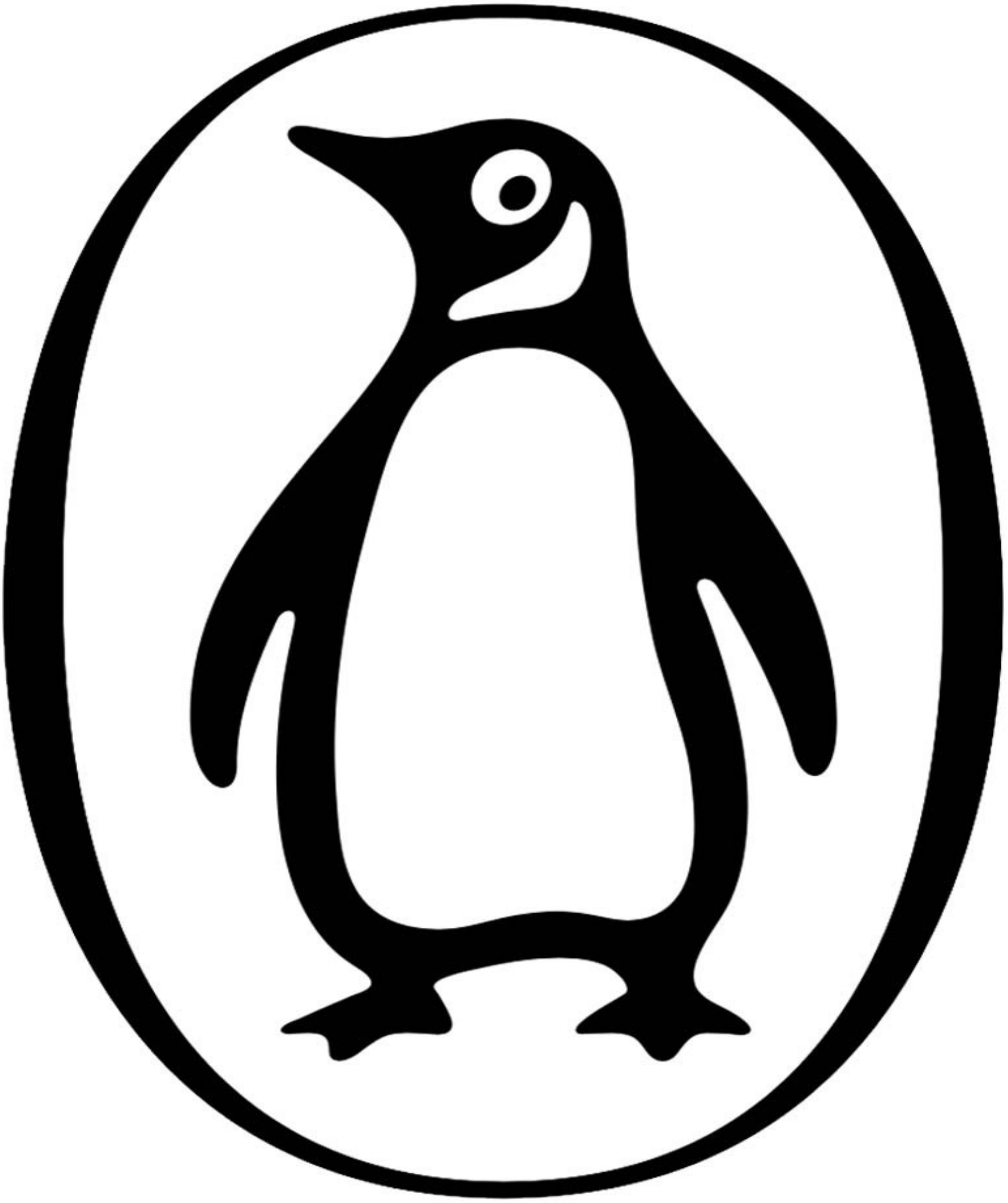

THE SECRET LIFE OF TREES

‘The best nature writing’ *The Times*

‘Page after page of astonishing tree-facts … makes us look anew at the familiar, to understand a little more of the hidden ar constantly enacted miracles taking place in the woods all around us’ *Sunday Times*

