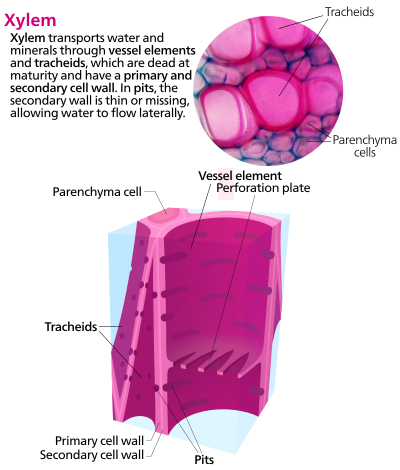
**XYLEM & PHLOEM TISSUES**

Xylem is one of the two types of transport [tissue](https://en.wikipedia.org/wiki/Tissue_(biology)) in [vascular plants](https://en.wikipedia.org/wiki/Vascular_plant), [phloem](https://en.wikipedia.org/wiki/Phloem) being the other. The basic function of xylem is to transport [water](https://en.wikipedia.org/wiki/Water) from roots to stems and leaves, but it also transports [nutrients](https://en.wikipedia.org/wiki/Plant_nutrition). The word "xylem" is derived from the [Greek](https://en.wikipedia.org/wiki/Greek_language) word  meaning "wood"; the best-known xylem tissue is [wood](https://en.wikipedia.org/wiki/Wood), though it is found throughout a plant.The term was introduced by [Carl Nägeli](https://en.wikipedia.org/wiki/N%C3%A4geli) in 1858.

Structure

[](https://en.wikipedia.org/wiki/File:Xylem_cells.svg)

Cross section of some xylem cells

The most distinctive xylem [cells](https://en.wikipedia.org/wiki/Cell_(biology)) are the long tracheary elements that transport water. [Tracheids](https://en.wikipedia.org/wiki/Tracheid" \o "Tracheid) and [vessel elements](https://en.wikipedia.org/wiki/Vessel_element) are distinguished by their shape; vessel elements are shorter, and are connected together into long tubes that are called *vessels*.

Xylem also contains two other cell types: [parenchyma](https://en.wikipedia.org/wiki/Parenchyma) and [fibers](https://en.wikipedia.org/wiki/Ground_tissue#Fibres)

Xylem can be found:

* in [vascular bundles](https://en.wikipedia.org/wiki/Vascular_bundle), present in non-woody plants and non-woody parts of woody plants
* in secondary xylem, laid down by a [meristem](https://en.wikipedia.org/wiki/Meristem) called the [vascular cambium](https://en.wikipedia.org/wiki/Vascular_cambium) in woody plants
* as part of a [stelar arrangement](https://en.wikipedia.org/wiki/Stele_(biology)" \o "Stele (biology)) not divided into bundles, as in many [ferns](https://en.wikipedia.org/wiki/Fern).

In transitional stages of plants with [secondary growth](https://en.wikipedia.org/wiki/Secondary_growth), the first two categories are not mutually exclusive, although usually a vascular bundle will contain *primary xylem* only.

The branching pattern exhibited by xylem follows [Murray's law](https://en.wikipedia.org/wiki/Murray%27s_law).

Primary and secondary xylem

Primary xylem is formed during primary growth from [procambium](https://en.wikipedia.org/wiki/Procambium" \o "Procambium). It includes protoxylem and metaxylem. Metaxylem develops after the protoxylem but before secondary xylem. Metaxylem has wider vessels and tracheids than protoxylem.

