Mécanismes anatomiques de défense de l'arbre en réponse aux blessures et maladies

Danny Rioux

SIAQ: Congrès annuel - CentrExpo Cogéco
Drummondville - 15 novembre 2018

Ressources naturelles Canada
Natural Resources Canada
Canada

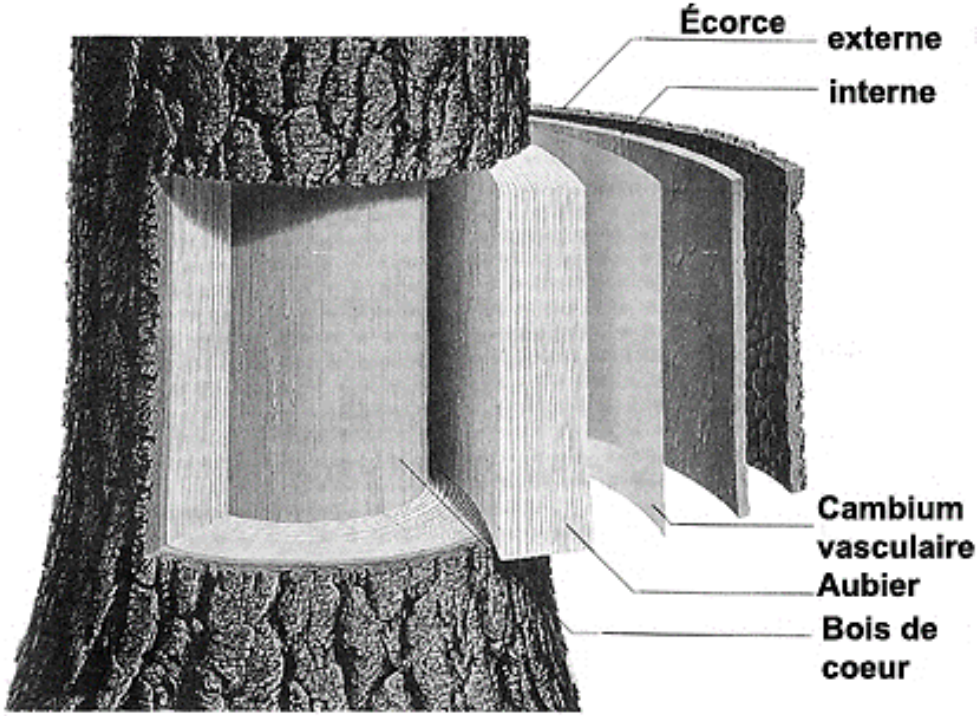
Aperçu

1. Introduction
2. Rappel : anatomie de l'arbre
3. Mécanismes de défense
   - Écorce
   - Bois
   - Compartimentage
   - Aspects pratiques
4. À retenir (conclusions)

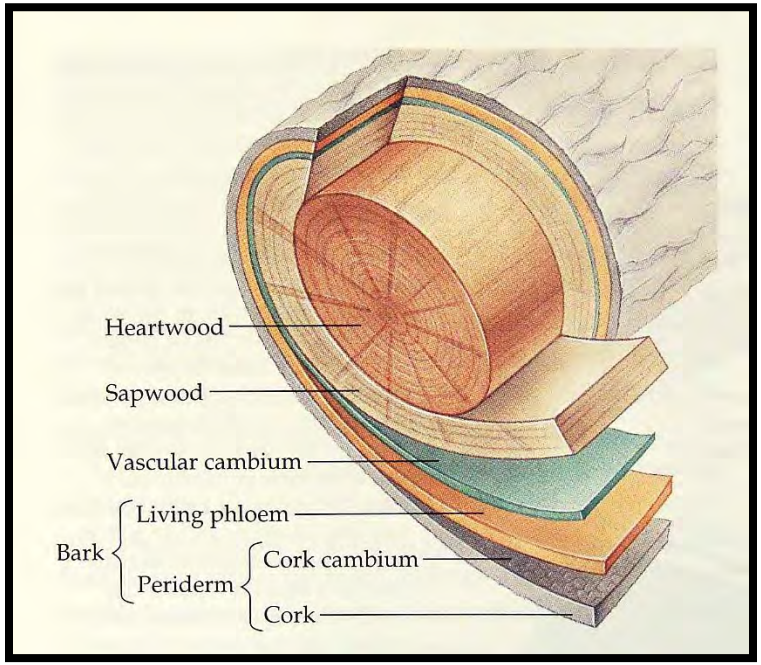
1. Introduction (objectifs)

- J'espère vous faire apprendre 1-2 trucs en anatomie et sur les mécanismes de défense sans que ça soit trop pénible ☺
- Microscopie (photonique, à fluorescence, électronique à transmission et à balayage)
- Apprécier les articles scientifiques
- Susciter des échanges (vos besoins…)

2. Rappel : anatomie de l'arbre

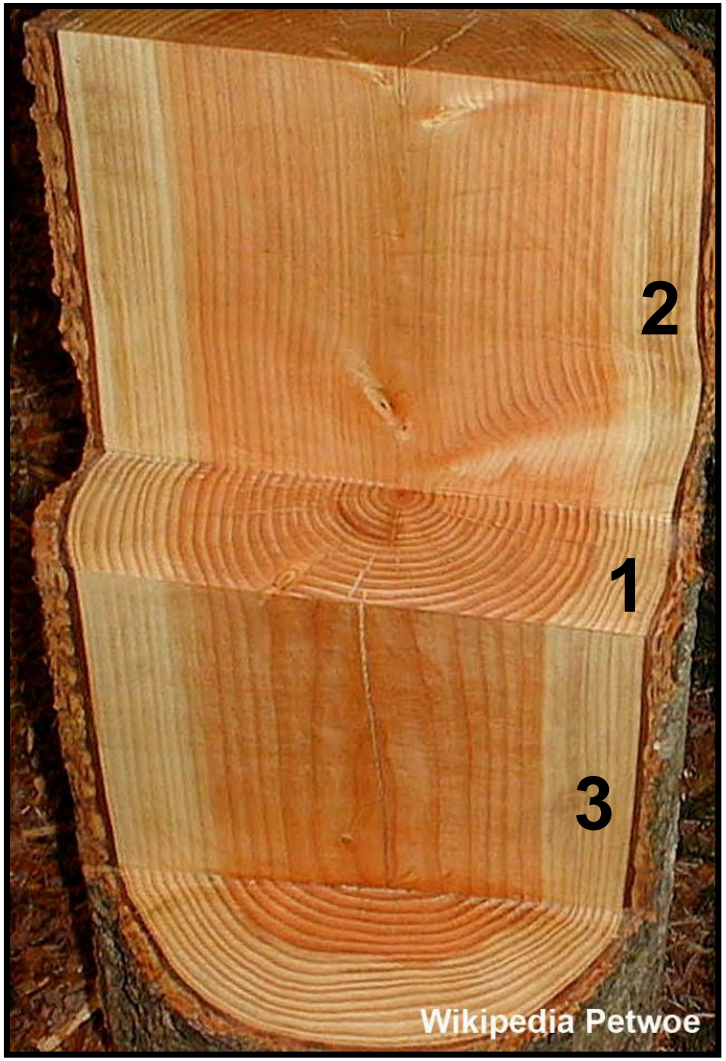


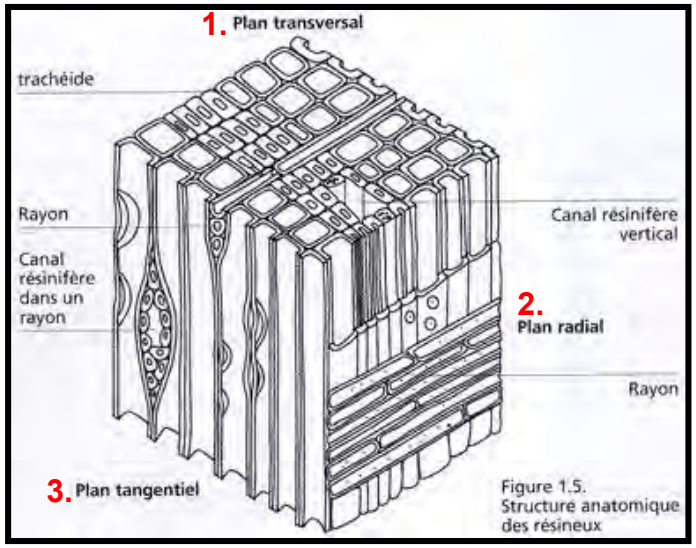
Adapté de St. Regis Paper Co.



