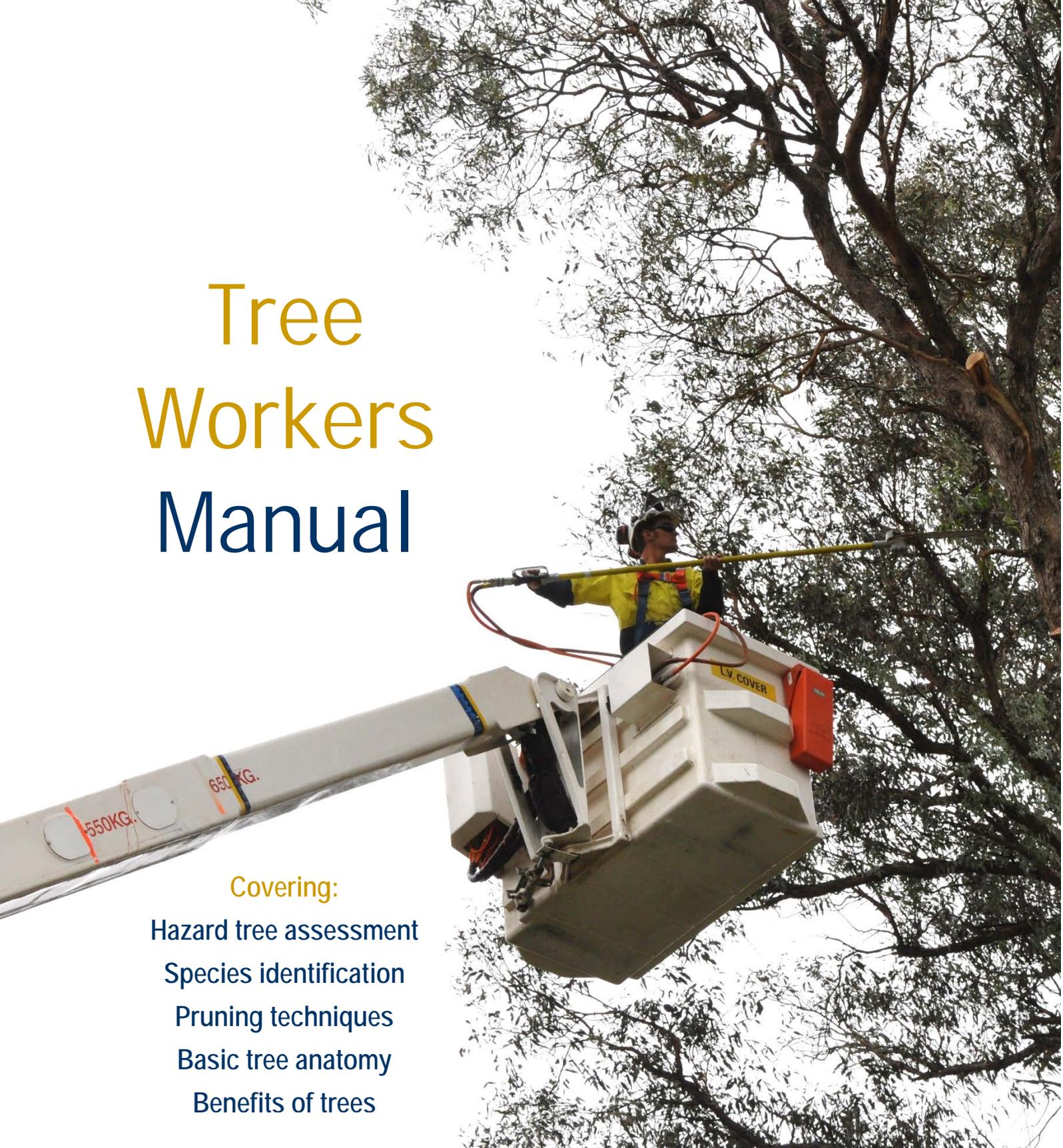


# Tree Workers Manual



## Covering:

- Hazard tree assessment
- Species identification
- Pruning techniques
- Basic tree anatomy
- Benefits of trees

**For apprentice arborists and ESI vegetation workers**

Supporting a range of competencies  
from the AHC and UET Training Packages

VERSION: January 2021



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All line drawings were produced by Kath Ware. Many of these are based on images that appear in the reference documents listed in the Introduction section of this book.

## Acknowledgements

The technical information presented in this book is drawn from a wide range of authoritative sources, including the reference documents listed in the Introduction section and the technical advisory committee members listed below. Readers are encouraged to obtain their own copies of the publications referenced throughout this book, in order to continue their learning beyond the information presented in this introductory text.

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## Disclaimer

The purpose of this book is to assist students who are undertaking training in units of competency relating to arboriculture and powerline vegetation control work.

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# Tree Workers Manual

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# Introduction

This manual has been written for apprentice arborists, powerline tree trimmers and other tree workers undertaking accredited training.

It is designed to help you with the background knowledge requirements for a range of units of competency.

