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The pattern of photosynthesis

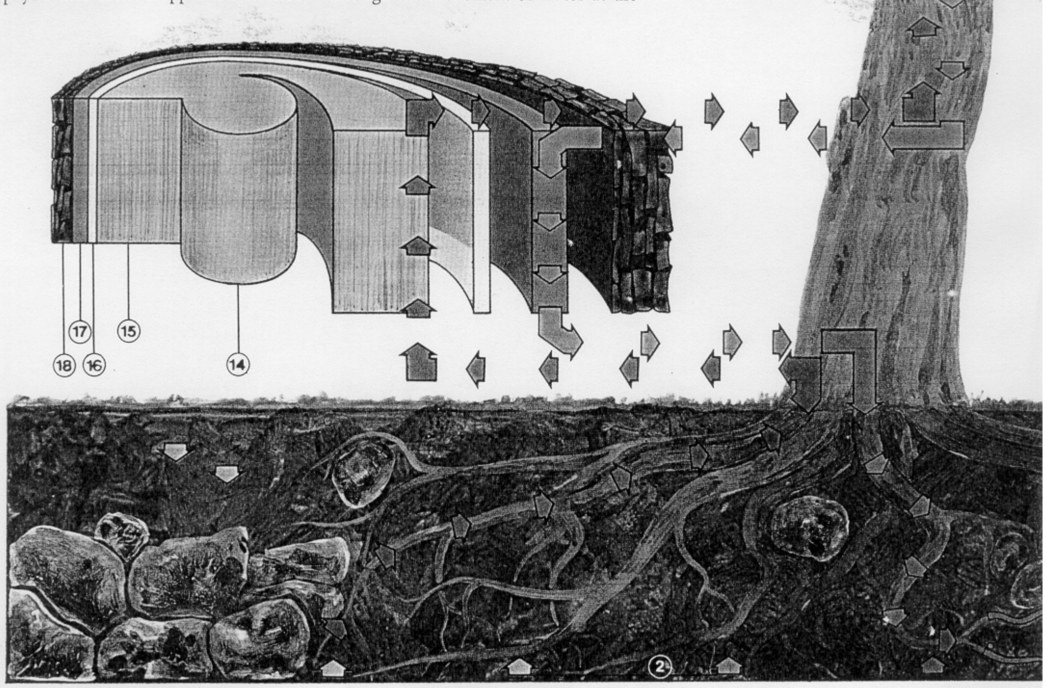
Photosynthesis is the most important chemical reaction taking place on earth, the process whereby energy from the sun is transformed by plants into energy in the form of food. It is the very basis of life itself.

Chlorophyll, the green pigment of plants, occurs in several forms, but it is *chlorophyll-a* in the leaf that is the principal catalyst bringing photosynthesis about. Another essential element here is water, containing dissolved mineral salts; it is brought to the leaf from the thousands of root hairs in the soil by the xylem vessels. A leaf will orientate itself towards the sun to obtain maximum light.

Carbon dioxide from the atmosphere enters through the leaf stomata. Water and gas mingle in the central section of the leaf and here, in the presence of chlorophyll located in the *grana* of the chloroplasts in the palisade and spongy mesophyll cells, the photosynthetic reaction takes place.

During the reaction, energy from sunlight excites electrons within the chlorophylla molecule. Trapped on an electron, this energy can be used directly by transferring it to a phosphate compound present in all living cells. From this compound the energy can be used by cells as required in growth, movement, physiological processes and so on. Some energy trapped on an excited electron may be directed along another pathway and used to split a molecule of water into hydrogen and oxygen, the latter being liberated to the atmosphere through the stomata. The hydrogen, through a series of reactions known as the carbon fixation process, is converted to a simple hydrocarbon compound which is then built up to form sugars and other vital compounds.

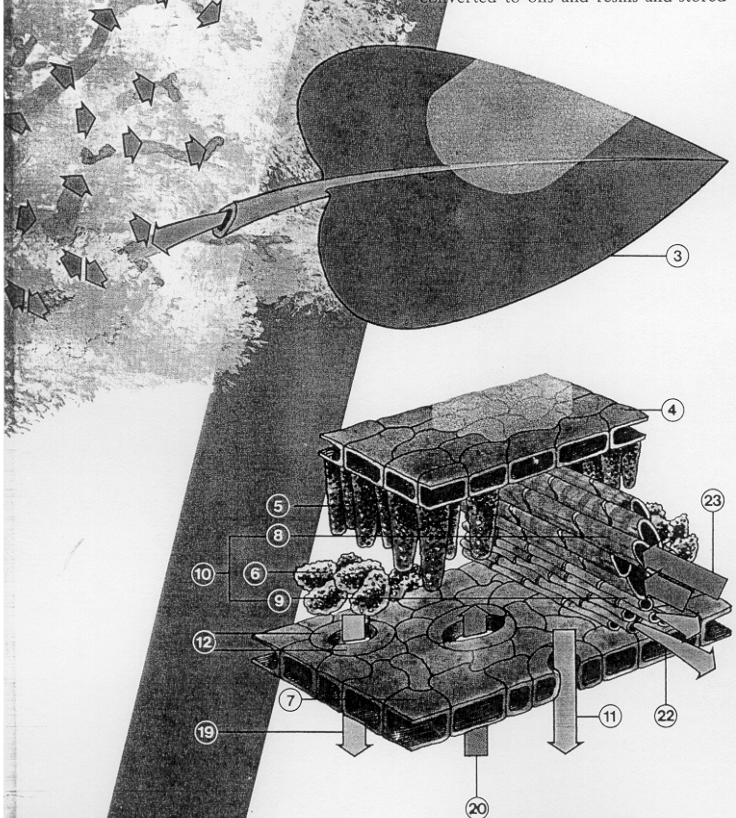
The carbohydrates formed in photosynthesis are transported in solution, mainly as sugars, from the leaves to the lower trunks, roots and other growing regions. This movement of the sugars in the phloem tubes is called *translocation;* it involves movement from the *source,* the leaf, to a *sink,* for example, the roots, and is brought about by changes in pressure through the movement of water at the



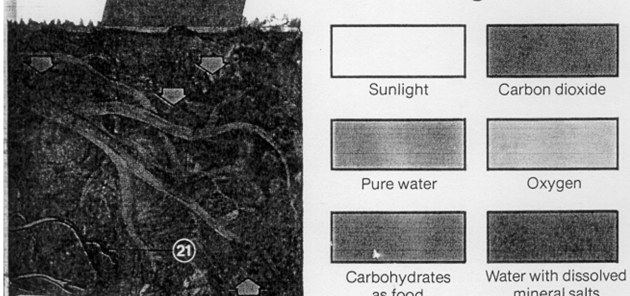
source and the sink. Sugar is formed in a leaf within seconds of irradiation by the sun and can be transported within the tree at a rate of 100 cm per hour.

