Wood Anatomy

Microscopic structure of hardwoods

presentation

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Wood microstructure

Hardwoods

Hardwoods differ from softwoods:

1) vessels occurrence
2) the lack of radial arrangement of the longitudinal cells (X section)
3) much more complex in structure
4) rays are more variable in width

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Structure of hardwoods

Types of anatomical elements:

- vessel elements
- fibres
- parenchyma cells
- tracheids

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Structure of hardwood

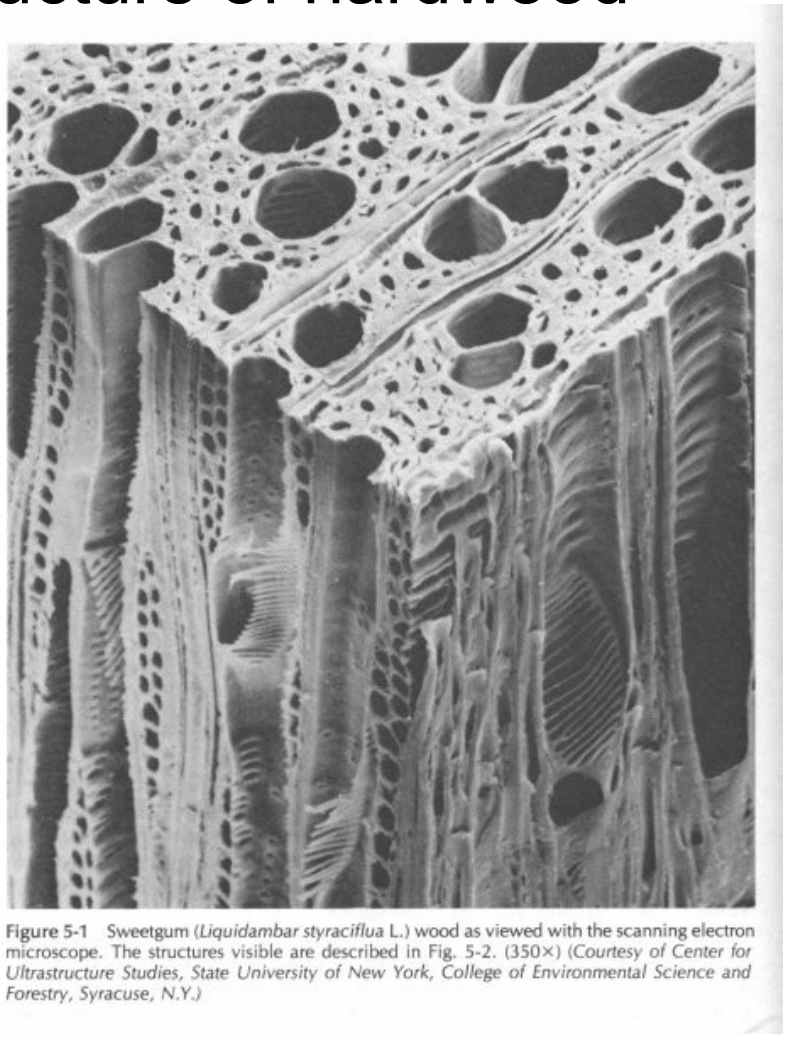

Figure 5-1 Sweetgum (*Liquidambar styraciflua* L.) wood as viewed with the scanning electron microscope. The structures visible are described in Fig. 5-2. (350×) (*Courtesy of Center for Ultrastructure Studies, State University of New York, College of Environmental Science and Forestry, Syracuse, N.Y.*)

3D structure of hardwood

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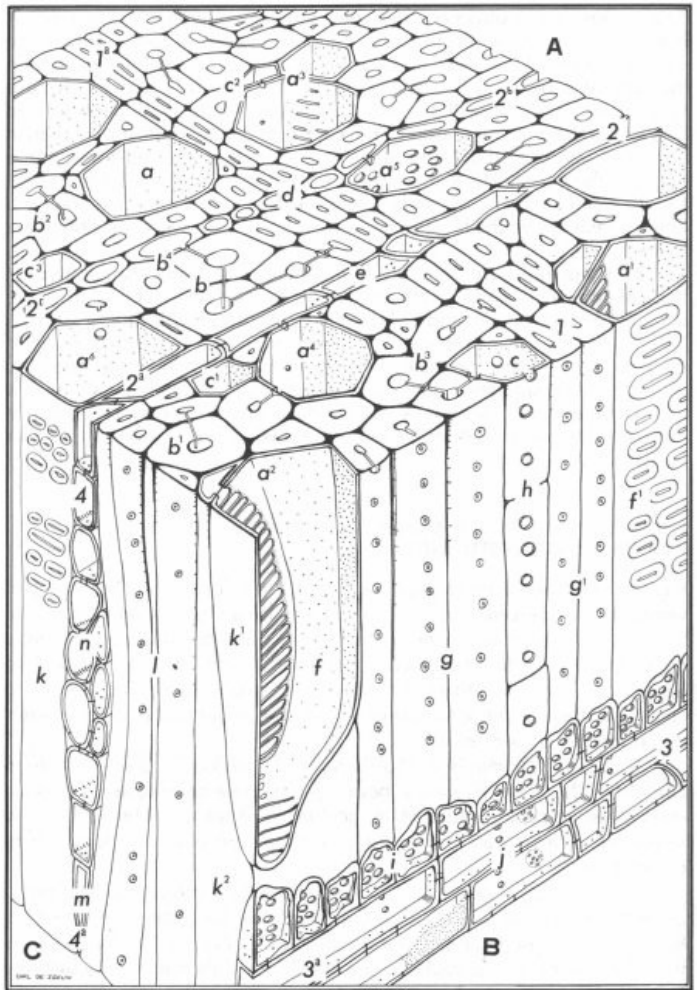
Anatomické elementy dřeva listnáčů



3D structure of hardwood -- drawing

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Vessel elements

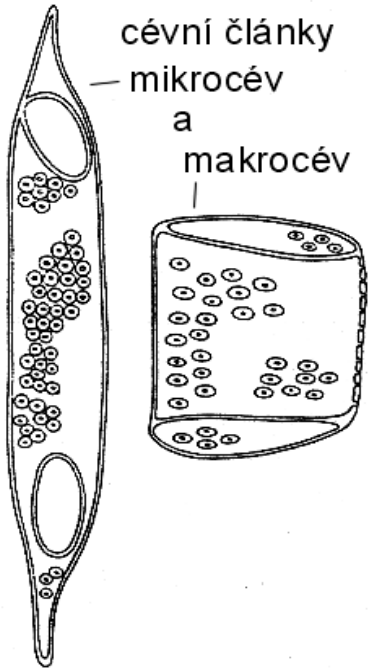
shape
Vessel element is a cell with perforated endnings.

volume: 10-20 %
- increasing along the stem height

function
- water transporting

types
earlywood vessel elements diameter > 100 µm
latewood vessel elements diameter < 100 µm,

dimensions
lemgth: 150-1200 µm



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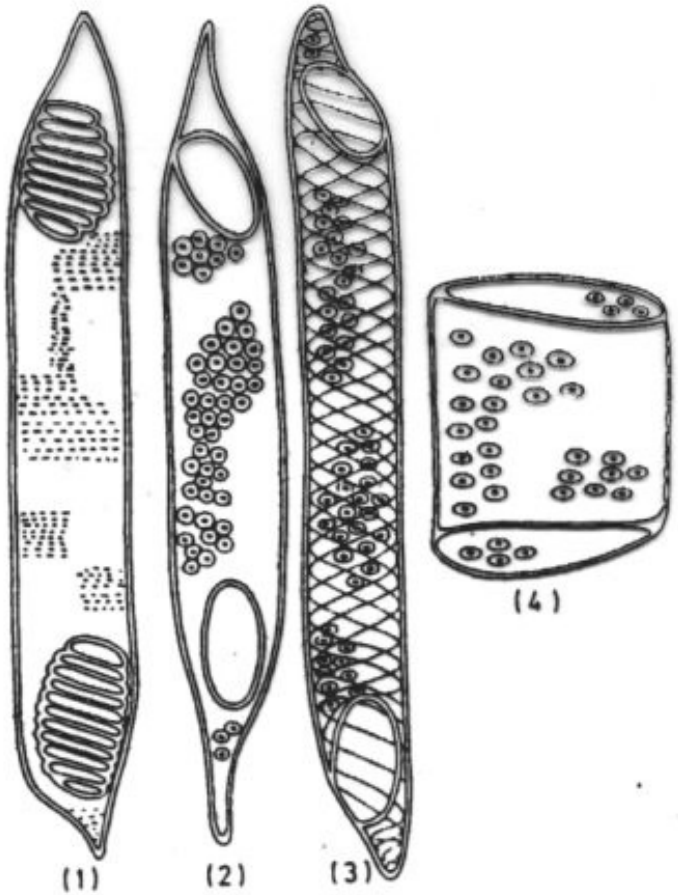
Vessel elements



