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Introduction to the identification of archaeological charcoal

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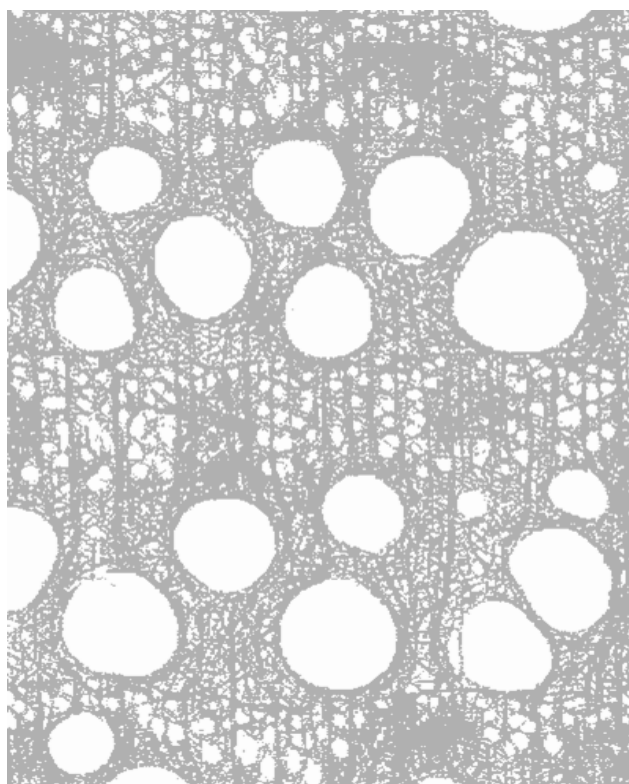
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Introduction to the identification of archaeological charcoal



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PREAMBLE

This guide was written as part of teaching (lectures and practical work) on charcoal analysis given as part of the Anatomical and taxonomic diversity in archaeobotany module (QPB22) in the [Quaternary, Prehistory and Bioarchaeology](#) course of the MNHN's BEE master's degree.

It aims to present the main criteria to be observed under the microscope in order to determine charcoal from reference collections and archaeological samples. The guide is aimed at students who are not biologists but who nevertheless have a basic knowledge of the development of woody tissues (for the MNHN, follow the QPB09, biology refresher course).

For any errors, comments or suggestions, please contact me by email [salavert\[at\]mnhn.fr](mailto:salavert[at]mnhn.fr)

Most of the photographs are taken from the following website:

<http://www.woodanatomy.ch>

1. INTRODUCTION

Wood combines a longitudinal and transversal system. To observe wood anatomy, anthracologists make manual cuts in wood/charcoal fragment in three cutting sections (transverse, longitudinal tangential, longitudinal radial). **Each plane provides information on a given anatomical element and allows the identification of the taxon¹.** The identification is performed under a reflection light microscope with magnifications ranging from X50 to X1000. The anthracologist/xylologist uses identification atlases² corresponding to the region in which he works and a reference collection of modern charcoal.

This document is an introduction to wood identification. The taxonomic identification range most often reaches the genus (e.g., *Salix* sp., *Acacia* sp., *Acer* sp., *Quercus* sp.), sometimes the grouping of species (e.g., *Prunus* type *avium/padus*; *Quercus* deciduous or evergreen), or, more rarely, the species. Sometimes, only the subfamily can be proposed (e.g., Maloideae/Maleae).

The guide is organised by major taxonomic group (Gymnosperms/Angiosperms), by type of element (main and secondary) and then by type of tissue/cell.

¹ Any unit (genus, family, species, subspecies, etc.) of hierarchical classifications of living things.

² Book that gathers the main woody species that can potentially be identified in a given region. The description and photographs of the three observation sections (transverse, longitudinal tangential and radial) are presented. In general, a identification key based on various discriminating anatomical criteria allows a preliminary identification of the species. Atlases are not available for all regions of the world, particularly tropical areas.

2. GYMNOSPERMS

Gymnosperm wood has a homogeneous appearance, because the wood is formed essentially of **tracheids** which form the main mass of the wood and ensure both the support and the conduction of raw sap. In addition to tracheids, all gymnosperms are composed of **horizontal parenchyma** (rays). There are no vessels in gymnosperms (figure 1).

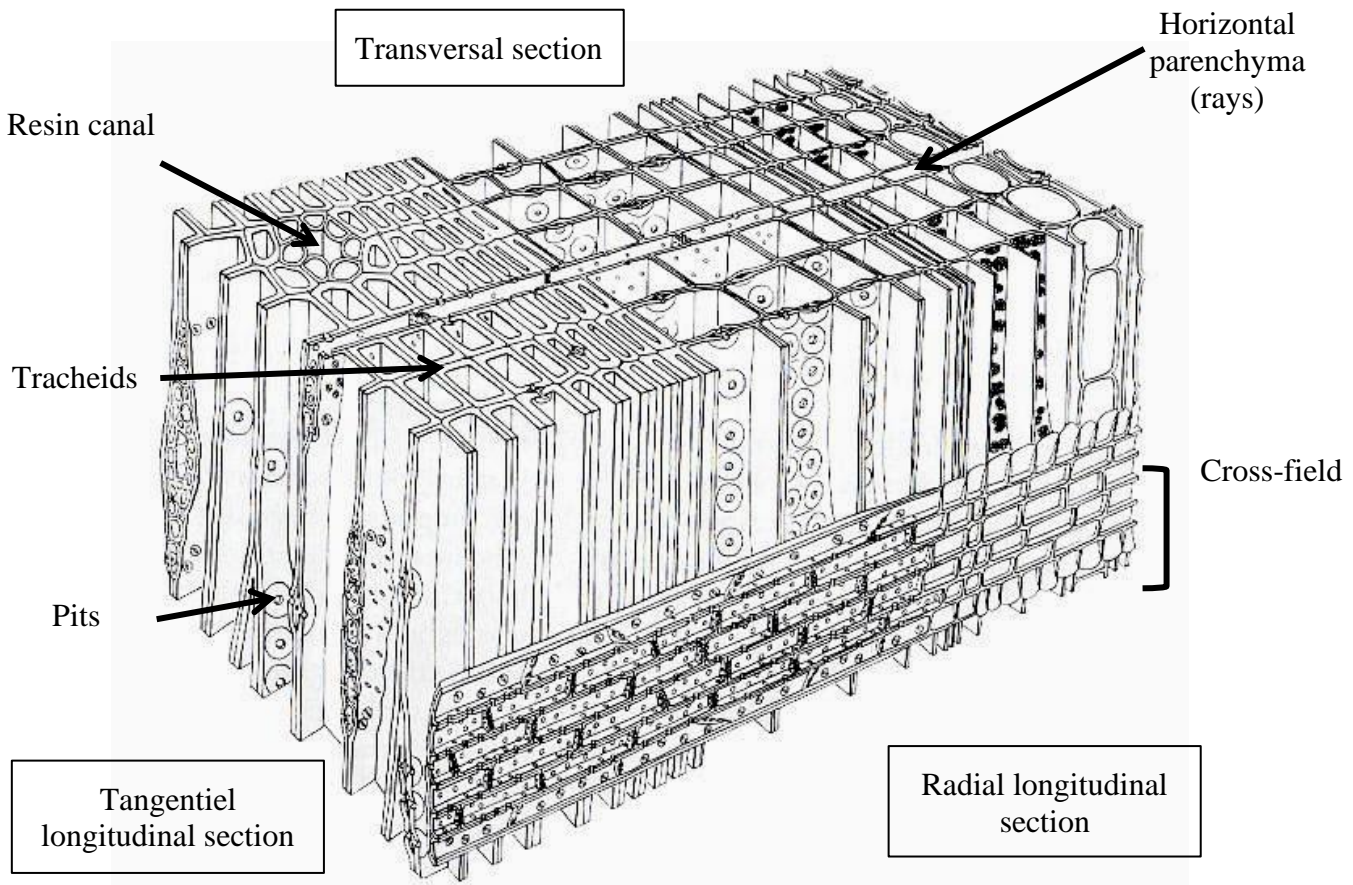


Figure 1 Main cells observed on the three observation planes of a homoxylate wood (gymnosperm).

