscape or an immaculate, symmetrical, grand design, garden planning and maintenance is not just a hobby, it has become an art form.

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 planted in gardens mainly for purely decorative purposes.

Trees provide many benefits to the garden-owner apart from looking beautiful. They break up the straight edges of buildings and other hard landscaping, and while a single specimen tree can act as a focal point in the garden, informal groups of trees can frame and highlight notable areas and viewpoints. Planting the right tree in the right place can also create microclimates by reducing wind speeds and softening noise pollution created by traffic.

There are great environmental benefits to planting trees as they reduce air pollution by absorbing harmful greenhouse gas into their foliage and bark. They also reduce surface water run-off and the risk of flooding after heavy rainfall, and 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 are very important, providing a rich habitat and food source for a diverse range of wildlife, including mammals, birds and pollinating insects, and we can never have enough trees in our gardens.

*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



# Flower Types

Like all other flowering plants, most trees produce flowers as a means of natural reproduction – their seeds germinate to become the next generation of trees. Broadleaved trees produce pollen from the anthers (male flowering part), which is transferred to the stigma (female flowering part) by wind, insects or animals (see page 86). Once fertilised, a new seed grows, often enclosed within a fruit.

There are several flowering types. Most trees are 'monoecious', and have separate male and female flowers on the same tree. These trees, including oak (*Quercus* spp.), beech (*Fagus* spp.), birch (*Betula* spp.), maple (*Acer* spp.), hornbeam (*Carpinus* spp.) and walnut (*Juglans* spp.), can set seed with a little help from the wind, but without the need for individual pollinators.

Some trees are 'dioecious', having separate male and female flowers on different trees. In these instances, both the male and female tree will need to produce fruits and seeds. The male flowers will be needed to pollinate the female flowers. Dioecious trees are rare, but examples include the Osage orange (*Maclura pomifera*), the yew (*Taxus baccata*) and the Chinese fringe tree (*Chionanthus retusus*).

Trees like the silver lime (*Tilia tomentosa*) and dogwood (*Cornus florida*) are known as 'hermaphrodites', with flowers containing both male and female reproductive parts. These flowers are often small or inconspicuous, and need a helping hand to attract pollinators. They do this by producing large, brightly coloured, or white, bracts, which will stand out from all its neighbours – the tree's way of waving a flag for attention.

However, not all trees produce flowers. Conifers have both male and female cones instead, and pollen is usually transferred from the male to the female by wind. When the pollen lands on the female cone it moves between the cone scales, where it fertilises the ovule and grows into a seed. Unlike broadleaved trees, which enclose the seeds inside a fruit, conifer seeds remain naked, but attach to the cone scale, usually in pairs.

*Key to plate*

*1:* **Chinese fringe tree**
*Chionanthus retusus*
Height: 20m
a) male flowers b) female flowers
The flowers of the fringe tree are dioecious, with male and female flowers on different trees. The male trees are more impressive when in bloom as the petals are much longer than the females. They are scented to attract pollinating insects.

*2:* **Common ash**
*Fraxinus excelsior*
Height: 30m
a) terminal bud b) flowers
The ash is primarily hermaphrodite, with male and female parts in the same flower. It can also bear individual male and female flowers, however, or a combination of all three types at the same time.

*3:* **Silver lime**
*Tilia tomentosa*
Height: 30m
a) modified leaf with flowers
b) underside of leaf
Lime trees are also hermaphrodites, so the flowers have both male and female parts. The tree produces a modified leaf with the flower, to attract insect pollinators and to help with seed dispersal by the wind.

*4:* **Hop hornbeam**
*Ostrya virginiana*
Height: 18m
a) female flowers b) male flowers
Hop hornbeams are monoecious, with individual male and female flowers on the same tree. Behind each bract of the catkin is a sheltered group of male flowers, which produce pollen. The female catkins are similar in appearance, but the female parts protrude beyond the bracts to catch the released pollen.



# Pollination Types

There is nothing quite like sitting in a garden on a spring or summer's day, taking in the bright, colourful flowers of a tree, listening to the hum of insects and feeling the warm breeze. While providing a feast for the senses, the garden is also a hive of activity, with both the insects and the breeze playing a key role in pollination.