‘Tudge’s delight in the world of trees is infectious’ *Herald*

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‘Reminds us just what we spend our lives not knowing, and all of it is not only wondrous and important but entirely free’ *Guardian*

‘A love-letter to trees, written with passion and scientific rigour … a pleasure to read. Tudge writes with warmth and wit’ *Financial Times*

Colin Tudge started his first tree nursery in his garden aged eleven, becoming an accomplished Cacti grower by the age of eighteen and marking his life-long interest in trees. Always interested in plants *and* animals, he studied zoology at Cambridg and then began writing about science, first as features editor at the *New Scientist* and then as a documentary maker for the BBC. Now a full-time writer, he appears regularly as a public speaker, particularly for the British Council and is a Fellow of the Linnean Society of London and visiting Research Fellow at the Centre of Philosophy at the London School of Economics His books include *The Variety of Life: A Survey and Celebration of All the Creatures that have Ever Lived* and *So Shall we Reap. The Secret Life of Trees* brings together Colin Tudge's knowledge of trees and his fascination with them, built up from trips t the rainforest in Costa Rica, Panama and Brazil, to his time in India, Australia, New Zealand, China, the United States… an his own back garden. He is unable to choose a favourite tree, believing that variety's the thing.

The Secret Life of Trees

How They Live and Why They Matter

PENGUIN BOOKS

To my grandchildren

PENGUIN BOOKS

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the Cerrado than by growing yet more soya. Hugely instructive, too, as well as enjoyable, was our stay with Robin and Binka Le Breton, at Iracambi, who are seeking among other things to restore at least some of the sadly depleted Atlantic rainforest. At the Smithsonian Tropical Research Institute in Panama I was prodigiously instructed by Drs Anthony G. Coat (continental drift), Neal G. Smith (mainly birds), Stanley Heckadon-Moreno (mangroves), Egbert G. Leigh (particularly on the tropical forest on Barro Colorado Island) and Allen Herr (whose extraordinary researches on figs are a key theme in Chapter 13). Boundless gratitude to all of them, and to Beth King for fixing up the entire trip. At the Tropical Agricultural Research and Higher Education Center (CATIE) in Costa Rica Dr Bryan Finegan was wonderfully generous with his time and showed, as we stood in the rain, how physically har as well as magical it can be to carry out research in tropical forest; while Dr Muhammad Ibrahim introduced me to CATIE's excellent researches in agroforestry and Dr Wilberth Philips showed me the local trees. Then to India, and in particular to the vast and extraordinary campus and arboretum of the Forestry Research Institute at Dehra Dun, where I have particular cause to be grateful to FRI's then director, Dr Palab Parkash Bhojavid, for excellent discussions and hospitality (including Christmas dinner with his family), and in particular among his colleagues to Dr Sas Biswas. In Latvia, I was introduced to the forest (and its beavers) by leva Muizniece of the British Council, Anita Upite, editor of *Hunting, Angling and Nature,* and Monvids Strautins, forester. I am grateful, too, to the British Council in general and to Dr Gavin Alexander in particular, who arranged some of my most illuminating trips.

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AUTHOR'S NOTE

The following abbreviations have been used throughout the text:

‘Judd’ refers to Walter S. Judd, Christopher S. Campbell, Elizabeth A. Kellogg, Peter F. Stevens and Michael J. Donoghue (eds), *Plant Systematics* (Sinauer Associates Inc., Sunderland, Massachusetts; 2nd edn, 2002.).

‘Heywood’ refers to V. H. Heywood (ed.), *Flowering Plants of the World* (Oxford Universit Press, Oxford, 1978).