In particular, it supports the following competencies from the AHC Training Package:

- *AHCPCM204: Recognise plants*
- *AHCARB214: Recognise trees*
- *AHCARB315: Inspect trees for access and work*
- *AHCARB316: Perform pruning operations*
- *AHCARB323: Identify trees*
- *AHCARB408: Perform a ground-based tree defect evaluation.*



The manual is also a useful background resource for the botanical and pruning elements from the following UET Training Package competencies:

- *UETTDRVC23: Plan the removal of vegetation up to vegetation exclusion zone near live electrical apparatus*
- *UETTDRVC24: Assess vegetation and recommend control measures in an ESI environment*
- *UETTDRVC33: Apply pruning techniques to vegetation control near live electrical apparatus.*

The concepts presented in this manual are drawn from a range of authoritative sources – some are standard arboricultural and botanical textbooks that you can buy, and others are on-line resources or publications that you can download from the web. These source documents are listed on the following pages, and referenced from time to time throughout the text.

The concepts and suggested techniques described in this manual are also in line with the ‘minimum industry standards’ (MIS) developed by Arboriculture Australia.

## Arboriculture students

If you're undertaking a qualification in arboriculture, this book should be treated as a first step in your studies. You will need to build up a library of specialist text books and other reference sources as you continue your learning and move beyond the basic principles. You should also subscribe to relevant industry journals to stay up-to-date with the latest developments in the arboriculture sector.

There are literally thousands of reference books, websites and other resources relating to botany and arboriculture. Your trainer will give you various materials as you undertake particular units in your course, and will also advise you on other publications that are available.

Below are some examples of worthwhile resources. Speak to your trainer if you have any questions about them or would like advice on where to find them.

### Publications you should consider buying:

*A field guide to Australian trees* – Ivan Holliday; New Holland Publishers (2002)

*Cronin's key guide: Australian trees* – Leonard Cronin; Allen and Unwin (2013)

*The Body Language of Trees – Encyclopedia of Visual Tree Assessment* – Mattheck C., Bethge K. and Weber K., Karlsruhe Institute of Technology (2015)

*The tree climber's companion* – Jeff Jepson; Beaver Tree Publishing (2014)

*Tree inspection for access and work (MIS306)* – Arboriculture Australia (2018)

### Australian Standards relevant to tree works:

*AS 4373:2007 Pruning of amenity trees* (the standard reference document for approved pruning techniques)

*AS 2303:2018 Tree stock for landscape use* (a good reference source for workers involved in purchasing plants)

*AS 4970-2009 Protection of trees on development sites* (which includes sections on arboriculture reports and impact assessments, plus various types of tree damage)

### Mobile phone apps, websites and downloadable documents:

*Animated Knots* – <http://www.animatedknots.com/>

*Urban Tree Risk Management: A Community Guide to Program Design and Implementation* (2003), available as a download from the web at:

<https://www.fs.usda.gov/naspf/publications/urban-tree-risk-management-community-guide-program-design-and-implementation>

*Multi-access Key to the Eucalypts of Victoria* (Royal Botanic Gardens Victoria):

<https://vicflora.rbg.vic.gov.au/static/keys/eucalypts>

*PlantNET – NSW Flora Online Identification Keys* (Royal Botanic Gardens Sydney):

[http://plantnet.rbgsyd.nsw.gov.au/trad\\_keys.htm](http://plantnet.rbgsyd.nsw.gov.au/trad_keys.htm)

*Flora of Australia Online Database* (Australian Biological Resources Study):

<https://profiles.ala.org.au/opus/foa/about>

*EUCLID – Eucalypts of Australia* (Centre for Australian National Biodiversity Research, Australian National Herbarium, CSIRO):

<http://keyserver.lucidcentral.org:8080/euclid/data/02050e02-0108-490e-8900-0e0601070d00/media/Html/index.htm>

### **Other resources you may find useful:**

*The Complete A-Z of Gardening in Australia* – Sheat W.G. and Schofield G. (2005)

*What Tree Is That*; 3<sup>rd</sup> Ed – Stirling Macoboy, New Holland Publishers (2006)

*Arboriculture: Integrated Management of Landscape Trees, Shrubs, and Vines*; 4<sup>th</sup> Ed– Harris, Clark, Matheny; Prentice Hall Publishers (2004)

*A New Tree Biology* – Shigo A., Dodge Printers, Littleton, New Hampshire (2002)

*Principles of Tree Hazard Assessment and Management* – Lonsdale D., Arboricultural Association UK (1999)

*A Photographic Guide to the Evaluation of Hazard Trees in Urban Areas* – Matheny N. and Clark J., International Society of Arboriculture, USA (1994)

*Tree identification manual for the north-east Darling Downs region* – North East Downs Landcare Group (2011):

<https://www.nedlandcare.org.au/pdf/Manual%209-11-11.pdf>

*Arborist industry safe work practices* – Workplace Safety & Prevention Services, (2011): [http://www.wsps.ca/WSPS/media/Site/Resources/Downloads/arborist\\_manual\\_3rd\\_edition\\_final2.pdf](http://www.wsps.ca/WSPS/media/Site/Resources/Downloads/arborist_manual_3rd_edition_final2.pdf)

*Evaluation of current rigging and dismantling practices used in arboriculture* – UK Health and Safety Executive and Forestry Commission (2008):

<http://www.hse.gov.uk/research/rrpdf/rr668.pdf>

*International Society of Arboriculture* (includes on-line learning, podcasts, resources and membership): <https://www.isa-arbor.com/>

*Educated Climber.com* (includes many resources, video clips, blogs and membership): <https://www.educatedclimber.com/>

*TreeFlip: Life-Sized Guide to the Trees of Tasmania* – University of Tasmania (2009)

# Tree anatomy

It's sometimes said that trees are built from thin air and water.

