# Chapter 1: An overview

## What is a tree?

Everyone knows what a tree is: a large woody thing that provides shade. Oaks, pines and similarly large majestic trees probably come immediately to mind. Such big trees are characterised by the enormous changes in size from seed to mature tree: a mature giant sequoia (*Sequoiadendron giganteum*) is a billion, billion times heavier than the seed it came from (that's 1 with 12 zeros after it). A stricter, but more inclusive, botanical definition is that a tree is any plant with a self-supporting, perennial woody stem (i.e. living for more than 1 year). The first question that normally comes back at this point is to ask what then is a shrub? To horticulturalists, a 'tree' is defined as having a single stem more than 6 m (20 ft) tall which branches at some distance above ground, whereas a shrub has multiple stems from the ground and is less than 6 m. This is a convenient definition for those writing tree identification books who wish to limit the number of species they must include. In this book, however, shrubs are thought of as being just small trees since they work in exactly the same way as their bigger neighbours. Thus, 'trees' cover the towering giants over 100 m through to little sprawling alpine willows no more than a few centimetres tall.

Some plants can be clearly excluded from the tree definition. Lianas and other climbers are not self-supporting (although some examples are included in this book), and those plants with woody stems which die down to the ground each year, such as asparagus, do not have a perennial woody stem. Bananas are not trees because they have no wood (the trunk is made from leaf stalks squeezed together). Nor are bamboos since they are just hardened grasses even though they can be up to 25 m tall and 25 cm thick (see Box 1.1).

There are estimated to be 100 000 species of tree in the world, about 25% of all living plant species. An interesting feature of all these trees is how unrelated they are. It is usually easy to say whether a plant is an orchid or not because all orchids belong to the same family, have a common ancestor and share a similarity in structure (especially the flowers). This is true of most plant groups such as grasses and cacti (in their own families) and chrysanthemums (all in the same genus). But the tree habit has evolved independently in a wide range

| **Box 1.1** The range of trees found in different plant groups | |
|---|---|
| **Ferns (Pteridophytes):** | Tree ferns: mostly in the families of Cyatheaceae and Dicksoniaceae; rarely branched, no true bark and with a trunk containing woody strands; need frost-free shaded habitats |
| **Seed plants:** | Contains the Conifers and the Flowering plants. The ferns above produce spores but not seeds and so are not included here |
| **Conifers and their allies (Gymnosperms):** This term means 'naked seeds' (as in gymnasium where the Greeks exercised naked); the seeds are exposed to the air and can be seen in the cone or fruit without having to cut anything open | Conifers: 630 species in eight families<br>• Cupressaceae: cypress, junipers, and now including the former Taxodiaceae: redwoods<br>• Araucariaceae: including monkey puzzle (*Araucaria araucana*), kauri (*Agathis australis*) and the Wollemi pine (*Wollemia nobilis*)<br>• Podocarpaceae: more than 150 species in the southern hemisphere including the podocarps (*Podocarpus* spp.) and rimu (*Dacrydium cupressinum*)<br>• Pinaceae: pines, spruces, larches, hemlocks, firs, cedars<br>• Cephalotaxaceae: 11 species of *Cephalotaxus*, plum yews/cowtail pines<br>• Phyllocladaceae: 4 species of *Phyllocladus*, celery-pines<br>• Sciadopityaceae: only *Sciadopitys verticillata*, Japanese umbrella-pine<br>• Taxaceae: yews<br>Ginkgo: 1 species<br>• Ginkgoaceae: the ginkgo or maidenhair tree (*Ginkgo biloba*)<br>Cycads: palm-like with stiff leathery leaves<br>Gnetales: a strange group with a few interesting woody plants<br>• *Welwitschia mirabilis*: single species in SW Africa<br>• *Gnetum* spp.: mostly tropical climbers<br>• *Ephedra* spp.: 30+ low shrubs of dry deserts |