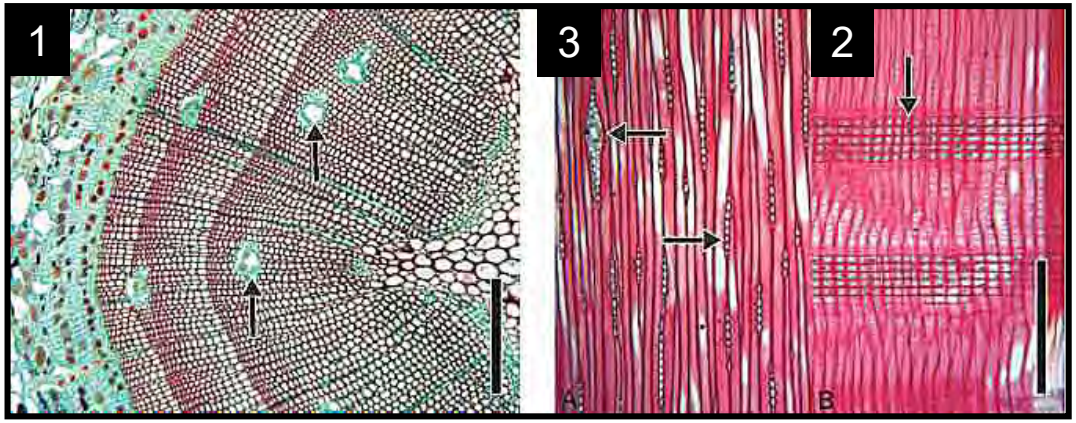
Campbell et al. 1999

Le tronc – Les plans d'étude



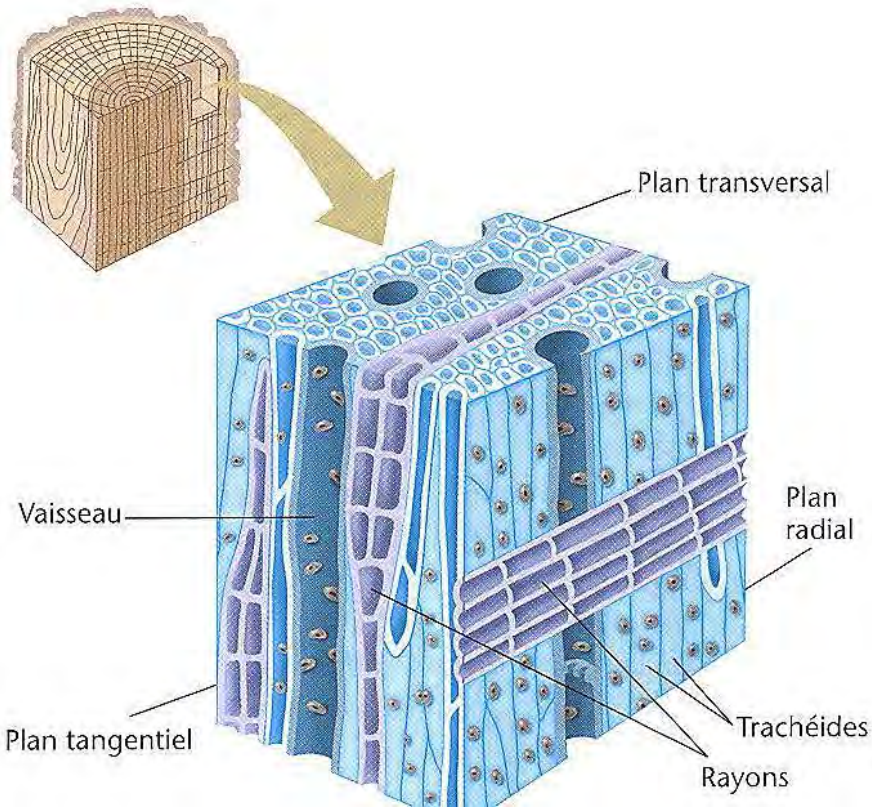


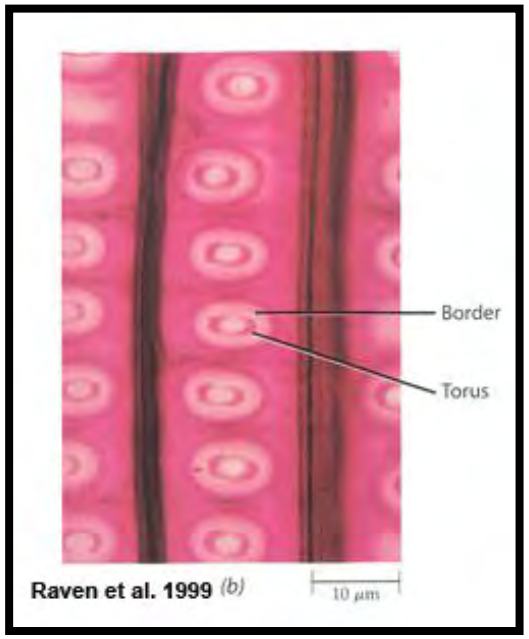
cerig.pagora.grenoble-inp.fr

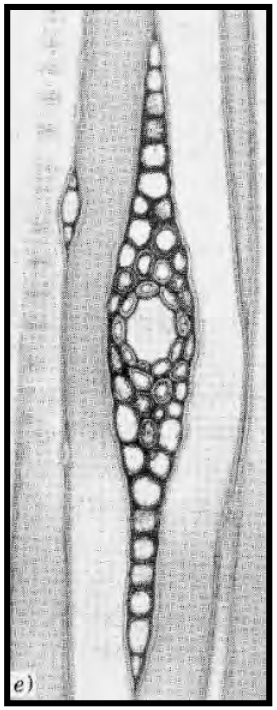


The Virtual Plant

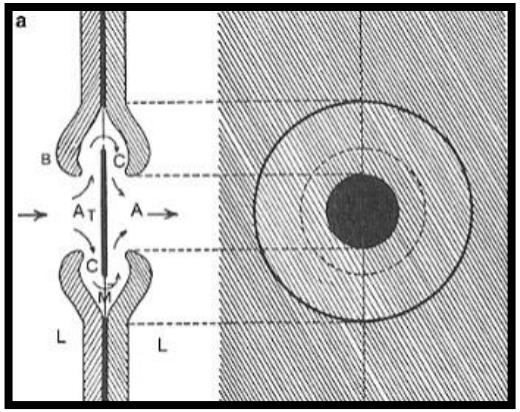
Le tronc – Plans et ponctuations





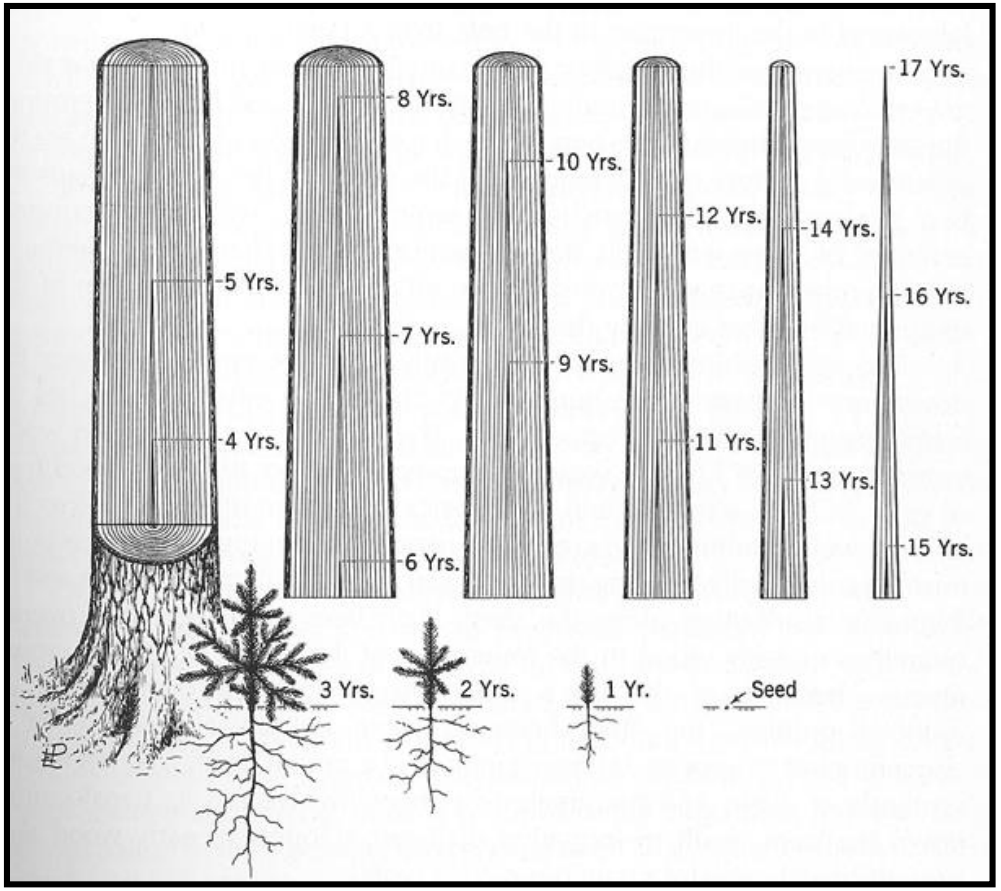


Panshin et de Zeeuw 1980

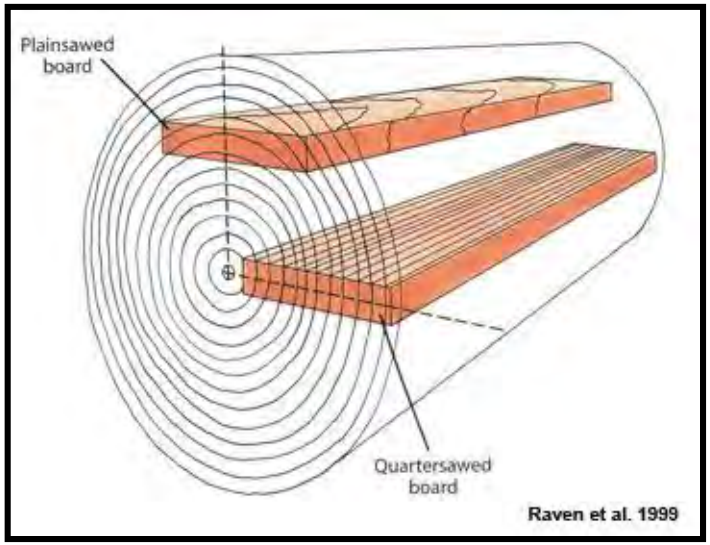


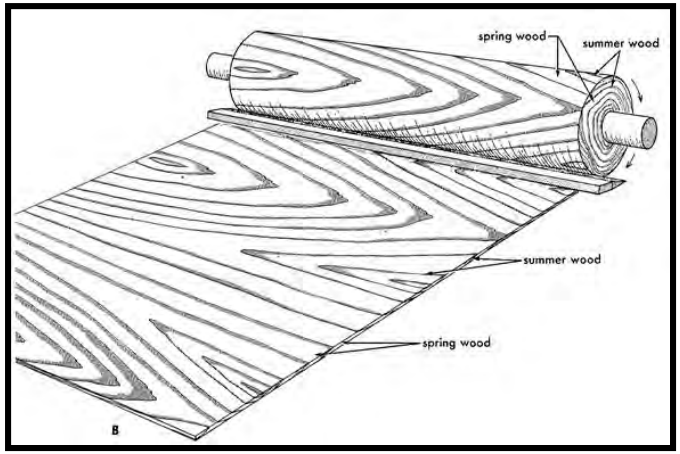
R. Dute 2015

Le tronc – Les cernes



Panshin et de Zeeuw 1980

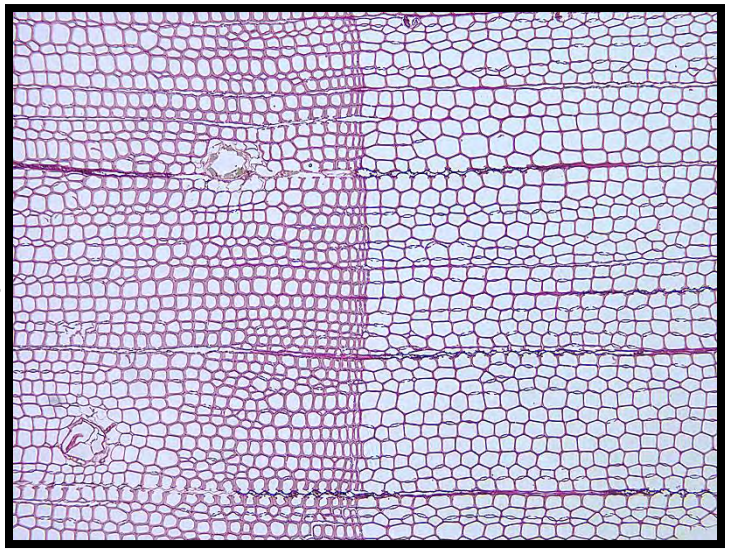




Weir et al. 1982

Le tronc – Les cernes

Conifères



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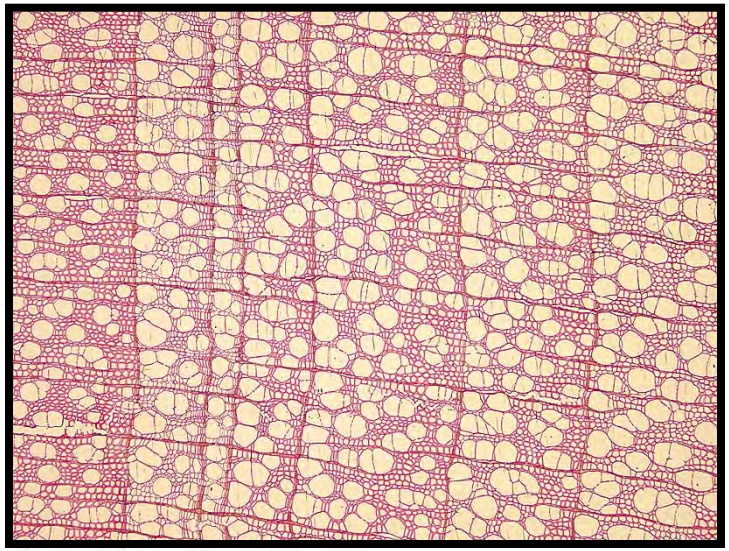
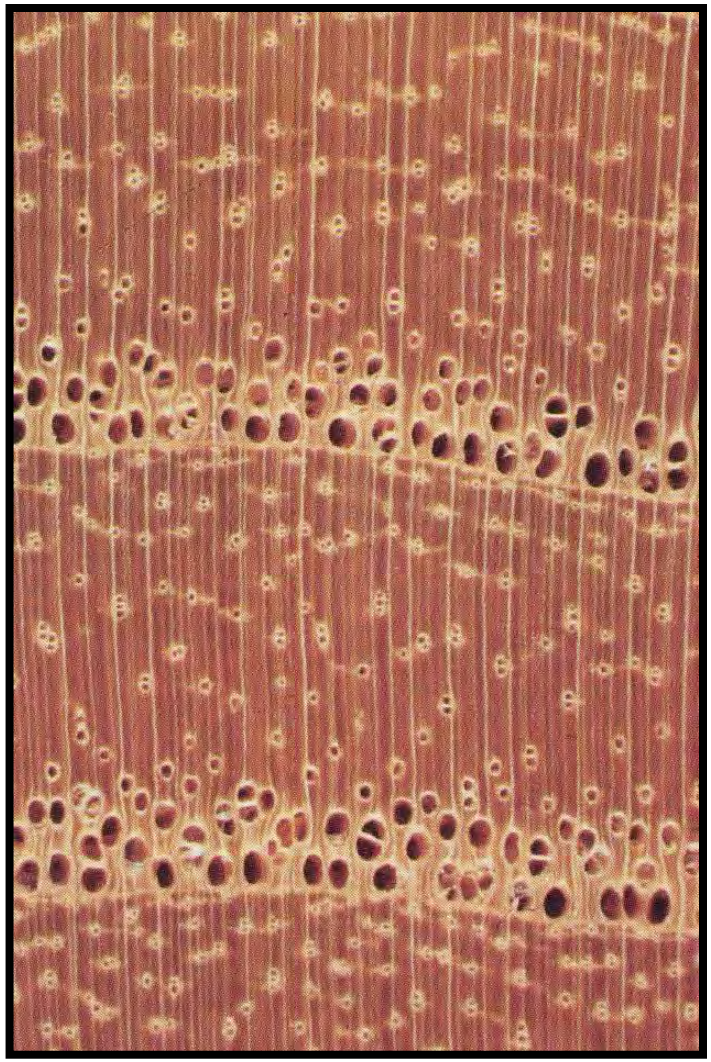
Pores diffus