2.1 TRACHEIDS

Tracheids constitute 90-95% of gymnosperm wood cells. The thickness of the tracheid walls is variable. The transition between initial and final wood of the same year can be abrupt (clearly visible to the naked eye) or not very visible. This is due to the marked contrast between tracheids formed early in the growing season (spring, thin wall, wide cavity/lumen) and those formed late in the season (summer, thick to very thick wall, narrow cavity/lumen).

The transition between **initial and final wood** (abrupt or continuous) is observed in *transversal section* (figure 2).

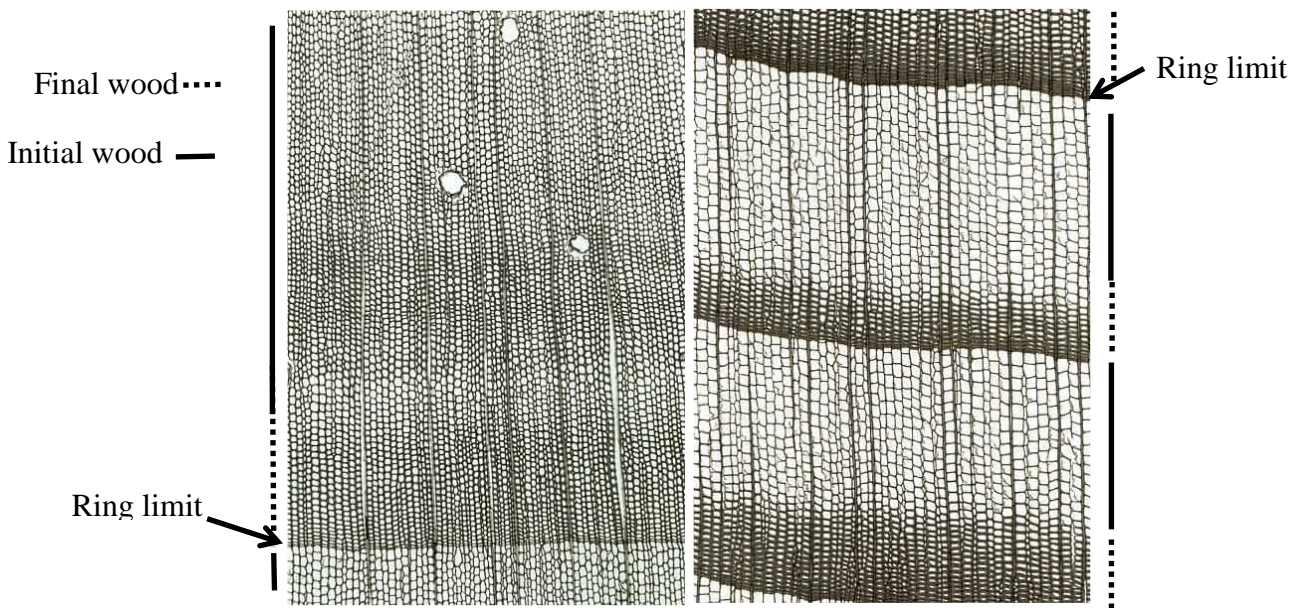


Figure 2 On the left, *Pinus sylvestris* transversal section (TS), transition is continuous, on the right, *Abies alba* TS, transition is abrupt.

Tracheids communicate laterally with each other by **simple areolated pits** that allow the circulation of sap from one tracheid cell to another (figure 3). **Pits in crossing fields**⁴ (ray/tracheid intersections) allow the sap circulation from tracheids to rays (parenchyma cells).

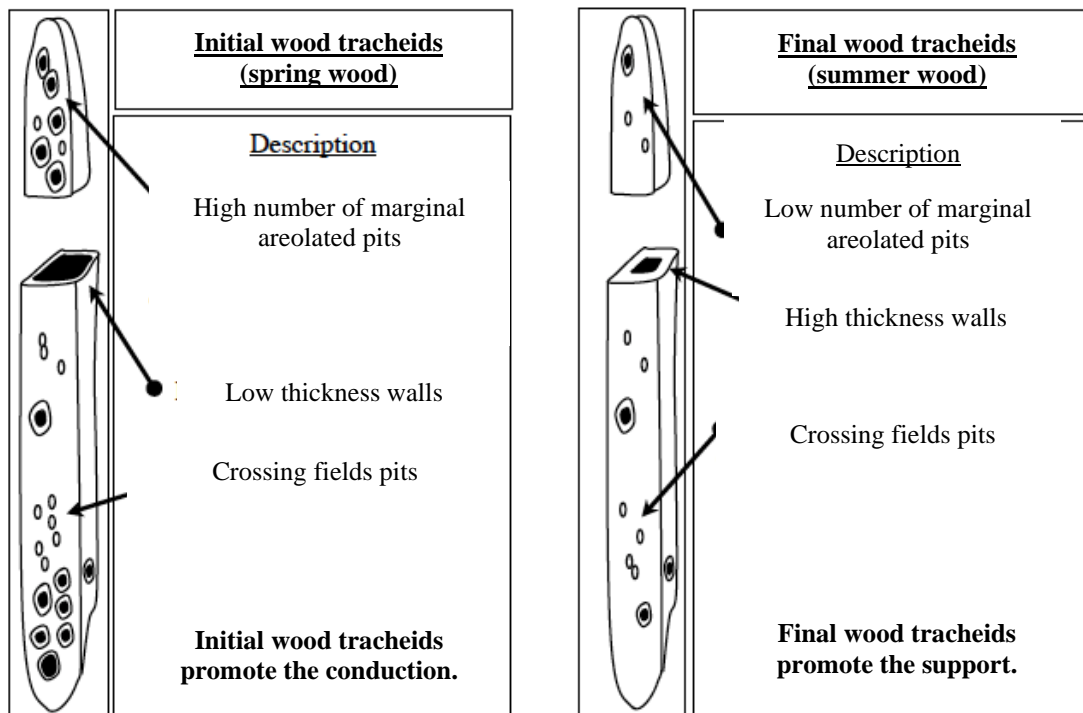
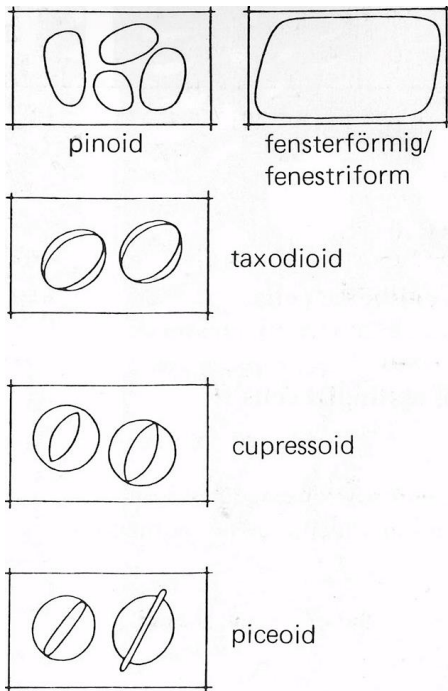


Figure 3 Transverse and longitudinal views of tracheids in initial and final wood (unknown source).