| **Box 1.1** (cont) | |
|---|---|
| **Flowering plants (Angiosperms):** This means hidden seeds: contained inside a fruit | Dicotyledons (two 'seed leaves' in the seed): The main group of trees such as oaks, birches, etc. Around 75 of the world's 180 families contain trees.<br><br>Monocotyledons (one 'seed leaf'): A wide ranging set of trees concentrated in a few families<br><br>• Palmaceae (Arecaceae): palms; mostly tropical, a few temperate; nearly 3000 species<br>• Asparagaceae: a large family with a number of trees<br>Dragon trees (*Dracaena* spp.); mostly N African<br>Cordyline palms (*Cordyline* spp.); Australia and New Zealand<br>European butcher's brooms (*Ruscus* spp.)<br>Yuccas (including the Joshua tree, *Yucca brevifolia*)<br>• Pandanaceae: screw pines (*Pandanus* spp.); Old World Tropics; stilt roots supporting a stout forked trunk<br>• Xanthorrhoeaceae: grass trees (*Xanthorrhoea* spp.) from Australia with short trunk with forked branches and long narrow leaves, and aloes (*Aloe* spp.) from Southern Africa<br>• Sterlitziaceae: traveller's palm (*Ravenala madagascariensis*)<br><br>**Monocotyledons that are not trees**<br><br>• Musaceae: bananas (*Musa* spp.); the trunk is made from leaf stalks squeezed together<br>• Poaceae: bamboos (e.g. *Dendrocalamus* spp.) – are just hardened grasses with no wood |

of plants: at least 20 families in temperate areas and so probably hundreds worldwide. Given this wide range it is not surprising that the only common feature of trees is having a perennial woody skeleton. Box 1.1 illustrates how many major groups have evolved the tree habit. This is a superb example of 'convergent evolution' where a number of unrelated types of plant have evolved the same answer – height – to the same problem: how to get a good supply of light.

On the whole, this book is concerned with the two biggest groups of trees. These are the **conifers** and their allies, and the **hardwoods** like oak, birch and so on. (As you can see from Box 1.2 the terminology can be confusing so throughout this book we will stick to conifers and hardwoods as shorthand for gymnosperms and dicotyledon angiosperms.) The monocotyledon trees such as palms and dragon trees are mentioned in passing but on the whole they grow in a different way from conifers and hardwoods and the book can only be so long. Purists might indeed argue that since the trunks of these trees contain no real 'wood' (Chapter 3) they are not trees anyway. Tree ferns (Box 1.1) come into the same category.

## A short history of trees

Back in the Silurian, over 400 million years ago, the first vascular plants (those with internal plumbing) appeared on the earth. Initially this plumbing was just for conducting water up the plant with no structural strength. The tree habit took off once a way of making the plumbing (particularly the xylem; see *Parts of the tree* below for a definition of this) thicker and stronger had evolved; this was the cambium (again see below for a definition). The first trees (protogymnosperms) evolved in the early Devonian around 390 million years ago, capable of living for several decades and reaching up to 30 m tall and a metre wide. Within 100 million years, the coal-producing swamps of the Carboniferous (360–290 million years ago) were dominated by lush forests. We would have recognised the tree ferns from today's forests but the others – giant horsetails and clubmosses – have long since disappeared, leaving us just a few small relatives. The horsetails such as *Calamites* were up to 9 m tall and 30 cm in diameter but the clubmosses (notably *Lepidodendron*) must have been magnificent at up to 40 m high and a metre in diameter. In these forests the first primitive conifers appeared around 300 million years ago and by around 250 million years ago (the late Permian) trees such as cycads, ginkgos and monkey puzzles were recognisable: the sort of trees found fossilised in the petrified forest of Arizona from the late Triassic, 200 million years ago (Figure 1.1). The pines were not far behind, probably evolving around 180–135 million years ago (Jurassic) to share the earth with the dinosaurs. And by the end of the Cretaceous around 65 million years ago all the modern families of conifers had evolved.