This is because the food that fuels a tree's growth basically comes from *carbon dioxide* (breathed in through the leaves) and *water* (absorbed through the roots).

There are other nutrients that the roots extract from the soil, but these are only required in small quantities.

Unlike animals, trees manufacture their own food internally. They also retain their own waste products produced during growth, storing them internally in the *heartwood* cells.

Trees are extremely efficient solar-powered production plants, since the only external energy source needed to carry out these functions is the sun.

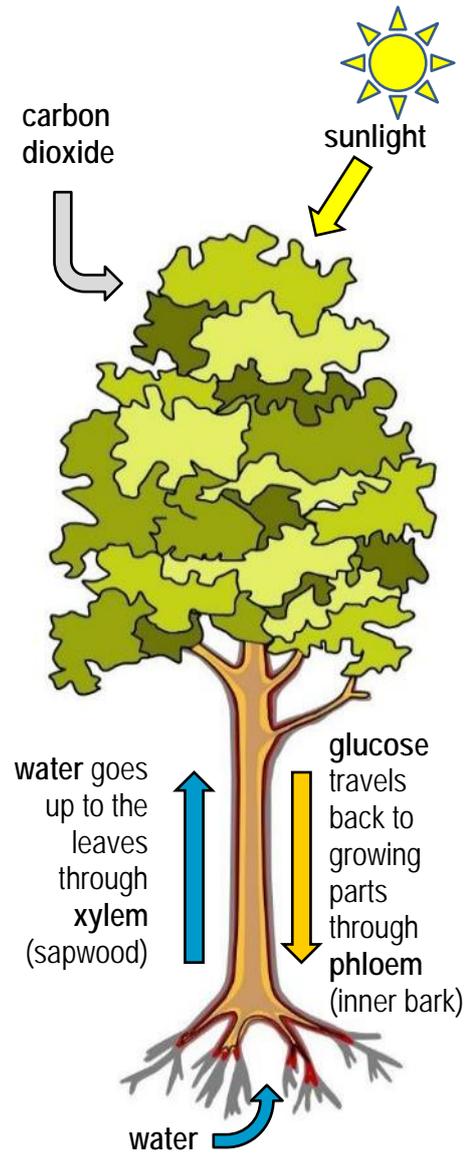
## Photosynthesis

The process used by plants to manufacture food is called *photosynthesis*, because it uses the power of sunlight ('photo' meaning 'light') to 'synthesise' the carbon dioxide with water.

Air enters through thousands of tiny pores called *stomata*, which are mostly found on the underside of the leaves. The sunlight is turned into energy by *chlorophyll*, a green pigment in the leaves. Water and other nutrients are absorbed by the roots and transported to the leaves through the *sapwood*, or *xylem* tissue.

The carbon dioxide and water are converted into *glucose* in the leaves. Glucose is a sugar, sometimes referred to as a simple carbohydrate. It is carried to all the growing parts of the tree through the *phloem*, or inner bark.

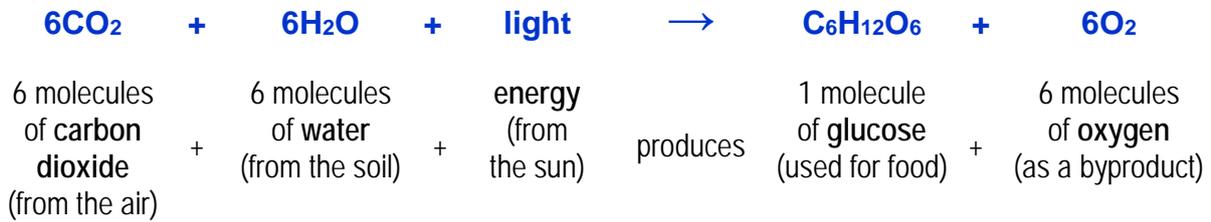
When the glucose reaches the areas where it will be used, it's converted to more complex carbohydrates, such as *cellulose* and *starch*. Cellulose is the basic body-building material of plants, and the main component in wood.



Ingredients of photosynthesis

Starch is used for storage purposes when there is excess food being produced. This reserve supply is mostly stored in the *ray cells*, which extend outwards from the centre of the tree towards the bark.

The basic formula used to describe the process of photosynthesis is:



## Vascular system

Trees have a *vascular system* for transporting water and food.

The **upward** system is in the sapwood, which comprises the living cells in the xylem tissue.