types of vessel elements

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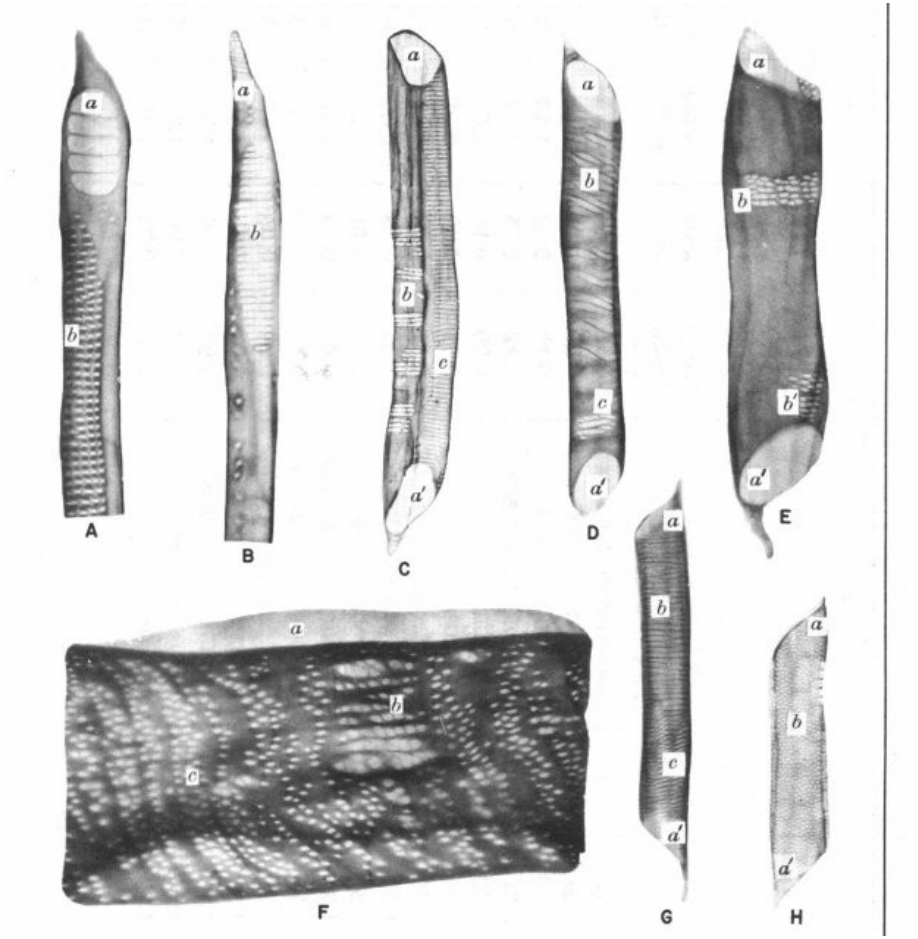
Vessel elements



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Vessel elements

Figure 5-4 Types of vessel elements in hardwoods. (115×)
(A) Portion of a vessel element of yellow-poplar (*Liriodendron tulipifera* L.) showing a scalariform perforation plate with few bars (*a*), and opposite pitting (*b*).
(B) Portion of a vessel element of sweetgum (*Liquidambar styraciflua* L.) showing spiral thickening at tip (a), and scalariform perforation plate with many bars (*b*).
(C) A vessel element of cucumbertree (*Magnolia acuminata* L.) showing simple perforations at the ends (*a, a'*), several cross fields on the radial face (*b*), and scalariform pitting composed of linear pits on the tangential wall (*c*).
(D) A vessel element of yellow buckeye (*Aesculus octandra* Marsh.) showing simple perforations at the ends (*a, a'*), spiral thickening (*b*), and a cross field (*c*).
(E) A vessel element of black willow (*Salix nigra* Marsh.) showing simple perforations at the ends (*a-a'*), and two cross fields (*b-b'*).
(F) Annular (ring-shaped) vessel element from the early wood of chestnut [*Castanea dentata* (Marsh.) Borkh.] showing simple perforations at the upper end (a), a cross field (*b*), and strips of pits leading to vasicentric tracheids (*c*).
(G) A vessel element of silver maple (*Acer saccharinum* L.) showing tailed ends (*a-a'*) on the same side, spiral thickening (*b*), and pits leading to longitudinal parenchyma (*c*).
(H) A vessel element of butternut (*Juglans cinerea* L.) showing short tails (a-á) on opposite sides, and intervessel pitting on the tangential wall (*b*).
(*Photographs* (A), (B), (D), (E), (F), (G), *and* (H), *inclusive, by C. H. Carpenter; photograph* (C) *by W. M. Harlow.*)

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Vessel elements

Types after length:

a) short (< 350 μm): Robinia, Fraxinus, Ulmus, Salix
b) *middle* (350–800 μm): Betula, Acer, Platanus, Carpinu, Juglans
c) long (> 800 μm): Alnus

Types after diameters:

a) very narrow (< 50 μm): Acer, Pyrus, Fagus, Fraxinus, Ulmus
b) *narrow* (50–100 μm): Betula, Alnus, Populus, Carpinus, Cerasus, Robinia, Quercus, Castanea
c) middle wide(100–200 μm): Juglans, Robinia, Ulmus
d) *very wide* (> 200 μm): Quercus, Castanea, Fraxinus, Ailanthus

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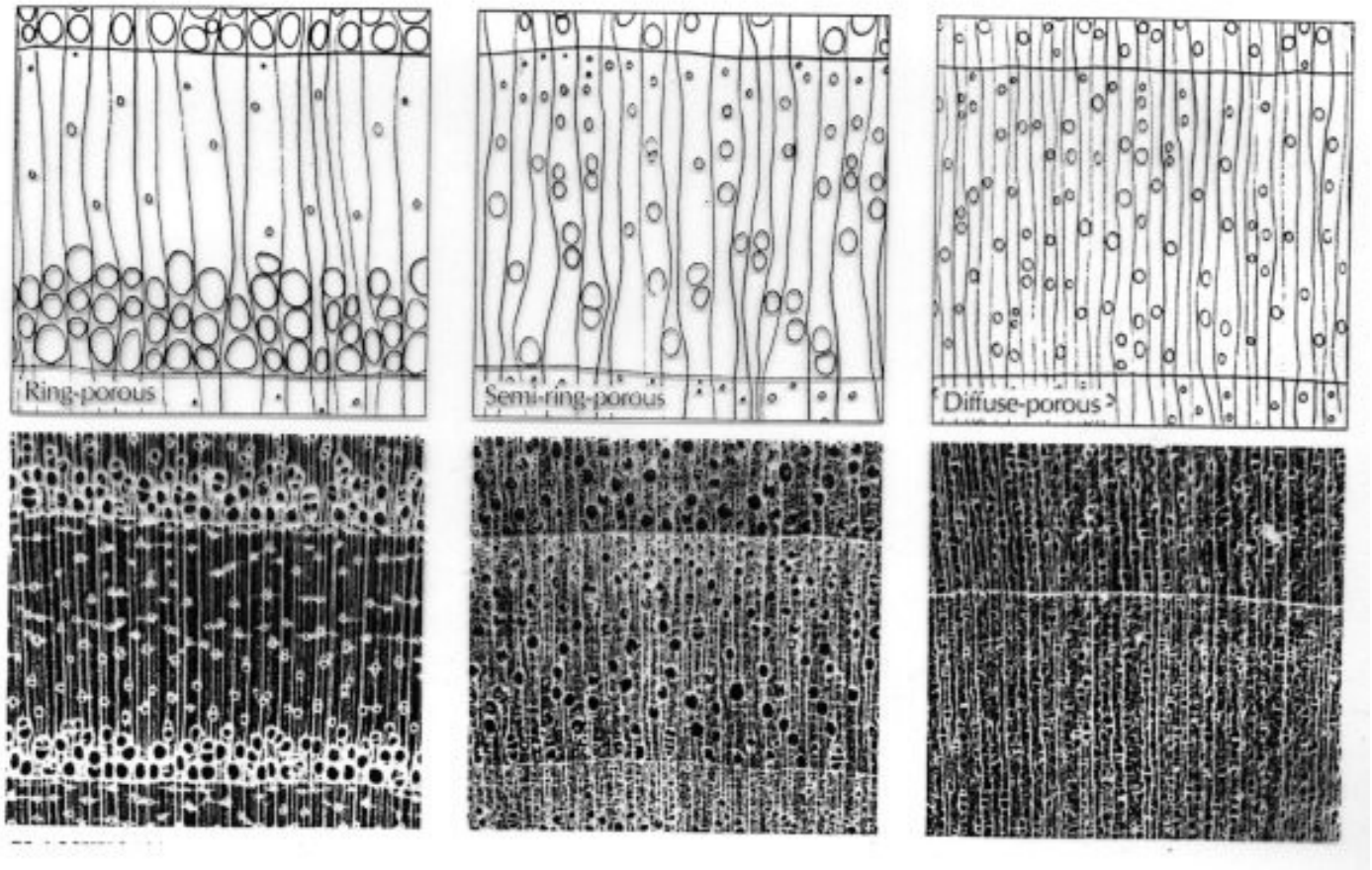
Vessels



Rozdělení dřev listnatých dřevin na skupiny podle uspořádání a typu cév na P řezu

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Vessels

Oak groups in the Northern America

TABLE 10.1: SOME MAJOR SPECIES OF THE RED OAK AND WHITE OAK GROUPS *(QUERCUS)*

Red Oak Group		White Oak Group	
Q. coccinea	Scarlet oak	*Q. alba*	White oak
Q. falcata	Southern red oak	*Q. bicolor*	Swamp white oak
Q. kelloggii	California black oak	*Q. garryana*	Oregon white oak
Q. palustris	Pin oak	*Q. lyrata*	Overcup oak
Q. rubra	Northern red oak	*Q. macrocarpa*	Bur oak
Q. velutina	Black oak	*Q. petraea*	Sessile oak
		Q. prinus	Chestnut oak
		Q. robur	European oak
		Q. stellata	Post oak