Secondary xylem is formed during secondary growth from [vascular cambium](https://en.wikipedia.org/wiki/Vascular_cambium). Although secondary xylem is also found in members of the [gymnosperm](https://en.wikipedia.org/wiki/Gymnosperm) groups [Gnetophyta](https://en.wikipedia.org/wiki/Gnetophyta" \o "Gnetophyta) and [Ginkgophyta](https://en.wikipedia.org/wiki/Ginkgophyta" \o "Ginkgophyta) and to a lesser extent in members of the [Cycadophyta](https://en.wikipedia.org/wiki/Cycadophyta" \o "Cycadophyta), the two main groups in which secondary xylem can be found are:

1. [conifers](https://en.wikipedia.org/wiki/Conifers) (*Coniferae*): there are approximately 600 known species of conifers. All species have secondary xylem, which is relatively uniform in structure throughout this group. Many conifers become tall trees: the secondary xylem of such trees is used and marketed as [softwood](https://en.wikipedia.org/wiki/Softwood).
2. [angiosperms](https://en.wikipedia.org/wiki/Angiosperms) (*Angiospermae*): there are approximately 250,000 known species of angiosperms. Within this group secondary xylem is rare in the [monocots](https://en.wikipedia.org/wiki/Monocots).[[10]](https://en.wikipedia.org/wiki/Xylem#cite_note-10) Many non-monocot angiosperms become trees, and the secondary xylem of these is used and marketed as [hardwood](https://en.wikipedia.org/wiki/Hardwood).

Main function – upwards water transport

The xylem, vessels and tracheids of the roots, stems and leaves are interconnected to form a continuous system of water-conducting channels reaching all parts of the plants. The system transports water and soluble mineral nutrients from the roots throughout the plant. It is also used to replace water lost during [transpiration](https://en.wikipedia.org/wiki/Transpiration) and photosynthesis. Xylem [sap](https://en.wikipedia.org/wiki/Plant_sap) consists mainly of water and inorganic ions, although it can also contain a number of organic chemicals as well. The transport is passive, not powered by energy spent by the [tracheary](https://en.wikipedia.org/wiki/Vessel_elements" \o "Vessel elements) elements themselves, which are dead by maturity and no longer have living contents. Transporting sap upwards becomes more difficult as the height of a plant increases and upwards transport of water by xylem is considered to limit the maximum height of trees.[[11]](https://en.wikipedia.org/wiki/Xylem#cite_note-11) Three phenomena cause xylem sap to flow:

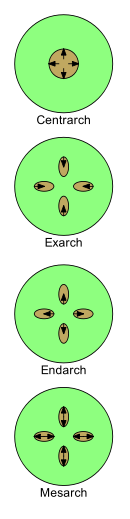
* [Pressure flow hypothesis](https://en.wikipedia.org/wiki/Pressure_Flow_Hypothesis): Sugars produced in the leaves and other green tissues are kept in the phloem system, creating a [solute pressure](https://en.wikipedia.org/wiki/Water_potential) differential versus the xylem system carrying a far lower load of solutes- water and minerals. The phloem pressure can rise to several MPa, far higher than atmospheric pressure. Selective inter-connection between these systems allows this high solute concentration in the phloem to draw xylem fluid upwards by negative pressure.
* Transpirational pull: Similarly, the [evaporation](https://en.wikipedia.org/wiki/Evaporation) of [water](https://en.wikipedia.org/wiki/Water) from the surfaces of [mesophyll](https://en.wikipedia.org/wiki/Mesophyll_tissue) cells to the atmosphere also creates a negative pressure at the top of a plant. This causes millions of minute [menisci](https://en.wikipedia.org/wiki/Meniscus_(liquid)) to form in the mesophyll cell wall. The resulting [surface tension](https://en.wikipedia.org/wiki/Surface_tension) causes a negative pressure or [tension](https://en.wikipedia.org/wiki/Tension_(physics)) in the xylem that pulls the water from the roots and soil.
* [Root pressure](https://en.wikipedia.org/wiki/Root_pressure): If the [water potential](https://en.wikipedia.org/wiki/Water_potential) of the root cells is more negative than that of the [soil](https://en.wikipedia.org/wiki/Soil), usually due to high concentrations of [solute](https://en.wikipedia.org/wiki/Solution), water can move by [osmosis](https://en.wikipedia.org/wiki/Osmosis) into the root from the soil. This causes a positive pressure that forces sap up the xylem towards the leaves. In some circumstances, the sap will be forced from the leaf through a [hydathode](https://en.wikipedia.org/wiki/Hydathode" \o "Hydathode) in a phenomenon known as [guttation](https://en.wikipedia.org/wiki/Guttation). Root pressure is highest in the morning before the stomata open and allow transpiration to begin. Different plant species can have different root pressures even in a similar environment; examples include up to 145 kPa in *[Vitis riparia](https://en.wikipedia.org/wiki/Vitis_riparia" \o "Vitis riparia)* but around zero in *[Celastrus orbiculatus](https://en.wikipedia.org/wiki/Celastrus_orbiculatus" \o "Celastrus orbiculatus)*.