⁴ In gymnosperms, this is the intersection of tracheids with the ray (parenchyma) cells; in angiosperms, the appropriate term is "ray/vessel intersection".



Cross-fields pits are important characters to determine gymnosperm wood genus but difficult to look at, especially in archaeological charcoal/wood.

Their type (**dimension, number per crossing field, shape**) are visible in high magnification (>x500) in *radial longitudinal* section.

Figure 4- Main type of cross-field pits (Schweingruber 1990).

2.2 HORIZONTAL PARENCHYMA

The horizontal parenchyma, or **ray**, is involved in the storage of nutrient reserves in gymnosperms.

Diagnostic elements of the rays are mainly observable on the *tangential longitudinal section*. **Ray width** is generally of one cell (uniseriate rays), sometimes of two cells (biseriate rays) in tangential section (figure 5). Their height can vary from 1 to 40 cells, sometimes more. Homogeneous rays are only composed of parenchyma cells. Heterogeneous rays have additional elements as transverse tracheids or resin ducts

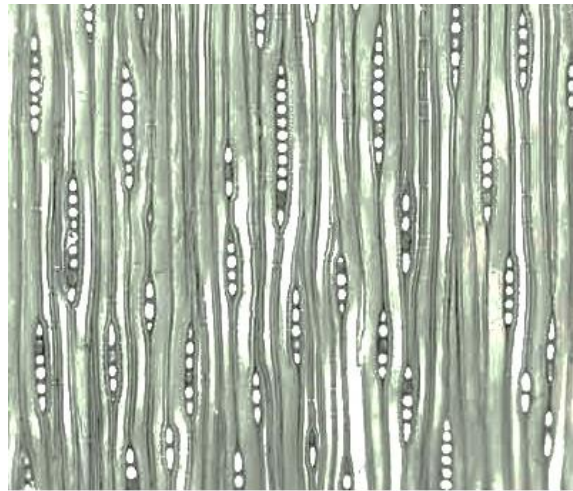


Figure 5 Homogeneous rays and uniseriate of *Abies alba* (fir).

2.3 SECONDARY ELEMENTS

Other elements are not systematically present in gymnosperms wood (figure 6). Their absence/presence can be of great help to identify the genus.

- Presence/absence of **axial resin ducts**, visible in *transverse, longitudinal tangential and radial sections*.
- Presence/absence of **spiral thickenings** that are helical type reinforcements of the internal wall of the tracheids. They are visible in *both longitudinal sections*.

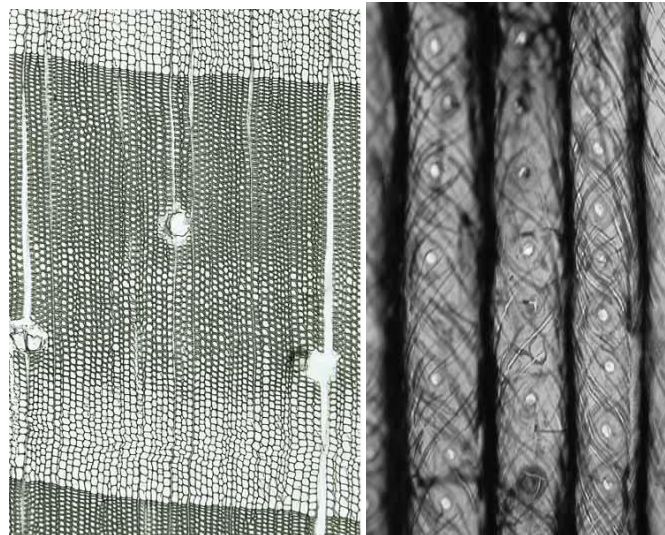
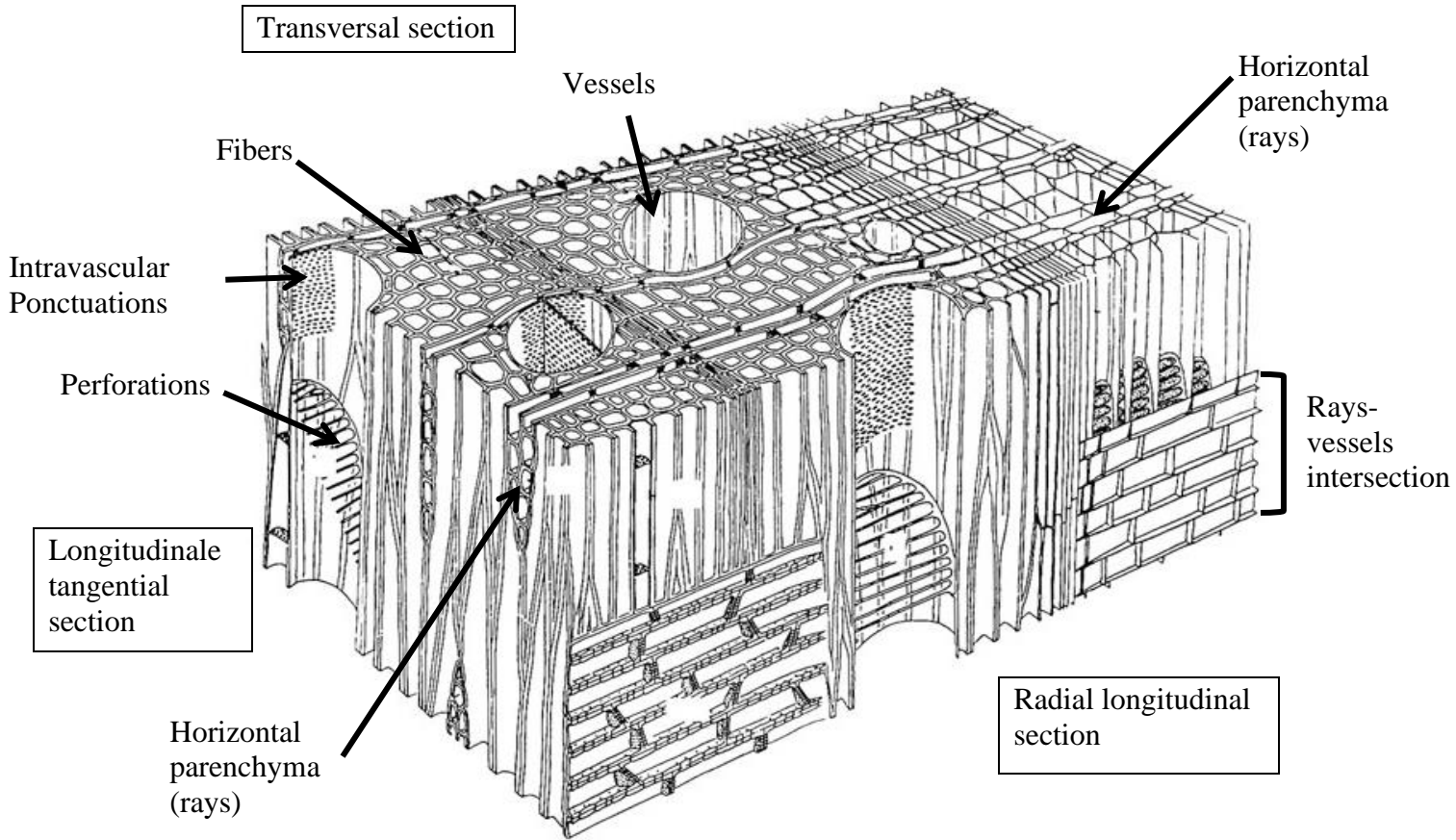


Figure 6 Secondary elements in gymnosperms. On the left, in tangential section of *Pinus sylvestris* (pine), resin ducts are visible in final wood; on the right, spiral thickenings are visible in longitudinal sections in *Taxus baccata* (yew).