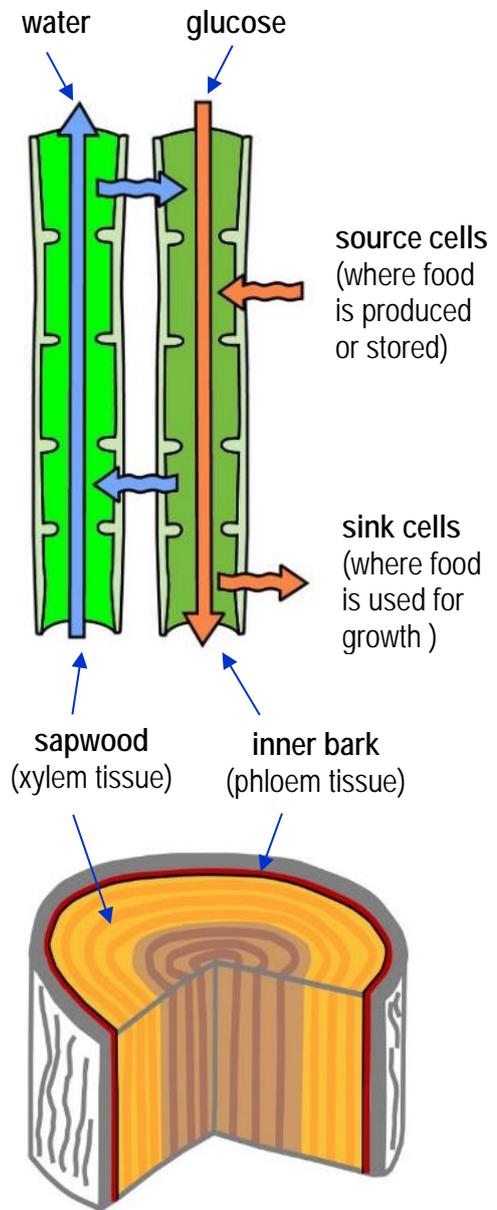
Water from the soil is carried up through the sapwood to the leaves, where photosynthesis takes place.

The **downward** (and outward) system is in the inner bark, or phloem.

This is where the food is transported from the *source cells* – where food is produced or stored – to the *sink cells* – where food is used for growth or put into storage.

The suction force that pulls the moisture up to the leaves is powered by the process of *transpiration*, where water vapour evaporates into the atmosphere through the stomata when they are open.

In some trees, it has been estimated that for every one tonne of wood produced (as a rough average), the tree will take about 1000 tonnes of water from the soil and transport it from the roots, through the stem and up into the leaves.



Vascular system in a tree

## Cross section of a tree

In a growing tree, the stem comprises the following main parts.

**Outer Bark:** This is the dead, corky, material that protects the stem from damage and stops the tree from drying out. As the tree grows in circumference, the bark gradually splits and falls off, and is replaced by new bark.

**Phloem:** The phloem forms the inner bark. It carries the food made in the leaves to all of the growing parts of the tree – that is, the branches, roots and stem.

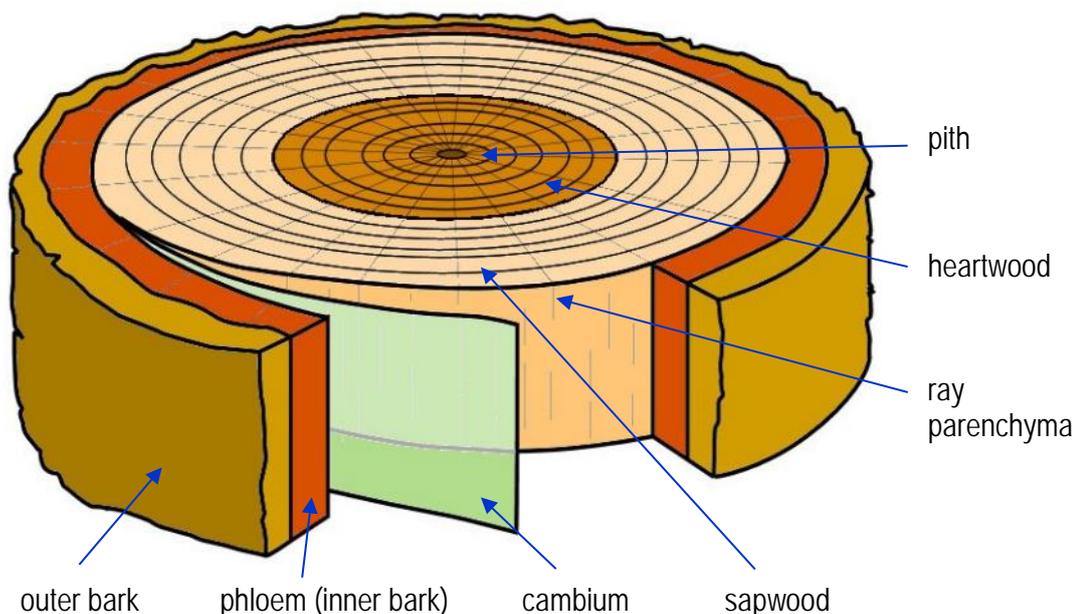
**Cambium:** Underneath the phloem is a thin slimy layer of cambium. As its cells multiply, it forms new phloem tissue on the outside and new wood tissue on the inside. The cambium layer gradually moves outwards as the tree grows in girth.

**Sapwood:** The sapwood carries water and nutrients upwards from the roots. It is made up of living cells and is often lighter in colour than the heartwood. The sapwood and heartwood together are known as the 'xylem'.

**Heartwood:** As new sapwood is formed by the cambium, some of the inner sapwood becomes inactive and is converted to heartwood. The dead cells are used to store waste products from the growing tree, so the vessels become blocked and are no longer able to carry sap. This often makes the heartwood turn a darker colour.

**Pith:** The small, soft core near the centre is called the pith. It is the original tissue in the tree from its early growth as a sapling.

**Ray cells:** The ray parenchyma cells run from the centre of the tree out to the bark. They are used to transport and store food supplies.