Conifer domination was long and illustrious, from around 245 till 67 million years ago, but the early hardwoods were diversifying during the early Cretaceous around 120 million years ago. The hardwoods probably

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**Box 1.2** Definitions that go with the two main groups of trees

Throughout this book the terms **Conifers** and **Hardwoods** will be used as shorthand for Gymnosperm and Angiosperm trees.

| Gymnosperms | Angiosperms |
|---|---|

As explained in Box 1.1, these are the proper botanical terms but a little hard to digest. Both are seed plants but the angiosperms are also flowering plants; gymnosperms have no proper flowers.

| **Conifers** and their Allies | All other trees |
|---|---|

As you can see from Box 1.1 the gymnosperms include more than just the conifers but they are the major component.

| Softwoods | **Hardwoods** |
|---|---|

The problem with these descriptive terms (which stem from the timber industry) is that although most gymnosperms *do* produce softer wood, there are many exceptions, and many hardwoods can be physically soft. Yew (*Taxus baccata*, a Softwood) produces very dense and hard wood whereas some Hardwoods, like balsa (*Ochroma pyramidale*), are very soft and easily broken or indented with a fingernail.

| Evergreens | Deciduous trees |
|---|---|

It is often considered that conifers are evergreens and hardwoods are deciduous, losing all of their leaves at some point in the year. Exceptions can be found here as well. The dawn redwood (*Metasequoia glyptostroboides*), the swamp cypress (*Taxodium distichum*) and larches (*Larix* spp.), for example, are deciduous gymnosperms. In contrast, European holly (*Ilex aquifoilium*), rhododendrons and many tropical angiosperms are evergreen.

| Needle trees | Broad-leaved trees |
|---|---|

Most conifers do indeed have needle-shaped leaves but again there are exceptions. The ginkgo tree (*Ginkgo biloba*) and monkey puzzle (*Araucaria araucana*) have definite broad flat leaves (admittedly these trees are easily identified oddities). Cycads, which are primitive gymnosperms, have long divided leaves that resemble palms. Some angiosperms have reverted to needle leaves or have largely lost their leaves and use their needle-like branches as leaves, e.g. gorses (*Ulex* spp.) and brooms (*Cytisus* spp.).

Figure 1.1 Sections of petrified tree (in this case about 1 m in diameter) in the Petrified Forest National Park, Arizona, USA. These trees were growing in the late Triassic (200 million years ago) and became buried under river sediments which prevented rotting. Water flowing through the sediments deposited silica into the wood's tubes with other colourful minerals, such as iron, manganese and copper, and so preserved the original wood structure.

evolved from a now extinct conifer group that had insect-pollinated cones. The magnolias are some of the earliest types of hardwood that we still have around. During the Cretaceous period and into the early Tertiary (65–25 million years ago) the hardwoods underwent a massive expansion displacing the conifers, undoubtedly helped by the warm humid global climate of the early Tertiary. But further changes to the climate came to the rescue of the conifers with the development of polar ice caps at the end of the Eocene (35 million years ago), which allowed the northern pines to diversify, spread and take over the boreal forest. This was not without a price; others such as the dawn redwood (*Metasequoia glyptostroboides*), which had been very extensive around the world including on Axel Heiberg Island in the Arctic (79 °N) 60–50 million years ago, became severely limited in its distribution, now found natively only in eastern Asia.

At the end of the Permian period, around 250 million years ago, most of the earth's land masses were squashed together into the super-continent of Pangaea. By the time the hardwoods had evolved, Pangaea had broken into Laurasia (which gave rise to the northern hemisphere continents) and Gondwanaland (containing what is now Australia, Africa, S America, India and Antarctica) trapping the pines primarily in the northern hemisphere.