3. ANGIOSPERMS

The woody of angiosperms is heterogeneous, complex and very diversified depending on the species. It is composed of four main types of cells: **vessels**, **fibers**, **horizontal parenchyma** (ray) and **longitudinal parenchyma**.



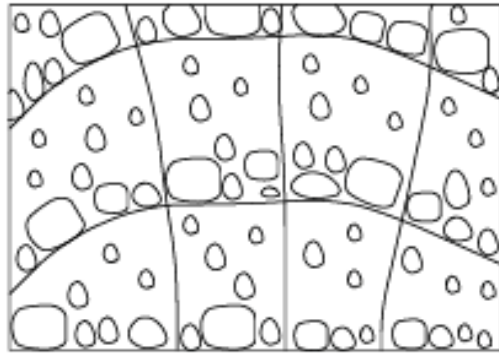
3.1 Vessels

These hollow cells serve to conduct raw sap from the roots up to the leaves. The vessels occupy 5 to 30% of the wood and sometimes contain various deposits such as starch, tannin, resins, crystals and thylls.

The three elements to observe are:

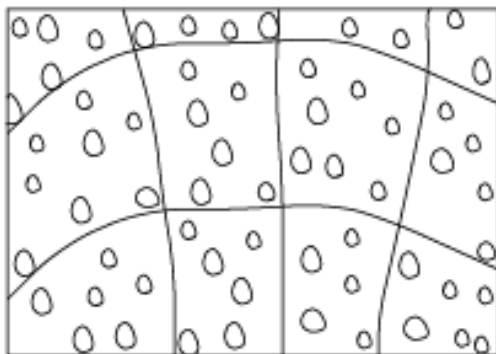
(a) **Size, arrangement, and number of vessels**⁵, in *transversal section* allows a first classification into two groups: porous woods and diffuse to semi-porous (or semi-ring) woods. This is the first entry in identification keys: porous wood and semi-ring to diffuse wood (figure 7).

⁵ We also talk about pores.



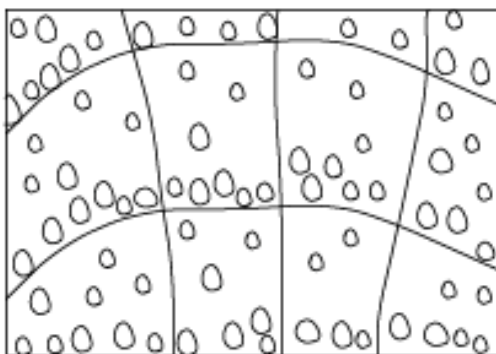
Bois à zone poreuse

Porous wood: vessels in the initial wood are much larger in diameter than those in the final wood (ex: *Quercus*, *Fagus*, *Fraxinus*).



Bois à pores diffus

Diffuse wood: distribution of vessels in the annual rings is uniform and vessels have the same diameter (ex: *Betula*, *Populus*, *Acer*).



Bois à zone semi-poreuse

Semi-ring porous wood: vessels have the same diameter throughout the annual ring but are more abundant in the initial wood (ex: *Prunus avium*).

Figure 7 Different wood porosities (drawing: AS).

(b) Perforations at each vessel elements extremity ensure conduction (figure 8). These perforations, visible in both longitudinal sections, can be simple or scalariform (the number of bars is a diagnostic criterion).

(c) Deux types of punctuations can be observed:

Inter-vessel punctuations promote exchanges between joined vessel elements. Some of them may be diagnostic. For example, the punctuations of birch (*Betula*) are very small and numerous. Moreover, their arrangement - alternating or opposite - can also guide the identification (Figure 9).

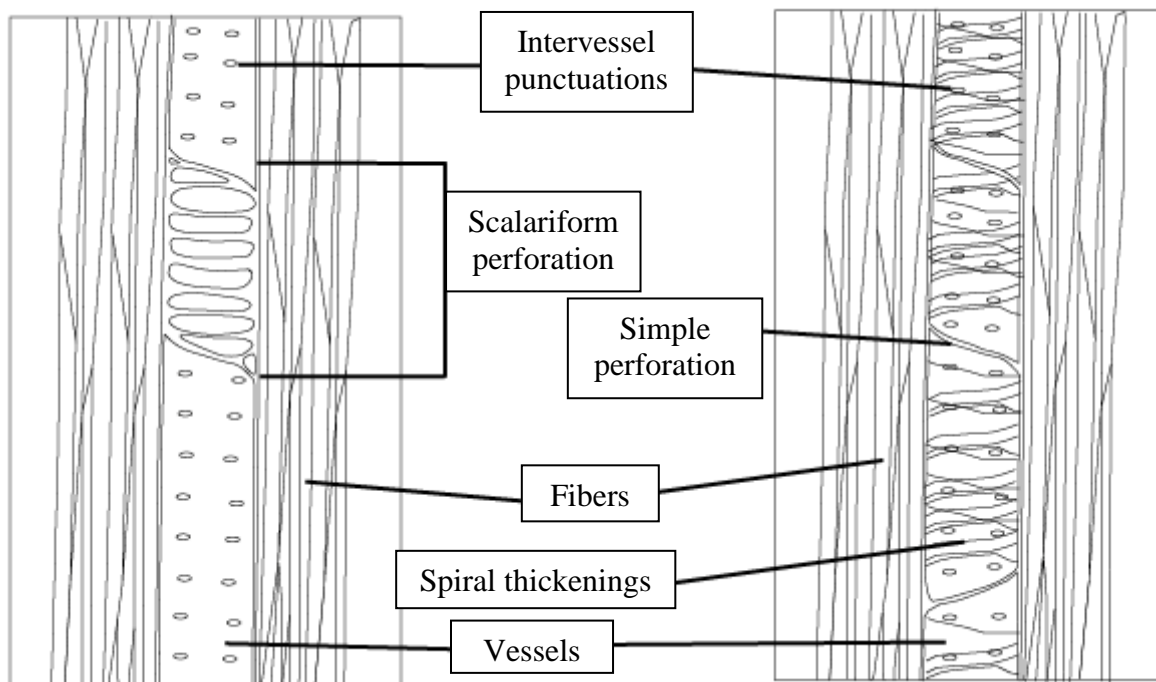


Figure 8 Schema of a vessel in longitudinal with main elements to look at (drawing: AS).

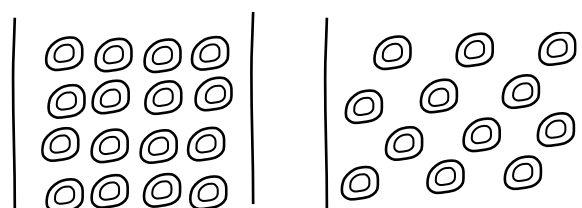


Figure 9 Inter-vessels punctuations: opposite (left) and alternate (right), dessin: AS.

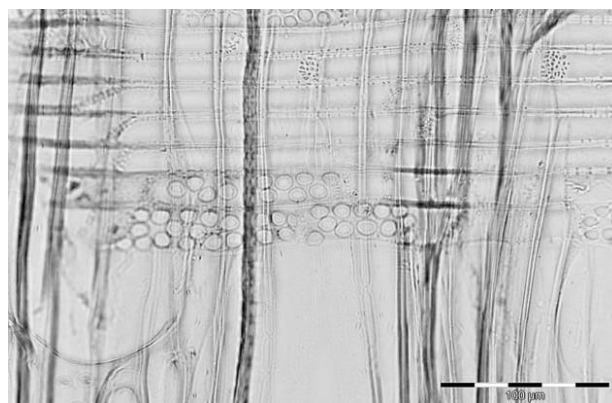


Figure 10 Cross-field punctuations, *Populus* (poplar).