Most temperate trees are pollinated by the wind, a process called 'anemophily', and these flowers are very different in appearance to those pollinated by insects. Wind-pollinated flowers are small and usually lack the colour, scent and nectar that would attract insects. They have tiny petals, or none at all, and the male and female parts are completely exposed to the elements. These flowers, such as those growing on sugar maples (*Acer saccharum*), send out large quantities of lightweight pollen, which can travel for hundreds of miles on air currents. Wind pollination usually takes place in early spring when there is less foliage on the trees, allowing free movement. This type of pollination is less common in tropical jungles, where there is little wind, but in freezing boreal forests, where there are few insects, most trees are wind pollinated.

'Entomophily' is where the pollen is distributed between the different sexual flowering parts by means of an insect. Insect pollinated flowers are generally larger and brighter than wind-pollinated flowers and put on show-stopping displays to entice insects. These flowers also emit a sweet scent from their nectar, which acts as a reward to the bee, fly or butterfly, and may mimic the pheromones of the pollinating insects.



### *Key to plate*

*1:* **Indian horse chestnut**
*Aesculus indica*
Height: 30m
The throats of this flower's petals have a yellow guide spot to attract bees. Once the flower is pollinated, this spot turns red, and nectar and scent production are reduced or stopped. These red spots are unattractive to bees, and possibly indicate that they should not waste time visiting already pollinated flowers.

*2:* **Cucumber tree**
*Magnolia acuminata*
Height: 20m
Magnolias are among some of the earliest flowering trees and evolved long before there were bees. The only available pollinators were primitive, wingless beetles that would burrow into the closed flower bud, clumsily transferring the pollen between the male and female parts. The beetle remains the main pollinator today.

*3:* **Sugar maple**
*Acer saccharum*
Height: 25m
The flowers of the sugar maple are monoecious. They are long, green and dangle from the twigs – a clear indicator that they are wind pollinated. To guarantee an individual pollen grain landing on a stigma of a female flower of the same species, the tree invests in the production of large quantities of pollen, much of which is wasted.

*4:* **Pedunculate oak**
*Quercus robur*
Height: 40m
All oaks are monoecious, and are wind pollinated. The male flowers are long catkins, which hang down. The very small, female flowers are on stalks above the male flowers to minimise self-pollination.

# Handkerchief Tree

Of all the ornamental trees that are planted in gardens and arboreta, the handkerchief tree (*Davidia involucrata*) 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. They also look like white doves perched on the branches, hence the tree's other often-used name – the dove tree. Similarly to dogwoods, these bracts are produced to attract bees, who are the main pollinators of this tree.

Aside from its outstanding beauty, the handkerchief tree also has an exciting history, one that is synonymous with nineteenth-century plant exploration in the temperate forests of Western China's mountains. In 1869, a French missionary and keen naturalist and botanist, Father Armand David (Père David), was the first European to see this tree (he was also the first to see the giant panda). Almost 30 years later, a botanical race would ensue between French and English botanists as to who would become the first to introduce it to western gardens, knowing that its ornamental features would be alluring.

In 1899, armed with a small, hand-drawn map, plant hunter Ernest Henry Wilson was sent to China from Kew Gardens to find the tree, collect as many seeds as possible and send them back to England where they could be germinated. The journey was perilous, but Wilson survived travelling in what was a very unsafe country for foreigners during the Boxer Rebellion. His boat was capsized in rapids on the mighty Yangtze River, but eventually Wilson found the very spot that was described to him, only to find out that the tree had been felled to build a house in the village! Although disappointed, the following spring he saw groves of the handkerchief tree growing wild in the nearby mountains and managed to collect some seeds.

The journey home was as eventful as the expedition itself, 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**
The leaves are typically heart-shaped, with a toothed margin that makes the tree easy to identify in a garden when there are no flowers present.

*2:* **Flowers with bracts**
The species name *involucrata* refers to the bracts surrounding the flowers. These bracts start green, gradually turning a brilliant white, which attracts bees, but also acts as an umbrella, protecting the pollen from rain.

*3:* **Fruits**
These hard, green nuts turn purple when ripe. The seeds can take more than two years to germinate, but if they are frozen before being sown, germination will take place soon after 12 months. The freezing of the seed mimics two winters, which shortens the period of dormancy.

*4:* **Twig with winter buds**
The winter twigs are smooth with alternate short, stout, pointed red buds.

*5:* **Bark**
Smooth on young twigs, the bark on older branches and the main trunk gets rougher with age.