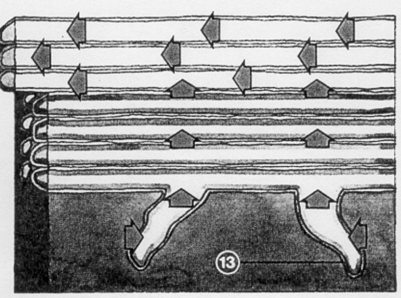
In the roots the sugars are converted to starch and stored. Some sugar may be converted to oils and resins and stored throughout the tree. Both starch and oils can be reconverted to sugars when required and translocated through the body of the tree to provide food and energy for new growth.

The water for photosynthesis is drawn up through the tree partly by evaporation pressure created by transpiration pulling on the columns of water in the xylem vessels and partly by osmotic pressure from the roots. The excess of water passing upwards to the leaves is evaporated off as the water of transpiration into the atmosphere. Like all living things a tree also respires, but the respiratory process during daylight hours is masked by photosynthesis.



1. Water of transpiration. About ninety per cent of the water absorbed by a tree is lost as the water of transpiration. **2.** Water as groundwater which is absorbed by roots. **3.** The blade or lamina of the leaf irradiated by sunlight. **4.** Upper epidermis of the leaf. **5.** Palisade cells of the leaf with chloroplasts. **6.** Spongy mesophyll cells with chloroplasts are loosely packed so air and water can permeate between them. **7.** Lower epidermis of the leaf. **8.** Xylem vessels of the leaf vein. **9.** Phloem vessels of the leaf vein. **10.** The vascular system of the leaf is the leaf vein. **11.** Water of transpiration leaving the leaf through the stomata. **12.** Guard cells which can open and close the stomata. **13.** A root hair. **14.** Dead xylem at the centre of the stem or trunk. **15.** Active conducting xylem carries water and dissolved salts. **16.** The cambium layer of actively proliferating cells. This layer produces phloem cells on its outer edge and xylem cells on its inner edge. **17.** Active conducting phloem layer. **18.** Outer bark or protective layer. **19.** Oxygen released to the atmosphere. **20.** Carbon dioxide taken from the atmosphere. **21.** Storage of starches in the roots forms the sink. **22.** Carbohydrates, mainly sugars, being transported to the roots. **23.** Water containing dissolved mineral salts drawn up from the roots.





The structure of a tree

The roots

When the seed of a tree germinates, the first structure to appear outside the seed is the *taproot,* which grows downwards into the soil to anchor and support the seedling tree. According to the species of tree this taproot may extend deep down, to 12 m or more. Some trees, such as lacebark, kowhai and pohutukawa, do not grow extensive taproots but instead develop widely extending systems of fibrous roots that grow laterally from the taproot near the soil surface. Taprooted trees also extend lateral roots to help anchor them more firmly in the ground and to tap water and nutrients.

As the roots extend outwards, always into moist soil, the growing portion of each root is thickly provided with masses of root hairs. By means of the osmotic process, these hairs draw water and dissolved nutrients through their walls and thence into the root. The water passes onwards and upwards through the roots and stems partly by osmosis and partly by the loss of water vapour from the aerial parts, but the complete mechanism by which water can be brought to the top of a tree perhaps 90 m high is not yet properly understood.

Within the root are conducting tubes called *xylem* and *phloem.* Xylem carries water and nutrients and phloem sugars in solution. These tubes form a central core to the root, but in the region where roots combine and pass upwards into the stem of the seedling tree there is a special zone where the xylem and phloem are rearranged to lie near the surface of the stem. This rearrangement permits the stem to grow outwards and enlarge with the growth of the tree. As roots age they lose their root hairs and become covered by a layer of thick corky cells that usually become impregnated with tannins and resins.

The trunk

A tree may be distinguished from all other plants by its woody framework of trunk and branches, which persists above ground for year after year. The familiar tree has a trunk enclosed in a covering of corky cells impregnated with waxes and tannins. This covering is known as the bark. The outer surface of the bark is usually coloured and either smooth or rough through cracking, flaking or peeling. It is these processes which give to the bark of each species its characteristic surface appearance. The bark pattern is largely determined by the manner in which it is formed and later ruptured by growth pressures. As the tree grows and swells the outer bark cracks into flakes or strips that fall or peel away from the inner bark.