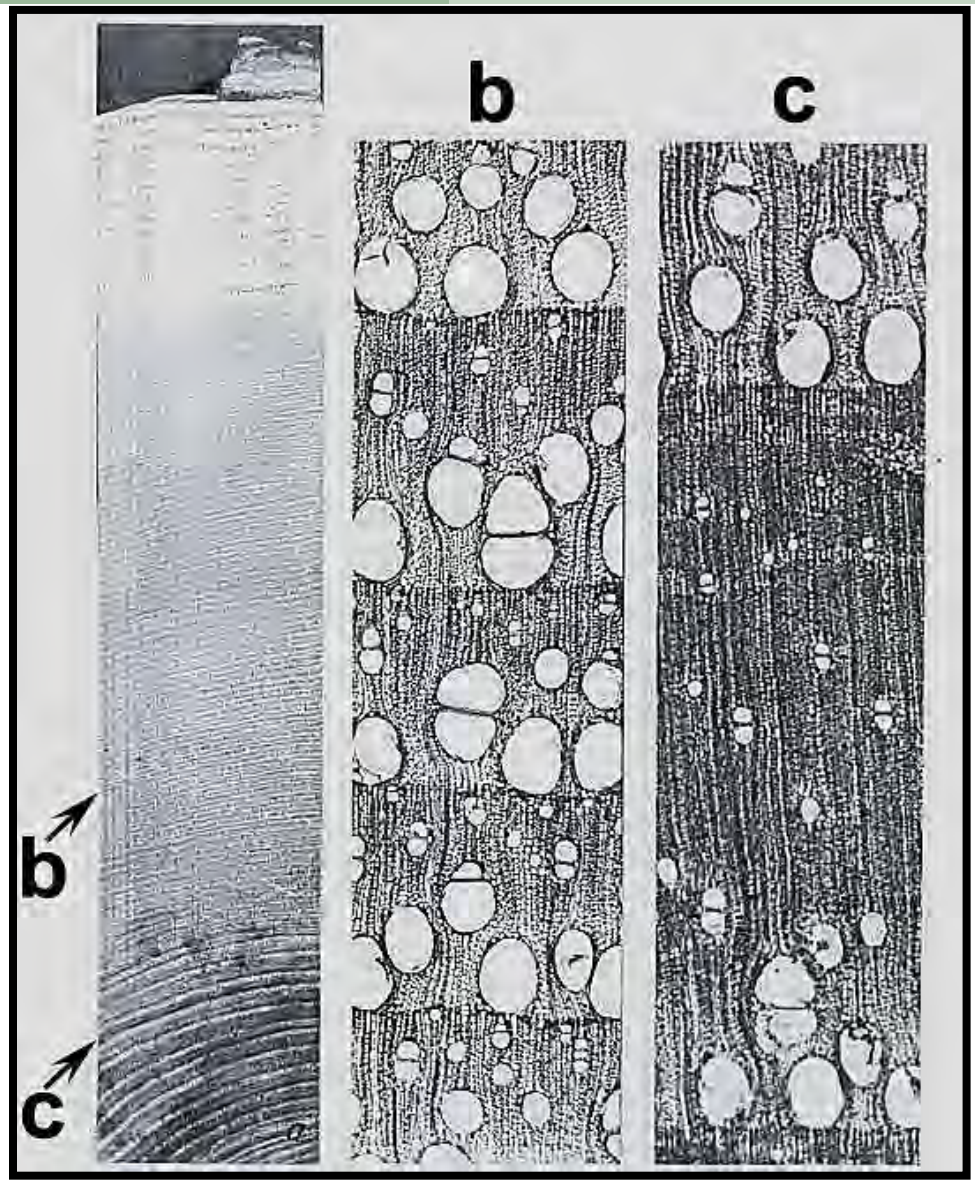


Zone poreuse



Hoadley 1990

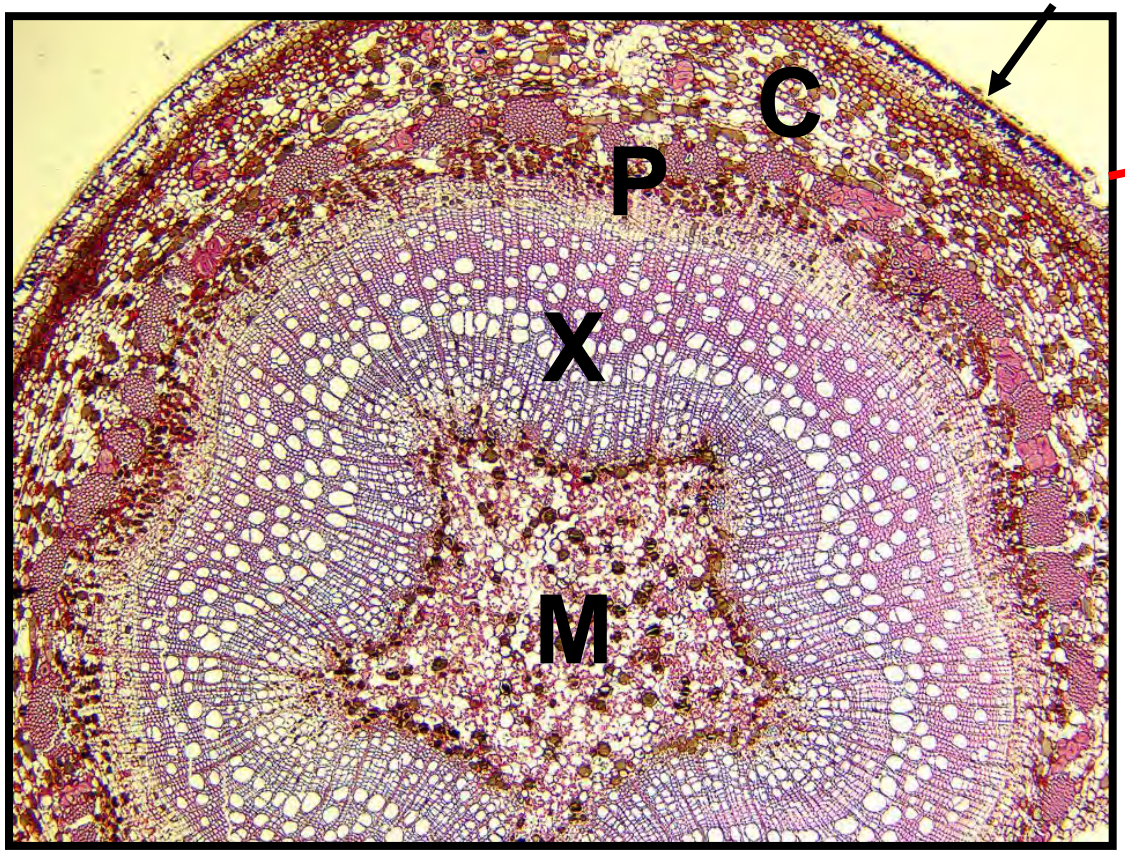
Frêne blanc

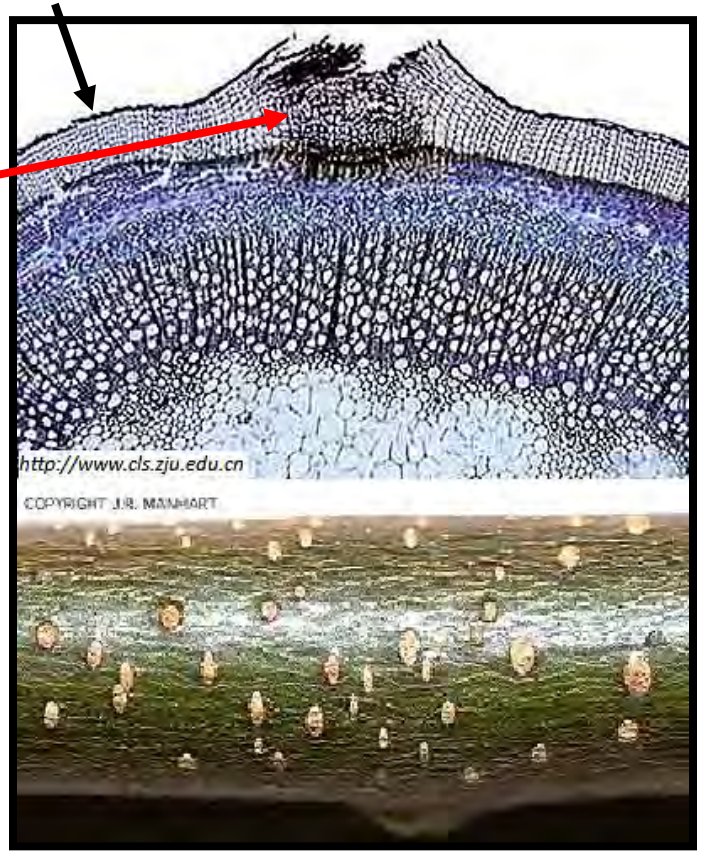


D = 0,48 D = 0,65

Adapté de Paul 1963

Branches – Rameaux - Lenticelles





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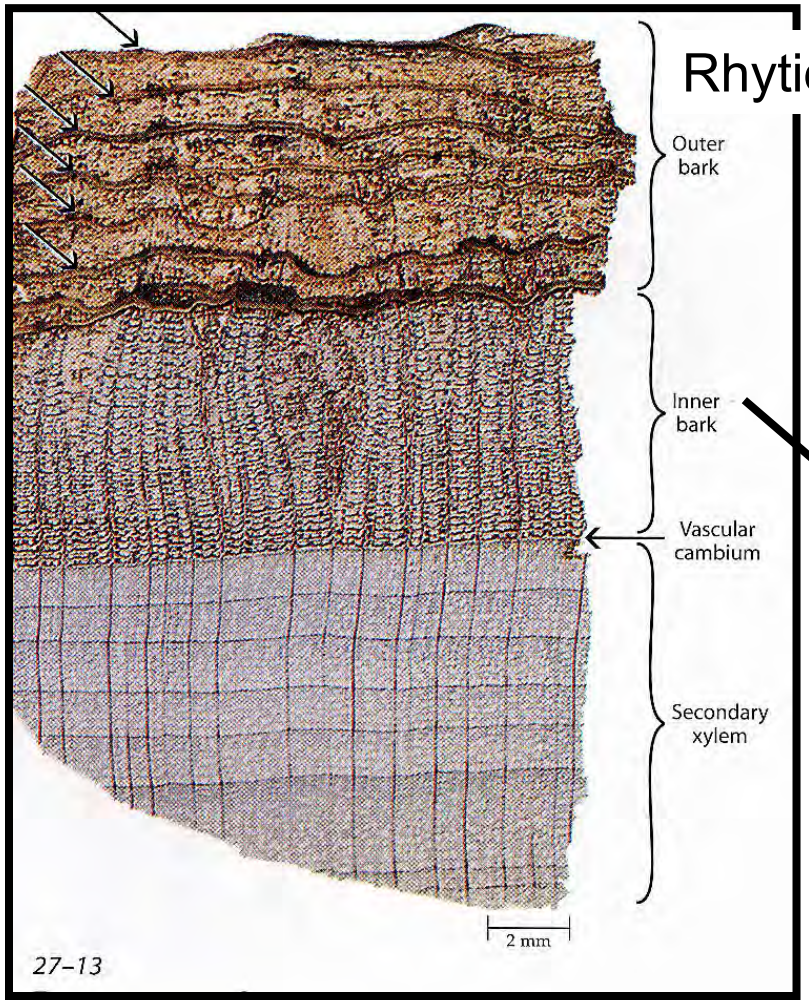
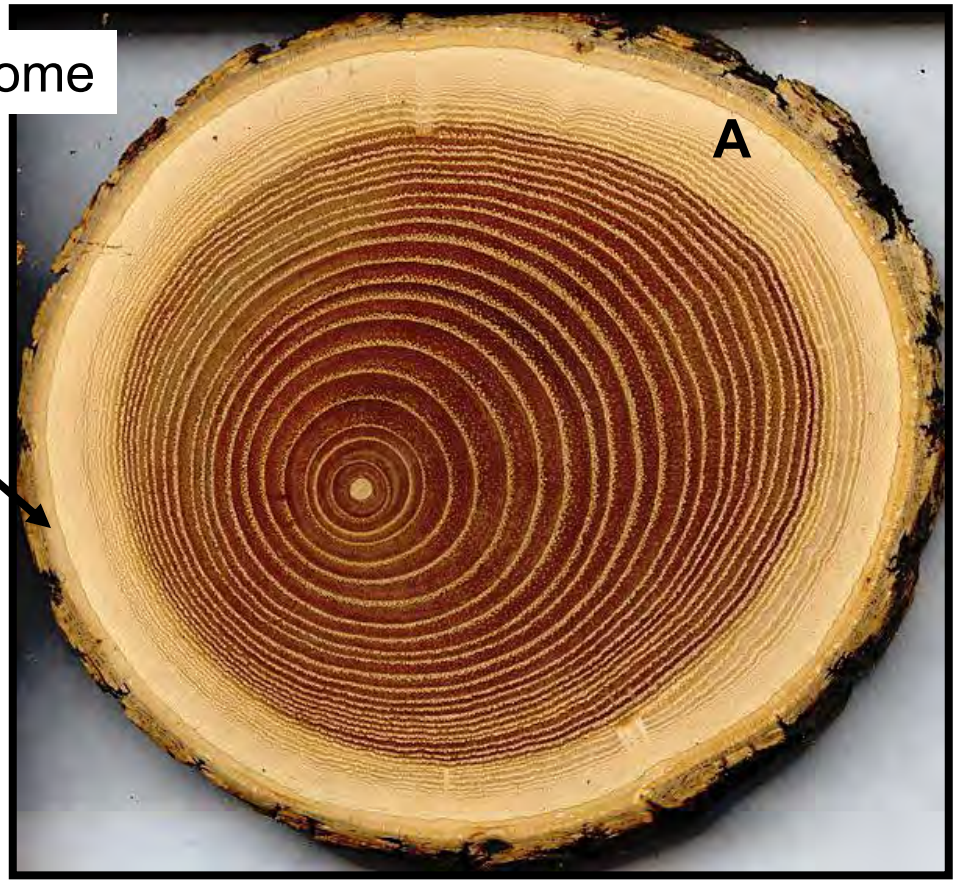
Tronc ou grosses branches