Other types of punctations can be identified in the **crossing fields (ray/vessel intersection)**. They favor exchanges between vessels and horizontal parenchyma cells. Some of them can be diagnostic of a species. For example, in willow (*Salix*) and poplar (*Populus*), crossing field punctuations are large (figure 10).

3.2 HORIZONTAL PARENCHYMA

Woody rays are composed of **parenchyma cells**. Rays are mainly observed in *longitudinal tangential and radial sections*.

The most diagnostic identification features are **(a) width/size of the rays** and **(b) cells arrangement**.

(a) Cells can be uni-seriate (one cell wide), bi-tri-seriate (2 or 3 cells wide) and multi-seriate (more than 3 cells wide). The number of cells composing the ray, in its height, has to be observed in longitudinal sections (figure 11).

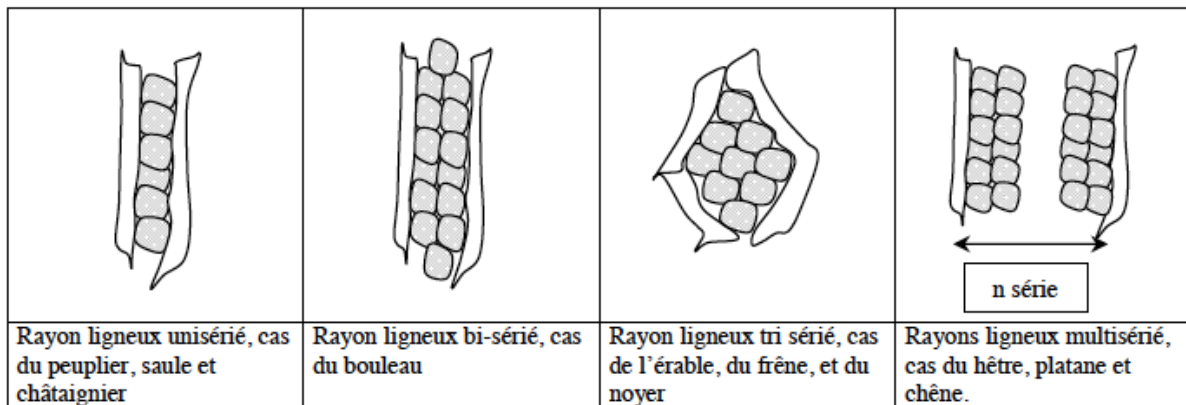


Figure 11 Les différents types de rayons chez les angiospermes.

(b) Furthermore, when the parenchyma cells are of the same size/shape over the entire height of the ray, the ray is said to be “homogeneous”. On the other hand, when the cells are of different sizes, it is called a “heterogeneous” ray. To describe accurately, we count the number of cells lying (i.e. procumbent) and/or upright and/or square in radial longitudinal section (figure 12, figure 13).

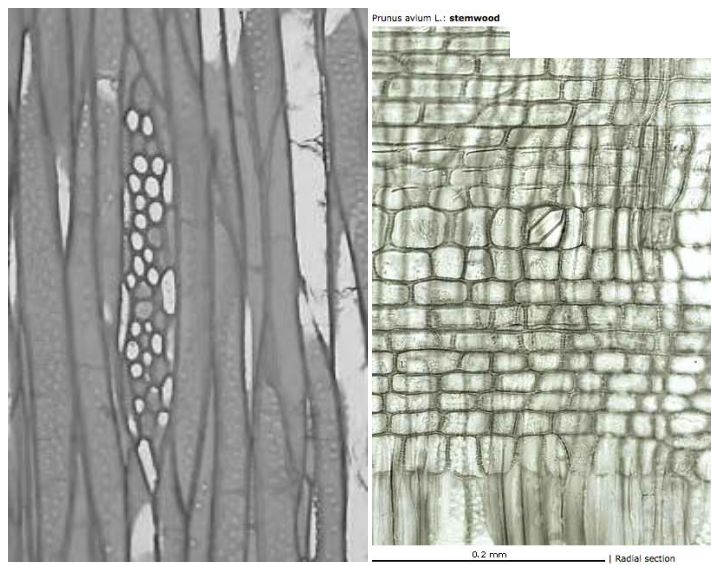


Figure 12 Les rayons de *Prunus* sp. sont multisériels (3-4 cellules de large). En coupe tangentielle (à gauche) et radiale (à droite), les cellules présentent des formes très variables (rayon hétérogène).

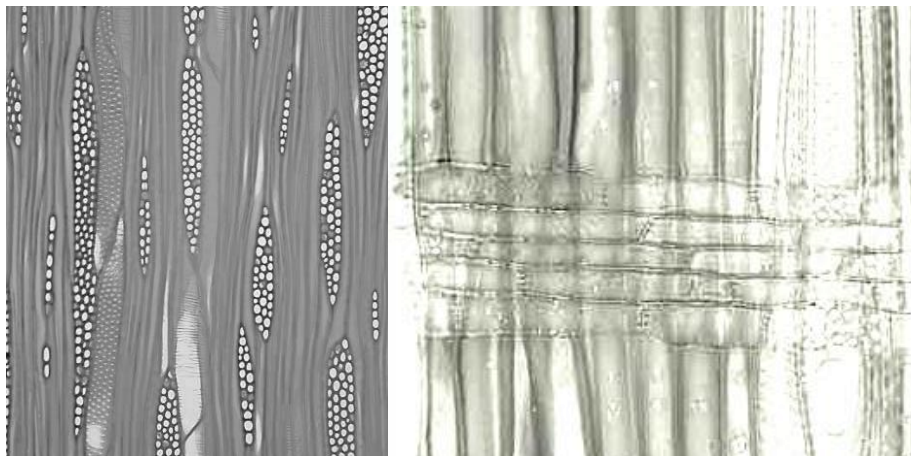
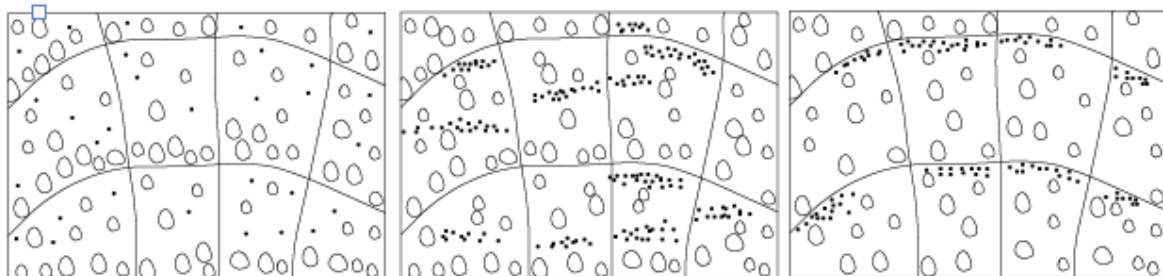


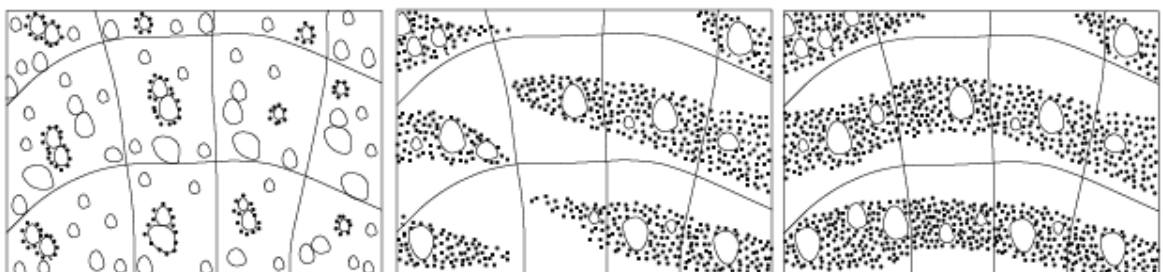
Figure 13 Les rayons d'Acer (érable) sont trisériés dans leur majorité (coupe longitudinale tangentielle, à gauche) et présentent uniquement des rangées de cellules couchées (rayon homogène) en coupe longitudinale radiale (à droite).