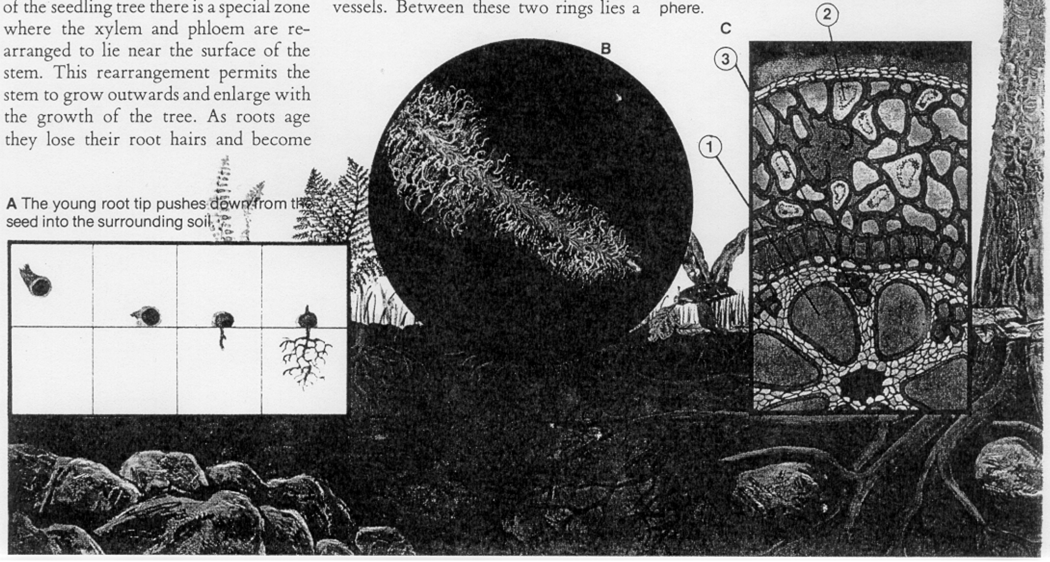
The trunk supports the branches and leaves, and, in season, the flowers and fruits. It also carries a system of communicating tubes through which water, nutrients and sugars pass upwards and downwards between the roots and the leaves. A cross-section through the trunk reveals several types of tissue arranged concentrically. Just inside the bark is a ring of vascular tissue made up of an outer ring of thin-walled phloem tubes and an inner ring of larger thick-walled xylem vessels. Between these two rings lies a narrow band of proliferating tissue, the *cambium,* which is the growth tissue of the trunk from which all new phloem and xylem vessels and connecting tissues are formed.

As the tree grows the end walls of the xylem tubes break down leaving long, narrow, continuous water-conducting vessels which traverse the trunk and branches like bundles of water pipes. The phloem tubes do not elongate like xylem. They multiply and retain their end walls as perforated end plates, called *sieve plates.*

B Root hairs developing behind the root tip absorb water and nutrient salts from the soil. Behind the apical portion the hairs atrophy and the root becomes corky.

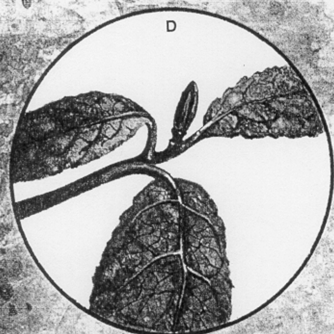
C Root cross-section. **1.** Xylem cells. **2.** Cortex or outer cellular layers. **3.** Phloem cells.

D Branchlet growing tip. Individual leaves on the branchlets are the seat of photosynthesis and the organs where gases are exchanged between the tree and the atmosphere.



A The young root tip pushes down from the seed into the surrounding soil.

As the tree grows, this band of living tissue continually moves outwards, leaving xylem in the centre which slowly becomes impregnated with deposits of resins and tannins to form a non-living core, the *heartwood.* This wood is traversed by thin strands of tissue, known as *rays.* They extend from the centre outwards, and function as transport routes for nutrients, oils and resins.



Annual rings

After the dormancy of winter there is a burst of intense growth activity in the spring. The xylem vessels formed at this time are large in diameter with thin walls so that they may carry the considerable sap flow necessary for the bursting of new buds, leaf and branch growth. During the summer, as growth and other activity slows down, the vessels become smaller and thicker-walled. There is a visible difference, therefore, between spring and summer growth which shows as a variation in the shapes of the xylem vessels, and this gives rise to the *annual rings,* by which we can count the age of a tree. However, with trees growing in tropical climates where the growth rate varies only slightly between spring and summer annual rings are not so clearly demarcated.

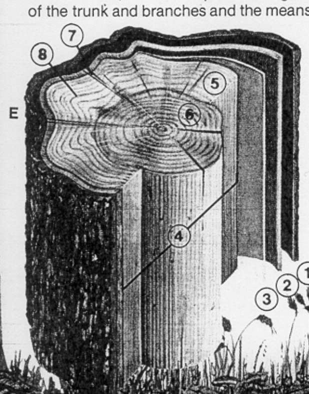
Palms and cabbage trees are monocotyledons. Although their trunks serve the same purposes as in dicotyledons, they are differently constructed. The trunk consists of connective tissue with groups of fibrous bundles scattered throughout; the familiar ringed pattern of dicotyledon wood is absent.

The branches

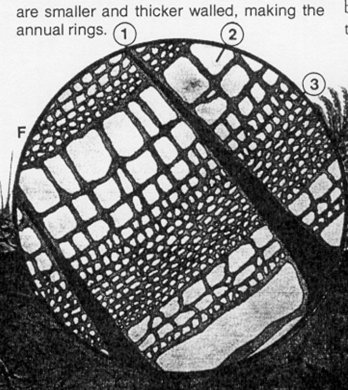
The trunk sprouts branches at varying heights from the ground according to the species of tree and the conditions under which it is growing. The branches may ascend, as in a kauri, pigeonwood or cabbage tree, or they may spread outwards and tend to droop, as in titoki or pohutukawa. The main branches grow outwards, dividing and redividing to form smaller branchlets and twigs which bear the leaves. When these branchlets grow and thicken to become branches they develop bark like that which clothes the trunk.

As summer growth reaches a maximum, buds for the next spring's new growth are forming at the tips of the branchlets and between the leaves and their parent stems. Buds are formed as the precursors of branches, leaves and flowers, each bud containing within its tightly closed sheathing the embryonic structures for whatever it is destined to become. Each spring, leaves and new branches emerge from their buds to add to the size and stature of the tree.

E The layers of a typical trunk. **1.** Outer bark, a protective layer produced from the living inner layer of cork cambium. **2.** Phloem or inner bark, a soft, somewhat spongy tissue that conducts sap downwards from the leaves. **3.** Cambium or growth layer is only one cell thick, but it is the proliferating tissue of the trunk and branches and the means by which the tree grows in thickness, producing phloem on its outer side and xylem on its inner side. **4.** Xylem forms the main wood of the tree and contains the water-conducting vessels. It is divided into the outer sapwood **5,** and the inner heartwood **6. 7.** Rays are produced by the cambium and traverse both the phloem and xylem. **8.** Annual rings mark the phases of growth.