Cross section of a tree

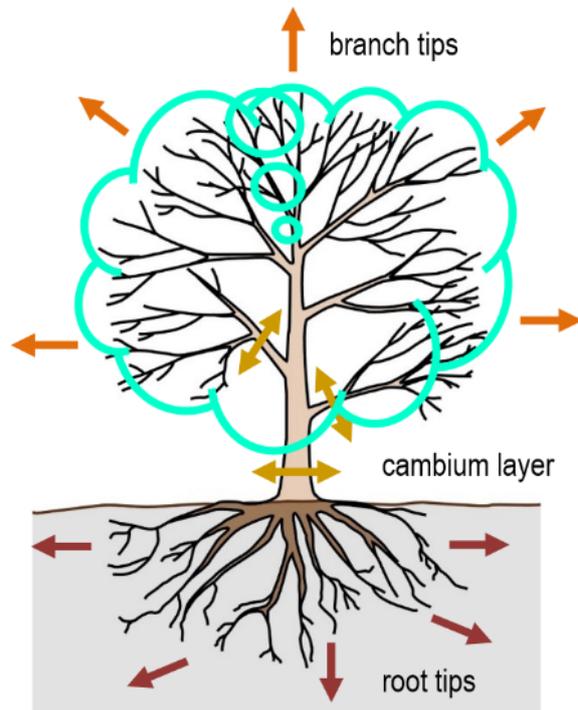
## Growing Parts

Trees grow in three directions:

**Upwards** (and outwards in branch length). The tree grows in height and width as its shoots build new cells onto the growing tips to make the branchlets longer.

**Downwards** (and outwards in root length). The root tips grow as they search for water and nutrients in the soil. Absorption occurs mostly in the root hairs, which start just behind the tips.

**Outwards** (in branch, trunk and root thickness). The cambium layer makes the tree grow in girth. On the phloem side in the stem, it forms new inner bark, and on the sapwood side it forms new wood tissue.

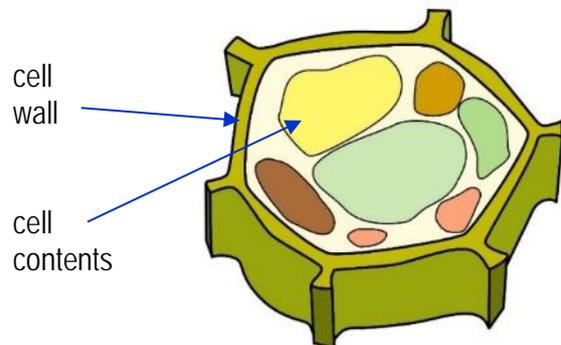


Directions of growth

## Primary growth and secondary growth

One of the fundamental differences between animal cells and plant cells is that animal cells don't have a rigid wall around them, whereas plant cells do.

In this sense, you could say that 'all plant cells live in a wooden box', since the cell's contents are surrounded by a fibrous wall made up mostly of *cellulose* strands.



Cross section of a plant cell

### Primary growth

*Primary growth* occurs when the shoots and roots increase in length as the cells divide and multiply.

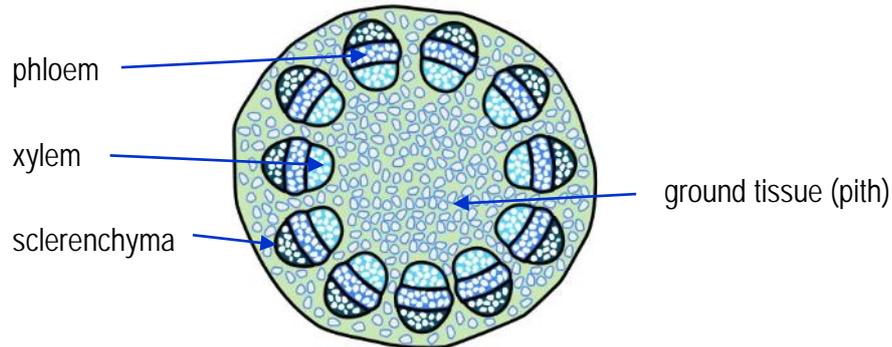
Most primary growth occurs at the tips of these parts, which allows the shoots to continue growing towards sunlight and roots to seek out water.



Primary growth in a eucalypt sapling

The *phloem tissue* is made up mainly of tube-like cells, joined end-to-end to allow the tree's food supply to flow through. The *xylem tissue* also has cells that join up like drinking straws, although the purpose of these cells is to transport water from the roots to the leaves.

The *sclerenchyma cells* have thickened walls which contain lignin, giving the cells extra strength. Their purpose is to provide structural support to the *vascular bundles* – which comprise discrete bundles of phloem, xylem and sclerenchyma cells.

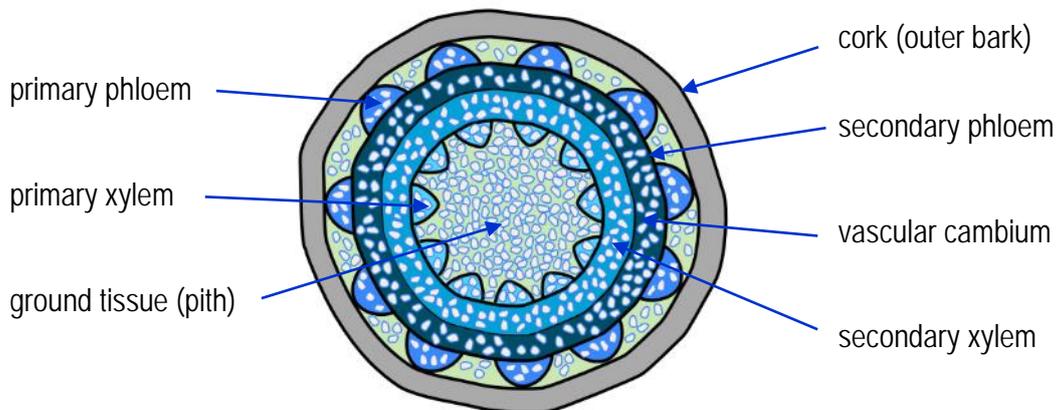


Primary growth in a stem (shown in cross section)

## Secondary growth

*Secondary growth* takes place in particular cells when the walls thicken on the inside. It occurs in the *cambium* layer, which results in an increase in the thickness of the plant's stem, branches and roots.