# Ornamental Trees

Whether delicate flowers, seen in the beautiful Japanese cherry tree (*Prunus* spp.), or abundant fruit, seen in the flowering crab apple (*Malus* Evereste), ornamental trees all have unique attributes that make them outstanding specimens for gardens. Interesting leaf shape or colour, bark effect, fragrance, or even overall shape and height are all highly sought-after features, and the perfect tree can become a centrepiece of the garden.

Nurserypersons and 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 recorded trees being 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 were sent out to explore faraway lands, to find and gather new exotic plants that could be grown in our gardens. These expeditions were often dangerous, but with plants quickly becoming a status symbol among the wealthy, plant collectors were happy to risk the perils of long boat journeys, such as shipwreck or disease, for the right incentive. The discovery of new ornamental trees prompted wealthy landowners to plant arboreta, or to build ornate glasshouses, with the ultimate aim of being the first to grow a new tree species and get it to flower in cultivation.

Cultivating trees to show consistent features is not an easy task. If a tree is grown sexually from a seed, the seedling will have a genetic make-up that reflects both of its parents, but will not be an exact replica. To guarantee a tree with identical outstanding attributes, the tree must be propagated and reproduced asexually. This can be done 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). These new trees will be a clone of the original tree, complete with all the desired characteristics. Japanese flowering cherries are an excellent example of asexual propagation – they are identical the world over.

*Key to plate*

*1:* **Yoshino cherry**
*Prunus* x *yedoensis*
Height: 12m
This tree is a hybrid cherry tree from Japan, introduced to gardens in Europe and North America in 1902. It is now the most widely planted flowering cherry around the world.

*2:* **Contorted willow tree**
*Salix babylonica* var. *pekinensis* 'Tortuosa'
Height: 15m
Native to China and Korea, this is a cultivated form of the willow tree raised for its twisted, snake-like stems. Its appearance has resulted in many common names, including dragon's claw willow and corkscrew willow.

*3:* **Flowering crab apple**
*Malus* 'Evereste'
Height: 5m
Originating from Central Asia, this small, ornamental tree is a symbol of love and marriage. It is grown in the garden primarily for the abundance of crab apples it produces in winter.



ARBORETUM

# *Library*

# Index

# Curators

**Tony Kirkham MBE, VMH** has cared for the Royal Botanic Gardens, Kew collection of 14,000 trees for over 40 years, retiring in 2021 as Head of Arboretum, Gardens and Horticulture Services. He was awarded the Royal Horticultural Society's Victoria Medal of Honour in 2019. He has written and co-authored numerous books on trees and has also featured on TV programmes including *Judi Dench: My Passion for Trees* and has presented two television series of *The Trees That Made Britain* for the BBC.

**Katie Scott** graduated from the University of Brighton in 2011. She draws influences from traditional medical and botanical illustration, both in aesthetic and subject matter. Her work plays with the ideas of scientific uncertainty and speculation, fabricating the inner and outer workings of the world. Her illustrations depict a familiar, yet fantasy, vision of plants, humans and minerals.

# To Learn More

**American Conifer Society**
This is a database with information, photographs, growth rates, hardiness statistics and historical data of many conifers from all around the world.
www.conifersociety.org

**Ancient Tree Forum**
This website brings together people from different backgrounds and levels of expertise, all of whom have a shared love for ancient and veteran trees, their history and wildlife.
www.ancienttreeforum.org.uk

**Botanic Gardens Conservation International**
BGCI has published a list of nearly 60,000 tree species worldwide obtained from information supplied by its member organisations. The aim of the project was to identify trees that are in danger of extinction and promote efforts to conserve them.
www. bgci.org

**Global Trees Campaign**
Launched in 1999, the GTC is dedicated to saving the world's threatened tree species in their natural habitats benefiting more than 400 threatened tree species in over 50 countries worldwide.
www. globaltrees.org

**The International Dendrology Society**
This society aims to promote the study and enjoyment of trees and other woody plants, bringing together dendrologists all around the world, to protect and conserve rare and endangered species worldwide.
www.dendrology.org

**The Linnean Society**
The world's oldest active biological society. Online collections for research and educational resources. Learn about Carl Linnaeus and taxonomy.
www.linnean.org

**Monumental Trees**
With over 52,000 trees registered on this website, you can find any champion tree of any species around the world.
www. monumentaltrees.com

**Royal Botanic Gardens, Kew**
Learn about Kew's global and collaborative scientific work, making an invaluable contribution to solving some of the biggest environmental challenges facing humanity.
www.kew.org
plantsoftheworldonline.org
www.kew.org/kew-gardens/plants
www.kew.org/science/