F Cross-section of a stem showing the rays and the differential summer-winter growth pattern of cells in the xylem which produces the familiar pattern of annual growth rings. **1.** Ray. **2.** Spring xylem cells are large and thin-walled. **3.** Autumn and winter cells are smaller and thicker walled, making the annual rings.



The leaves

Leaves are energy trappers and food factories for the tree, playing a central role in the photosynthesis process. They are also the breathing organs for the tree, which must respire and use oxygen from the air like other living organisms. Water as well, in huge quantities, is transpired from trees through the leaves, passing out from the stomata. The water itself with dissolved salts is drawn up to the leaves to be used in the chemical processing that occurs there.

In deciduous trees the leaves live for one season only, withering and falling from the tree in autumn, their fall often preceded by a magnificent display of colour. Leaves on evergreen trees may live as long as six to eight years before falling; they are continually being lost in small groups from these trees. They usually do so without great displays of colour, but in the New Zealand beeches leaves about to fall often colour up and impart a dispersed gaiety to the tree.

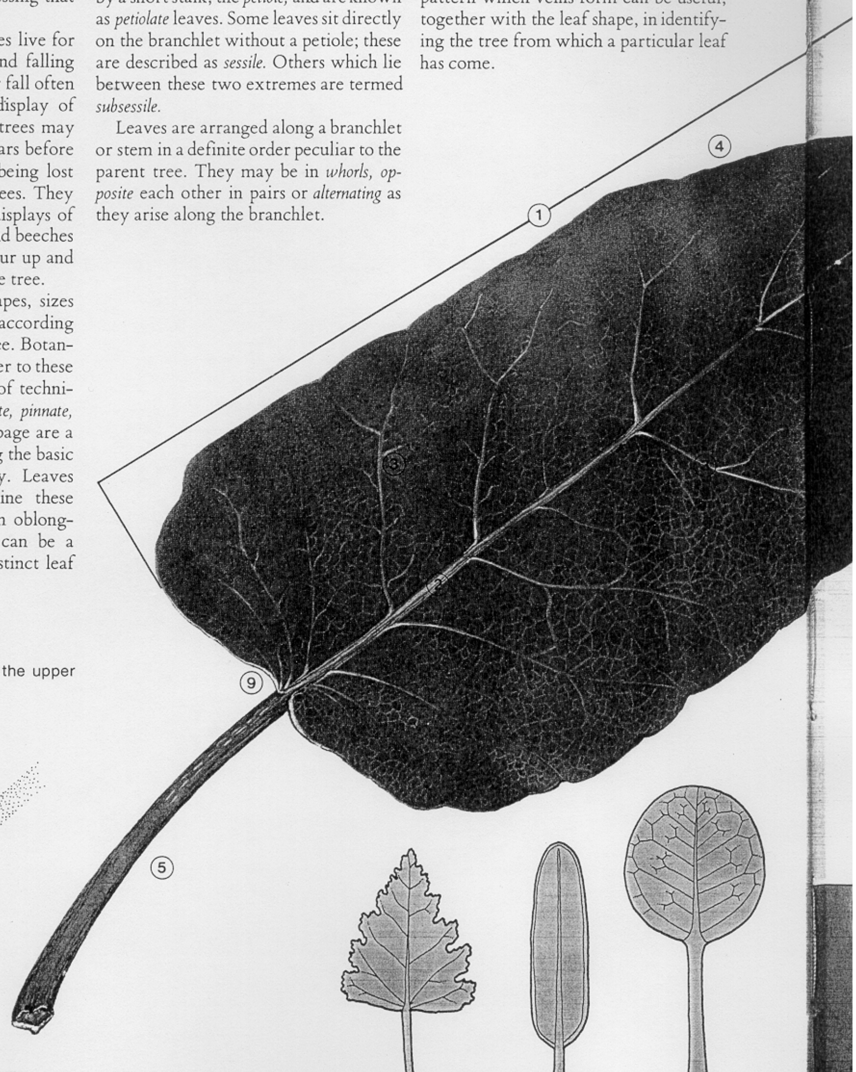
Leaves take on various shapes, sizes and ornamenting structures, according to the species of the parent tree. Botanical works describing trees refer to these shapes for leaves by a series of technical terms such as *elliptic, obovate, pinnate,* and so on. Illustrated on this page are a number of leaf forms, showing the basic shapes and their terminology. Leaves from some trees can combine these shapes, as in, for example, an oblong-obovate specimen; or there can be a combination of these with distinct leaf base and leaf tip shapes.

Some leaves are *wavy,* or have *sinuate* margins, while others are divided or made up of many tiny leaflets. Each tree has its own individual leaf shape and marginal and surface embellishments such as teeth, hairs (*pubescence*), sinuate margins, scales or *tomentum,* which is a dense, matted covering of appressed hairs.

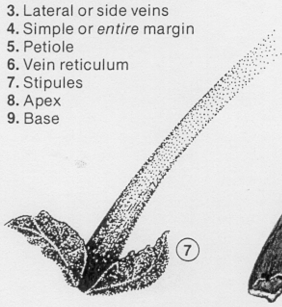
Most leaves are held to the branchlet by a short stalk, the *petiole,* and are known as *petiolate* leaves. Some leaves sit directly on the branchlet without a petiole; these are described as *sessile.* Others which lie between these two extremes are termed *subsessile.*

Leaves are arranged along a branchlet or stem in a definite order peculiar to the parent tree. They may be in *whorls, opposite* each other in pairs or *alternating* as they arise along the branchlet.

The central vein which extends into the leaf from the petiole is known as the main or *midvein,* sometimes as the midrib. The veins extending sideways from the midvein are the *lateral* veins; these usually give rise to a *reticulum* of fine veins pervading the blade or *lamina* of the leaf. The midvein and all lateral veins of a leaf carry the xylem and phloem tubes into every corner of the leaf structure. The pattern which veins form can be useful, together with the leaf shape, in identifying the tree from which a particular leaf has come.