During secondary growth, the network of cellulose strands is filled in with *hemicelluloses*, which provide additional support, and *lignin*, which acts like a binder. This lignified wood tissue forms the structural fibres that are characteristic of all 'woody' plants, including trees, shrubs and some vines.



Secondary growth in a woody stem (shown in cross section)

## Difference between woody plants and herbaceous plants

Herbaceous plants generally only have primary growth in their stems, which makes them much more flexible than those of woody plants.

The stems and leaves tend to die down to soil level at the end of every growth season.

*Annual herbaceous plants* die off completely every year, and then regenerate from seed in the following year.

Most garden vegetables are annual herbaceous plants. So too are the garden bed flowers that are simply referred to as 'annuals'.

*Perennial herbaceous plants* still die off above ground every year, but the roots and other underground parts survive, enabling the plants to grow back year after year. Asparagus and rhubarb are both perennial vegetables.



Flowering annuals in a public park

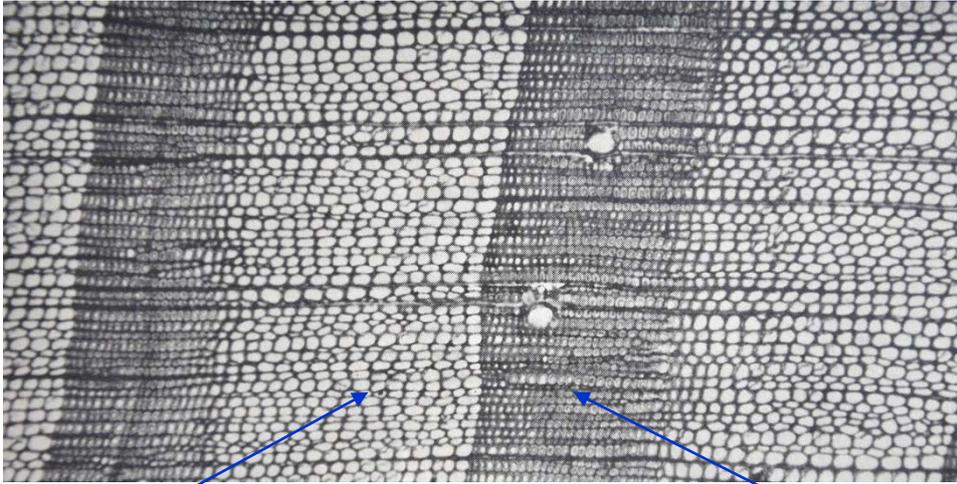
By contrast, plants that have woody fibres in their structure don't die off at the end of each season, but continue to build new layers of wood tissue into their stems every year, increasing the diameter of the stem. This *seasonal growth* often appears as growth rings in the stem.

## Growth rings

In spring and early summer, when there's lots of water and sunlight and the temperature is increasing, trees grow fastest. The cells formed during this rapid growth phase tend to have thinner cell walls, with larger cavities to conduct water.

This area of fast-growing wood tissue is known as *earlywood* (or *springwood*) and often appears as a wide light-coloured growth ring.

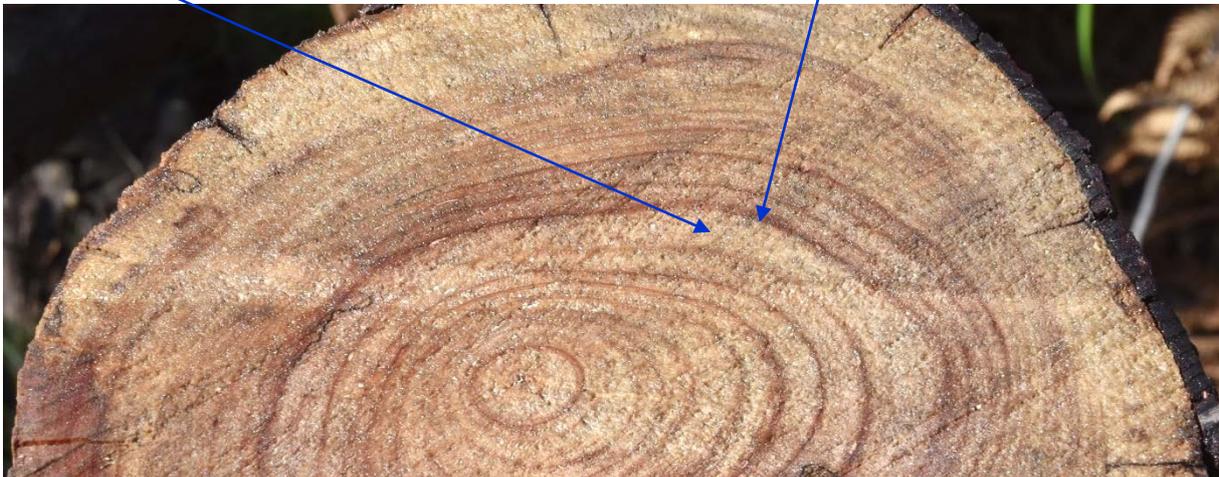
As summer progresses into autumn, the water supply becomes less available, days become shorter, and temperatures get cooler. The tree's growth slows down and the cells develop thicker walls and thinner cavities. This shows up as much denser and narrower growth rings, called *latewood* (or *summerwood*).