Trees inspire: the Buddha received enlightenment under a peepul tree

At Boscobel in Shropshire in the English Midlands stands the Royal Oak, where the provisional King Charles II is alleged to have hidden from Cromwell's men after the Battle o Worcester, which ended his premature attempt to restore the monarchy. Why not? All this happened only about three and a half centuries ago (1651) and oaks may live for two or three times as long as that. Robin Hood and his Merry Men are said to have feasted beneath the Major Oak in Sherwood Forest in Nottinghamshire – and so they might have, for if they existed at all it was in the time of Richard I, in the late twelfth century, and the Major Oak was alive and well at that time. A yew I met in a churchyard in Scotland has a label suggesting that the young Pontius Pilate may once have sat in its shade – 'and wondered wha the future held'. It's an audacious claim. But the tree was there, even if Pilate wasn't – already some centuries old at the time of Christ.

There's a kauri tree in New Zealand called Tane Muhuta (the oldest and biggest kauris ar given personal names), with a trunk like a lighthouse, that was 400 years old when the

Maoris first arrived from Polynesia. For the first 900 years or so of Tane Mahuta's life the moas, related to ostriches but some of them half as tall again, would have strutted their stuf around its buttressed base, threatened only by the commensurately huge but short-winged eagles that threaded their way through the canopy to prey upon them. Now the moas and their attendant eagles are long gone but Tane Muhuta lives on. Many a redwood still standin tall in California was ancient by the time Columbus first made Europe aware that the Americas existed. Yet the redwoods are striplings compared to some of California's pines, which germinated at about the time that human beings invented writing and so are as old as all of written history. These trees out on their parched hills were already impressively old when Moses led the Israelites out of Egypt, or indeed when Abraham was born. So it is that some living trees have seen the rise and fall of entire civilizations.

Some redwoods, Douglas firs and eucalypts are as tall as a perfectly respectable skyscraper, and there's an extraordinary banyan in Calcutta that would cover a football field Many are host to so many other creatures that each is a city: as cosmopolitan as Delhi or Ne York and far more populous than either. Creatures of all kinds may feed on trees, or maraud among their branches. At least, I know of no arboreal octopuses – but there could be, out in the mangroves. There's many a tree-happy crab in the mangroves, as I have seen for myself, and the robbers of the Pacific islands, giant hermit crabs, come on land (as many crabs do) t feed on coconuts. When the Amazon is in flood – deep enough to submerge well-grown trees entirely, over an area not far short of England – the fish feed on fruit and river dolphins race through the upper branches of what should be the canopy, while monkeys hop and swim from crown to crown like ducks. In New Zealand little blue penguins nest in the forest at night with ground parrots (or at least they do on the sanctuary of Maud Island). In the 1970s in the crown of one fairly modest tree in Panama a scientist from the Smithsonian Institution counted 1,100 different *species* of beetle – yet he didn't bother with the weevils, although they are beetles too, or look closely at the host of creatures that are not beetles, or those tha were living in the roots. I once found myself in an old kapok tree in Costa Rica in which biologists had thus far listed more than 4,000 different species of creatures.

Yet a tree cannot afford simply to serve as someone else's monument and feeding ground From the moment the seed falls on to the forest floor (or the sand of the savannah, or a fissure in some mountain crag, or a glacier's edge, or a lakeside, or a tropical seashore) to th moment of its final demise, perhaps a thousand years later, the tree must compete through

every second – for water, nutrients, light and space; and to fend off cold, heat, drought, flood, toxicity, and the host of parasites and predators of all conceivable kinds (from a tree's point of view, squirrels or giraffes are 'predators'). A village or a civilization may choose to make a tree their symbol. The entire nation of Brazil is named after a tree – for brazil wood was known to Europeans before the country was. But however we may choose to ennoble it the tree must fight its corner, a creature like all the rest. If it did not fight it would be dead. Even when it sheds its leaves to ride out frost or drought its cells are still busy beneath its armoured bark. Were it not so the leaves could not burst out as they so spectacularly do when the temperate spring or the tropical rains return – or sometimes in advance of the rain to the delight of camels and goats, which thus may find green fodder in the depths of drought. In many trees, too, tropical and temperate, the flowers emerge before the leaves – which keeps the path clear for pollinating winds, bees or bats. Since there are no leaves to provide nourishment, the flowers must be fed from the tree's reserves in its trunk and roots. The living timber is multipurpose: a prop, a conduit, a larder.