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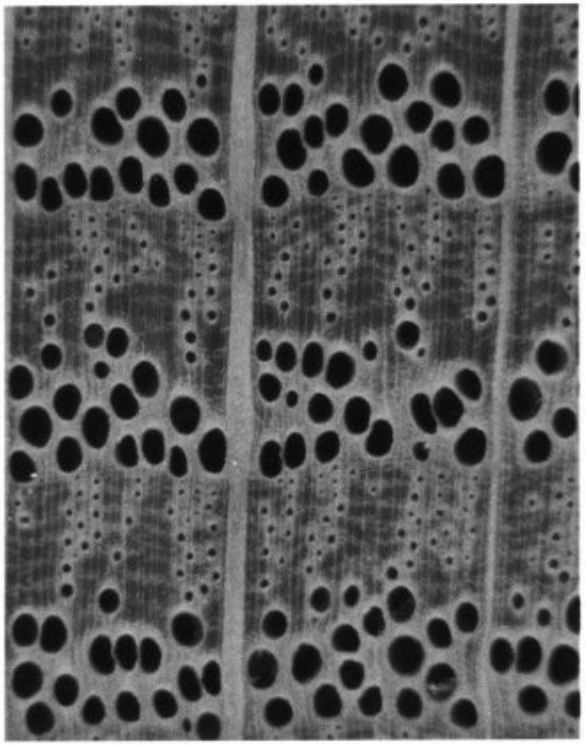
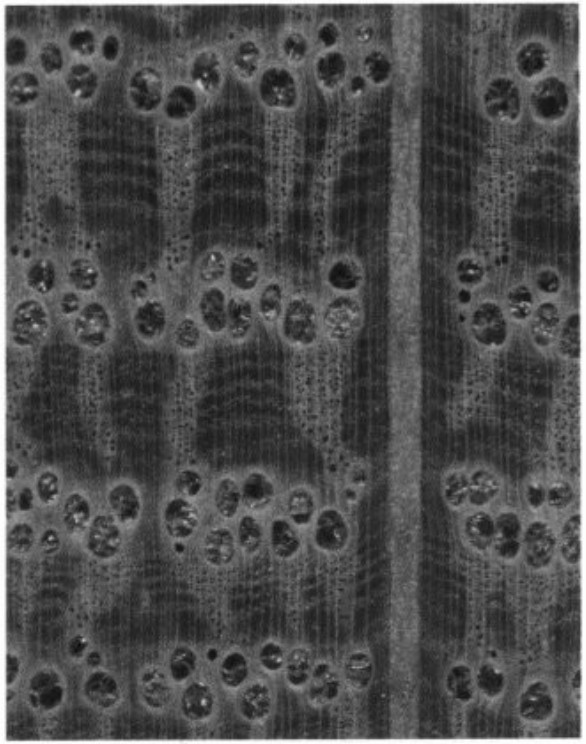
Vessel elements

RED OAK AND WHITE OAK

The oaks are recognized by their ring-porous arrangement and extremely large rays. When viewed with a hand lens, a transverse surface of red oak has fewer distinct latewood pores, as compared to the numerous, indistinct latewood pores in white oaks. Tyloses are usually abundant in white oak heartwood, sparse to absent in red oaks.



NORTHERN RED OAK



WHITE OAK

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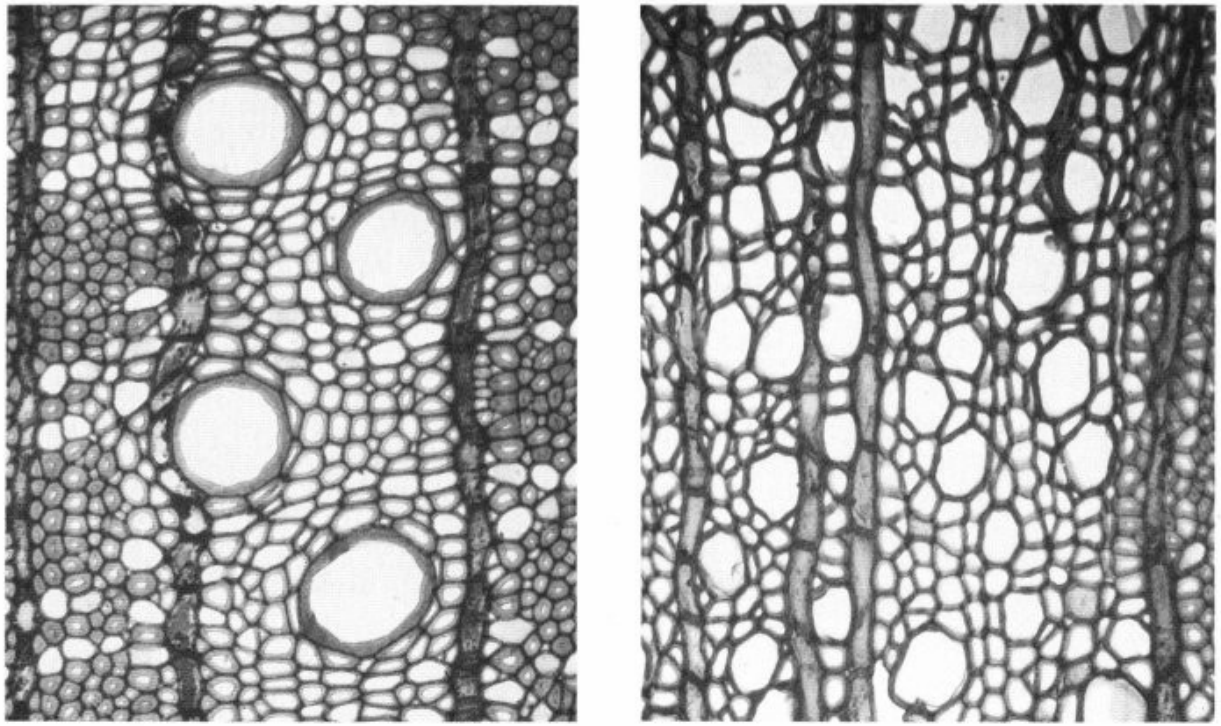
Vessel elements

LATEWOOD PORES IN OAKS

In red oaks (left), latewood pores are solitary, with thick walls. In white oaks (right), the smaller, more numerous latewood pores have thin walls and may occur in multiples. (125x)



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Vessel elements

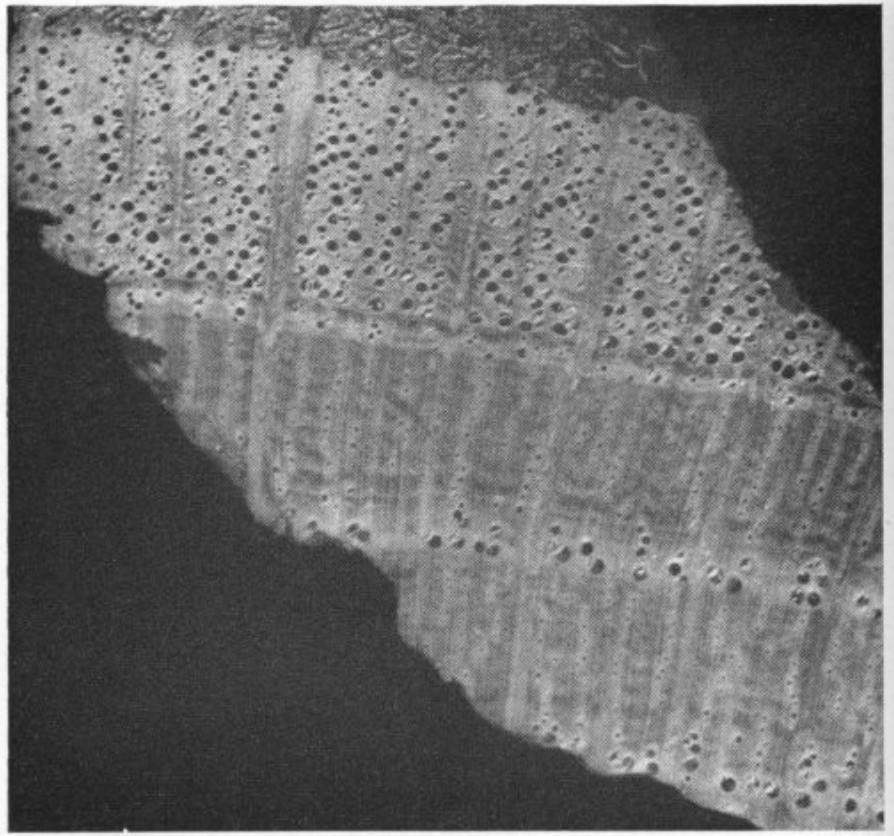

Fig. 102.—An Oak, ? Turkey Oak (*Quercus cerris*); a small piece of transverse surface showing apparent change in structure from ring porous to diffuse porous wood. In fact, the lower two growth rings are relatively wide, the wood being fairly fast grown; the upper apparent ring is about twenty rings of very slow grown wood, in which late-wood is, virtually, non-existent (× about 8).

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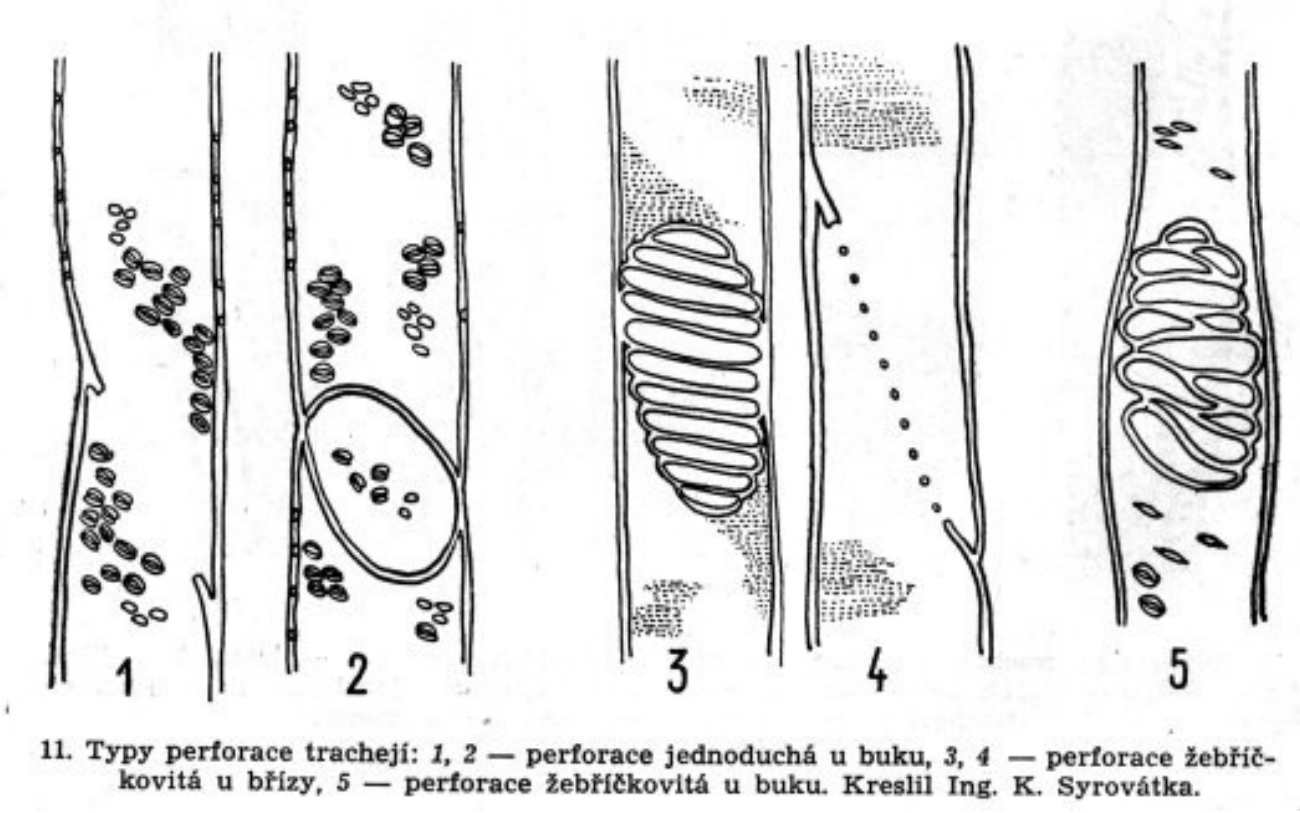
Vessel elements



11. Typy perforace trachejí: *1, 2* — perforace jednoduchá u buku, *3, 4* — perforace žebříčkovitá u břízy, *5* — perforace žebříčkovitá u buku. Kreslil Ing. K. Syrovátka.