3.3 FIBERS AND LONGITUDINAL PARENCHYMA

Fibers provide support. They are bundles of resistant cells, arranged in the longitudinal direction, which ensure the rigidity and mechanical resistance of the wood. The libriform fibers are dead elements of fusiform shape, arranged longitudinally, in the direction of the tree axis. They only participate in the support of the tree. They do not have any punctuations. The tracheid fibers have a double function of support and conduction (punctuations present), but are not present in all species (ex : present in *Castanea*).



Diffuse apotracheal parenchyma Apotracheal parenchyma in band Marginal apotracheal parenchyma.

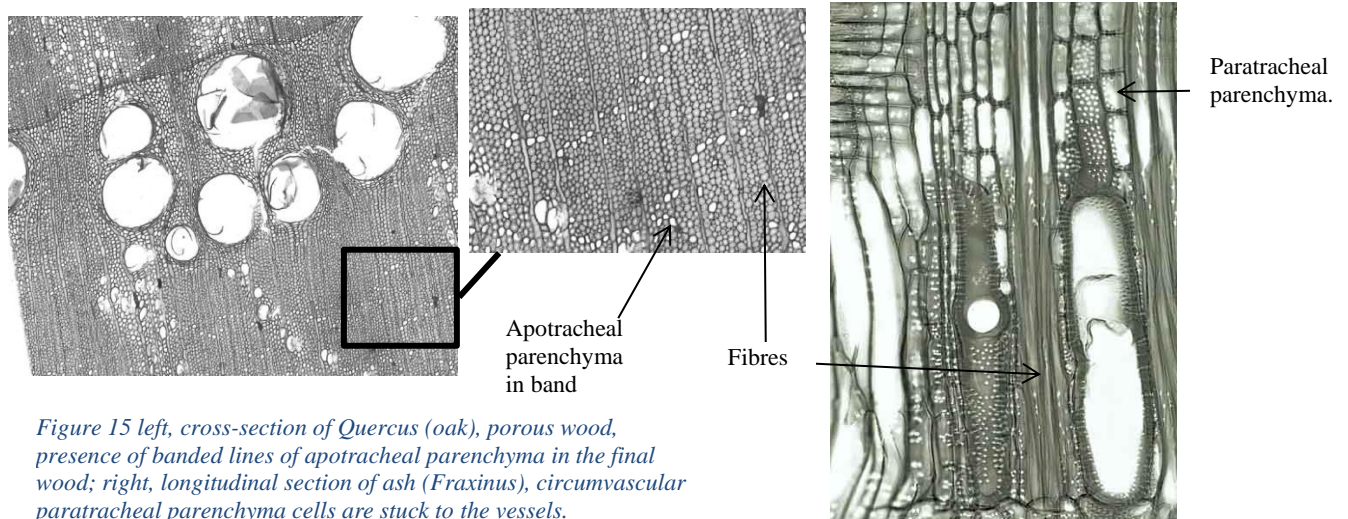


Circum-vascular/vasicentric paratracheal parenchyma Aliform paratracheal parenchyma Paratracheal parenchyma in band

Longitudinal parenchyma are living wood cells. These cells can be:

- Independent of the vessels (apotracheal parenchyma).
- Associated with vessels (paratracheal parenchyma).

The distribution of longitudinal parenchyma cells can be observed in cross section (figure 14, figure 15). When observed under the microscope, it may be difficult to distinguish the fibers from the parenchyma cells. It is then, most often, diffuse apotracheal parenchyma.



*Figure 15 left, cross-section of *Quercus* (oak), porous wood, presence of banded lines of apotracheal parenchyma in the final wood; right, longitudinal section of ash (*Fraxinus*), circumvascular paratracheal parenchyma cells are stuck to the vessels.*

3.4 SECONDARY ELEMENTS

Helical-type reinforcements of the inner vessel wall, i.e. spiral thickenings, may be present. They are visible in tangential and radial longitudinal sections.

4. TO SUM UP

The main features to observe to identify **Gymnosperms**:

- Transition between initial and final wood (transversal/cross section).
- Nature of the rays (homogeneous or heterogeneous) (*longitudinal sections*).
- Presence, or not, of resin canals (*transverse and longitudinal sections*).
- Punctuations inside the crossing-fields (*radial longitudinal section*).

The main features to observe to identify **Gymnosperms**:

- Arrangement of vessels: diffuse/porous or semi-porous wood (*cross section*).
- Arrangement of longitudinal parenchyma cells: paratracheal or apotracheal (*transverse section*).
- Nature of the rays (width/height/homogeneous or heterogeneous) (*longitudinal sections*).
- Perforations in vessels (simple, scalariform) (*longitudinal sections*).
- Presence or not of spiral thickenings in vessels (*longitudinal sections*).

See also the observation guide below (6.2).

5. USEFUL REFERENCES

5.1. BIBLIOGRAPHIC OR INTERNET RESOURCES

- **IDENTIFICATION ATLASES**

- 1 - Benkova, V., Schweingruber, F.H. (2004) *Russian Wood Anatomy*. Paul Haupt, Bern.
- 2 - Fahn, A., Werker, E., Baas, P. (1986) *Wood Anatomy and Identification of Trees and Shrubs of Israel and Adjacent Regions*. Israel Academy of Sciences and Humanities, Jérusalem.
- 3 - Hather, J. (2000) *The identification of northern European woods*. Left coast Press, London.
- 4 - Jacquot C. (1955) *Atlas d'anatomie des bois de conifères*. 2 vol. Centre Technique du bois.
- 5 - Jacquot C. (1976) *Atlas d'anatomie des bois des angiospermes*. 2 vol. Centre Technique du bois.
- 6 - Neumann, K., Schoch, W., Détienne, P., Schweingruber, F.H., Richter, H. (2000) *Woods of the Sahara and the Sahel*. Paul Haupt, Berne.
- 7 - Parsa Pajouh, D., Schweingruber, F.H. (1993): *Atlas des bois du nord de l'Iran*. Publication de l'Université de Téhéran, Tehran. 2nde édition.
- 8 - Schweingruber, F.H. (1990) *Anatomie europäischer Hölzer – Anatomy of european woods*. Eidgenössische Forschungsanstalt für Wald, Schnee und Landschaft, Birmensdorf. Haupt, Bern und Stuttgart.

- **ONLINE IDENTIFICATION KEYS AND OTHERS USEFUL SITES**

<http://www.woodanatomy.ch>

<http://www.holzanatomie.at>

<http://www.iawa-website.org>

<https://insidewood.lib.ncsu.edu/welcome>

5-2. MAIN ANTHRACOLOGY LABORATORIES IN FRANCE

UMR 7209 – Archéozoologie et Archéobotanique : Sociétés, Pratiques et environnements (Paris).

UMR 5059 – Centre de Bio-Archéologie et d'Ecologie (Montpellier).

UMR6566 – Centre de Recherche en Archéologie, Archéosciences, Histoire (Rennes, Nantes, Le Mans).

UMR7041 – Archéologies et Sciences de l'Antiquité (Nanterre).