Magnified view of a typical softwood cross section (in this case *Pinus strobus*) showing the individual cells.  
  
(Photo reproduced with permission from CSIRO – see Acknowledgements section for publication details)

earlywood (also called 'springwood')

latewood (also called 'summerwood')



Example of growth rings in a typical softwood species

In species where separate growth rings are formed reliably every year, they are also called *annual rings*. Although annual rings are common in the softwoods, and in some hardwoods that grow in colder regions, many hardwoods don't have obvious growth rings, because the outer boundaries tend to merge with neighbouring rings.



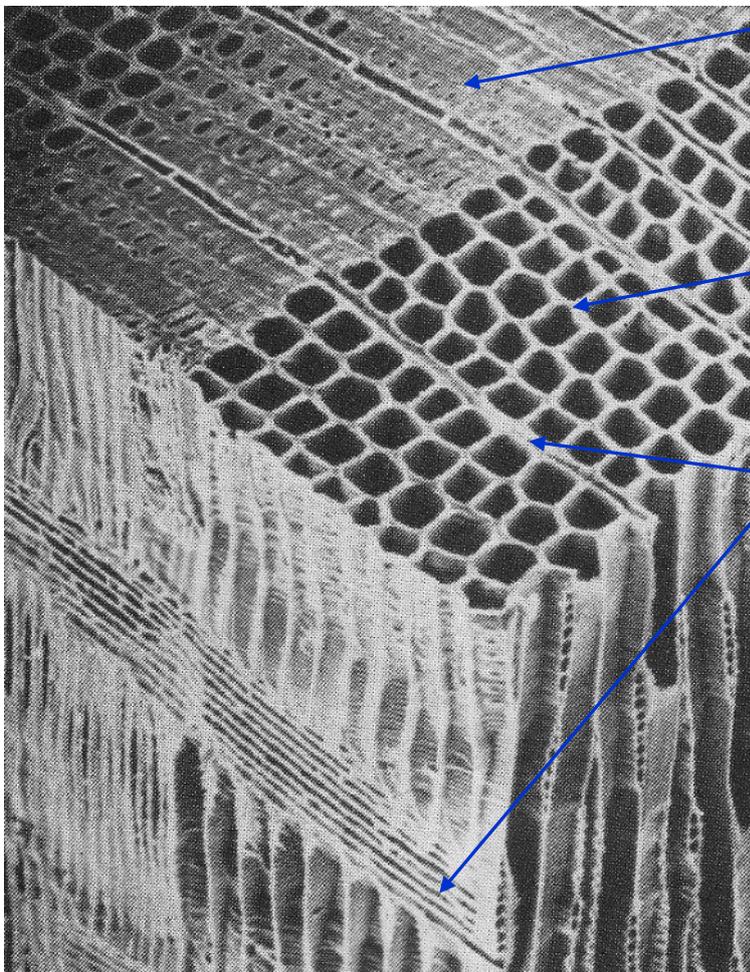
Hardwood logs in a sawmill. Note that the growth rings are much less obvious than in the softwood above, since the pores tend to be more even in size. This is particularly the case in eucalypt species.

## Softwoods and hardwoods

When trees are processed and used for timber, the wood that's produced is commonly referred to as either a **softwood** or **hardwood**. Although it's true that most hardwoods are harder than most softwoods in terms of the effort required to cut or work with the timber, it's not universally the case. The fundamental difference between hardwoods and softwoods is in their cell structure.

Botanically speaking, **softwoods** are *gymnosperms*, which means 'naked seeds'. This is a reference to the fact that the seeds are exposed when the scales on a softwood cone open up. (See the next chapter: 'Plant taxonomy', for more details on seed dispersal in gymnosperms.)

The photo below, taken by the CSIRO through a microscope shows the cell structure of the xylem tissue in a typical softwood species.



**Latewood tracheids:** thick cell walls, small cell cavities, corresponding to the dark growth ring that is formed during 'summer growth'

**Earlywood tracheids:** thin cell walls, large cell cavities, corresponding to the wide band of 'spring growth' in a growth ring

**Ray parenchyma** (also called medullary rays): radiating from the centre of the tree to the bark

**Tree species:** *Pseudotsuga menziesii* (Douglas fir, also called oregon) – an evergreen conifer in the pine tree family.