Types of vessel perforations

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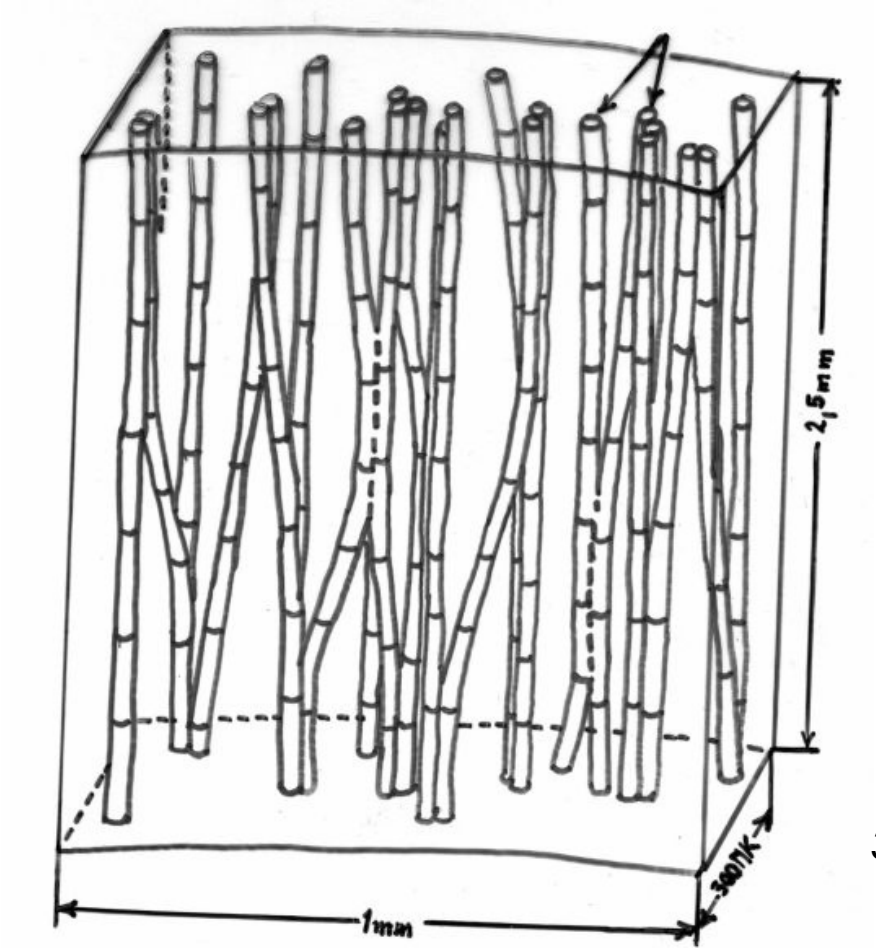
Vessel elements



3D structure of vessels in wood of Populus

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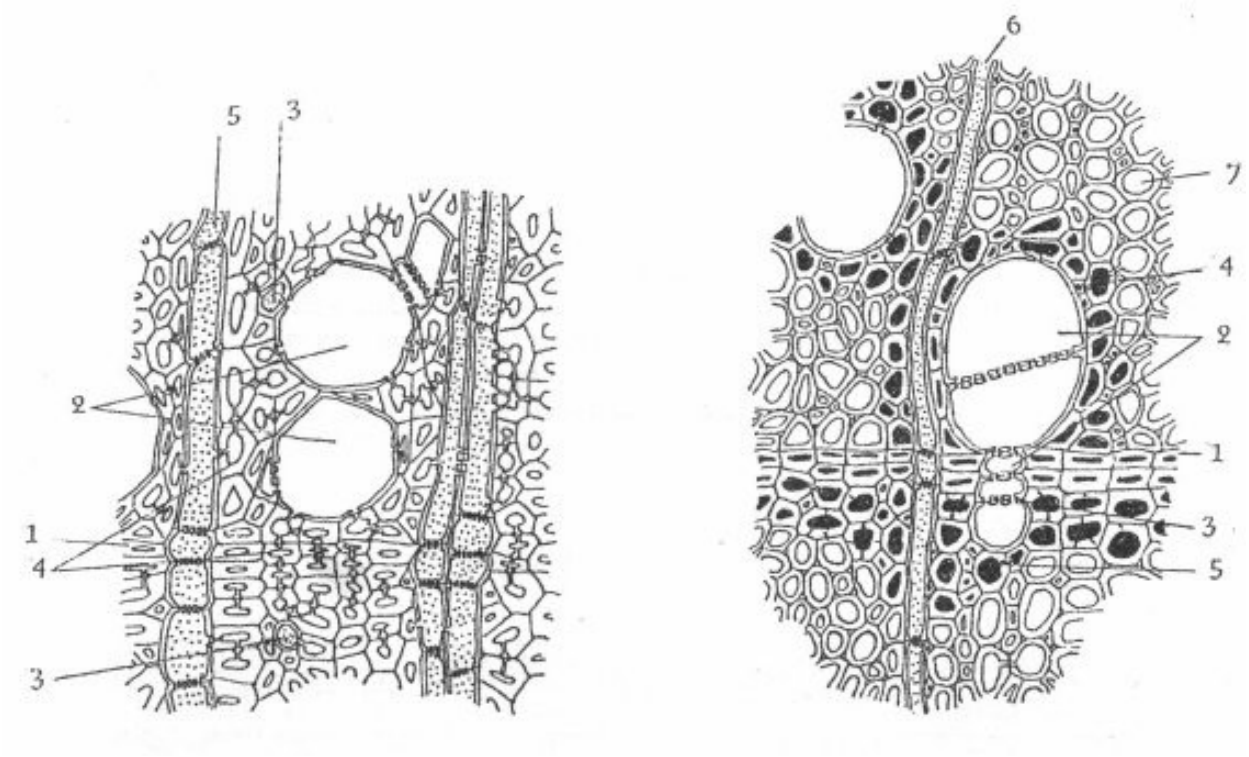
Vessel elements



Nepropojené (vlevo) a propojené (vpravo) cévy na hranici letokruhu u dřeva BK a JV

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Vessel elements

Pitting of the cell wall of vessels

- type of pits: bordered pit without torus
- size:
  - very small (< 4 μm): birch
  - small (4–7 μm): alder
  - medium (7–10 μm): hornbeam
  - big (> 10 μm): chestnut

- number of pits per 1 mm^2 of vessel cell wall:
  - non-numerous (n < 10): exotic woods
  - numerous (n = 10–20): exotic woods
  - very numerous (n > 20): the most of European species

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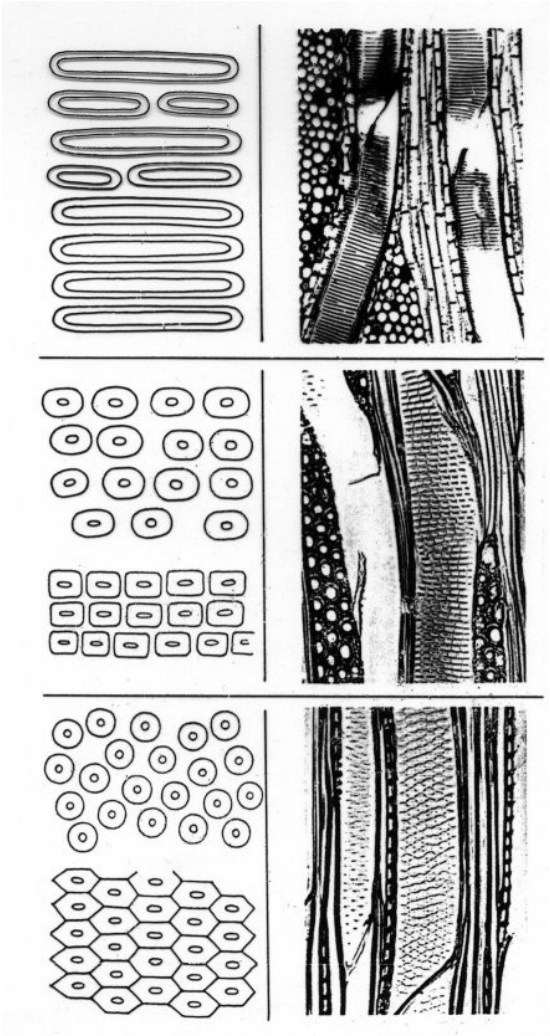
Vessel elements



Types of pitting

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Vessel elements

Thyloses – parenchyma cells that grew into lumina of vessels

- types:
  - thin-walled, i. e. living
  - thick-walled, i. e. dead
- presence: in ring-porous hardwoods and in walnut, beech, ...