UMR 7264 – Cultures et Environnements. Préhistoire, Antiquité, Moyen-Âge (Nice).

UMR 6042 – Laboratoire de Géographie Physique et Environnementale (Limoges).

UMR 6298 – Archéologie, Terre, Histoire, Sociétés (Dijon).

UMR 5602 – Géographie de l'Environnement (Toulouse).

Certaines bases de l'Institut National de Recherche et d'Archéologie Préventive (INRAP) sont aussi équipées.

6. SIMPLIFIED IDENTIFICATION KEYS⁶ AND OBSERVATION GUIDE

From Schoch, W., Heller, I., Schweingruber, F.-H., Kienast, F. (2004) *Wood anatomy of central European species*. Online version <http://www.woodanatomy.ch>.

Schweingruber, F.H. (1990) *Anatomie europäischer Hölzer – Anatomy of european woods*. Eidgenössische Forschungsanstalt für Wald, Schnee und Landschaft, Birmensdorf. Haupt, Bern und Stuttgart.

For gymnosperms, the first entry in the key is the size and shape of the dots in the crossing fields visible at high magnification in radial longitudinal section (p.5). For angiosperms, it is the porosity of the wood in cross-section (p.8-9) followed by the width of the rays in tangential longitudinal section (p.10).

During the practical exercise, you will have to (1) describe the three sections of a modern gymnosperm and angiosperm charcoal using the observation guide (6.3), (2) by yourself, identify a mystery taxon (angiosperm) using the simplified key (6.1) and the atlases provided on the Plateau d'archéobotanique.

⁶ The following simplified key is dedicated to the support of practical work. It is not translated in English. Nevertheless, the majority of the comparison atlases (see section 5.1) are in English.

6.1 LES GYMNOSPERMES

ponctuations de champs de croisement	Canaux résinifères	Trachéides transversales	Épaississements spiralés dans les trachéides	Taxon	Remarques					
larges (pinoïdes)	présents	présentes	absents	<i>Pinus sylvestris</i>	Trachéides transversales avec les parois dentées					
				<i>Pinus mugo</i>						
				<i>Pinus nigra</i>						
		absentes	absents	<i>Pinus cembra</i>	Trachéides transversales à parois fines. Généralement, bois final toujours étroit.					
				<i>Pinus strobus</i>						
petites	présents	présentes	absents	<i>Picea abies</i>	Transition continue entre le bois initial et final. Ponctuations dans les trachéides axiales généralement unisériées.					
				<i>Larix decidua</i>		Transition abrupte entre le bois initial et final. Ponctuations dans les trachéides axiales souvent bisériées.				
	absents			présents			<i>Pseudotsuga taxifolia</i>	Transition abrupte entre le bois initial et final. Fins épaissements spiralés.		
		absentes	absents	<i>Abies Alba</i>	Transition abrupte entre le bois initial et final.					
				<i>Juniperus communis</i>		Parois de cellules de rayon fines.				
				présents		absents				
							<i>Taxus baccata</i>	Épaississements spiralés distincts.		

6.2 LES ANGIOSPERMES

BOIS POREUX

Largeur rayon	Type de rayon	Perforation	Épaississements spiralés	Taxon	Remarques
1 cellule	homogène	simple	absents	<i>Castanea</i>	Bois final avec organisation des pores dentritiques. Rayons rarement bisériés.
2 à 3 cellules	homogène	simple	absents	<i>Fraxinus</i>	Pores souvent solitaires dans le bois final ou en petits groupes radiaux.
3 à 5 cellules	hétérogène	simple	présents	<i>Pistacia</i>	Dans les larges cerne, les groupes parenchyme/vaisseaux peuvent avoir une orientation oblique ou tangentielle.
	homo- à hétérogène			<i>Ulmus</i>	Pores, trachéides vasculaires et cellules de parenchyme dans le bois final organisés en petits groupes ou en bandes courtes.
> 5 cellules	hétérogène	simple	absents	<i>Vitis</i>	Dans le bois final, pores en file radiale ou petits groupes. Rayons très larges et ponctuations intervasculaires scalariformes.
				<i>Tamarix</i>	Parenchyme vasicentrique, paratracheal ou en groupes larges. Parenchyme étagé.
			présents	<i>Clematis</i>	Bois final généralement étroit.
			<i>Berberis</i>	Bois poreux à semi-poreux. Pores du bois final et trachéides vasculaires en groupes avec une orientation tangentielle à diagonale ou dentritique.	
			<i>Laburnum</i>	Rayons souvent larges de plus de 5 cellules.	
unisériés à multisériés	homogène	simple	absents	<i>Quercus</i>	Groupes de pores du bois final présentant l'aspect d'une flamme.
	hétérogène		présents	<i>Rosa</i>	Répartition régulière des pores.

BOIS DIFFUS A SEMI-POREUX

Largeur rayon	Type de rayon	Perforation	Épaississements spiralés	Taxon	Remarques
1 cellule	homogène	simple	absent	<i>Populus</i>	Larges poncturations des champs de croisement.
			présent	<i>Euonymus</i>	Nombreux petits pores.
		scalariforme	absent	<i>Alnus</i>	Perforations scalariformes de 10 à 20 barreaux. Présence de faux-rayons.
				<i>Corylus</i>	Perforations scalariformes de 5 à 10 barreaux.
	<i>Betula</i>	Très petites ponctuations dans les champs de croisement, occasionnellement rayons de 2-4 cellules de largeur.			
	hétérogène	simple	absent	<i>Salix</i>	Larges poncturations des champs de croisement.
			présent	<i>Daphne</i>	Disposition détritique des vaisseaux.
2-3 cellules	homogène	simple	absent	<i>Juglans</i>	Pores larges, peu nombreux, solitaires ou en files radiales de 2 à 4 cellules.
			absent (présence occasionnelle)	<i>Maloideae</i>	Pores nombreux à très nombreux, occasionnellement fins épaississements spiralés.

BOIS DIFFUS A SEMI-POREUX (suite)								
Largeur rayon	Type de rayon	Perforation	Epaississements spiralés	Taxon	Remarques			
2-3 cellules	homogène	simple	présent	<i>Acer</i>	Pores espacés, solitaires ou en file radiale de 2 ou 3 pores.			
				<i>Prunus</i>	Voir 3-5 cellules (largeur rayon), légèrement hétérogène.			
				<i>Tilia</i>	Contours des vaisseaux angulaires, orientés en file radiale et en groupe. Elargissement des rayons à la transition bois final/ bois initial.			
			scalariforme	absent	<i>Betula</i>	Très petites ponctuations dans les champs de croisement. Pores épars en files radiales de 2 à 4 cellules, ou en groupe.		
		homo- à hétérogène	simple	présent	<i>Rhamnus</i>	Répartition dentritique des pores.		
		hétérogène	simple	absent	<i>Olea</i>	Pores alignés en courtes bandes radiales. Rayons avec une ou deux rangées de cellules marginales dressées.		
	<i>Punica</i>				Rayons nuni-bisériés, hauts jusqu'à 20 cellules.			
			simple	présent	<i>Frangula</i>	Généralement semi-poreux, pores largement espacés, surtout dans le bois final.		
					<i>Lonicera</i>	Rayons clairement multisériés avec nombre de rangées de cellules carrées et dressées marginales.		
					<i>Ligustrum</i>	Rayons avec souvent 1-2-(4) rangées de cellules carrées et dressées marginales.		
					<i>Ostrya</i>	Pores peu fréquents, en ligne radiale de 2 à 10 pores.		
					<i>Prunus</i>	Voir 3-5 cellules (largeur rayon), légèrement hétérogène.		
			scalariforme	absent	<i>Buxus</i>	Pores étroits, perforations scalariformes de forme ronde à ovale avec <10 barreaux.		
					<i>Viburnum</i>	Rayons clairement hétérogènes, perforations scalariformes avec <20 barreaux. Parfois épaisissements spiralés dans les fibres trachéïdes (<i>V. lantana</i>).		
					<i>Cornus</i>	Souvent rayons 3-5 cellules de large, perforations scalariformes avec de nombreux barreaux.		
	3-5 cellules	homogène	simple	absent	<i>Juglans</i>	Pores larges, peu nombreux, solitaires ou en files radiales de 2 à 4 cellules.		
					<i>Acacia</i>	Selon l'espèce, pores isolés ou en groupe, parfois disposés en files radiales. Parenchyme paratracheal vasicentrique, aliforme ou en bande.		
					présent	<i>Prunus</i>	Pores solitaires ou en file radiale de deux à quelques cellules, ou en groupe. Chez certaines espèces, rayons avec plus de 5 cellules de large.	
<i>Acer</i>				Pores espacés, solitaires ou en file radiale de 2 ou 3 pores.				
			<i>Tilia</i>	Contours des vaisseaux angulaires, orientés en file radiale et en groupe. Elargissement des rayons à la transition bois final/ bois initial.				
			scalariforme	absent	<i>Betula</i>	Très petites ponctuations dans les champs de croisement. Pores épars en files radiales de 2 à 4 cellules, ou en groupe.		