(Photo reproduced with permission from CSIRO – see Acknowledgements section for publication details)

Structure of xylem in a typical gymnosperm tree

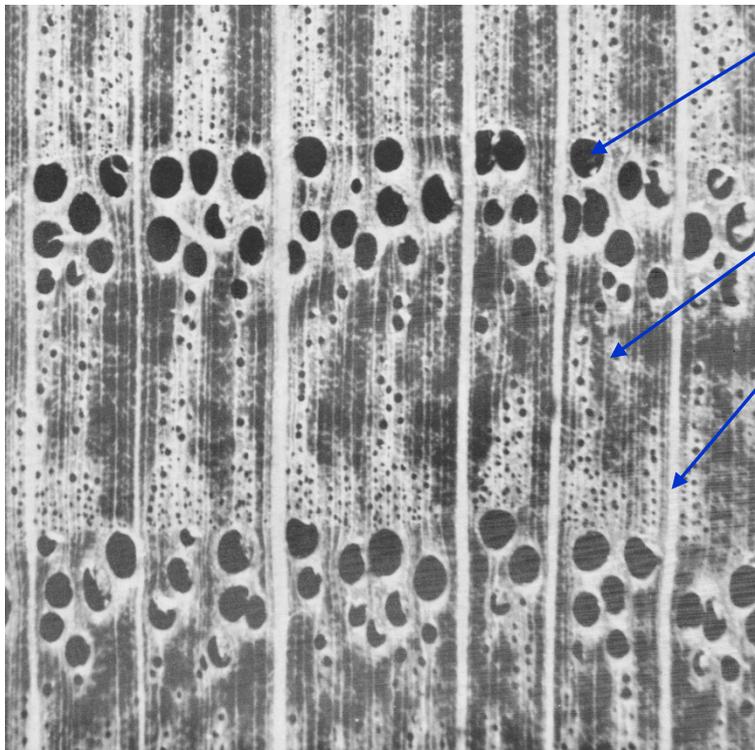
The *tracheids* perform two functions – they transport liquids from the roots to the leaves, and also provide structural support to the tree. Depending on the species of tree, the tracheids may be from about 3 mm long to 10 mm long individually.

The water travels through the cell cavities, and moves from one tracheid to the next through bordered pits in the cell walls. The pits provide gaps or holes in the secondary wall of the cell, allowing liquid to pass through the porous primary wall membrane.

The *ray parenchyma* (or *medullary rays*) are used to transport and store food supplies. Food that isn't needed immediately for growing is stored in the form of starch.

**Hardwood** trees have a different cell structure in the xylem tissue. In botanical terms they are called *angiosperms*, which literally means 'covered seeds', because the seeds are contained in gum nuts or flowers. (See the next section, 'Plant taxonomy', for more information.)

The photo below shows the cell structure of a typical hardwood species.



**Vessels:** thin-walled cells arranged vertically to form columns – also called 'pores', in reference to the open cavities

**Fibres:** narrow, thick-walled cells with very small cavities

**Ray parenchyma:** (also called medullary rays): radiating from the centre of the tree to the bark

**Type of timber:** Oak (ring porous hardwood)

(Photo reproduced with permission from CSIRO – see Acknowledgements section for publication details)

#### Structure of xylem in a typical angiosperm tree

The function of the *vessels* is to transport liquids up the stem of the tree. The ends of the cells are either pitted or completely open, to allow water to move through. Small pits also occur on the side walls to connect the cells with adjacent vessels or ray cells.

*Fibres* provide structural support to the stem, and make up the bulk of the wood. The cavities are generally too small to allow the movement of liquids. The *ray parenchyma* perform a similar function to the ray cells in softwoods.

## Examples of softwoods and hardwoods used for timber

Below are some examples of commercial timbers that are commonly used in building work, furniture making and wood turning.

If you have used any of these timbers yourself in building or woodwork projects, you'll know how hard or soft they feel relative to other species, and how the structure of their fibres tends to respond differently when cut, planed or sanded.

Some of the angiosperms obviously fit into the 'hardwood' category – such as ironbark and tallowwood, which are among the hardest timbers in the world. And some of the gymnosperms obviously fit into the 'softwood' category – such as radiata pine and western red cedar, which are both soft and easy to work with.



Radiata pine being harvested for timber

But there may be other species that might surprise you, such as balsa wood, which is extremely soft and lightweight, and yet botanically speaking is a hardwood. By contrast, cypress pine is a softwood, and yet it does an excellent job as a hard-wearing and durable flooring products.

Examples of softwoods (gymnosperms)	Examples of hardwoods (angiosperms)
<i>Agathis robusta</i> (kauri pine)	<i>Corymbia maculata</i> (spotted gum)
<i>Araucaria cunninghamii</i> (hoop pine)	<i>Eucalyptus delegatensis</i> (alpine ash)
<i>Callitris glaucophylla</i> (white cypress pine)	<i>Eucalyptus marginata</i> (jarrah)
<i>Pinus radiata</i> (radiata pine)	<i>Eucalyptus microcorys</i> (tallowwood)
<i>Pinus sylvestris</i> (Baltic pine, also called Scots pine)	<i>Eucalyptus sideroxylon</i> (red ironbark)
<i>Pseudotsuga menziesii</i> (Douglas fir, also called oregon)	<i>Nothofagus cunninghamii</i> (beech)
<i>Thuja plicata</i> (western red cedar)	<i>Ochroma pyramidale</i> (balsa wood)
<i>Tsuga heterophylla</i> (western hemlock (also called Canada pine))	<i>Populus balsamifera</i> (poplar)
	<i>Pterocarpus indicus</i> (rosewood)
	<i>Shorea argenifolia</i> (light red meranti)
	<i>Toona ciliata</i> (Australian red cedar)