Raven et al. 1999



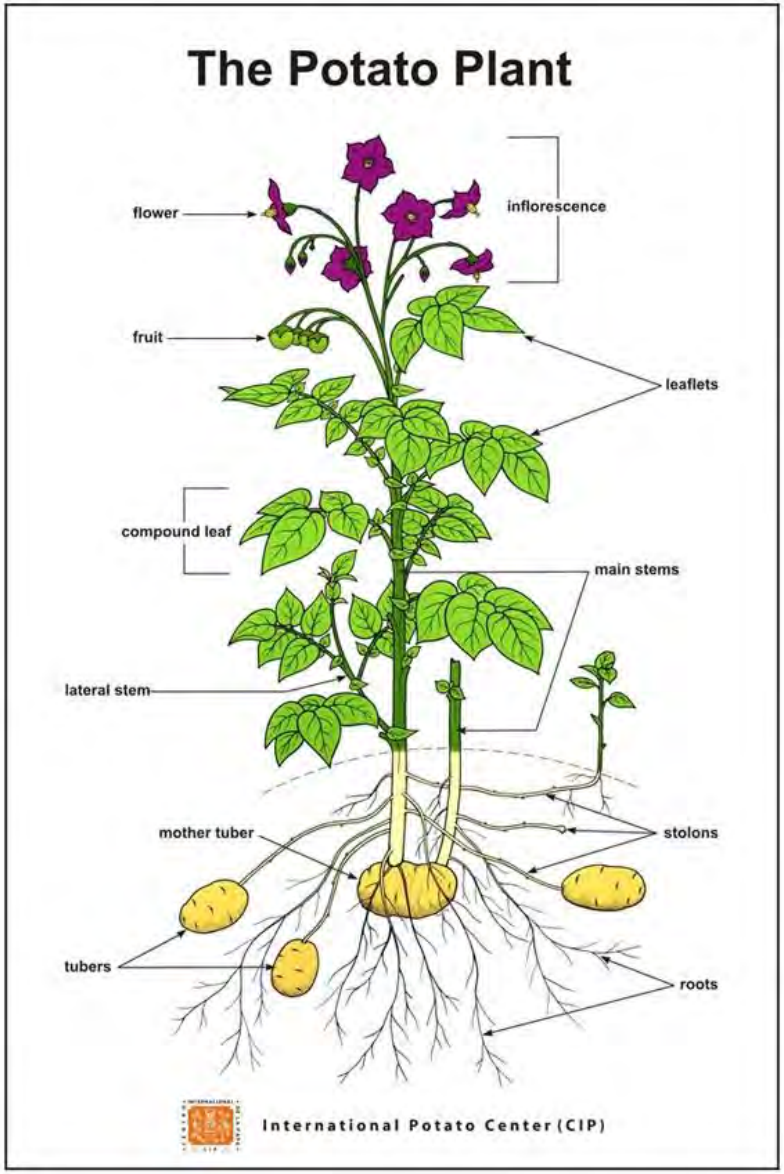
Grissino-Mayer

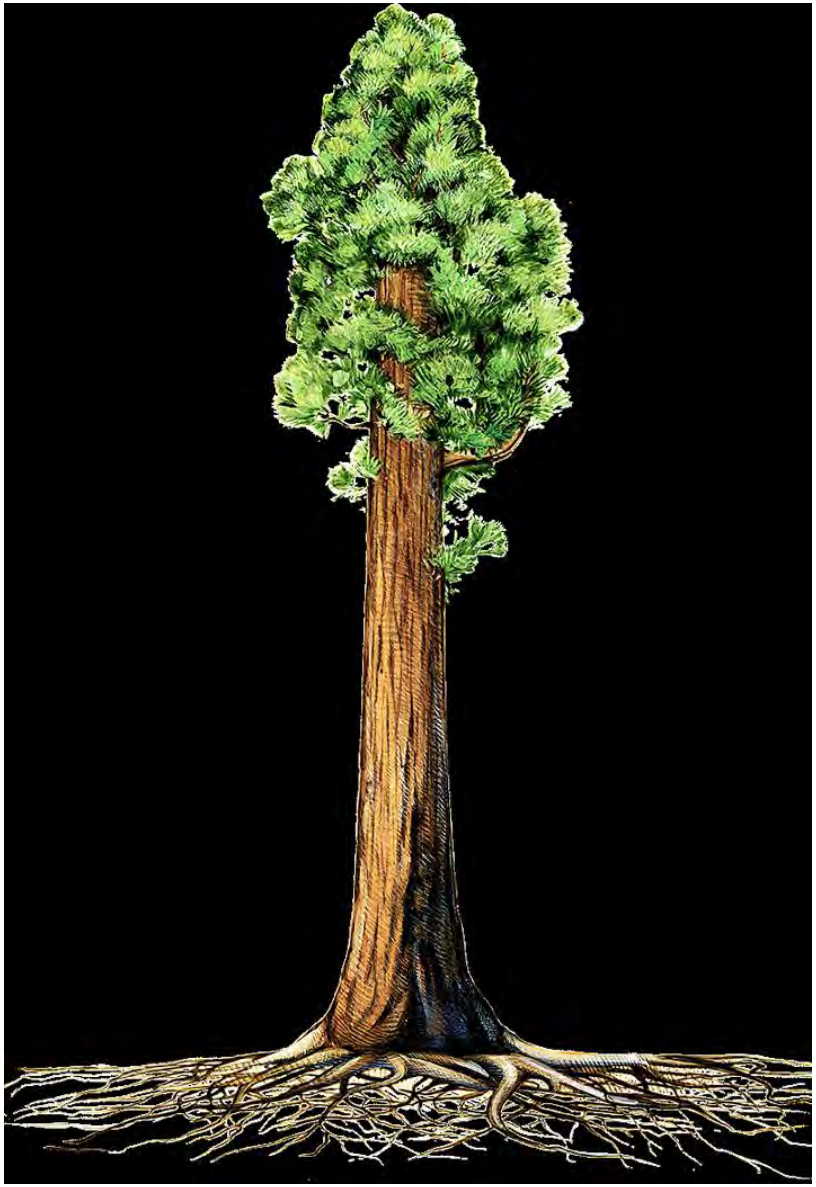
3. Mécanismes de défense

D. Lauzon, Ville de Montréal

- Constitutifs vs Induits
- Chimiques vs Anatomiques
- Agents causals: abiotiques vs biotiques

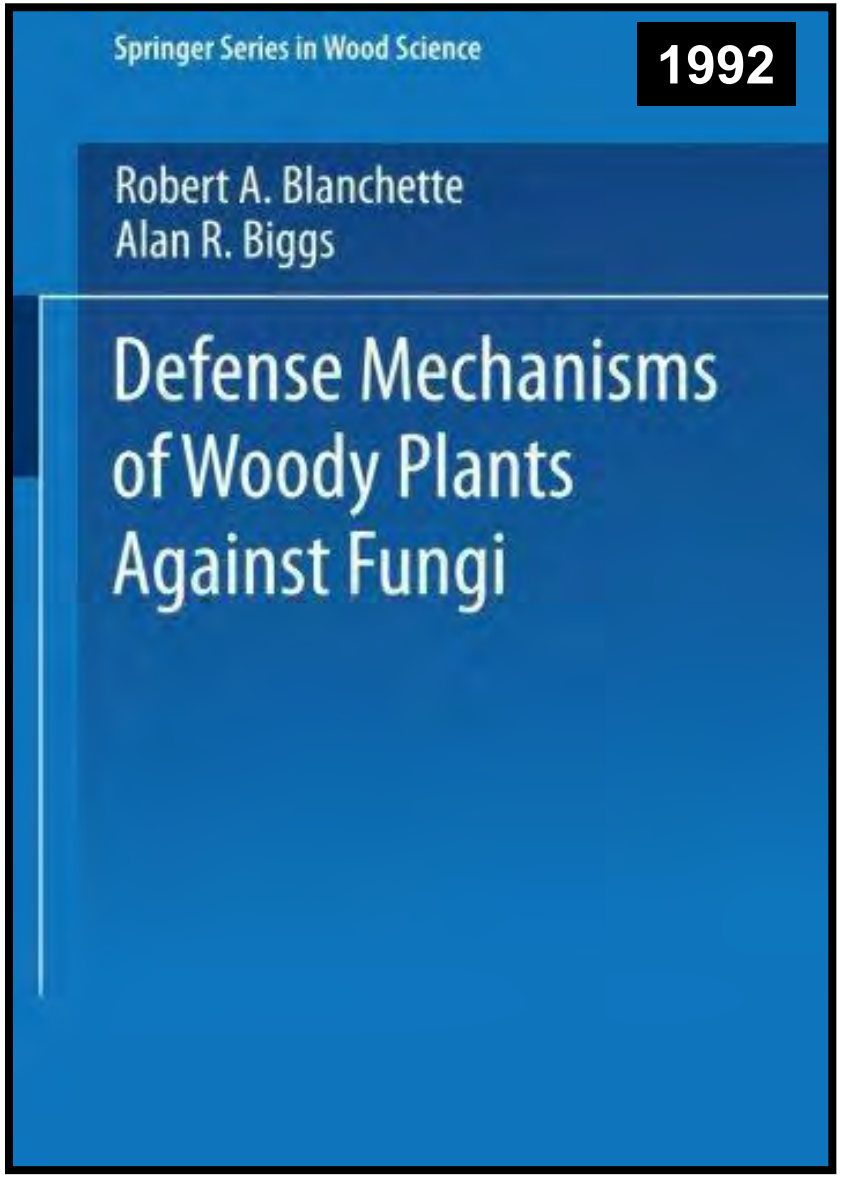
3. Mécanismes de défense





bioGraphic.com

3. Mécanismes de défense



3. Mécanismes de défense

Sequoiadendron giganteum
Séquoia géant
Sierra redwood

Sequoia sempervirens
Séquoia toujours vert
Coast redwood

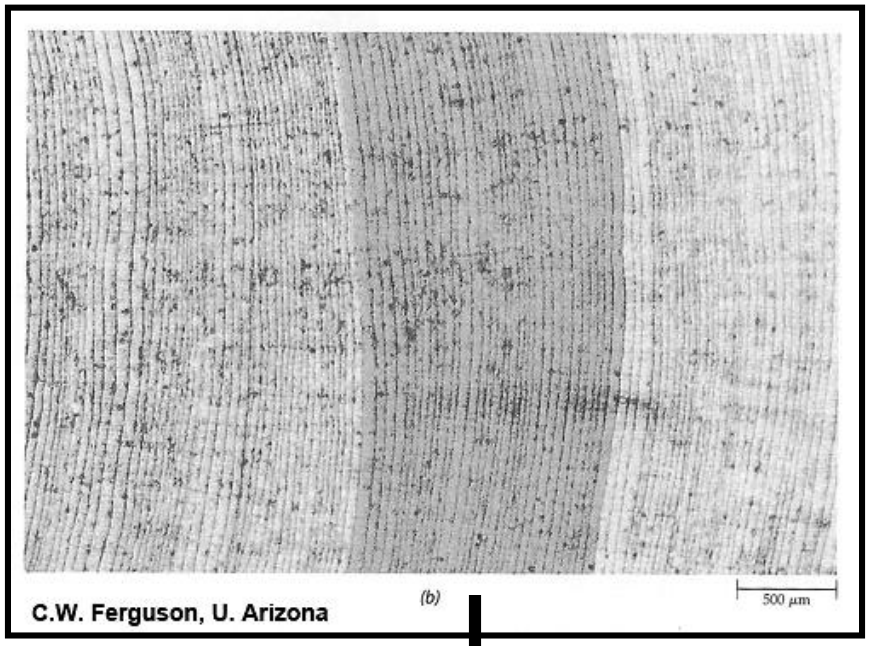
M.W. Moffett, National Geographic, Janvier 1997

Canada

3. Mécanismes de défense

J. Beaulieu, SCF

Pin de Bristlecone
Pinus longaeva
+ 5000 ans



4240 à 4210 av. J.C.

Séquoia géant - Écorce 60-90 cm

J. Beaulieu, SCF

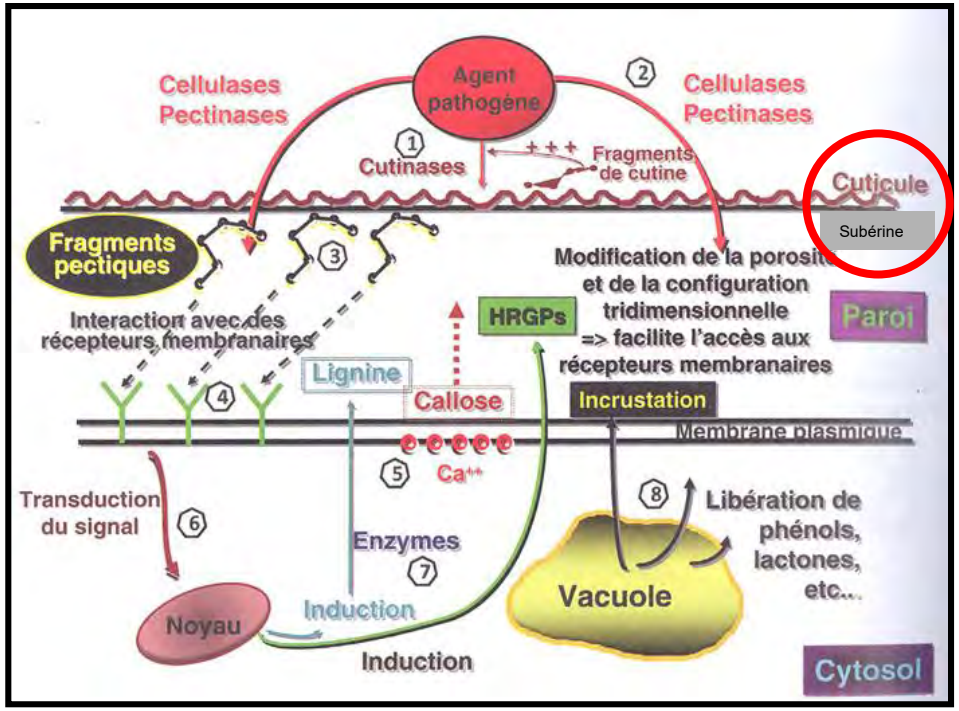
Constitutifs : bois de cœur
Induits : aubier