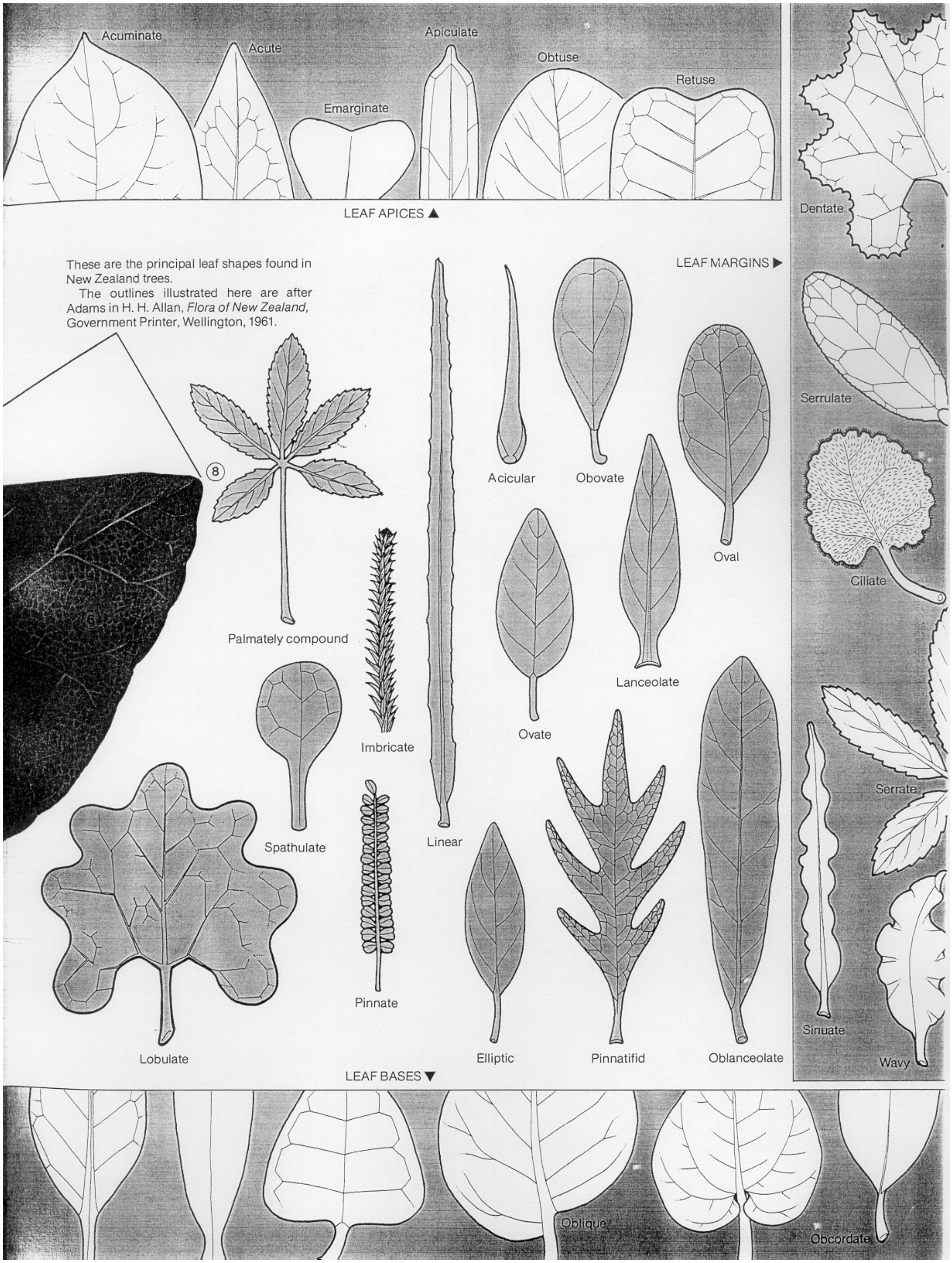


The central illustration shows the upper surface of a typical leaf.
1. Lamina
2. Midvein
3. Lateral or side veins
4. Simple or *entire* margin
5. Petiole
6. Vein reticulum
7. Stipules
8. Apex
9. Base



These are the principal leaf shapes found in New Zealand trees.

The outlines illustrated here are after Adams in H. H. Allan, *Flora of New Zealand*, Government Printer, Wellington, 1961.



Reproduction

The flowers

The flowers contain the tree's sex organs; their main purpose is to secure cross-pollination from another tree of the same species. In this way the virility and continuity of the species is secured. In gymnosperms, such as the podocarps, reproductive parts are arranged in strobili or cones; in angiosperms they appear in the more familiar flower form with petals arranged in circular fashion around the stamens and ovary.

Some trees have *perfect* flowers, in which both the male and female parts are present together. If the male and female flowers occur on the same tree the tree is termed *monoecious;* if on separate trees it is *dioecious.* Perfect flowers, such as those of manuka or kowhai, have sepals, petals, stamens and ovary all present. Imperfect flowers are unisexual, with either the male or the female parts absent, but the sepals or the petals may also be missing, as in the flowers of coastal maire, *Nestegis apetala.*

Flowers arise *terminally,* at the tips of branchlets, or are *axillary,* arising between a leaf petiole and the branchlet or the parent branch. Flowers adopt many different patterns of shape, form, perfection and arrangement and all these characteristics are of great importance in identifying and classifying trees.

Cross-pollination

To avoid self-pollination several kinds of preventive measures have been evolved by trees. For instance, pollen and ovules on the same tree may mature at different times; or the pollen may be incompatible with the stigma so that if self-pollination should occur the resulting union will be sterile and the ovule will wither away. Cross-pollination is brought about by wind, insects and sometimes by birds.

Pollination by wind is usual among trees of the dense forest, whereas insect pollination is common with trees that naturally grow isolated in the open or along the margins of forests and forest clearings. Pollination by wind is an extravagant method since vast quantities of pollen must be produced in order that one grain floating haphazardly in the air may land on a tiny pistil on another tree. On a windy day pollen can be observed blowing away in dense clouds from a tree like a kahikatea.