Flowers, of course – and the cones of conifers – meet life's other demand: not simply to survive and grow, but to reproduce. Here, the trees' immobility is a particular drawback. Many trees reproduce without sex, commonly though not exclusively by root suckers, but all trees (to my knowledge) practise sex as well. For sex, gamete must meet gamete: sperm and egg in the case of animals and primitive plants; pollen and ovule in the case of conifers and flowering plants. Since many flowers of many trees are hermaphrodite (male stamens and female carpels on the same flower), and many trees (like oaks and many conifers) are monoecious (the individual flowers are exclusively male or female, but both kinds occur on the same tree), it may seem easy enough for trees to pollinate themselves. But on the whole they don't. One of the botanical surprises of recent decades (finally proven by genetic studies) is the length to which most trees go to avoid self-fertilization. 'Out-crossing' is the norm: pollination of, and by, other individuals who of course are of the same species but preferably are not too similar genetically. To achieve out-crossing, trees must elicit the help of the wind – or bribe or otherwise coerce a variety of animals, from flies and beetles and bees to birds and bats – to carry their pollen for them. Some temperate trees (like apples and horse chestnuts) are pollinated by animals but most (like oaks and birches and beeches) are content to use the wind. But in tropical forests, where most kinds of trees live, animal pollination is the norm; and because life is competitive, the mechanisms that have evolved

for this have become more and more elaborate. Thus for every one of the 750 different species of fig there is a corresponding species of specialist wasp to pollinate it; and each was knows its own fig (although, as recent studies have shown, the relationship between figs and their wasps is not quite so cosy as had been supposed). When the ovules are fertilized and become seeds, encased in fruits (or some other kind of fruiting body) they must then be dispersed – sometimes again by wind but often by another, entirely separate, suite of animal accomplices – birds and fruit bats and rodents and orang-utans – whose help must again be actively co-opted.

Thus life is perforce competitive: hordes of creatures of thousands of different kinds are all after the same things, and most live directly at the expense of others. But it is also, just a inescapably, cooperative. Trees are good competitors. But they are also among the world's most exemplary cooperators, forming a host of mutualistic relationships for one purpose or another with an enormous variety of different creatures, from the bacteria and fungi that help them to feed to the many, many different kinds of animal that help them with different stages of their reproduction. Trees do not seem to be aware, as dogs and monkeys are aware They do not have brains. But they are sentient in their way – they gauge what's going on as much as they need to, and they conduct their affairs as adroitly as any military strategist. Why be 'aware' when you can simulate all that awareness brings? They surely don't think, a animals do. But they orchestrate their fellow creatures nonetheless. A forest is a forest because it has trees in it, not because it may have sloths and toucans or squirrels or chimpanzees. The trees are the prime players and the animals are the dependants.

The human debt to trees is absolute. Modern evolutionary theory has it that we owe our brains – our art, our inventiveness, and presumably much of our deviousness – to our sexuality. We dance and paint and joke and tell stories to impress potential mates – or such least was the crude beginning of our wits, on which we have built. But pigs and squirrels and elephants are clever too. They also must attract mates. So why have pigs produced no conce pianists, or professors of jurisprudence? Another ingredient is needed – one suggested a long time ago by more conservative biologists. Our brains and our dexterity evolved together: they are an exercise in co-evolution. Pigs are clever, but their hands are hoofs: nothing there with which to express their dreams and insights. We, by contrast, can translate our thoughts into action: our artefacts (as Robert Pirsig put the matter in *Zen and the Art of Motorcycle Maintenance*) are ideas in space. Brains are expensive organs (they require a huge amount of