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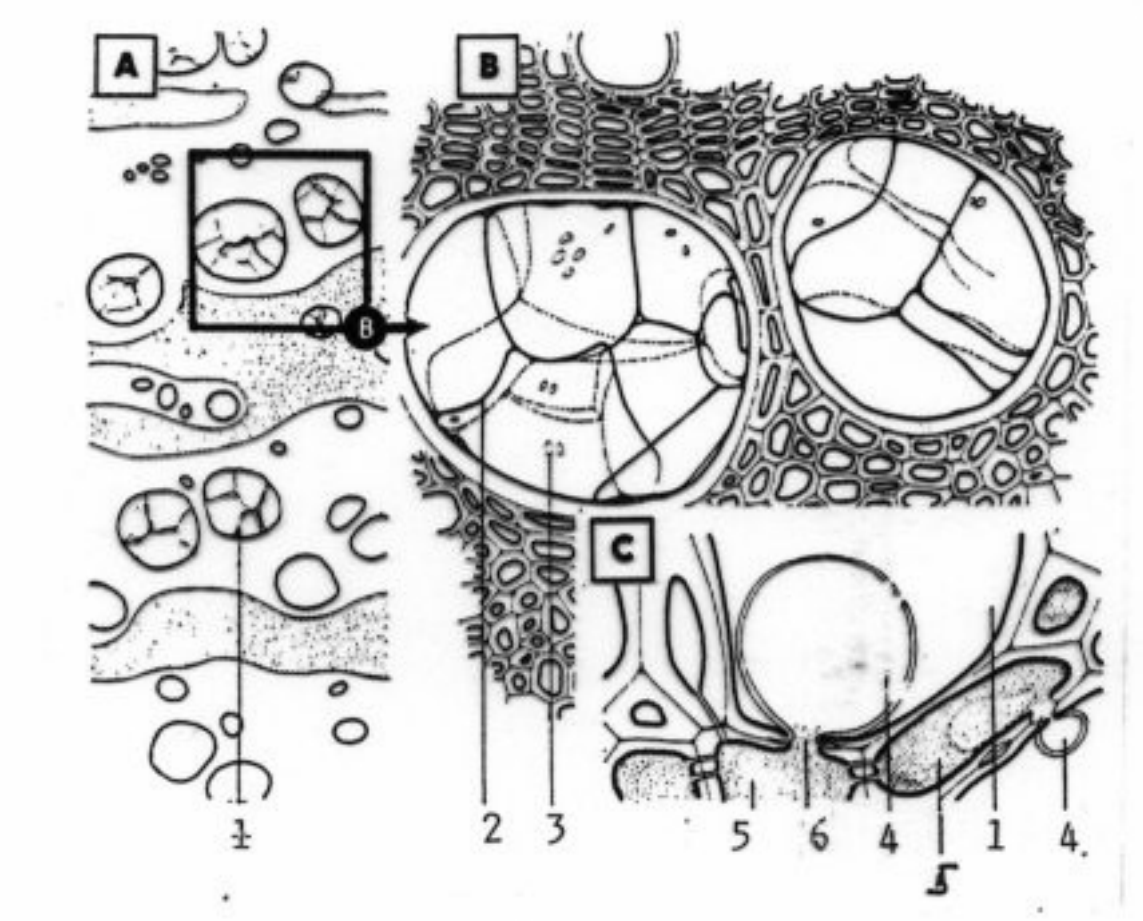
Vessel elements



Thyloses in vessels (Robinia pseudoaccacia)

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Vessel elements

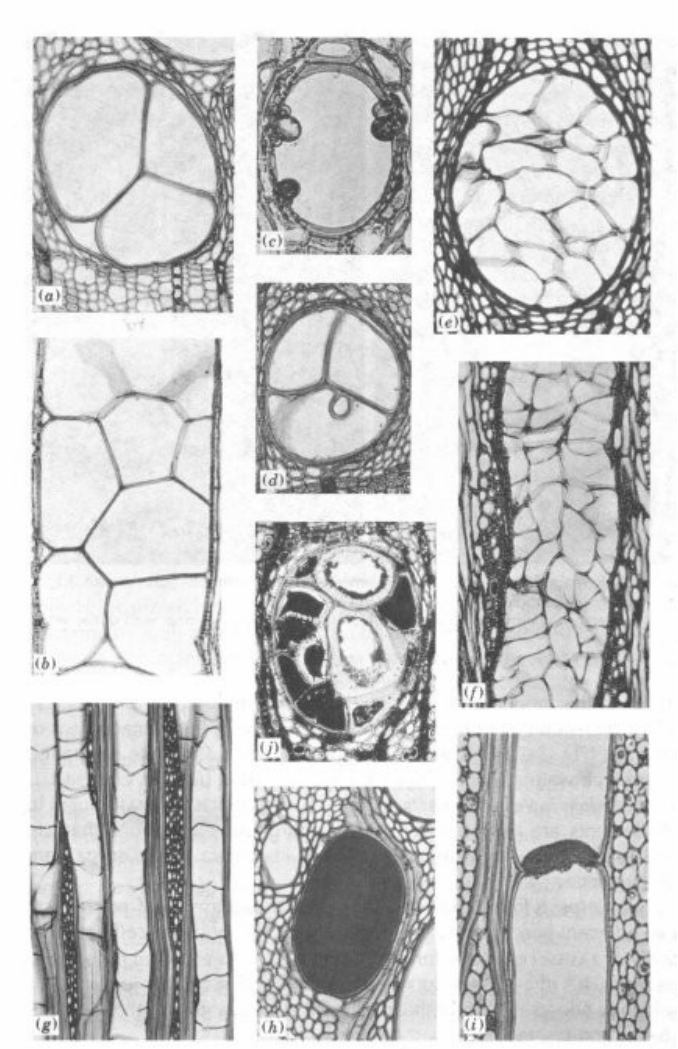

Figure 5-8 Inclusions in the vessels of hardwoods.
(*a*) Tyloses in an early-wood pore of post oak (*Quercus stellata* Wangenh.); walls somewha thickened. (115×)
(*b*) Portion of an early-wood vessel element (*t*) of post oak (*Q. stellata* Wangenh.) showin contiguous tyloses in lateral view. (115×)
(*c*) Tyloses in the bud stage in a late-wood pore of live oak (*Q. virginiana* Mill.). (225×)
(*d*) Secondary tylosis bud forming on the wall of a tylosis in blue oak (*Q. douglasii* Hook. & Arn.). (115×)
(*e*) Thin-walled tyloses in an early-wood pore of black oak (*Q. velutina* Lam.). (115×)
(*f*) Portion of an early-wood vessel (*t*) of black locust (*Robinia pseudoacacia* L.) showin thin-walled tyloses in lateral view. (115×)
(*g*) Uniseriate rows of tyloses in the vessels of beech (*Fagus grandifolia* Ehrh.); the upper an lower walls (which are in contact) appear as nearly horizontal transverse partitions arranged i a ladder-like series. (115×)
(*h*) A pore of honeylocust (*Gleditsia triacanthos* L.) occluded with gum. (115×)
(*i*) A gum plug at the juncture of two vessel elements in large-leaved mahogany (*Swietenia macrophylla* King). (115×)
(*j*) Sclerosed, pitted tyloses, with dark contents, in a pore in Emory oak (*Quercus emoryi* Torr.) (115×)
[*Photographs (a) to (f), inclusive, by S. Williams.*]

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Libriform fibres

shape and orientation

- Long cells with closed endings
- Parallel to the stem axis
- 50-60 % of wood volume

function: mechanical support

types

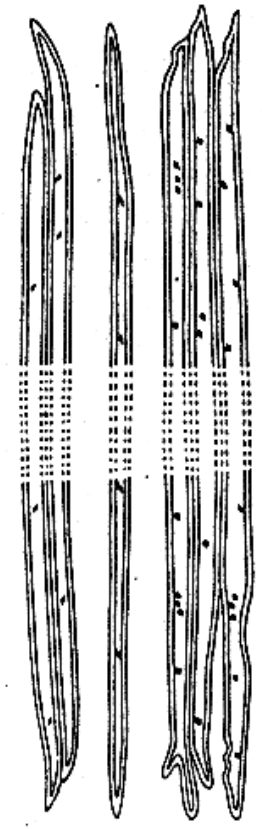
- length and thickness increase from e.w. to l.w.

dimensions

length: 0.2–2.2 mm

width: 15–50 μm

thickness of the cell-wall: 3–7 μm



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Tracheids

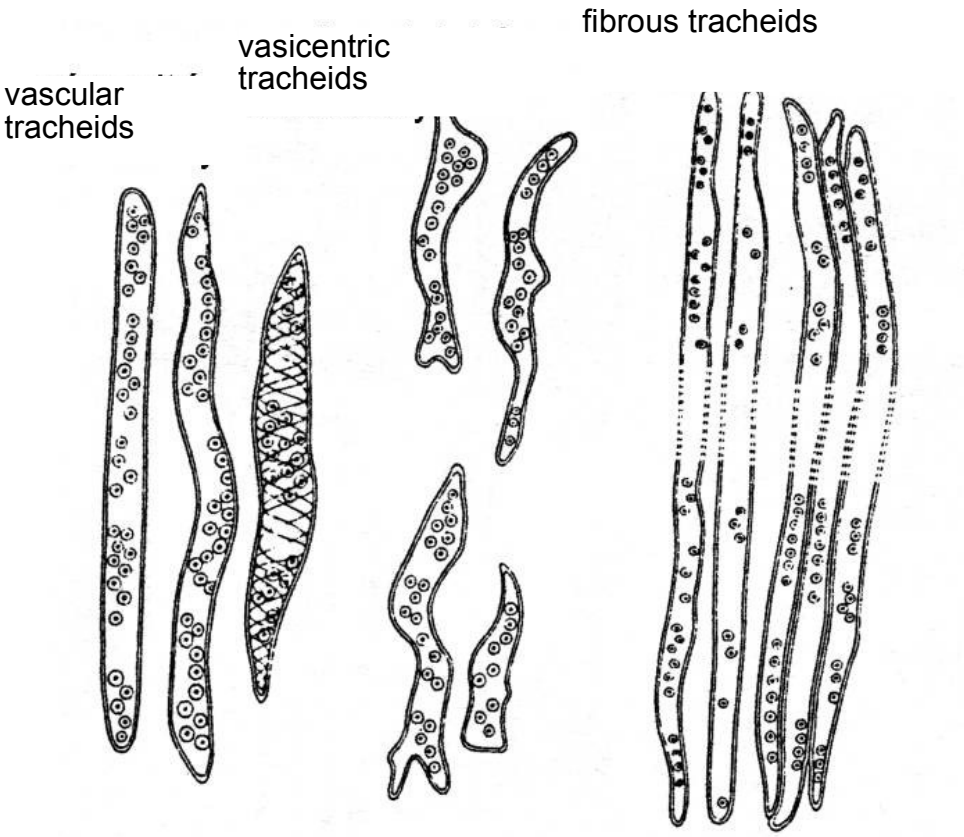
types:

- vascular
- vasicentric
- fibrous

function:

- water transport
- mechanical support

length: up to 0.5 mm



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Tracheids

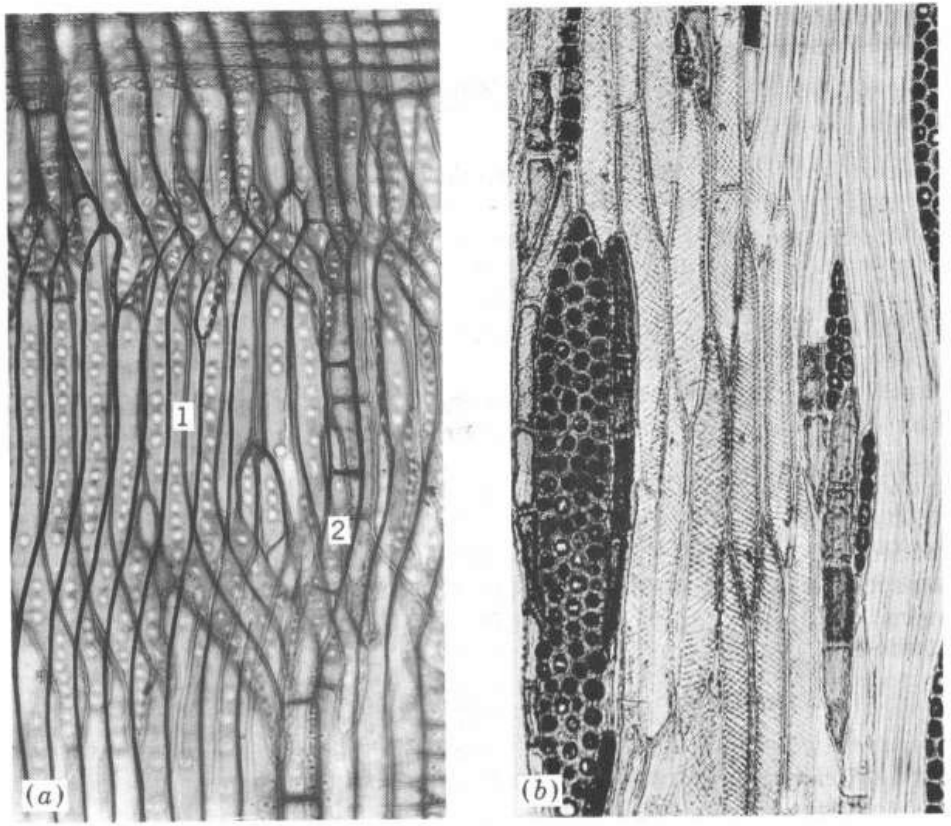


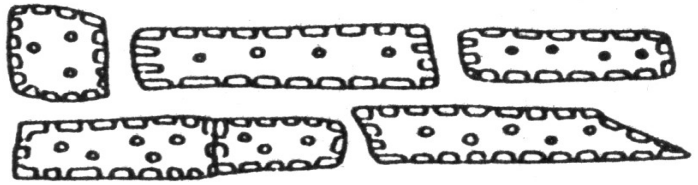
Figure 5-9 Vasicentric and vascular tracheids in hardwoods.
(a) Overlapping vasicentric tracheids with bordered pits (1) and a strand of longitudinal parenchyma (2), in chestnut [*Castanea dentata* (Marsh.) Borkh.] (*r*). (240×)
(*b*) Vascular tracheids with spiral thickening, which grade into small vessel members elsewhere in the wood. Slippery elm (*Ulmus rubra* Mühl.) (*t*). (160×)

Parenchyma cells

Shape

- rectangular or square-shaped or circle-like shape

amount: 8–35 % of wood volume



Parenchyma cells form:

- rays
- longitudinal parenchyma
- epithelial cells of resin canals
- thyloses and pith flecks

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Parenchyma cells

longitudinal parenchyma (up to: 20 % of wood volume)

orientation
Parallel to the stem axis

function
- food storageí

types
a) apotracheal
b) paratracheal
c) bounded

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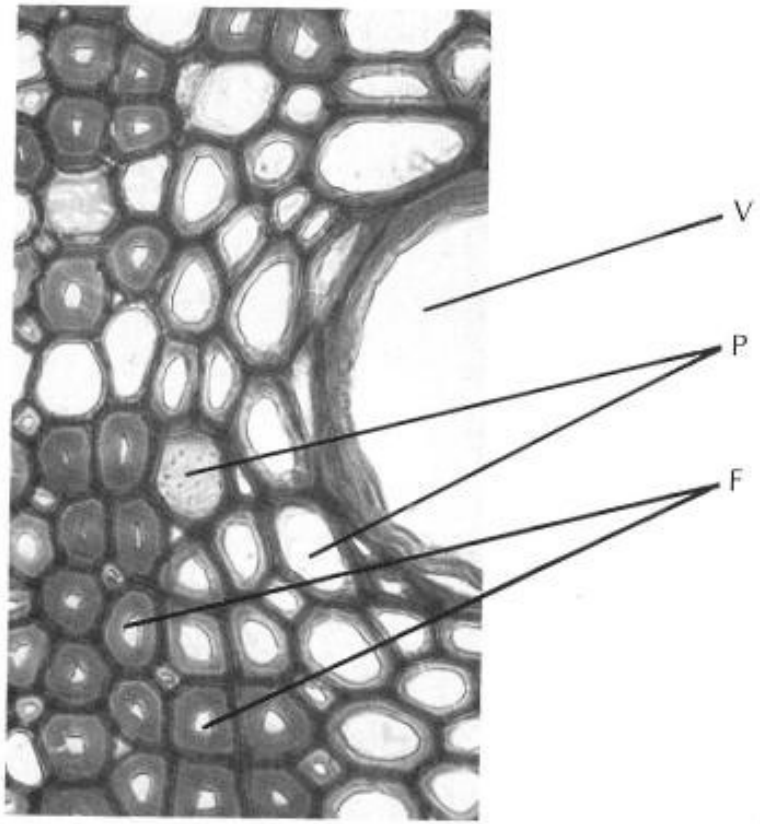
Parenchyma cells

Longitudinal parenchyma in transversal view



V – vessel

P – long. parenchyma

F – fibre

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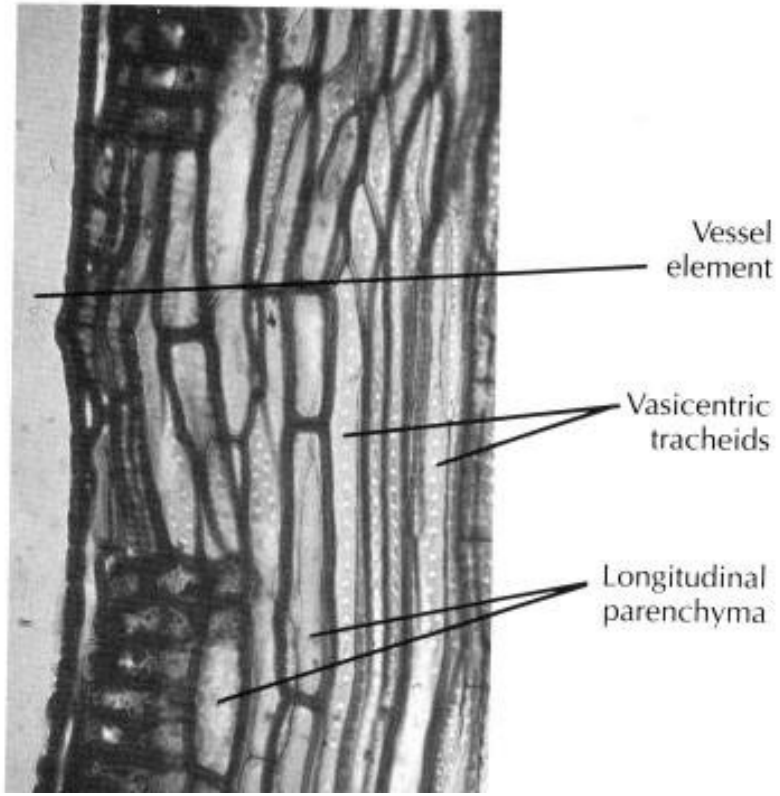
Parenchyma cells