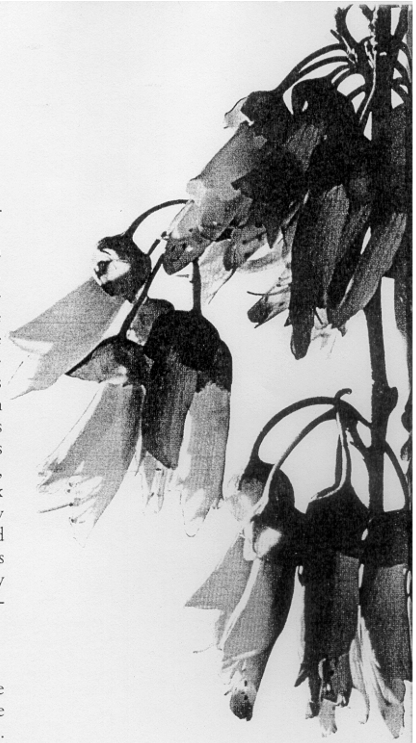
When pollen grains settle on a pistil a remarkable series of events takes place. The grains commence to grow downwards as elongating tubes towards the ovary, and the first to reach an ovule penetrates it and brings about the fertilisation of the egg within the ovule. This initiates the development of a seed; in some trees, such as rimu, this proceeds slowly, taking twelve to eighteen months to ripen, while in others, such as kowhai, it is rapid and produces ripe seeds in six to eight months. Flowers pollinated by wind tend to be small, insignificant and unscented; those pollinated by insects or nectar-feeding birds being usually larger, often bright coloured and sometimes scented.

The fruits

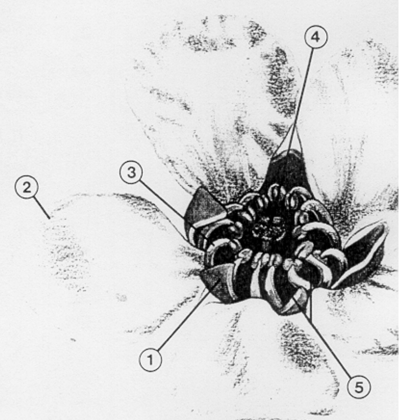
The fruit of a tree is formed when the female ovary with the fertilised ovule inside it grows to maturity and is ripened. The ovule is then the seed and the ovary has become the fruit coat. In some fleshy fruits the stalk of the seed has grown up and around the seed to form the fleshy covering or has swollen to form a fleshy base, as occurs in some podocarps.

Once ripe, the seeds are ready for germination and need to be borne away to a suitable place where they can take root and sprout into a seedling tree. Wind is important as a dispersing agent for many seeds. Wind-borne seeds, such as those of kauri, usually have wings or other devices to assist them to drift away from the parent tree. Other seeds — those of miro, for example — are adapted to being eaten by birds and pass unharmed through the bird's digestive tract to be voided in the faeces, often at a considerable distance away from the parent tree.

The ripe seed is in fact a tiny embryonic plant with a minute root and a shoot bearing either one or two seed leaves, the *cotyledons,* that function as food storage organs which nourish the seedling until the first leaves of the new plant are produced.

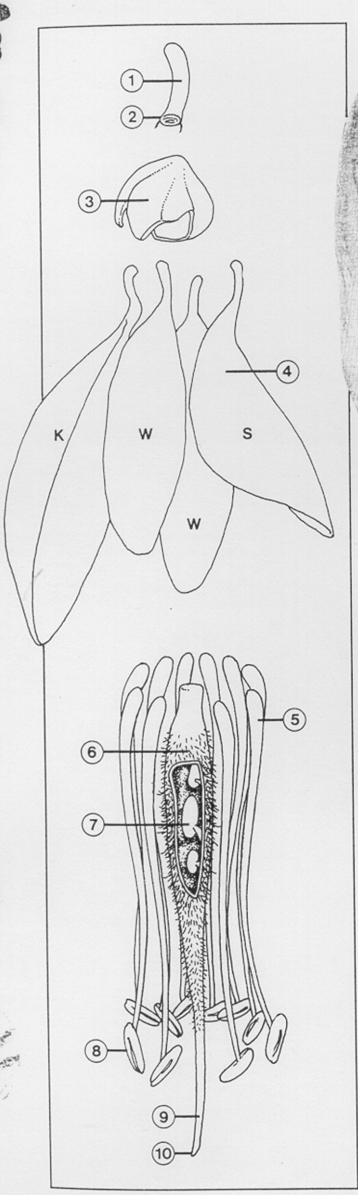


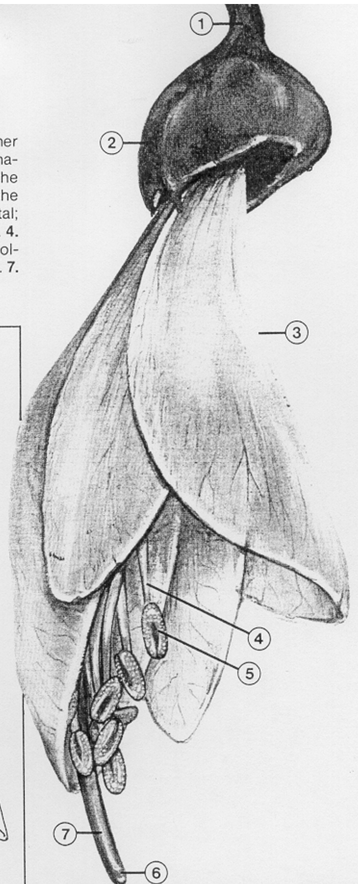
Right A kowhai with the parts separated. **1.** Pedicel. **2.** Receptacle, the cup-like expansion of the stalk surrounding the ovary. **3.** Sepals, forming the calyx. **4.** Petals, which in the kowhai are named according to their position in the corolla: **S** is the *standard,* **W** the *wings,* **K** the *keel.* **5.** Androecium, the stamens together. **6.** Ovary (in *Sophora* consists of a single carpel). **7.** Ovule. **8.** Anther. **9.** Style. **10.** Stigma. The style, stigma and ovary together form the gynoecium or pistil.

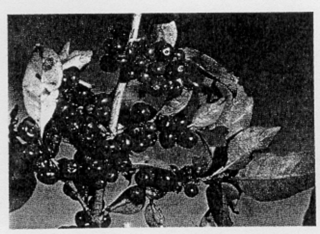


Right A manuka flower is a typical bisexual flower. **1.** Sepal. **2.** Petal. Together these form the perianth. **3.** Stamen with anther. **4.** Style with capitate (head-like) stigma. **5.** Nectary.