energy) and unless they produced some immediate pay-off, natural selection would select against them. But because we have hands (at the end of long, strong, extremely mobile arms brains do provide pay-offs, manifest not least in a thousand kinds of tools with which to effect further manipulations. Hands provided the encouragement, the selective pressure, to make our brains even brainier; and the growing brains in turn encouraged more dexterity. But the only reason we have such dextrous hands and whirling arms is that our ancestors had spent 80 million years or so (so some zoologists calculate) in the trees. Arboreal life requires dexterity and hand–eye coordination. Squirrels almost became intellectuals, but not quite. Monkeys and apes came closer – but they stayed up in the trees, where they are obliged to squander their fabulous skills just on getting around. Our ancestors, somewhere in Africa, came to the ground when the climate dried up and the trees retreated. They learned to walk on two legs (which no other primate or any other mammal of any kind has learned to do convincingly) and freed their versatile hands and arms for other purposes. Were it not for that pedigree we would remain as intellectually frustrated as elephants and dolphins sometimes seem to be.

Archaeologists speak of the Stone Ages, and the Bronze Age and the Iron Age and the Steam Age, and now we have the age of the internal combustion engine and nuclear power and space and IT. But every age has been a Wood Age – ours at least as much as any in the past; and perhaps, in the decades to come, even more so. Ice-Age Russians made houses from the bones of mammoths, the Inuit use ice, and the people of the Bronze-Age Orkneys built remarkable villages, with restaurants and mausoleums, from slabs of rock. But great architecture demands wood. The ruins that survive from classical times are all of stone but that's only because wood rots. Architecture in stone and bricks evolved from timber architecture, and needs wooden-handled tools and wooden scaffold for its construction — and timber roofs and rafters. Wood, in this energy-conscious age, may well begin to replace steel or much of it, in the grandest buildings.

Wood was the first serious fuel, too – and human beings clearly learnt the use of fire at least 500,000 years ago, long before we were as big-brained as we are now. No fuel: no smelting – so no Bronze Age or Iron Age or modern machines. No wood: no ships. No ships: no ocean travel – no human beings in Australia, New Zealand or any other island that could not be reached simply by hitching a lift on floating vegetation (as many a beast is thought to have done, from rats to monkeys and tortoises). No ocean travel: no empires: no modern

politics. A woodless world would have had advantages. But we could also say no wood: no civilization.

Yet timber is not the end of it. Trees are the source of drugs, unguents, incense, and poisons for tipping arrows, stunning fish and killing pests; of resins, varnishes, and industrial oils, glues and dyes and paints; of gums of many kinds including chewing gum; of a host of fibres for the rigging and hawsers of great ships (whether made of wood or not) and for the stuffing of cushions – and of course, perhaps above all these days, for paper. All that, plus a thousand (at least) kinds of fruits and nuts and – in traditional agrarian societies – a surprising amount of fodder for animals, including cattle and sheep, which most of us assume live primarily on grass. As a final bonus, the wooden husks of many a tree fruit make instant household pots and drums and ornaments.

In short, without trees our species would not have come into being at all; and if trees had disappeared after we had hit the ground we would still be scrabbling like baboons (assuming the baboons allowed us to live at all).

Perhaps this is why we feel so drawn to trees. Groves of redwoods and beeches are often compared to the naves of great cathedrals: the silence; the green, filtered, numinous light. A single banyan, each with its multitude of trunks, is like a temple or a mosque – a living colonnade. But the metaphor should be the other way around. The cathedrals and mosques emulate the trees. The trees are innately holy. Christians with their one omnipotent God may take exception to such pagan musing: but the totaras and the kauris were sacred to the Maoris, and the banyan and the bodhi and the star-flowered temple trees (and many, many others) to Hindus and Buddhists, and the roots of this reverence, one feels, run back not simply to the enlightenment of Buddha as he sat beneath a bo tree (in 528 BC, tradition has it), but to the birth of humanity itself.