© 2007 Thomson Higher Education

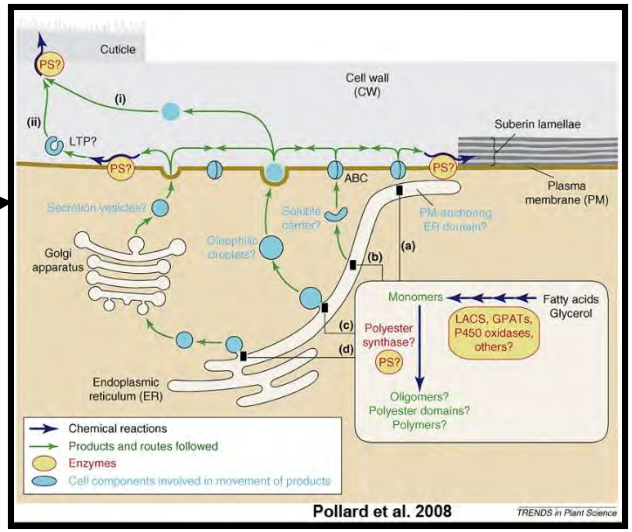
Fig. 7-11, p. 141

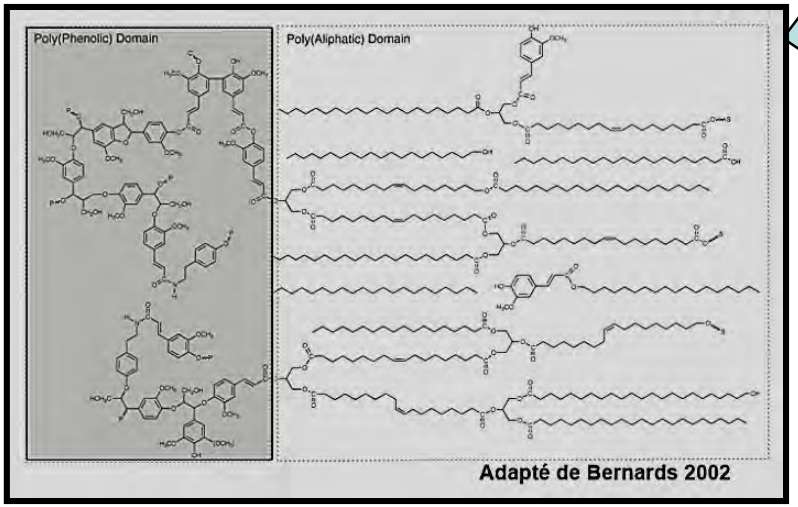
Noyer cendré (*Juglans cinerea*)

Chimiques – Épiderme et périderme

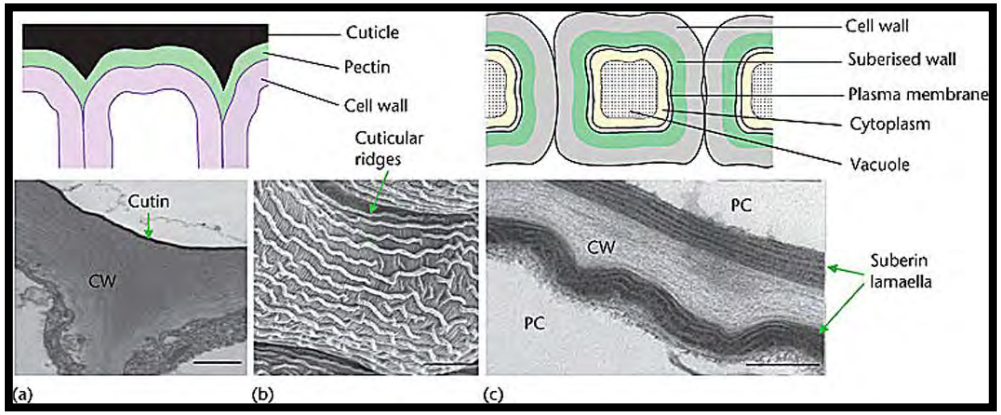


Adapté de Benhamou 2009

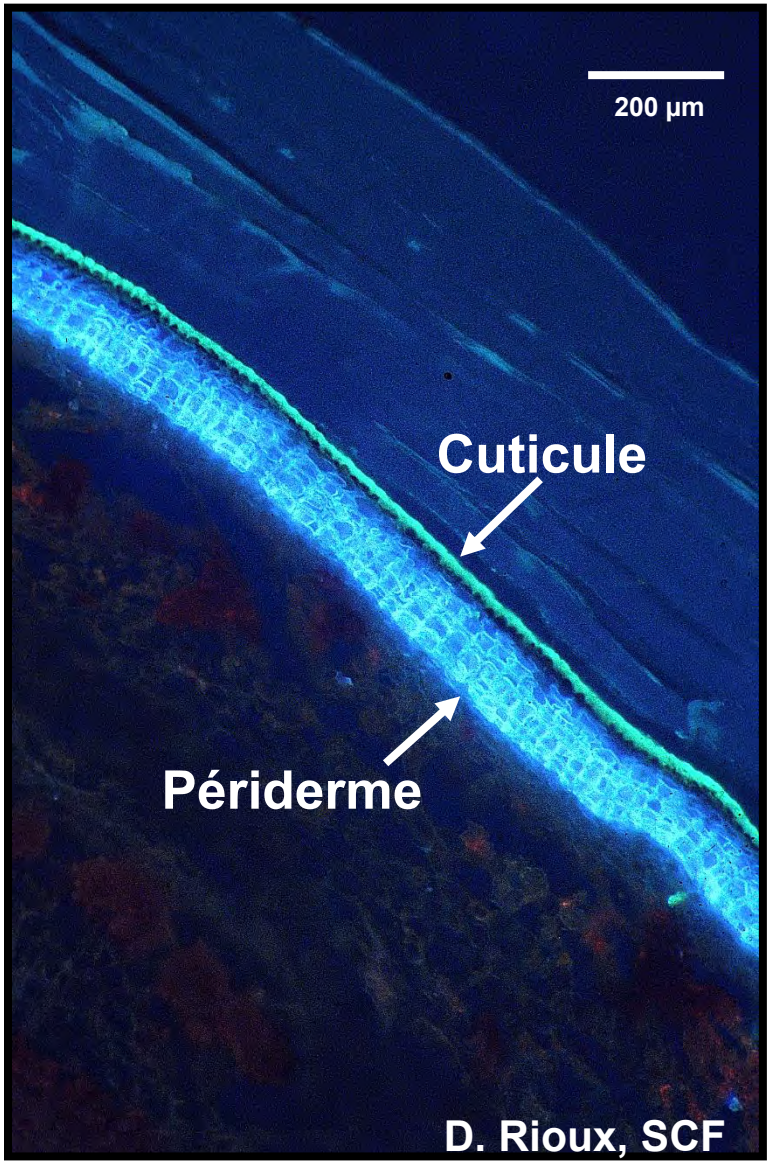




Épiderme (cuticule)
Périderme (subérine)