Right A kowhai flower. Compare this rather specialised flower form with that of the manuka below on the facing page. **1.** Pedicel, the stalk of the individual flower. **2.** Sepal; the sepals together are called the calyx. **3.** Petal; the petals together are called the corolla. **4.** Stamen. **5.** Anther, which produces the pollen. **6.** Stigma, which receives the pollen. **7.** Style, which bears the stigma.

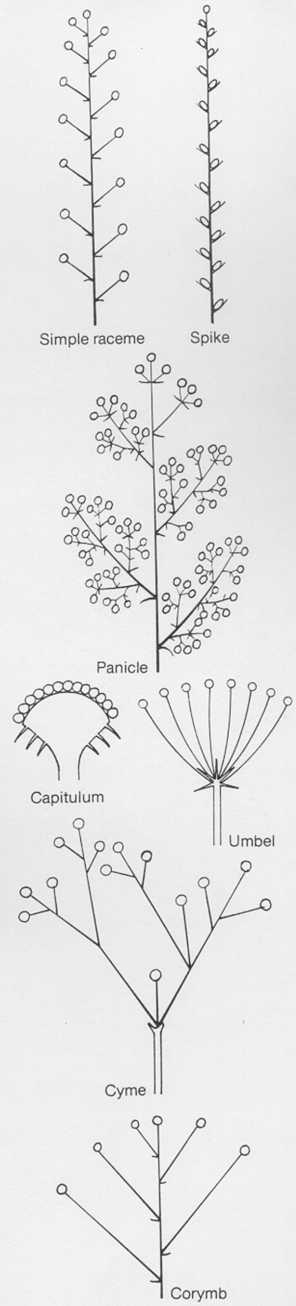






Fruits occur in many different forms. The following principal fruits occur among our native trees. (1) *Fleshy fruits.* A *berry* is a fleshy ovary containing one or more seeds *(Solanum laciniatum).* A *drupe* differs from a berry in having each seed enveloped by a hard, woody layer, the endocarp (puriri, *Vitex lucens*). (2) *Dry fruits.* An *achene* is a small, indehiscent fruit consisting of a single seed enveloped in a thin ovarian wall (Compositae). A *nut* is a one-seeded indehiscent fruit enveloped in a hard, woody shell (beech, *Nothofagus*). A *legume* or *pod* is a one-to-many-seeded fruit formed from a unicarpellate ovary; it may be dehiscent (all *Carmichaelia* tree species) or indehiscent (kowhai, *Sophora*). A *capsule* is a one-to-many-seeded dehiscent fruit formed from two or more united carpels *(Pittosporum).* **Above** Coprosma drupes.

FORMS OF INFLORESCENCE



How a tree grows

When a tree seed has germinated it must first establish its primary root system to hold it in the ground and to nourish it with water and mineral salts. Once the seedling has established its primary roots it starts the development of its main stem, providing an *apical* or *terminal* bud and one or more lateral branches, each of which terminates in a *lateral* bud.

After growth the development of form is the next requirement; this is attained through the development of *polarity* — its orientation with reference to the three axes of space — and *symmetry*. The vertical trunk-root axis of a tree is the principal guiding line around which a tree is developed and organised. The branches growing from the trunk give the tree spherical, radial or bilateral symmetry; or it may be asymetrical. Thus the tree develops its recognisable shape.

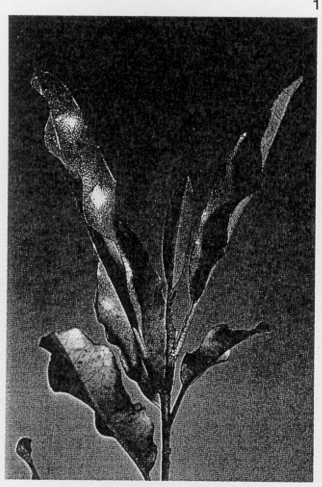
The influences within the body of the tree that control the growth of shape and structure are the hormones produced in the apical and lateral buds of the trunk and branches. The apical bud of the main stem or trunk is the leading bud of the tree. It controls future growth and exerts a profound influence over all the lateral buds, suppressing them, more or less, so that it may grow away from gravity and carry the stem apex upward faster than the lateral branches can grow outward. In this way the ultimate height and form of the tree is organised and controlled. We make use of this phenomenon when we top a tree to make it spread more; with the apical bud removed, the lateral buds take charge and extend the branches outwards.

In tall trees such as kahikatea the leading bud is very strong so the tree grows tall with minimum lateral spreading. In a pohutukawa tree the growing points of branches abort each year and growth continues from axillary buds so the tree spreads out over a wide area.

The vigour of the apical and lateral buds establishes, each year, the woody tracery of the tree's ultimate frame. The spread of the canopy is determined by the power of the lateral buds to promote outward growth. The height is determined by the apical bud and the ability of the main stem to maintain a column of water in its vessels to the height necessary to service the entire structure of the mature tree. In New Zealand trees such as rimu this can mean an internal water column 40 to 60 m high.

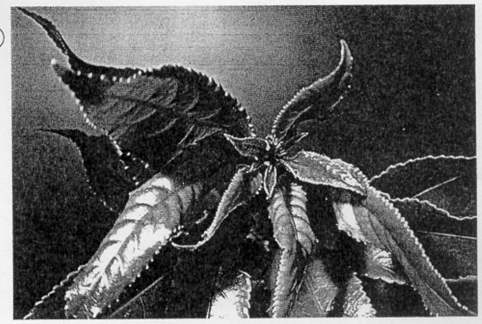
Branchlet growth also reveals the structural pattern of branching and leaf arrangement. The yearly growth of the main stem or a branch can be studied from the growth scars left on branchlets by the bud scales of the terminal buds as they push upward and outward and by the leaf scars left on the branchlet as the leaves fall away.

1



GROWING BRANCH

This diagram incorporates all the different aspects of a growing branch. It is basically modelled on a deciduous plant (to enable all the various points to be illustrated) and is not intended to represent any evergreen New Zealand tree species.