BOIS DIFFUS A SEMI-POREUX (suite)					
3-5 cellules	hétérogène	simple	absent	<i>Sambucus</i>	Pores en groupe, bandes marginales de trachéïdes vasculaires. Rayons cellules bordantes.
				<i>Ficus</i>	Larges pores peu nombreux, isolés ou en files radiales. Cernes de croissances presque indistincts. Parenchyme en bande.
	hétérogène	scalariforme	présent	<i>Prunus</i>	Pores solitaires ou en file radiale de deux à quelques cellules, ou en groupe. Chez certaines espèces, rayons avec plus de 5 cellules de large.
			absent	<i>Cornus</i>	Rayons hétérogènes, perforations scalariformes à nombreux barreaux.
			présent	<i>Ilex</i>	Petits pores, en files radiales longues, souvent rayons de plus de 4mm de haut.
< 5 cellules	homogène	simple	absent	<i>Fagus</i>	Rayons très larges, perforations simples et scalariformes.
				<i>Platanus</i>	Comme <i>Fagus</i> , rayons très larges plus nombreux, ponctuations intervasculaires opposées, en lignes horizontales.
				<i>Hedera</i>	Pores groupés, le plus souvent à orientation tangentielle.
			présent	<i>Clematis</i>	Pores très larges (voir bois poreux).
			<i>Berberis</i>	Voir bois poreux.	
	hétérogène	simple	absent	<i>Hedera</i>	Pores groupés, le plus souvent à orientation tangentielle.
				<i>Vitis</i>	Voir bois poreux.
		scalariforme	présent	<i>Ilex</i>	Petits pores, en files radiales longues, souvent rayons de plus de 4mm de haut.
				<i>Fagus</i>	Rayons très larges, perforations simples et scalariformes.
				<i>Platanus</i>	Comme <i>Fagus</i> , rayons très larges plus nombreux, ponctuations intervasculaires opposées, en lignes horizontales.
uni- et multisérié	homogène à hétérogène	simple	absent	<i>Fagus</i>	Rayons très larges, perforations simples et parfois scalariformes.
				<i>Quercus</i>	Rayons multisériés très larges.
			présent	<i>Carpinus</i>	Pores en file radiale. Présence de faux rayons.
				<i>Rosa</i>	Bois poreux avec beaucoup de cernes très étroits qui peuvent paraître similaires à du bois diffus, voir bois poreux.
				<i>Prunus</i>	Pores solitaires ou en file radiale de deux à quelques cellules, ou en groupe.
	scalariforme	absent	<i>Ribes</i>	Rayons avec des cellules bordantes.	
			<i>Corylus</i>	Pores en file radiale, perforations scalariformes de 5 à 10 barreaux. Rayons multisériés à proximité des faux rayons.	
		présent	<i>Corylus</i>	Pores en file radiale, perforations scalariformes de 5 à 10 barreaux. Rayons multisériés à proximité des faux rayons.	
			<i>Fagus</i>	Rayons très larges, perforations simples et scalariformes.	

6.3 OBSERVATION GUIDE

The purpose is to guide you in the observation of your first charcoal samples (of temperate or arid species). For each major type of wood (homoxylate/heteroxylate) are presented:

- the main questions to ask for each observation plan.
- the main cells/tissues to observe.
- the magnification⁷ to be used for the observations.

Please note that the list is not exhaustive. You can add to it or skip observation points depending on your experience.

Use this guide, as well as IAWA features (Wheeler, Baas, Gasson 1989) to help you!

Gymnosperm

In cross/transversal section:

- 1- Is the transition between the initial and final wood continuous or abrupt (X50 à x100)?
- 2- Are there any resin canals (X50)?
- 3- Observe differences in thickness cells of initial and final wood at high magnification (X200 à X500).
- 4- Observe horizontal parenchyma cells at high magnification (X200 à X500).

Longitudinal tangential section:

- 5- Observe pits in the tracheids at low and high magnification (X50 à X500).
- 6- What is the number of cells in the height of rays (take into account 5 rays, X200 à X500)?
- 7- What is the number of cells in the width of rays (take into account 5 rays, X200 à X500)?
- 8- Do you observe any particular cells inside rays (X500)? Are rays homogeneous or heterogeneous?

Longitudinal radial section:

- 9- Locate an area where rays and tracheids are crossing (X50), search for pits in the crossing fields (X500 à X1000).
- 10- What is the shape and the size of the crossing fields pits (X1000)? How many pits/parenchyma cells; are pits big or small?

Angiosperm

In cross/transversal section:

- 1- Observe the arrangement of vessels in a growth ring. Does the wood appear porous or semi-porous to diffuse (X 50)?
- 2- Do the vessels have a particular organization (groups, solitary, in flame, etc...)?
- 3- Do the rays appear wide, thin, or uniseriate (X50 to X100)? It has to be confirmed in longitudinal section.
- 4- Do you notice the presence of longitudinal parenchyma cells? If so, do they have a particular organization in relation to the vessels, or independently of the vessels (X100 to X500)?
- 5- Observe or try to locate parenchyma cells at high magnification (X200 to X500).

⁷ Since oculars have a magnification of X10, a magnification of X50 corresponds to an objective of X5. From magnification X20 (or X50), the microscope must be switched to white background.

Longitudinal tangential section:

6- Observe and distinguish vessel elements, fibers and rays (X100).

7- What is the number of cells in the width of the rays (take into account 5 rays, (X200 à X500)?

8- What is the number of cells in the height of the rays (take into account 5 rays, X200 à X500)?

9- Do you find the ray cells homogeneous or heterogeneous (X 500)? It has to be confirmed in radial section.

10- Observe the inter-vascular pits, and their organization (alternate, opposite); are the perforations simple or scalariform (X 200 à 500)?

11- Do you observe secondary elements (spiral thickenings) in the vessels?

12- Try to differentiate fiber (fusiform) and parenchyma cells (X500).

13- Do the parenchyma cells and/or the vessels has a particular organization, like storied parenchym (x100)?

In radial longitudinal section:

Points 9 through 12 can also be observed in radial section.

(14) Locate the crossing fields. Describe the arrangement and orientation of the horizontal parenchyma cells (X200 to X500), e.g. procumbent, upright....

Check your ID on Inside Wood or in atlases.

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