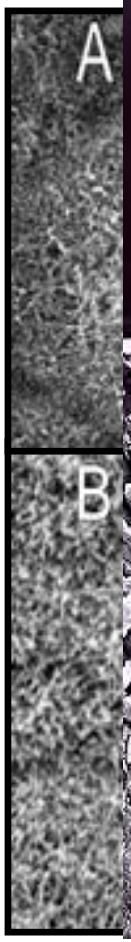


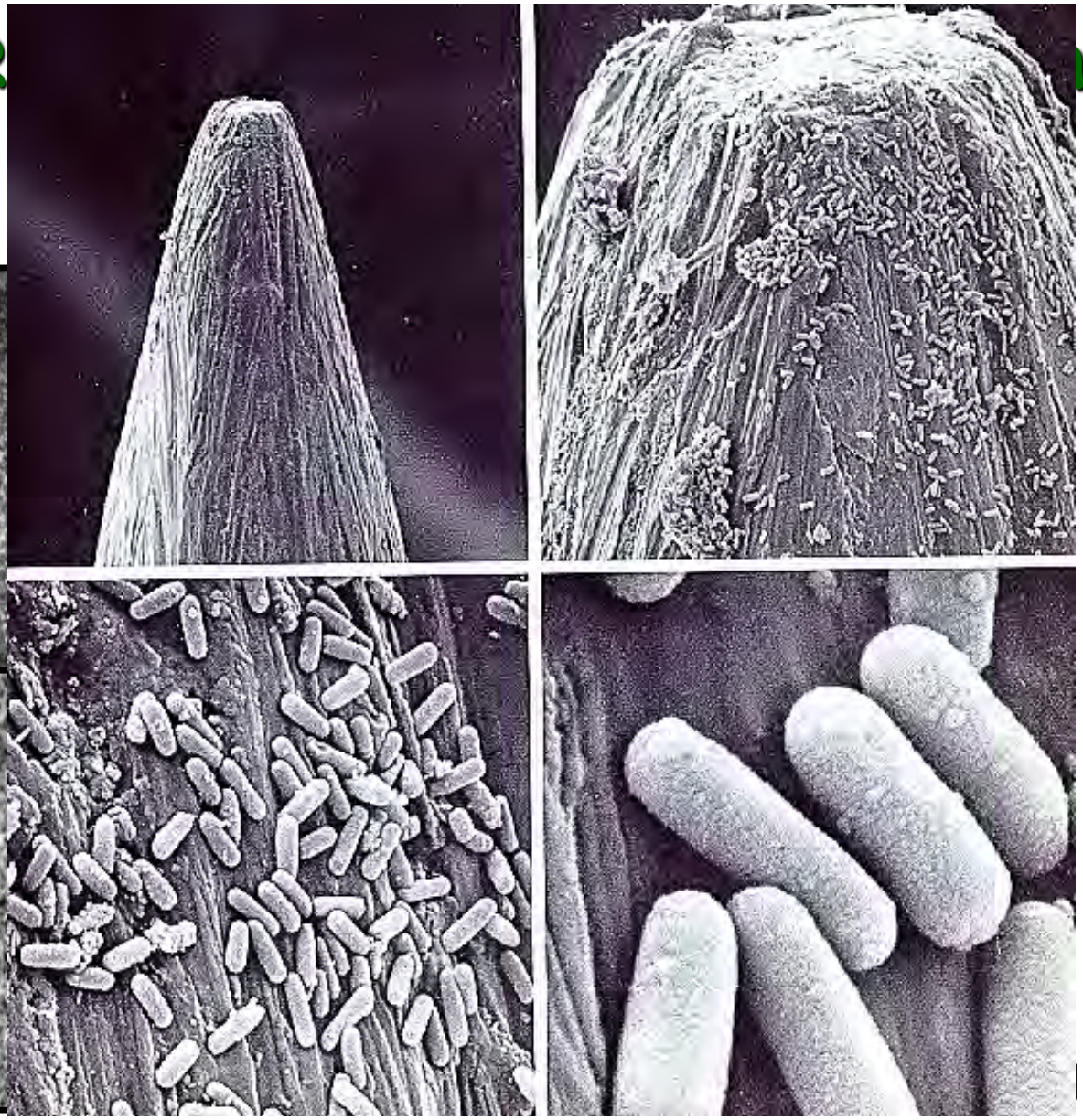
Li-Beisson 2011



3. Mécanismes de défense constitutifs

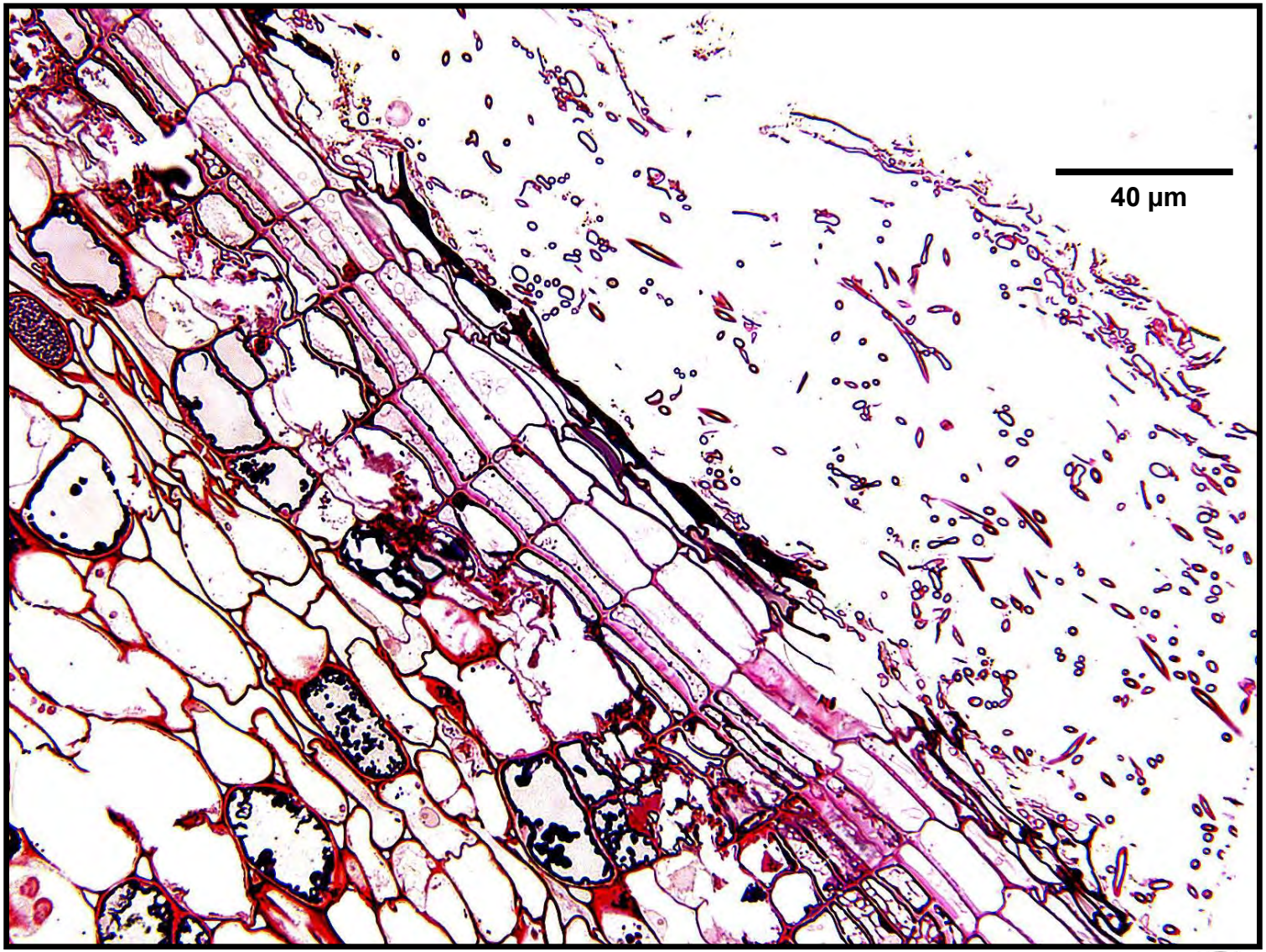
R ic





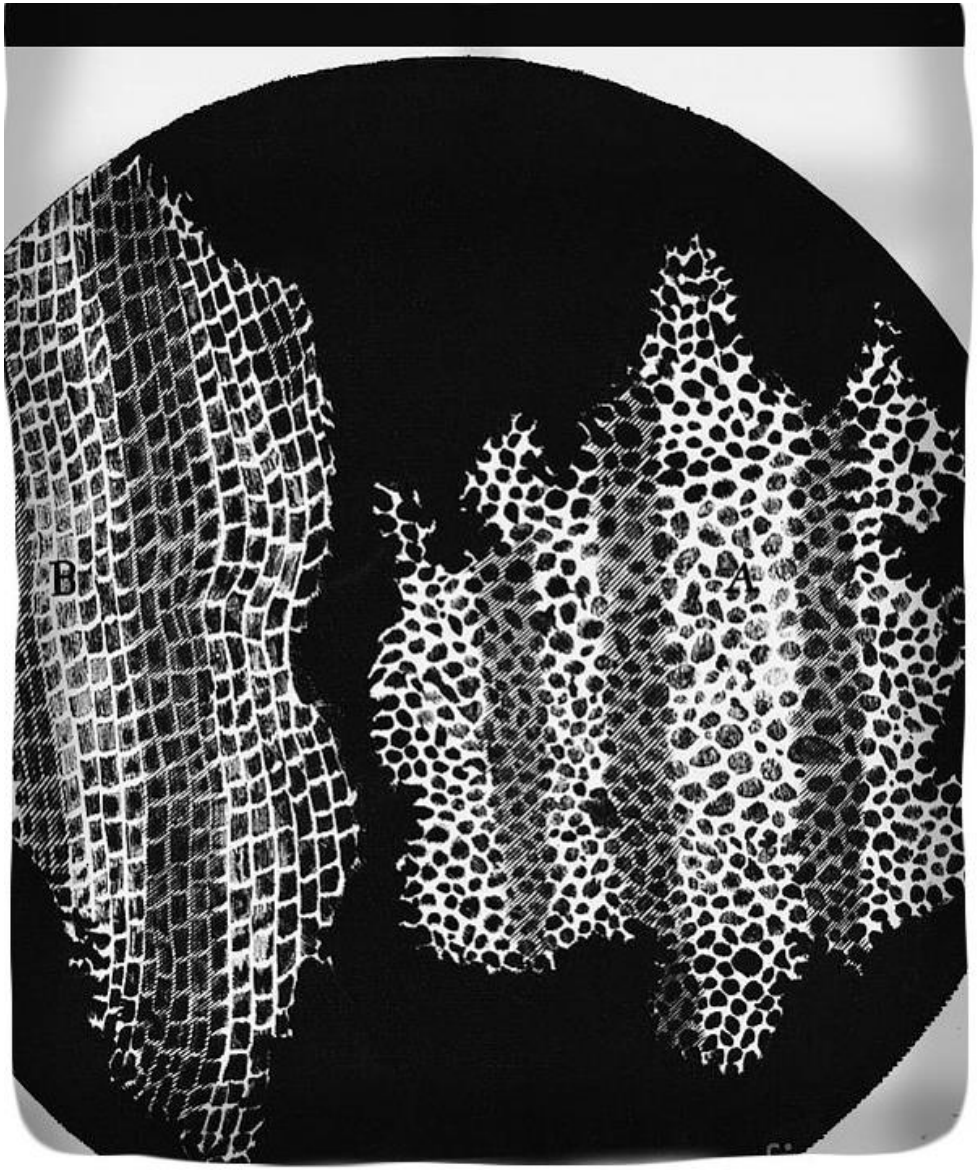
. 2006

Constitutifs - Périderme



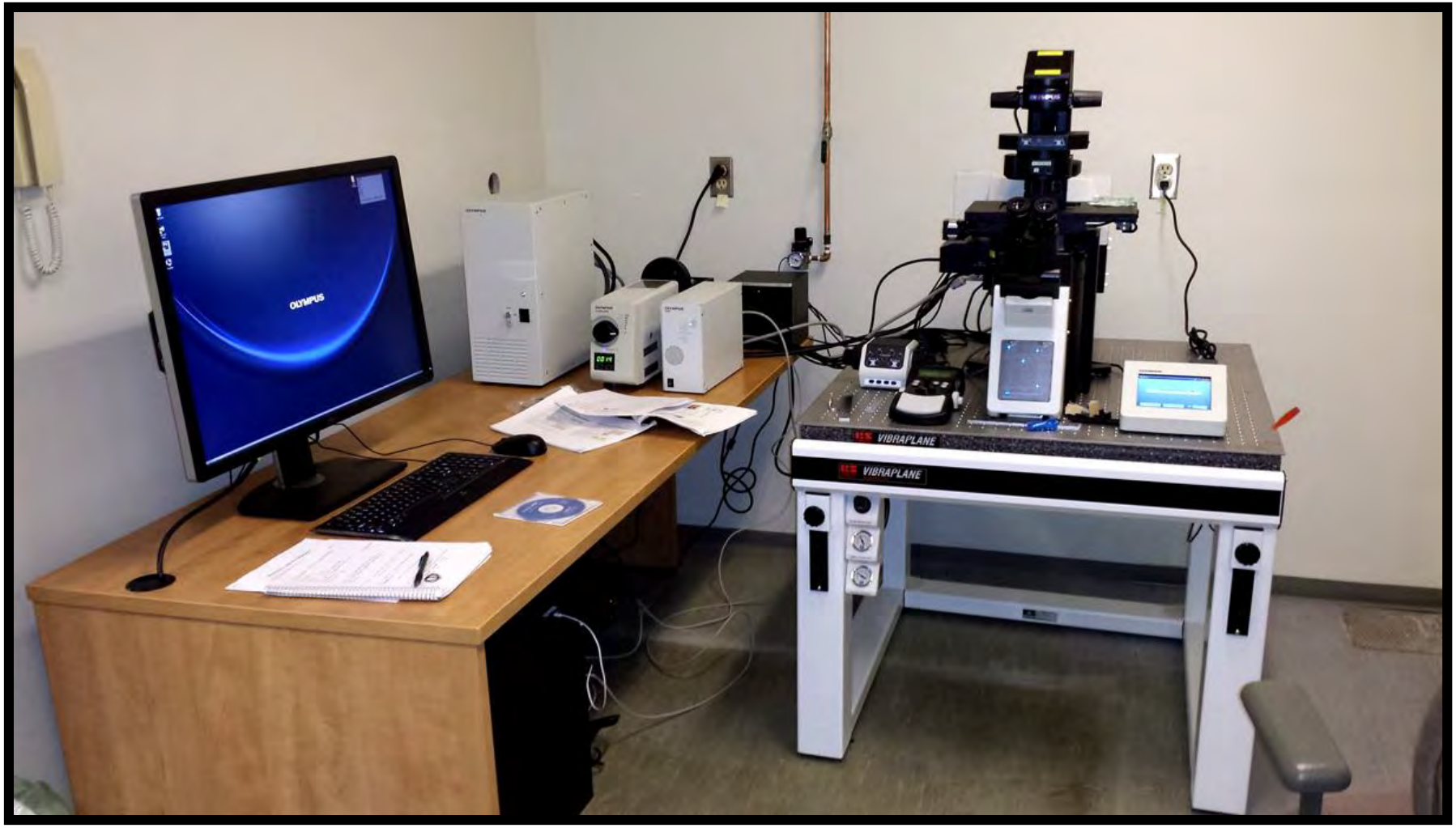
D. Rioux, SCF

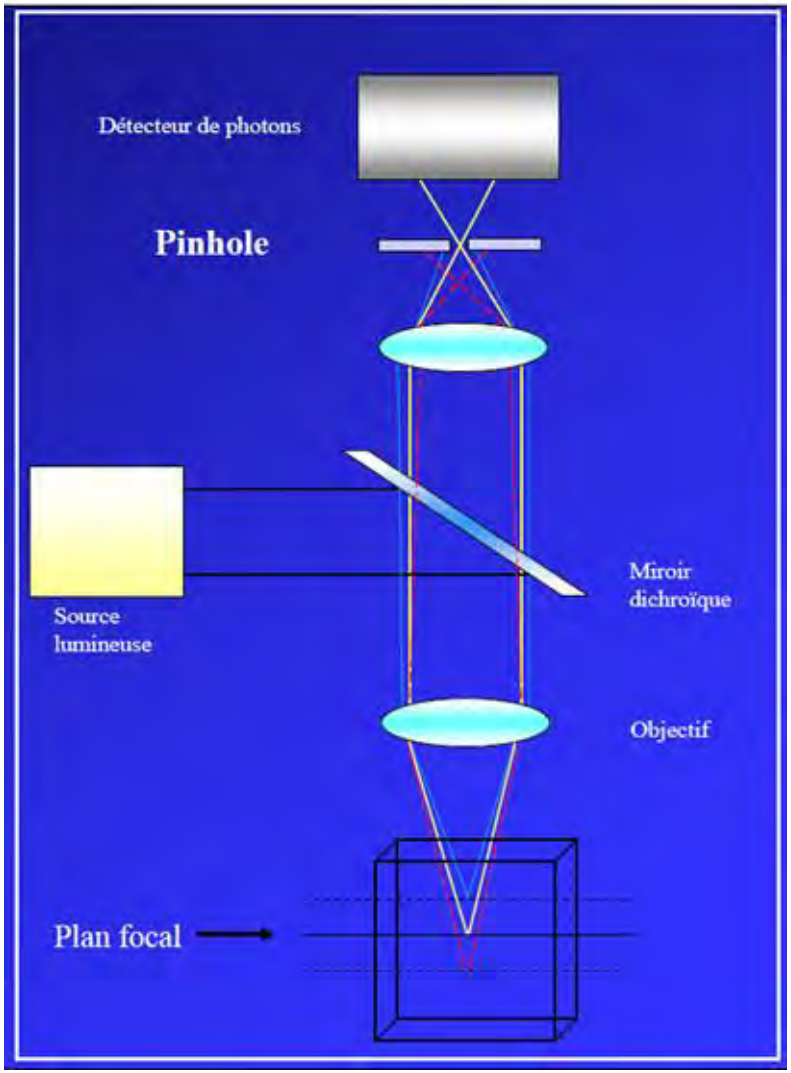
3. Défense : écorce



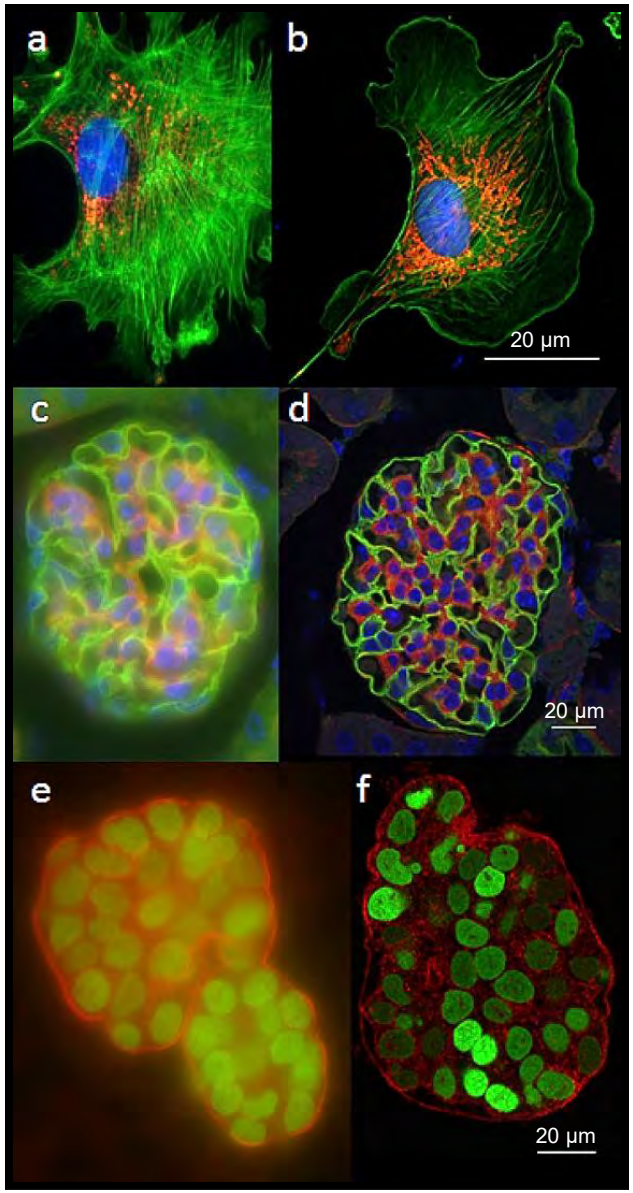
Robert Hooke 1665

Microscope confocal à balayage laser





Conv. Confocal



< 5 µm

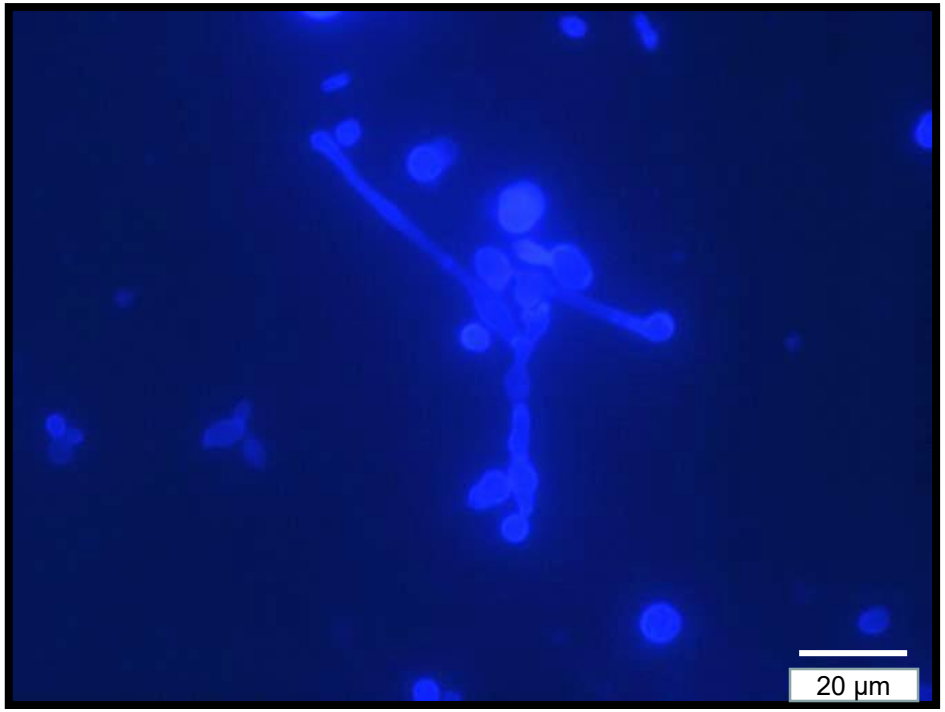
~20 µm

~50 µm

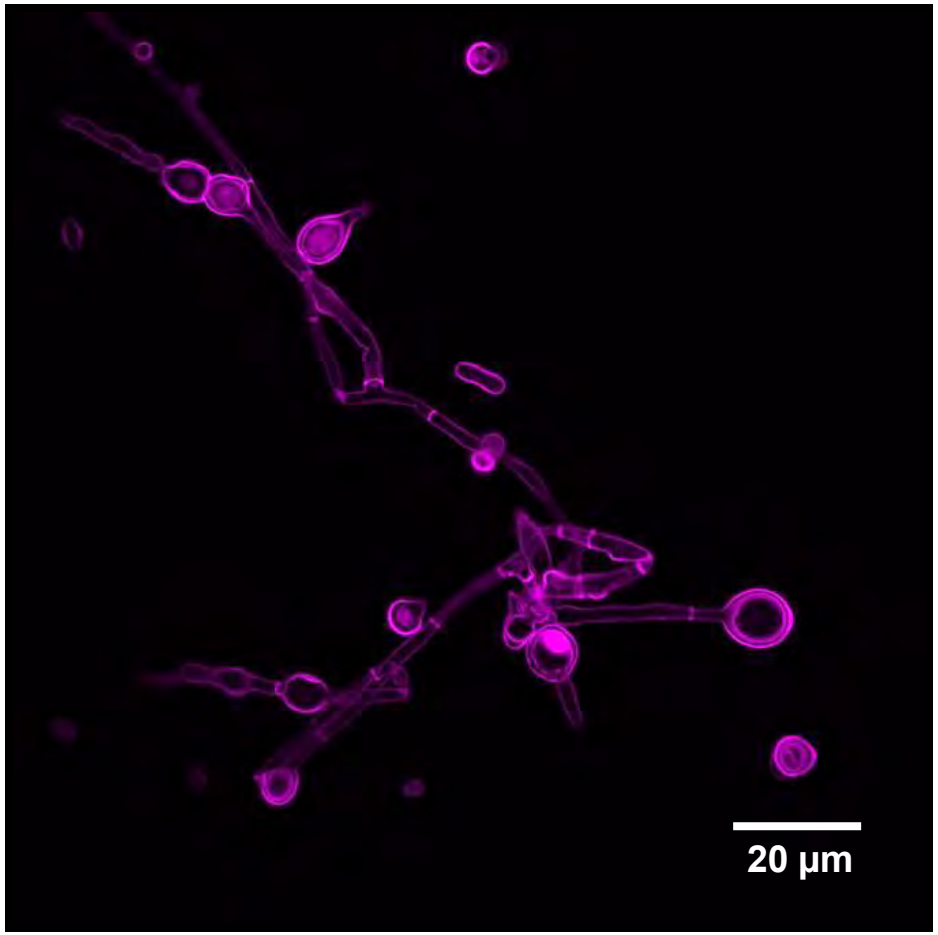
Jonkman et Brown 2015

Grosmannia clavigera
Calcofluor White MR2 (chitine)

Conventionnel (UV)



Confocal (405 nm)



A. DiCarlo, M. Blais
et P. Tanguay

Microscope confocal

- Coupes optiques nettes en florescence
- Observation en profondeur
- Images en trois dimensions
- Matériel fixé ou vivant (temps réel)
- Plusieurs fluorochromes en même temps
- Mesure quantitative de la fluorescence