The primary force that creates the [capillary action](https://en.wikipedia.org/wiki/Capillary_action) movement of water upwards in plants is the adhesion between the water and the surface of the xylem conduits. Capillary action provides the force that establishes an equilibrium configuration, balancing gravity. When transpiration removes water at the top, the flow is needed to return to the equilibrium.

Transpirational pull results from the evaporation of water from the surfaces of [cells](https://en.wikipedia.org/wiki/Cell_(biology)) in the [leaves](https://en.wikipedia.org/wiki/Leaf). This evaporation causes the surface of the water to recess into the [pores](https://en.wiktionary.org/wiki/pore) of the [cell wall](https://en.wikipedia.org/wiki/Cell_wall). By [capillary action](https://en.wikipedia.org/wiki/Capillary_action), the water forms concave [menisci](https://en.wikipedia.org/wiki/Meniscus_(liquid)) inside the pores. The high surface tension of water pulls the [concavity](https://en.wiktionary.org/wiki/Concavity) outwards, generating enough [force](https://en.wikipedia.org/wiki/Force) to lift water as high as a hundred meters from ground level to a [tree](https://en.wikipedia.org/wiki/Tree)'s highest branches.

Transpirational pull requires that the vessels transporting the water be very small in diameter; otherwise, [cavitation](https://en.wikipedia.org/wiki/Cavitation) would break the water column. And as water [evaporates](https://en.wikipedia.org/wiki/Evaporates) from leaves, more is drawn up through the plant to replace it. When the water pressure within the xylem reaches extreme levels due to low water input from the roots (if, for example, the soil is dry), then the gases come out of solution and form a bubble – an [embolism](https://en.wikipedia.org/wiki/Embolism) forms, which will spread quickly to other adjacent cells, unless [bordered pits](https://en.wikipedia.org/wiki/Pit_(botany)) are present (these have a plug-like structure called a torus, that seals off the opening between adjacent cells and stops the embolism from spreading).

Development

[](https://en.wikipedia.org/wiki/File:Xylem_Development.svg)

Patterns of xylem development: xylem in brown; arrows show direction of development from protoxylem to metaxylem.

Xylem development can be described by four terms: *centrarch, exarch, endarch* and *mesarch*. As it develops in young plants, its nature changes from *protoxylem* to *metaxylem* (i.e. from *first xylem* to *after xylem*). The patterns in which protoxylem and metaxylem are arranged is important in the study of plant morphology.

Protoxylem and metaxylem

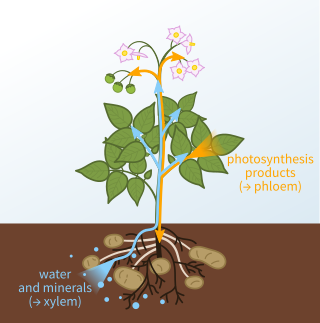
As a young [vascular plant](https://en.wikipedia.org/wiki/Vascular_plant) grows, one or more strands of primary xylem form in its stems and roots. The first xylem to develop is called 'protoxylem'. In appearance protoxylem is usually distinguished by narrower vessels formed of smaller cells. Some of these cells have walls which contain thickenings in the form of rings or helices. Functionally, protoxylem can extend: the cells are able to grow in size and develop while a stem or root is elongating. Later, 'metaxylem' develops in the strands of xylem. Metaxylem vessels and cells are usually larger; the cells have thickenings which are typically either in the form of ladderlike transverse bars (scalariform) or continuous sheets except for holes or pits (pitted). Functionally, metaxylem completes its development after elongation ceases when the cells no longer need to grow in size.