Laurasia and Gondwanaland themselves broke apart later, which goes some way to explaining why the hardwoods of the northern and southern hemisphere are so different from each other and yet remarkably similar around the globe within a hemisphere. It also explains why a number of genera are found throughout the northern hemisphere (their ancestors were found across Laurasia) but very few share species between the Old and New World; these evolved once Laurasia had separated. For example, the genus of tulip trees (*Liriodendron*) is found across the northern hemisphere but the Chinese tulip tree (*L. chinense*) is in the Old World and the tulip tree (*L. tulipifera*) in the New World. This similarity in genera but with different species leads to a striking similarity between south-east USA and south-east China. If you squint a bit so as not to notice exactly which species you are looking at, you could be in either.

By 95 million years ago (midway through the Cretaceous period) a number of trees we would recognise today were around: laurels, magnolias, planes, maples, oaks, willows and, within another 20 million years, the palms. When the dinosaurs were disappearing (by 65 million years ago) the hardwoods were dominating the world with the conifers exiled mostly into the high latitudes.

## Living fossils

Most of the types of tree we see every day have been around for a long time. Perhaps the most incredible are the growing number of rediscovered ‘living fossils’: trees know from the fossil record and which were thought to have become extinct and yet have been found hanging on in remote parts of the world. The most famous is the ginkgo (Japanese for ‘silver apricot’, named after the fruit) or maidenhair tree (*Ginkgo biloba*), a Chinese tree known from the fossil record back about 180 million years (the Jurassic era) and rediscovered in Japan by Europeans in 1690 (Figure 1.2).

The dawn redwood (*Metasequoia glyptostroboides*) was similarly refound in 1944 in China (Figure 1.2), and more recently in 1994 the Wollemi pine (*Wollemi nobilis*, a member of the monkey puzzle family, Araucariaceae) was found growing in two areas with less than 40 mature trees in Wollemi National Park near Sydney, Australia. The dawn redwood has fossils dating back 65 to 35 million years ago and the Wollemi pine from 200 to 2 million years ago. In these plants you can see real history (or prehistory) and touch plants that would have been familiar to the dinosaurs!

## Tree movement through history

As we’ve seen above, as climate changed through geological time, and as continents have moved around, so trees have moved around the world. Depending

**Figure 1.2** Living fossils. (a) Leaves of the ginkgo or maidenhair tree (*Ginkgo biloba*) and (b) the distinctive shape of ginkgo trees along a road in Seoul Korea. (c) A branch of dawn redwood (*Metasequoia glyptostroboides*) with the small leaves and (d) trees in winter, having lost their leaves, showing the characteristic spire shape. Keele University, England.

upon their climatic needs (or tolerances really) they have moved as climate moves. And although this may look static now, the process is still happening (as is discussed in Chapter 9 looking at the likely consequences of climate change).

The most recent large change in tree distribution was after the last glaciation. There have been many waves of glaciation and warmer ‘interglacial’ periods, with the last ice age starting 2 million years ago and reaching a maximum 18 000 years ago with an ice sheet up to 5 km (3 miles) thick extending from the Arctic down to below the Great Lakes reaching New York, London and Berlin. At this point, with so much water bound up in ice, sea level dropped by 130 m (425 ft). In the southern hemisphere ice extended up from Antarctica to cover Chile, much of Argentina and Africa. This ice age started to lose its grip on the landscape 14 000 years ago and the ice was largely gone by 10 000 years ago following several periods of dramatic warming. The disappearance of the ice marked the end of the Pleistocene and the beginning of the Holocene (which we are still in).