But Christianity did give rise to modern science. The roots of science run far back in time and from all directions – from the Babylonians, the Greeks, many great Arab scholars in what Europeans call the Middle Ages, the Indians, the Chinese, the Jews, and the much underappreciated natural history of all hunter-gatherers and subsistence farmers everywhere. But it was the Christians from the thirteenth century onwards, with an obvious climax in the seventeenth, who gave us science in a recognizably modern form. The birth of modern science is often portrayed by secular philosophers as the ‘triumph’ of ‘rationality’ over religious ‘superstition’. But it was much more subtle and interesting than that. The great

founders of modern thinking – Galileo, Newton, Leibniz, Descartes, Robert Boyle, the naturalist John Ray – were all devout. For them (as Newton put the matter) science was the proper use of the God-given intellect, the better to appreciate the works of God. Pythagoras, five centuries before Christ, saw science (as he then construed it) as a divine pursuit. Galileo Newton, Ray and the rest saw their researches as a form of reverence.

This book is written in that same spirit. Of course, I don't claim to walk on the same plan as Pythagoras and Galileo, but I don't think it's too pretentious to aspire at least to drink at the same spring. This book is mainly about the science of trees – what modern research is telling us about them. The last chapter is about the uses we make of them, and what they do for us, and why for reasons that are purely material they must be conserved: our survival depends on them. But most of this book is not about their usefulness, but about what they *are:* how they came into being; what kinds there are and where they live and why; how they live, competing and cooperating. The revelations build by the week: how they may live and grow huge on what seems like nothing at all; how they draw prodigious quantities of water from the ground, send it up into the atmosphere, and then (so some have claimed) may call in again, by releasing organic compounds that seed fresh clouds; how they speak to each other, warning others downwind that elephants or giraffes are on the prowl; how they mimi the pheromones of predatory insects, to summon them to feed upon the insects that are eating their own leaves. Every week the insights grow more fantastical – trees seem less and less like monuments and more and more like the world's appointed governors, ultimately controlling all life on land (and in the oceans too, vicariously), but also the key to its survival.

So this book presents science not as it is often presented, as a tribute to human clevernes and power, but truly in a spirit of reverence. I like the idea (I have found that some people don't, but I do) that each of us might aspire to be a connoisseur of nature, and connoisseurship implies a combination of knowledge on the one hand and love on the other, each enhancing the other. Conservation – of all living creatures, including trees – has little chance of long-term success without understanding, which depends in large measure on excellent science. But conservation cannot even get on to the agenda unless people care. Caring is an emotional response, to which science has often been presented as the antithesis. In truth, science cannot be done properly without a cool head. But when the science is done its primary role (to reverse an adage of Marx's) is not to change the world but to enhance

appreciation. That is the purpose of this book. Science in the service of appreciation, and appreciation in the service of reverence which, in the face of wonders that are not of our making, is our only proper response.

I

What Is a Tree?

1

Trees in Mind: Simple Questions with Complicated Answers

Round-leaved and altogether beautiful: the Judas tree

'I never stopped thinking like a child,' said Einstein. Neither should any of us. It's the way to get to the heart of things. Children ask ridiculously simple questions like 'Who made God?' that have kept theologians busy for many a century. In such a vein we might innocently inquire, 'And what, pray, are trees, that anyone should presume to write a book about them? And,' *Why* do plants grow into trees?' And, 'How many kinds are there?' Childish stuff: but it will serve to mark out the ground.

WHAT IS A TREE?

A tree is a big plant with a stick up the middle.

Everybody knows that. But that statement as it stands requires what modern philosophers would call a little 'deconstruction'.

What, for a start, is meant by ‘big’? It’s a relative term of course, although if we choose we can put a figure on it – say a minimum height of five or six metres. There is a case for doing this: if you are a forester, or are running a nursery, you need some guidelines. But guidelines are not definitions. They are ways of helping practical people to do practical things. They do not – and are not intended to – capture what Aristotle would have called the essence of nature.