Patterns of protoxylem and metaxylem

There are four main patterns to the arrangement of protoxylem and metaxylem in stems and roots.

* *Centrarch* refers to the case in which the primary xylem forms a single cylinder in the center of the stem and develops from the center outwards. The protoxylem is thus found in the central core and the metaxylem in a cylinder around it. This pattern was common in early land plants, such as "[rhyniophytes](https://en.wikipedia.org/wiki/Rhyniophyte" \o "Rhyniophyte)", but is not present in any living plants.
* The other three terms are used where there is more than one strand of primary xylem.
* *Exarch* is used when there is more than one strand of primary xylem in a stem or root, and the xylem develops from the outside inwards towards the center, i.e. centripetally. The metaxylem is thus closest to the center of the stem or root and the protoxylem closest to the periphery. The roots of [vascular plants](https://en.wikipedia.org/wiki/Vascular_plant) are normally considered to have exarch development.
* *Endarch* is used when there is more than one strand of primary xylem in a stem or root, and the xylem develops from the inside outwards towards the periphery, i.e. centrifugally. The protoxylem is thus closest to the center of the stem or root and the metaxylem closest to the periphery. The stems of [seed plants](https://en.wikipedia.org/wiki/Seed_plant) typically have endarch development.
* *Mesarch* is used when there is more than one strand of primary xylem in a stem or root, and the xylem develops from the middle of a strand in both directions. The metaxylem is thus on both the peripheral and central sides of the strand with the protoxylem between the metaxylem (possibly surrounded by it). The leaves and stems of many [ferns](https://en.wikipedia.org/wiki/Fern) have mesarch development.

Phloem

[](https://en.wikipedia.org/wiki/File:Xylem_and_phloem_diagram.svg)

Phloem (orange) transports products of photosynthesis to various parts of the plant.

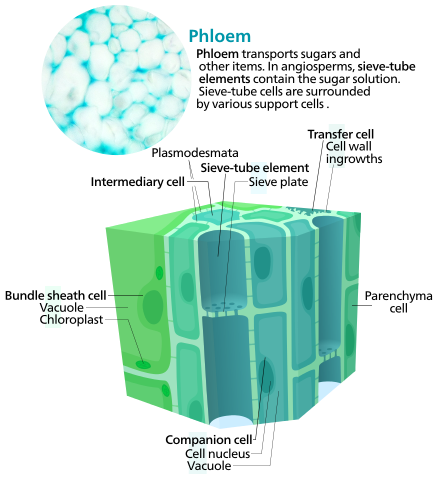
[](https://en.wikipedia.org/wiki/File:Stem-histology-cross-section-tag.svg)

Cross-section of a [flax](https://en.wikipedia.org/wiki/Flax) plant stem:

Phloem  is the living [tissue](https://en.wikipedia.org/wiki/Biological_tissue) in [vascular plants](https://en.wikipedia.org/wiki/Vascular_plant) that transports the soluble organic compounds made during [photosynthesis](https://en.wikipedia.org/wiki/Photosynthesis) and known as *photosynthates*, in particular the sugar [sucrose](https://en.wikipedia.org/wiki/Sucrose), to parts of the plant where needed. This transport process is called translocation. In [trees](https://en.wikipedia.org/wiki/Tree), the phloem is the innermost layer of the [bark](https://en.wikipedia.org/wiki/Bark_(botany)), hence the name, derived from the [Greek](https://en.wikipedia.org/wiki/Greek_language) word  *phloios*) meaning "bark". The term was introduced by [Carl Nägeli](https://en.wikipedia.org/wiki/Carl_N%C3%A4geli) in 1858.