Longitudinal parenchyma in tangential view



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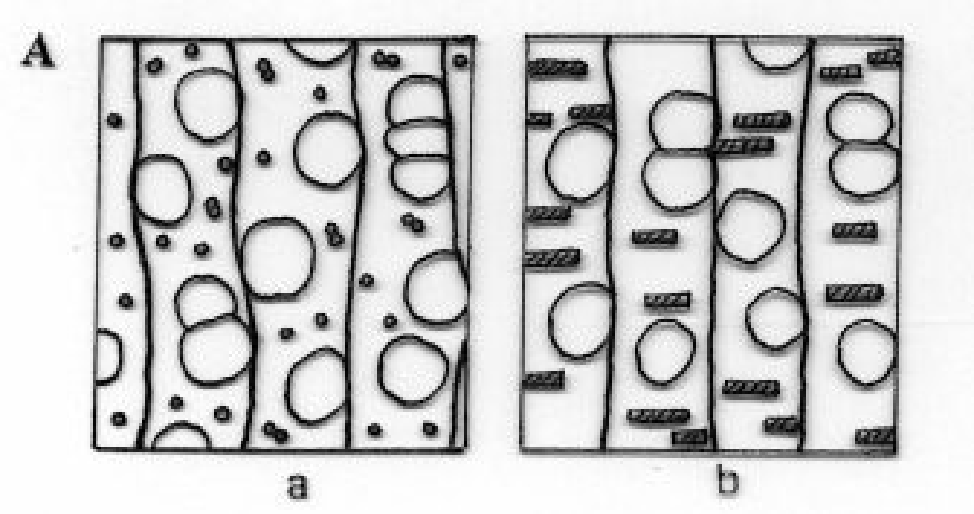
Parenchyma cells



JV, HB, HR

LP, HB, BK, OR

Axiální parenchym apotracheální difuzní (a) a rozptýleně nakupený (b)

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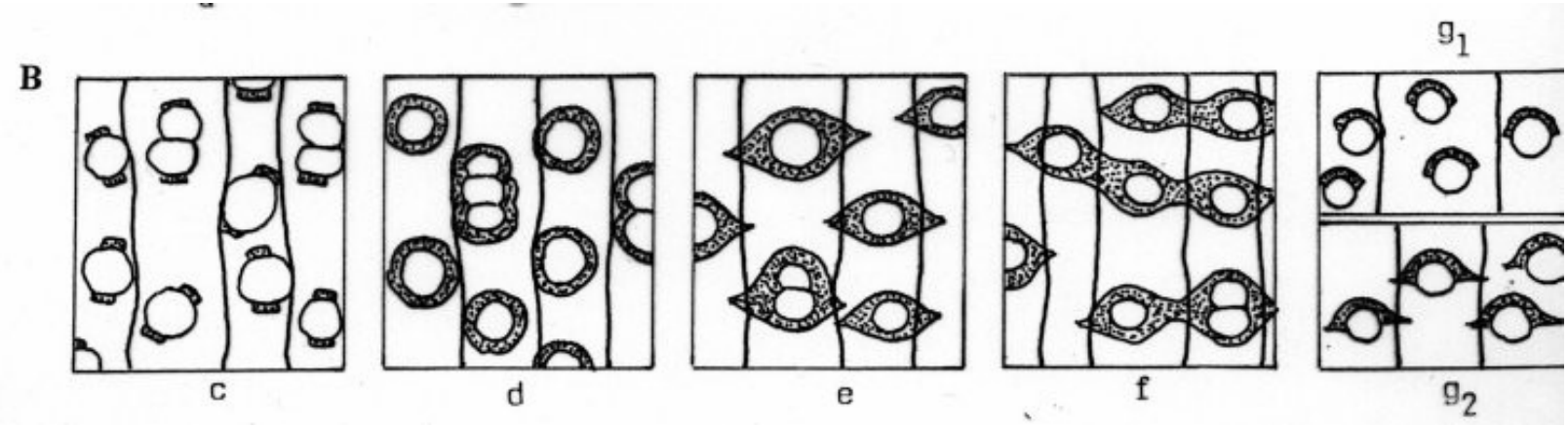
Parenchyma cells



PJ, TR, OR JS AK tropická dřeva

Axiální parenchym paratracheální skupinový (a), vazicentrický (b), vazicentrický křídlovitý (c), křídlovitě splývavý (f), jednostranně vazicentrický (g1) a jednostranně vazicentrický křídlovitý (g2)

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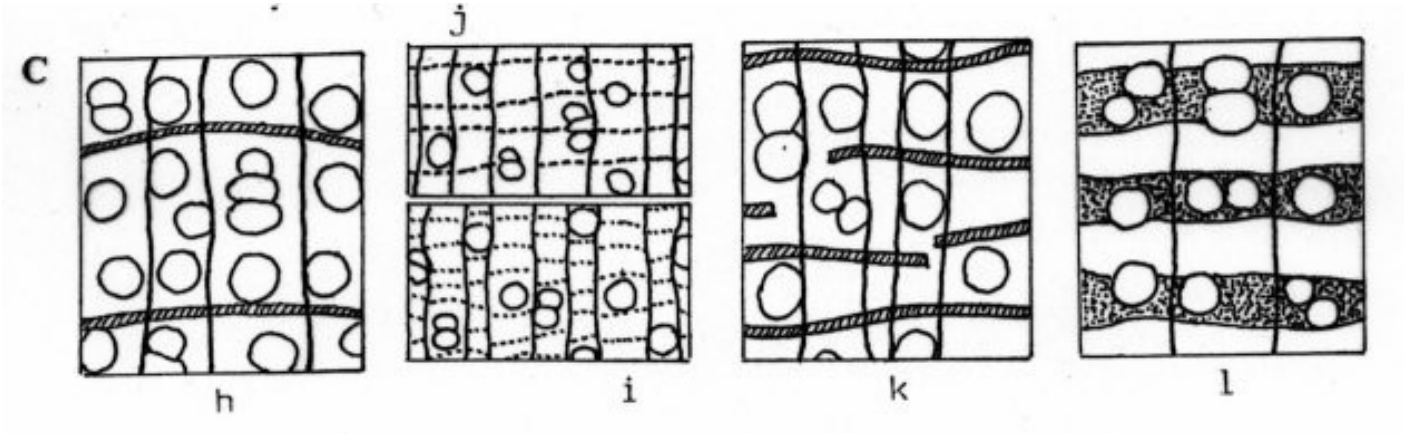
Parenchyma cells



JS, JM, MO DB, LP OR tropická dřeva

Axiální parenchym svazkový hraniční (h), tangenciálně síťovitý (j) a žebříčkovitý (i), koncentrický (k, l)

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Parenchyma cells

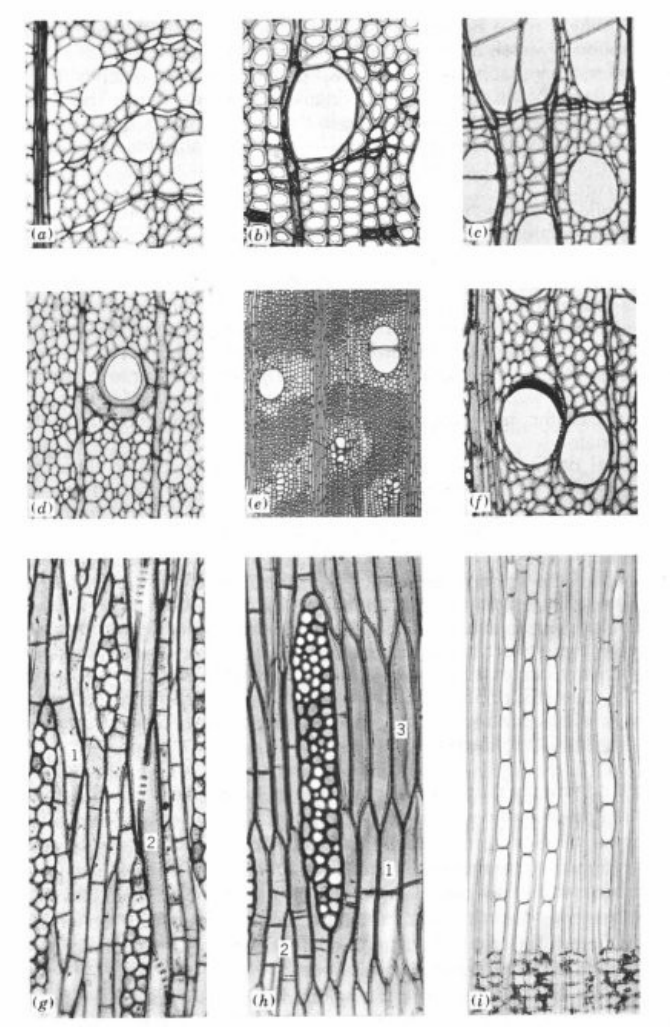

Figure 5-11 Longitudinal (axial) parenchyma in hardwoods.
(*a*) Longitudinal apotracheal-banded parenchyma (x) in basswood (*Tilia americana* L.). (150×)
(*b*) Longitudinal diffuse-in-aggregates parenchyma (dark cells) (x) in yellow birch (*Betula alleghaniensis* Britton). (150×)
(*c*) Marginal parenchyma (x) on the outer margin of an annual ring in eastern cottonwood (*Populus deltoides* Bartr.)
(*d*) Vasicentric paratracheal parenchyma (x) nearly encircling a late-wood pore in white ash (*Fraxinus americana* L.). (150×)
(e) Paratracheal confluent parenchyma (x) in honeylocust (*Gleditsia triacanthos* L.). (40×)
(*f*) Xylem tissue (x) devoid of axial parenchyma in black cherry (*Prunus serotina* Ehrh.). Axial parenchyma is extremely sparse in this wood. (150×)
(*g*) Strands of axial parenchyma (1), and a late-wood vessel (2), with scalariform perforation *plates, in lateral, tangential view*. [*Sassafras* albidum (Nutt.) Nees]. (150×)
(*h*) Strands of axial parenchyma composed of two (1) and four (2) units, and fusiform longitudinal parenchyma cells (3), in lateral, tangential view. Black locust (*Robinia pseudo-acacia* L.). (150×)
(*i*) Portions of a number of strands of axial parenchyma, separated by fibers, in lateral, radial view. Scarlet oak (*Quercus coccinea* Muenchh.). (150×)

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Parenchyma cells

rays

- strands of parenchyma cells in radial direction
- often living cells in sapwood

- orientation: perpendicular to the stem axis
- function: food storage, (water transport)
- amount: 10–20 % of wood volume
- types:
  - homogeneous – parenchyma cells of the same shape
  - heterogeneous – parenchyma cells of the differentshape
- seriation:
  - uniseriate, biseriate, ..., multiseriate