For many trees grow big when conditions are favourable, and stay small when they are not. An oak is a noble tree in a forest or a park but an acorn that falls in a fissure in some Scottish crag may spend a couple of centuries in bonsai’d mode, never more than a twisted stick. Yet it may turn out acorns which, if they should be carried to some fertile field, could again produce magnificence. Is the twisted stick less of an oak because it fell on stony ground? And if it remains an oak, is it not still a tree? Or then again – a different kind of cas – the world’s many kinds of birch form the genus *Betula.* None are as huge as an oak may often be, but most are perfectly respectable trees. Yet there is one, *Betula nana,* that is adapted to the tundra of the north of Scotland and mainland Europe and is very small indeed Do we say that all birches are trees except for the tough little *Betula nana*? Or do we say it’s dwarf tree?

What of the stick that runs up the middle, the ‘trunk’, that holds the ‘crown’ of the tree aloft? Should there be just one, a solitary pillar, or are several allowed? Many a gardener an forester has insisted that plants with a lot of supporting sticks should be called shrubs. Again for practical purposes such distinctions can be useful. If Alice’s Queen of Hearts had instructed her long-suffering gardeners to plant her an arboretum and they’d come up with a shrubbery, their heads would surely have come off. But wild nature is not so easily pinned down. In the Cerrado of Brazil – the vast dry forest, about the size of France, in the middle o the country to the south and east of Amazonia’s rainforest – there are trees that form bona fide, big, one-trunked trees when they grow along the banks of the occasional rivers, but become multi-stemmed, short shrubs where it’s drier. The shrub is not merely stunted, like the oak in the rock. It is a discrete life form. Many organisms exhibit what biologists call ‘polymorphism’, meaning ‘many forms’. Many kinds of fish, for example, have dwarf forms and full-size forms; some butterflies and snails are highly variable. Here we see a polymorphic tree – one form for the forest, another for the open ground.

Then again many big trees including some cedars, many a mulberry, or the beautiful blue

flowered jacaranda, may grow from ground level with several solid trunks of equal magnitude. Each may be as big as a respectable oak. Are they trees, or big shrubs? The famil of the heathers, Ericaceae, also includes the rhododendrons from the Himalayas, and the beautiful flaky, yellow/pink/grey-trunked madrone trees of the United States (which add ye more colour to the already wondrous hills of California). Rhododendrons tend to have many stems while madrones are commonly content with one. But the rhododendrons can be just as big and solidly wooden as the madrones. In nature, in short, trees and shrubs are not distinct Why should they be? Nature was not designed to make life easy for biologists.

Must the central stick be of wood? That, after all, is what we generally mean by 'stick'. How, then, should we categorize banana plants? In general shape they resemble palm trees, with a thick central stem and a whorl of huge leaves at the top. But the stem of the banana plant is not of wood. Its stem is formed largely from the stalks of the leaves, and its strength comes from fibres which are not bound together as in pines or oaks or eucalypts to form true timber; its hardness is reinforced, as in a cabbage stalk, by the pressure of water in the stem. So botanically the banana plant is a giant herb. But it looks like a tree and competes with trees on their own terms, as a big plant seeking the light (although like the trees of cocoa and tea and coffee, the banana prefers a little shade).

In fact there are many lineages of trees – quite separate evolutionary lines that have nothing to do with each other except that they are all plants. Many plants, in many of those lineages, have independently essayed the form of the tree. Each achieves freedom in its own way. 'Tree' is not a distinct category, like 'dog' or 'horse'. It is just a way of being a plant. The different kinds have much in common and it is good and necessary to have some feel for what is essential. But the essences of nature will not be pinned down easily. In the end, *all* definitions of nature are simply for convenience, helping us to focus on the particular aspect that we happen to be thinking about at the time. There is no phenomenon in all of nature – whether it's as simple as 'leg' or 'stomach' or 'leaf' or more obviously conceptual like 'gene' or 'species' – that does not take a variety of forms, and which cannot be looked at from an infinite number of angles; and each angle gives rise to its own definition. A horse cannot be encapsulated as Charles Dickens' Thomas Gradgrind insisted in *Hard Times* as 'A graminivorous quadruped'. There is more to horses than that. The way we define natural things influences the way we treat them – whether we speak of wild flowers or of weeds, of Mrs Tittlemouse or of vermin. But in the end nature is as nature is, and we must just try wit