Structure

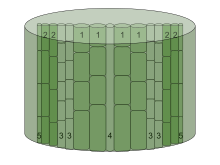
[](https://en.wikipedia.org/wiki/File:Phloem_cells.svg)

Cross section of some phloem cells

Phloem tissue consists of conducting cells, generally called sieve elements, [parenchyma](https://en.wikipedia.org/wiki/Ground_tissue#Parenchyma) cells, including both specialized companion cells or albuminous cells and unspecialized cells and supportive cells, such as [fibres](https://en.wikipedia.org/wiki/Fibres" \o "Fibres) and [sclereids](https://en.wikipedia.org/wiki/Sclereid" \o "Sclereid).

Conducting cells (sieve elements)[[edit](https://en.wikipedia.org/w/index.php?title=Phloem&action=edit&section=2" \o "Edit section: Conducting cells (sieve elements))]

*Main article:*[*Sieve tube element*](https://en.wikipedia.org/wiki/Sieve_tube_element)

[](https://en.wikipedia.org/wiki/File:Phloem_and_Xylem_in_stem.svg)

simplified phloem and companion cells:

1. [Xylem](https://en.wikipedia.org/wiki/Xylem)
2. Phloem
3. [Cambium](https://en.wikipedia.org/wiki/Cambium)
4. Pith
5. Companion Cells

Sieve elements are the type of cell that are responsible for transporting sugars throughout the plant.[[5]](https://en.wikipedia.org/wiki/Phloem#cite_note-Raven_et_al._1992-5) At maturity they lack a [nucleus](https://en.wikipedia.org/wiki/Cell_nucleus) and have very few organelles, so they rely on companion cells or albuminous cells for most of their metabolic needs. Sieve tube cells do contain [vacuoles](https://en.wikipedia.org/wiki/Vacuole) and other organelles, such as [ribosomes](https://en.wikipedia.org/wiki/Ribosome), before they mature, but these generally migrate to the cell wall and dissolve at maturity; this ensures there is little to impede the movement of fluids. One of the few organelles they do contain at maturity is the rough [endoplasmic reticulum](https://en.wikipedia.org/wiki/Endoplasmic_reticulum), which can be found at the plasma membrane, often nearby the [plasmodesmata](https://en.wikipedia.org/wiki/Plasmodesmata" \o "Plasmodesmata) that connect them to their companion or albuminous cells. All sieve cells have groups of pores at their ends that grow from modified and enlarged [plasmodesmata](https://en.wikipedia.org/wiki/Plasmodesmata" \o "Plasmodesmata), called *sieve areas*. The pores are reinforced by platelets of a [polysaccharide](https://en.wikipedia.org/wiki/Polysaccharide) called [callose](https://en.wikipedia.org/wiki/Callose" \o "Callose).

Parenchyma cells

They are of two types, aerenchyma and chlorenchyma. Other [parenchyma](https://en.wikipedia.org/wiki/Parenchyma) cells within the phloem are generally undifferentiated and used for food storage.

Companion cells

The metabolic functioning of sieve-tube members depends on a close association with the *companion cells*, a specialized form of [parenchyma](https://en.wikipedia.org/wiki/Parenchyma) cell. All of the cellular functions of a sieve-tube element are carried out by the (much smaller) companion cell, a typical nucleate [plant cell](https://en.wikipedia.org/wiki/Plant_cell) except the companion cell usually has a larger number of [ribosomes](https://en.wikipedia.org/wiki/Ribosomes) and [mitochondria](https://en.wikipedia.org/wiki/Mitochondria). The dense cytoplasm of a companion cell is connected to the sieve-tube element by plasmodesmata. The common sidewall shared by a sieve tube element and a companion cell has large numbers of plasmodesmata.

There are two types of companion cells.

1. *Ordinary companion cells*, which have smooth walls and few or no plasmodesmatal connections to cells other than the sieve tube.
2. [*Transfer cells*](https://en.wikipedia.org/wiki/Transfer_cells), which have much-folded walls that are adjacent to non-sieve cells, allowing for larger areas of transfer. They are specialized in scavenging solutes from those in the cell walls that are actively pumped requiring energy.

Albuminous cells

Albuminous cells have a similar role to companion cells, but are associated with sieve cells only and are hence found only in seedless vascular plants and gymnosperms.