The huge ice sheets pushed plants and animals further south into refuge areas. Much of Britain would have been devoid of plants as our trees found refuge in western France and northern Spain. As the climate warmed, animals, trees and other plants migrated polewards at a rate of 0.42 to 1 km per year (see Chapter 9 for a more detailed discussion on this). This migration produced some interesting patterns of trees. In N America the mountains tend to run north to south, so migration northwards was largely unimpeded and therefore eastern forests contain at least 10 major tree species making up the forests. In eastern Asia at similar latitudes, where the tree fauna is richer and the mountains run in a similar direction, forests can easily contain 20 major species. In Europe, however, the mountains (such as the Pyrenees and the Alps) tend to run east to west and were distinct barriers to migration, which explains why Europe has fewer tree species than eastern N America. Moreover in the British Isles, the land bridge joining us to Europe was submerged 8500 years ago leaving very little time for trees to reinvade; thus our forests have just five major trees species.

We've muddied the waters of natural distributions of trees by moving things around. The British Isles has around 35 tree species (depending upon what you count as a tree or shrub) that are regarded as native; that is they arrived in the islands by themselves after the last glaciation with no help from humans. Since then we've introduced another 500 species of tree that can be readily found in gardens and parks, and if you include rare species in botanic gardens then you can find upwards of 1700 species of tree in the British Isles. These new arrivals are described as non-native or exotic species. Of these an ever-increasing handful have become naturalised, that is they are non-natives that are sufficiently at home that they are reproducing and spreading by themselves. Sycamore (*Acer pseudoplatanus*) and Turkey oak (*Quercus cerris*) are in this category in the British Isles.

## Changing tree names and DNA

You will have undoubtedly noticed that after many years of just minor changes in plant names, we are now going through a period of rapid change. There is a reason! For hundreds of years plants that look similar have been put together in the same genus, and closely related genera have been put into the same family by looking at their detailed structure, particularly their flowers. This produced a fairly stable set of names for plants. The physical similarity was assumed to reflect their relatedness, so oaks in the same genus (*Quercus*) are closely related (like human siblings) while different genera lumped together in the same family (Fagaceae for the oaks along with beeches *Fagus* spp. and the chestnuts *Castanea* spp.) are a little less related (like cousins, aunts and uncles). In effect you can draw a family tree for these trees just as you can for your own family.

This relatedness also implies something about the evolution of these trees. Different oaks should share a fairly near common ancestor from which they all evolved, while members of a plant family may have split apart further back along the family tree. Since evolution is based on changes in genetic material inside the cells (the DNA), we should be able to say something about the relatedness of different trees by looking at the similarity of their DNA. Oaks should share more DNA than, say, an oak and a beech.

Since we can now look at the DNA of trees in detail, this has led to the discipline of molecular systematics which has produced so many of the recent name changes. From looking at the DNA that different trees share, new relationships have been worked out that sometimes change the old grouping of plants that were based just on physical features. Some plants that were thought to be closely related have been found to be less so. For example, the Kamtchatka rhododendron is not as closely related to other rhododendrons as was thought and has changed from *Rhododendron camtschaticum* to *Therorhodion camtschaticum*. On the other hand, *Ledum* species, such as the shrubby Labrador tea (*Ledum groenlandicum*), were found to be so closely related to the rhododendrons that that their name was changed to *Rhododendron groenlandicum*, etc. In a similar way, maples (*Acer* spp.), which were previously in their own family of Aceraceae, have now been put in the Sapindaceae family with other plants they are now known to be closely related to including the horse chestnuts (*Aesculus* spp.), the pride of India (*Koelreuteria paniculata*) and the lychee (*Litchi chinensis*)! As a last example, a whole group of trees that would appear to have little in common from just looking at them have now been moved together into the mallow family (Malvaceae) based on the similarity of their DNA. Thus the hibiscus is now joined by the cocoa tree (*Theobroma cacao*, previously in the Sterculiaceae), the baobab (*Adansonia* spp., Bombacaceae) and the limes/lindens (*Tilia* spp., Tiliaceae). If you have seen the first edition of this book, such changes also explain why Box 1.1 is somewhat different now from what it was. While this can all be very exasperating, these changes will slow as genetic relationships are sorted out once and for all and stability returns.

## Parts of the tree

Before we look at different aspects of trees in detail, we should start with an overview of the whole tree.