- Logiciels d'analyse d'images puissants

Liège

CorkLink

Unique Wood Floors

Chêne liège – Quercus suber

Chêne liège – Quercus suber

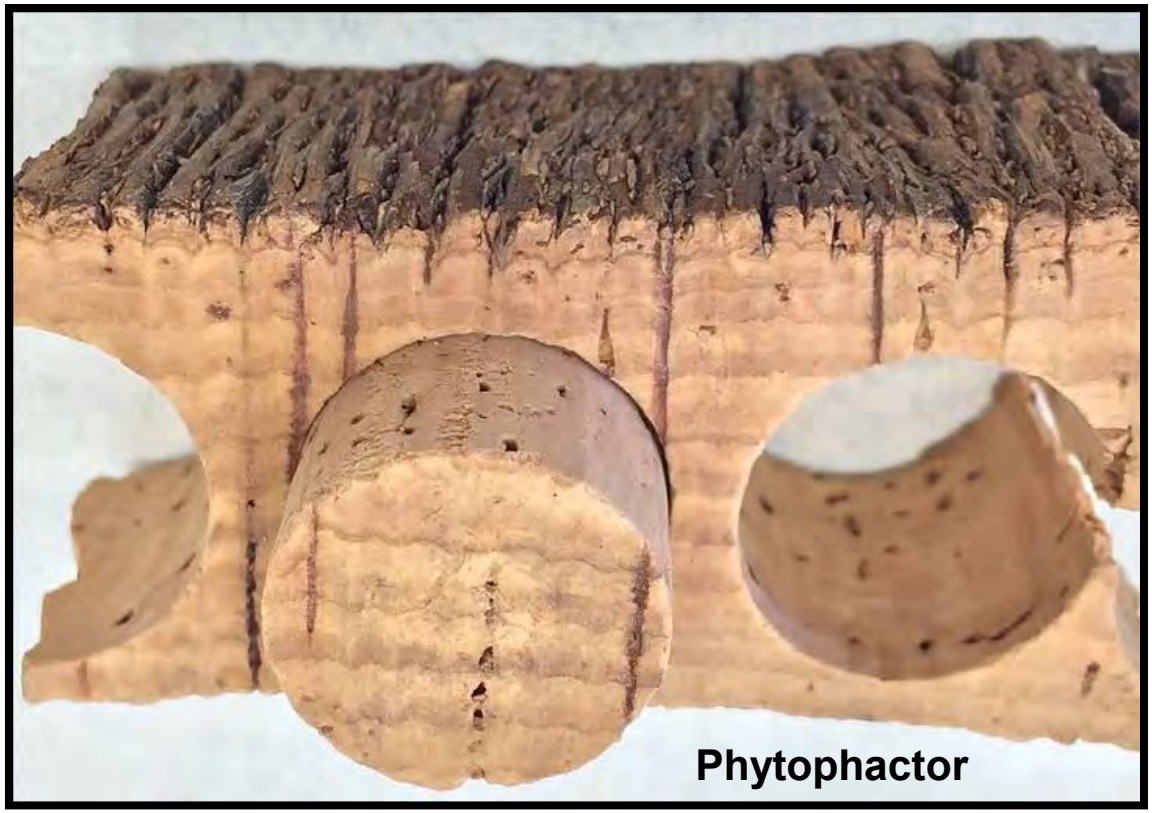
TABLE 5.1.

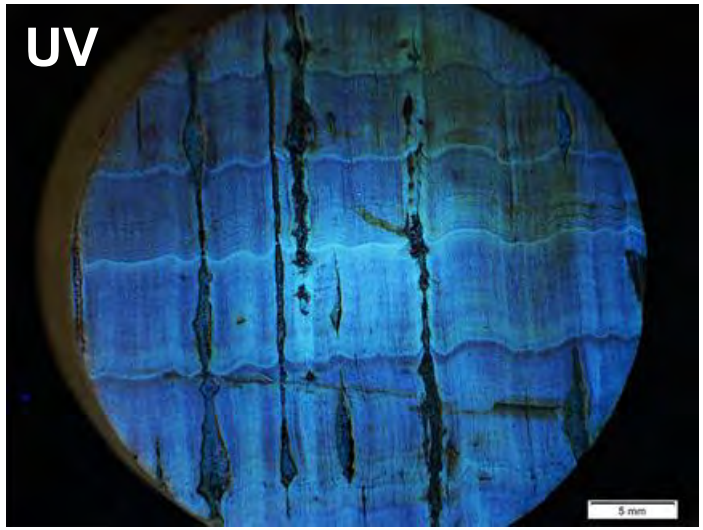
Direct use values for western Mediterranean woodlands (all types), excluding recreational value.

	Portugal	Spain	France	Italy	Morocco	Algeria	Tunisia	Total
Timber	506,321	725,000	49,000	529,475	47,724	671	2,009	1,860,200
Firewood	37,273	38,000	—	227,183	139,680	253	2,083	444,472
Cork	390,726	41,000	3,000	4,181	6,817	5,397	9,018	460,139
Grazing and acorns	112,377	203,000	—	61,811	255,485	206,550	74,704	913,927
Mushrooms, truffles, plants, and fruits	70,960	114,000	46,000	170,930	9,124	82	5,841	416,937
Honey	7,619	—	—	22,500	19,400	516	1,706	51,741
Hunting	21,383	180,000	5,800	71,250	8,924	—	1,942	289,299
Other	3,089	133,000	1,600	0	0	1,577	0	139,266

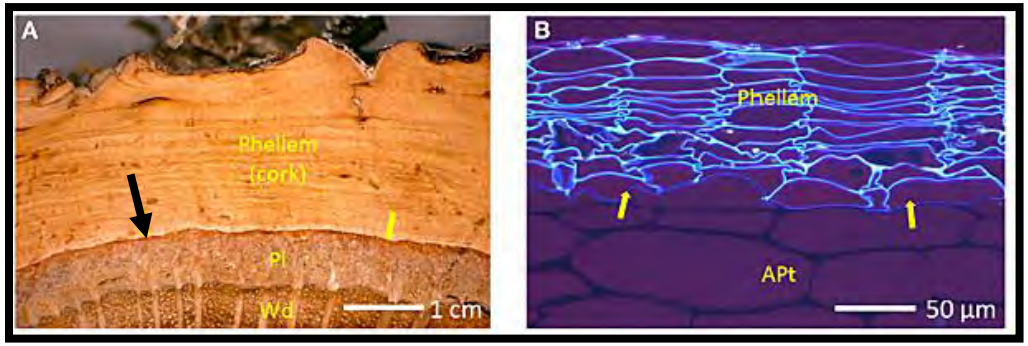
Data for 2001 (in 1,000 euros).
Source: Compiled from Merlo and Croitoru (2005b).