Supportive cells

Although its primary function is transport of sugars, phloem may also contain cells that have a mechanical support function. These generally fall into two categories: [fibres](https://en.wikipedia.org/wiki/Fibres" \o "Fibres) and [sclereids](https://en.wikipedia.org/wiki/Sclereid" \o "Sclereid). Both cell types have a [secondary cell wall](https://en.wikipedia.org/wiki/Secondary_cell_wall) and are therefore dead at maturity. The secondary cell wall increases their rigidity and tensile strength.

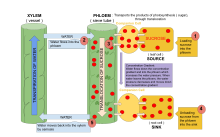
Fibres

[Bast fibres](https://en.wikipedia.org/wiki/Bast_fibre) are the long, narrow supportive cells that provide [tension](https://en.wikipedia.org/wiki/Tension_(physics)) strength without limiting flexibility. They are also found in xylem, and are the main component of many textiles such as paper, linen, and cotton.

Sclereids

[Sclereids](https://en.wikipedia.org/wiki/Sclereid) are irregularly shaped cells that add compression strengthbut may reduce flexibility to some extent. They also serve as anti-herbivory structures, as their irregular shape and hardness will increase wear on teeth as the herbivores chews. For example, they are responsible for the gritty texture in pears, and in winter bears

Function

[](https://en.wikipedia.org/wiki/File:Translocation_from_the_source_to_the_sink_within_the_phloem.svg)

Unlike [xylem](https://en.wikipedia.org/wiki/Xylem) (which is composed primarily of dead cells), the phloem is composed of still-living cells that transport [sap](https://en.wikipedia.org/wiki/Sap_(plant)). The sap is a water-based solution, but rich in [sugars](https://en.wikipedia.org/wiki/Sugar) made by photosynthesis. These sugars are transported to non-photosynthetic parts of the plant, such as the roots, or into storage structures, such as [tubers](https://en.wikipedia.org/wiki/Tuber) or bulbs.

During the plant's growth period, usually during the spring, storage organs such as the [roots](https://en.wikipedia.org/wiki/Root) are sugar sources, and the plant's many growing areas are sugar sinks. The movement in phloem is multidirectional, whereas, in xylem cells, it is unidirectional (upward).

After the growth period, when the [meristems](https://en.wikipedia.org/wiki/Meristem) are dormant, the [leaves](https://en.wikipedia.org/wiki/Leaf) are sources, and storage organs are sinks. Developing [seed](https://en.wikipedia.org/wiki/Seed)-bearing organs (such as [fruit](https://en.wikipedia.org/wiki/Fruit)) are always sinks. Because of this multi-directional flow, coupled with the fact that sap cannot move with ease between adjacent sieve-tubes, it is not unusual for sap in adjacent sieve-tubes to be flowing in opposite directions.

While movement of water and minerals through the xylem is driven by negative pressures (tension) most of the time, movement through the phloem is driven by positive [hydrostatic pressures](https://en.wikipedia.org/wiki/Hydrostatic_pressure). This process is termed *translocation*, and is accomplished by a process called [phloem loading](https://en.wikipedia.org/wiki/Phloem_loading) and *unloading*.

Phloem sap is also thought to play a role in sending informational signals throughout vascular plants. "Loading and unloading patterns are largely determined by the [conductivity](https://en.wikipedia.org/wiki/Electrical_resistivity_and_conductivity) and number of [plasmodesmata](https://en.wikipedia.org/wiki/Plasmodesmata" \o "Plasmodesmata) and the position-dependent function of [solute](https://en.wikipedia.org/wiki/Solution)-specific, [plasma membrane](https://en.wikipedia.org/wiki/Plasma_membrane) [transport proteins](https://en.wikipedia.org/wiki/Transport_proteins). Recent evidence indicates that mobile proteins and [RNA](https://en.wikipedia.org/wiki/RNA) are part of the plant's long-distance communication signaling system. Evidence also exists for the directed transport and sorting of [macromolecules](https://en.wikipedia.org/wiki/Macromolecules) as they pass through plasmodesmata.