2

Left: This diagram represents the growth of a branch over a period of about three years. It also depicts the three normal types of leaf arrangement on a twig or branchlet, useful in tree identification. **1.** The terminal bud enclosed in leaf-like scales contains the embryonic structures for the next season's growth. **2.** These leaf scars were left when their leaves withered and fell. **3.** These buds will form the next season's branchlets. **4.** The small pores scattered along the branchlet are lenticels or breathing pores. They perform on the branchlet the same functions undertaken in the leaves by the stomata. **5.** Growth of this branchlet from two seasons before has been partially suppressed by the terminal bud. **6.** These rings are the bud scars left by last season's terminal bud when growth commenced and the branch grew longer. **7.** These two small buds are still suppressed. **8.** This branchlet has developed fully and borne leaves. **9.** These leaves are arranged in *opposite* pairs. **10.** Leaves arranged in *whorls.* **11.** These leaves show *alternate* arrangement on the branchlet. **12.** These rings are the bud scars from growth which took place two years ago.

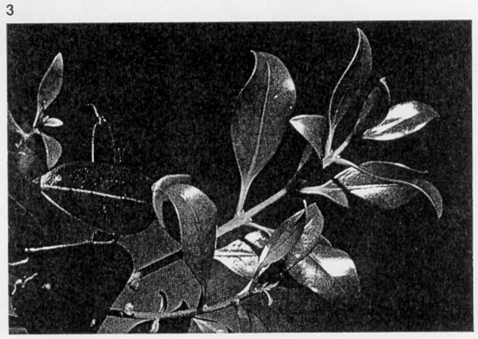
The new season's growth of buds and leaves is usually fresh and brightly coloured. In some trees it is green, in others yellow-green, in others reddish.

Fig 1 *Quintinia serrata.*

Fig 2 *Melicytus ramiflorus.*

Fig 3 *Nestigis apetala.*

3



Growth, age and longevity

Some species of trees live to a tremendous age. The oldest living things in the world are trees that grow at altitudes between 2,400 m and 3,300 m in some of the arid regions of the Rocky Mountains in Colorado, Nevada and Utah in North America. Known as bristle cone pines, *Pinus aristata,* these trees are never more than 12 m high. Examination of the growth rings of these trees by the University of Arizona has shown some of them to be over 5,000 years old. But great age in trees is not uncommon: the giant sequoias of California, which include the most massive of all living things, have some trees over 4,000 years old.

In New Zealand, too, we have had our veterans amongst the kauris, some of which have been estimated, by counting growth rings, to be over 2,000 years old. The massive kauri at Mercury Bay could have been over 4,000 years old. Amongst our New Zealand podocarps, trees up to 800 years old were not uncommon in the great lowland forests of the North Island. A huge totara slab at Victoria University came from a tree that was little more than a seedling when Columbus discovered America. It was felled at Taihape in 1906, when it was 435 years old.

In general, slow-growing trees live longer than fast-growing trees. They are tougher, their wood is more durable and they are more securely anchored by their roots than rapid growers whose wood is often brittle and more prone to decay when exposed to the elements. Fast-growing trees are more likely than slow growers to suffer damage during storms.

Growth rates

The rate of growth in trees varies between species and is also greatly influenced by the place in which an individual tree is growing. Such factors as climate (especially the rainfall and mean temperature), the porosity and the fertility of the soil, the availability of nutrients and of sunlight, all affect the rate of growth. Most trees have characteristic patterns of growth and these, along with growth rates, are fairly well established for most of the important European and North American trees. The rates and patterns of growth for New Zealand trees are, unfortunately, not so well known.

Most large New Zealand forest trees are regarded as slow growing but, from my observations, in their early stages at least this is not entirely correct. Under good conditions a kauri grows at about 30 cm per year in the young stage, but after reaching a height of about 5 m slows down considerably and takes hundreds of years to produce its fully developed spreading crown. A rimu seedling can grow at up to 22.5 cm per year until it reaches the conical stage at about 6 m high, when its growth rate becomes very much slower. The same applies with most of our other podocarps. A puriri can reach a sizable small tree in about twelve years but takes some hundreds of years to attain the height and spread of some of the giant puriri trees seen in the north.

More perhaps is known about the growth of our native beeches. Silver beech, *N. fusca,* can grow at 25 cm per year and become a sizeable, millable tree in sixty to eighty years. Small trees such as lacebarks (*Hoheria* spp.) and *Pittosporum* can grow at up to 75-100 cm per year, reaching maximum height in about ten years. Ngaio is also a fast-growing tree, spreading outwards and upwards at about the same rate. Many trees grow quickly to near maximum height after which growth slows and the tree spreads laterally.

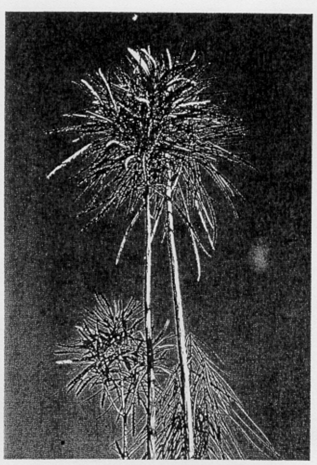


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Fig 1 Juvenile stages of some New Zealand species are strikingly different from adult trees. The most unusual of these is lancewood, *Pseudopanax crassifolius.* Shown here are long, drooping juvenile leaves and the shorter, more upright adult leaves.

Fig 2 The various shapes through which the kahikatea, *Dacrycarpus dacrydioides*, passes, from the straggly seedling on the forest floor to the mature forest giant. **a.** A very young seedling. **b.** The pyramidal structure at about eight to ten years old. **c.** This conical shape persists for many years. **d.** The adult begins to emerge as the mature crown starts to form. **e.** A mature adult kahikatea with its stout trunk and tight crown. **f.** The final stage: a very old tree.

Fig 3 Te Matua Ngahere, the Father of the Forest, is the largest tree in the Waipoua Kauri Forest and the second largest tree in New Zealand. It is 16.15 m in girth at about 1 m from the ground. The height to the first branch is 10.6 m. Its age is estimated at about 2,127 years.

2

Fig 3 ▸