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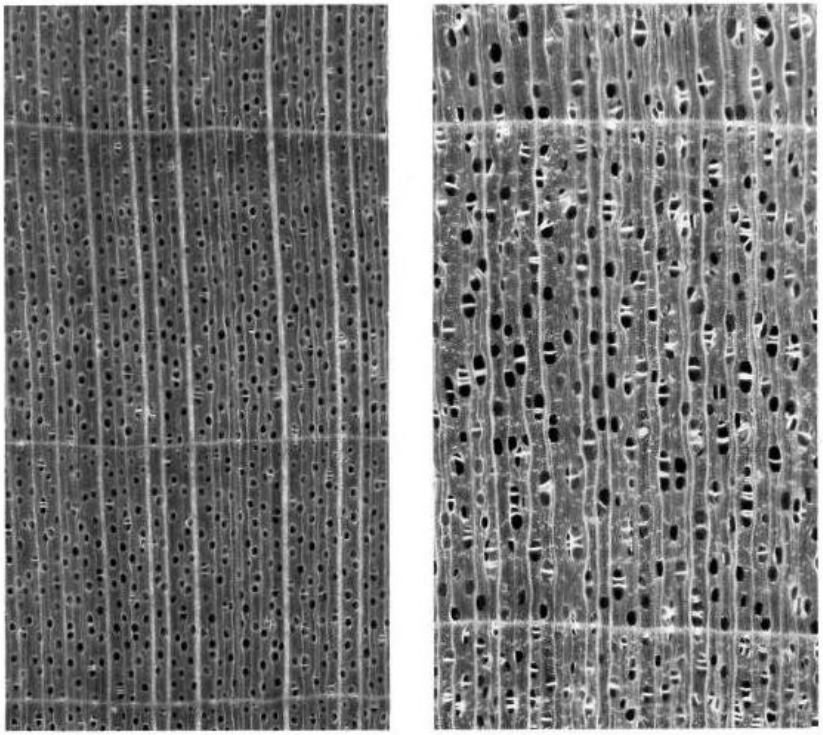
Parenchyma cells

Rays in transversal view

maple and birch



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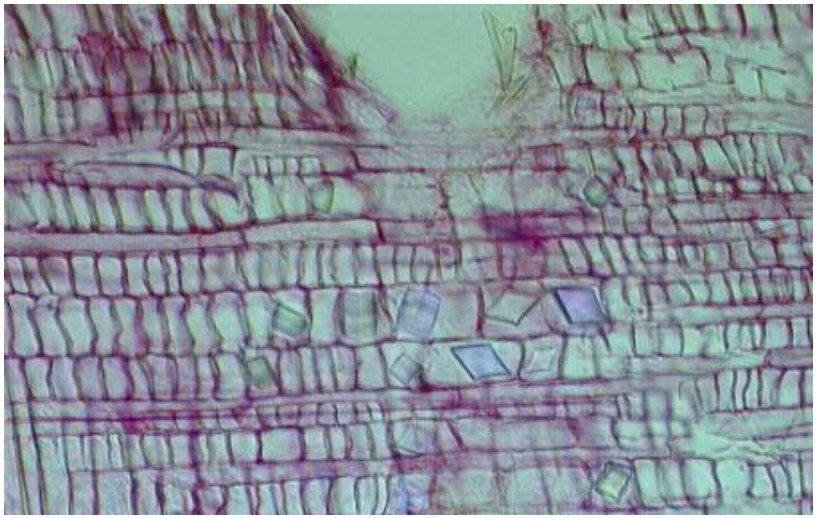
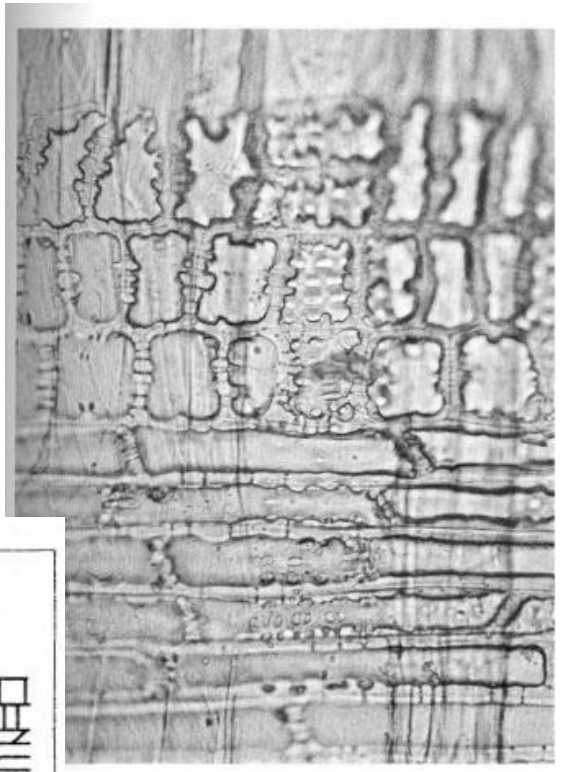
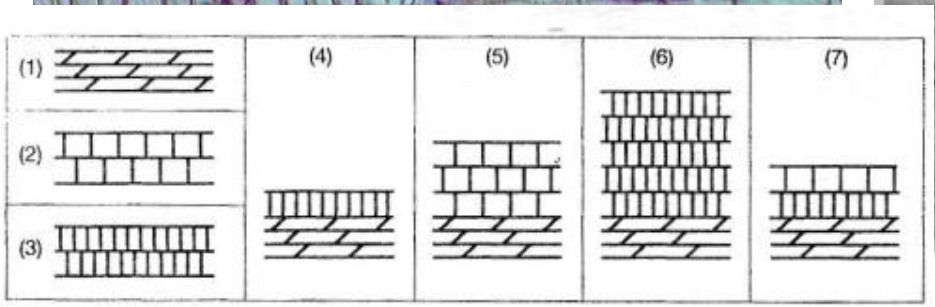
Parenchyma cells

Rays in radial view

- valuable for identification of ray type: *homogeneous* × *heterogeneous*







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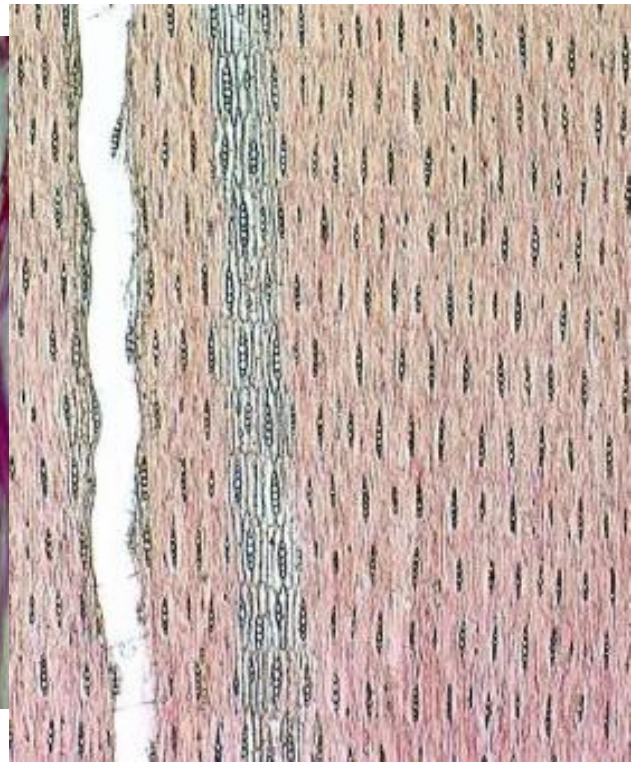
Parenchyma cells

Rays in tangential view

- valuable for identification of ray type: *homogeneous* × *heterogeneous*
- valuable for identification of seriation



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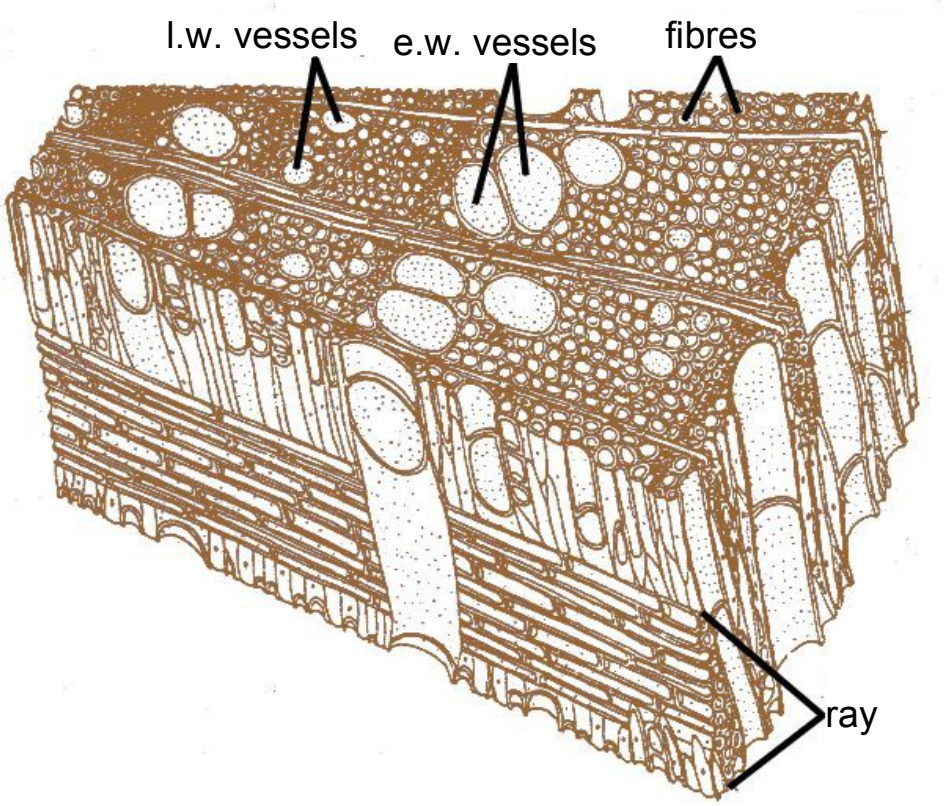
3D structure of hardwoods



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