**Royal Horticultural Society**
The world's leading gardening charity providing information and events on horticulture.
www.rhs.org.uk

**Trees and Shrubs Online**
An ambitious project by the International Dendrology Society creating a modern web-based encyclopaedia of woody plants hardy in the temperate parts of the world. Based on a core of data from the full text of Bean's *Trees and Shrubs Hardy in the British Isles and New Trees*.
Treesandshrubsonline.org

**The Tree Register of the British Isles**
A charity run by volunteers with a unique database of over 200,000 of the most notable trees in the UK and Ireland, recording our wonderful tree heritage and home to the definitive list of over 69,000 champion trees.
www.treeregister.org

**US Department of Agriculture Plants**
A plant database providing information on the characters and distribution of many native plant species in the US.
https://plants.usda.gov

**The Woodland Trust**
The UK's largest woodland conservation charity. Explore the British woodlands.
www.woodlandtrust.org.uk



# *Library*

# Index

# Curators

**Tony Kirkham MBE, VMH** has cared for the Royal Botanic Gardens, Kew collection of 14,000 trees for over 40 years, retiring in 2021 as Head of Arboretum, Gardens and Horticulture Services. He was awarded the Royal Horticultural Society's Victoria Medal of Honour in 2019. He has written and co-authored numerous books on trees and has also featured on TV programmes including *Judi Dench: My Passion for Trees* and has presented two television series of *The Trees That Made Britain* for the BBC.

**Katie Scott** graduated from the University of Brighton in 2011. She draws influences from traditional medical and botanical illustration, both in aesthetic and subject matter. Her work plays with the ideas of scientific uncertainty and speculation, fabricating the inner and outer workings of the world. Her illustrations depict a familiar, yet fantasy, vision of plants, humans and minerals.

# To Learn More

**American Conifer Society**
This is a database with information, photographs, growth rates, hardiness statistics and historical data of many conifers from all around the world.
www.conifersociety.org

**Ancient Tree Forum**
This website brings together people from different backgrounds and levels of expertise, all of whom have a shared love for ancient and veteran trees, their history and wildlife.
www.ancientreeforum.org.uk

**Botanic Gardens Conservation International**
BGCI has published a list of nearly 60,000 tree species worldwide obtained from information supplied by its member organisations. The aim of the project was to identify trees that are in danger of extinction and promote efforts to conserve them.
www. bgci.org

**Global Trees Campaign**
Launched in 1999, the GTC is dedicated to saving the world's threatened tree species in their natural habitats benefiting more than 400 threatened tree species in over 50 countries worldwide.
www. globaltrees.org

**The International Dendrology Society**
This society aims to promote the study and enjoyment of trees and other woody plants, bringing together dendrologists all around the world, to protect and conserve rare and endangered species worldwide.
www.dendrology.org

**The Linnean Society**
The world's oldest active biological society. Online collections for research and educational resources. Learn about Carl Linnaeus and taxonomy.
www.linnean.org

**Monumental Trees**
With over 52,000 trees registered on this website, you can find any champion tree of any species around the world.
www. monumentaltrees.com

**Royal Botanic Gardens, Kew**
Learn about Kew's global and collaborative scientific work, making an invaluable contribution to solving some of the biggest environmental challenges facing humanity.
www.kew.org
plantsoftheworldonline.org
www.kew.org/kew-gardens/plants
www.kew.org/science/

**Royal Horticultural Society**
The world's leading gardening charity providing information and events on horticulture.
www.rhs.org.uk

**Trees and Shrubs Online**
An ambitious project by the International Dendrology Society creating a modern web-based encyclopaedia of woody plants hardy in the temperate parts of the world. Based on a core of data from the full text of *Bean's Trees and Shrubs Hardy in the British Isles and New Trees*
Treesandshrubsonline.org

**The Tree Register of the British Isles**
A charity run by volunteers with a unique database of over 200,000 of the most notable trees in the UK and Ireland, recording our wonderful tree heritage and home to the definitive list of over 69,000 champion trees.
www.treeregister.org

**US Department of Agriculture Plants**
A plant database providing information on the characters and distribution of many native plant species in the US.
https://plants.usda.gov

**The Woodland Trust**
The UK's largest woodland conservation charity. Explore the British woodlands.
www.woodlandtrust.org.uk