Liège - Cernes



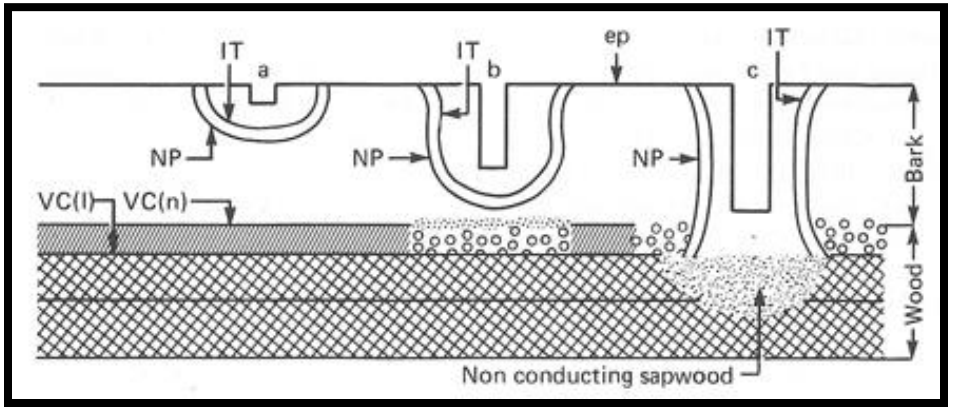


D. Rioux, SCF

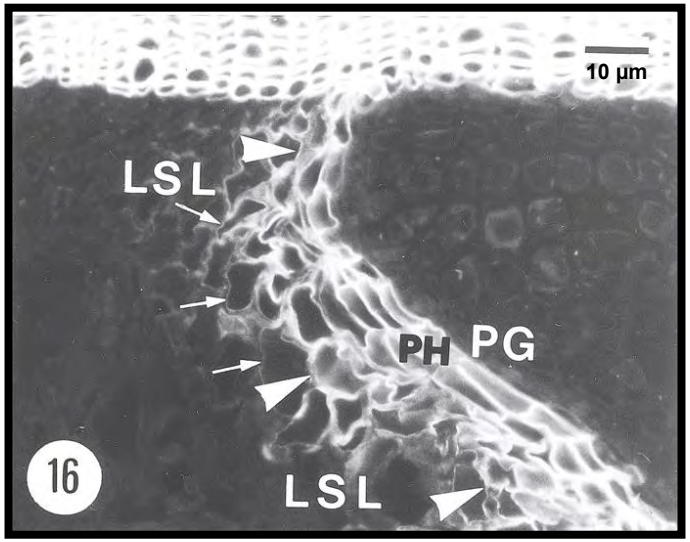


Graca 2015

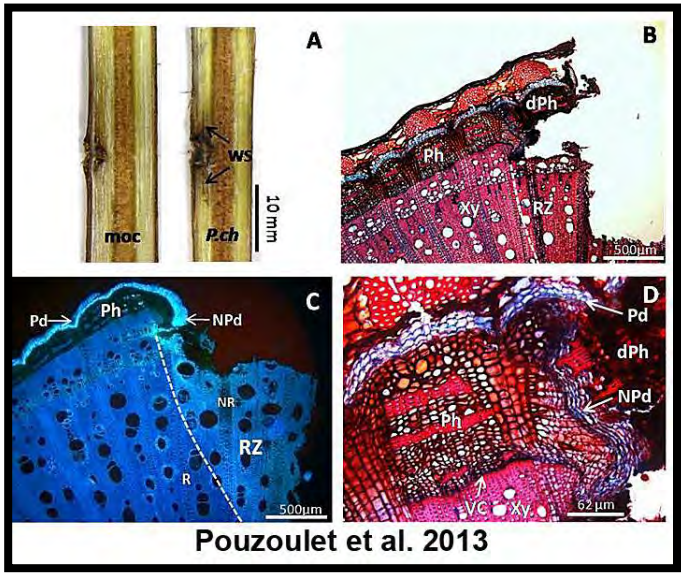
Induits : nouveau périderme (NP)



Biggs 1992 – Adapté de Mullick 1977



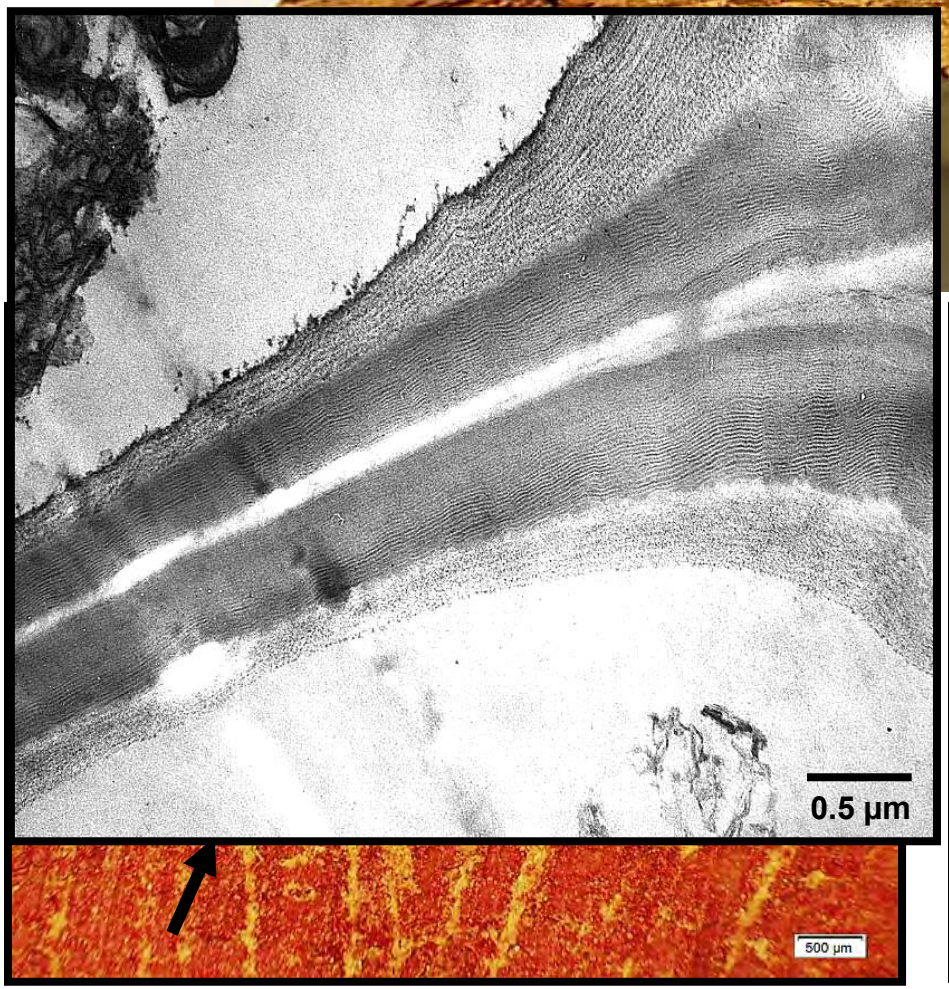
Rioux et Biggs 1994

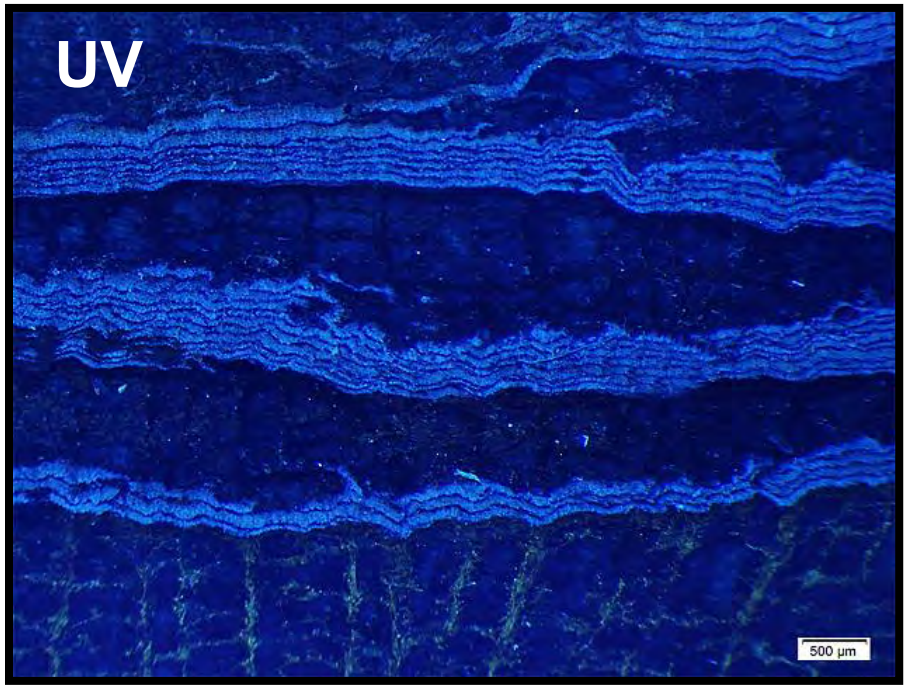


Pouzoulet et al. 2013

M. Blais, SCF

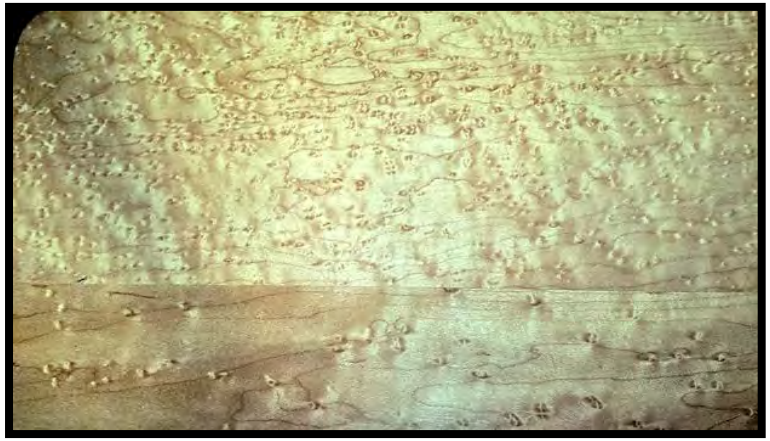
Érable à sucre - Écorce

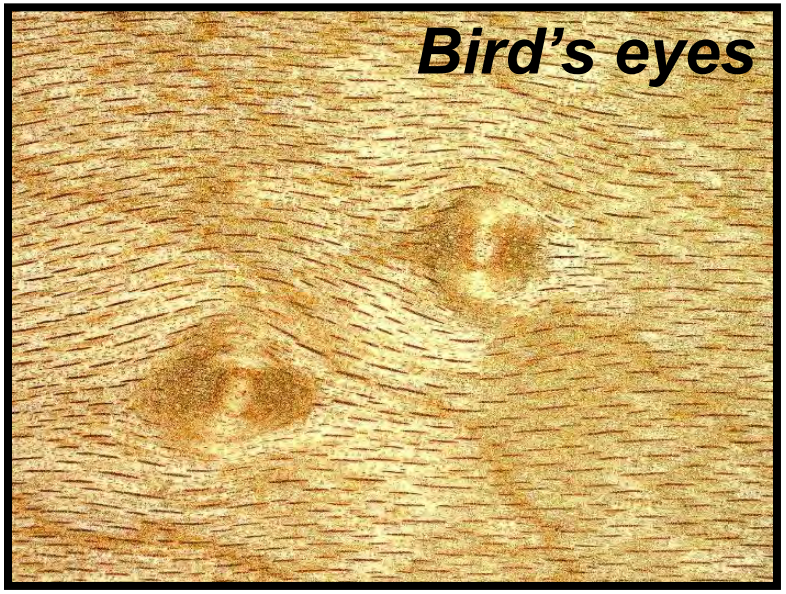




D. Rioux, SCF

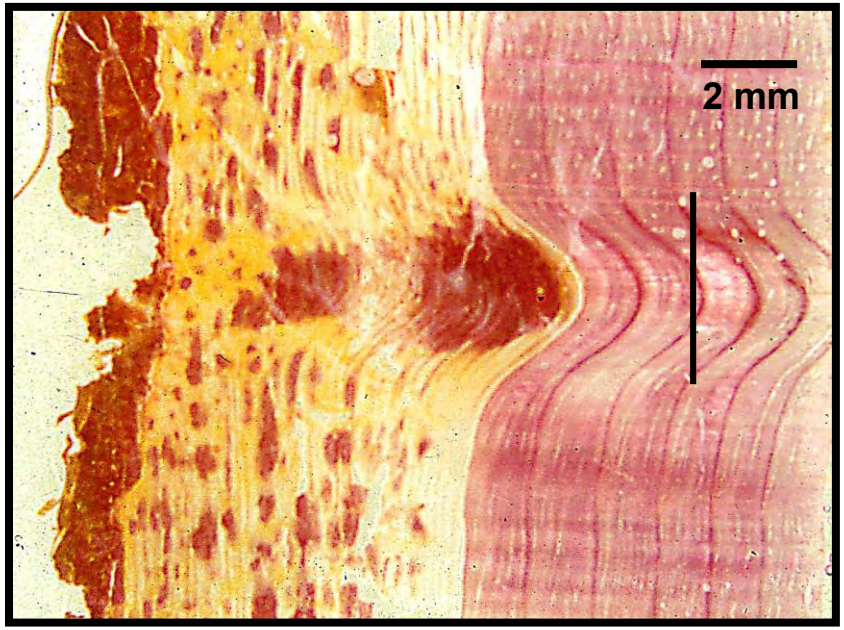
Déroulage : 70 000 $/Mpmp (Bragg et al. 1997)
Bois conventionnel 2 000 $/Mpmp

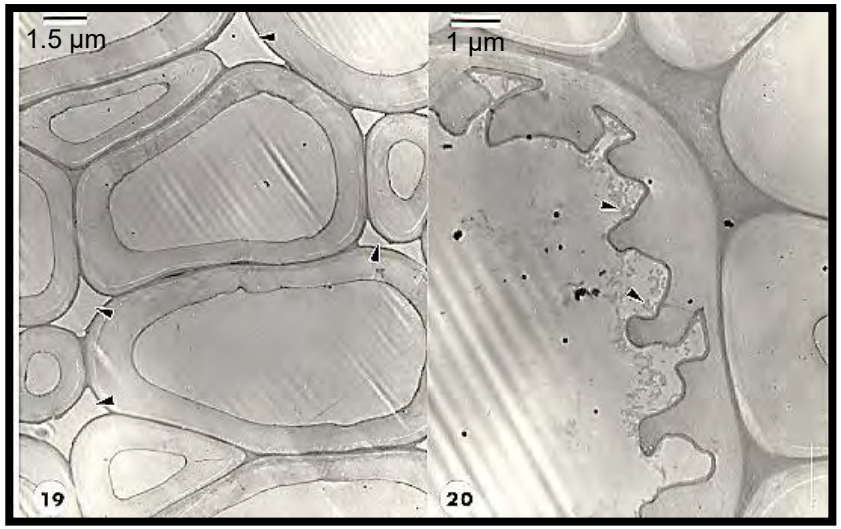


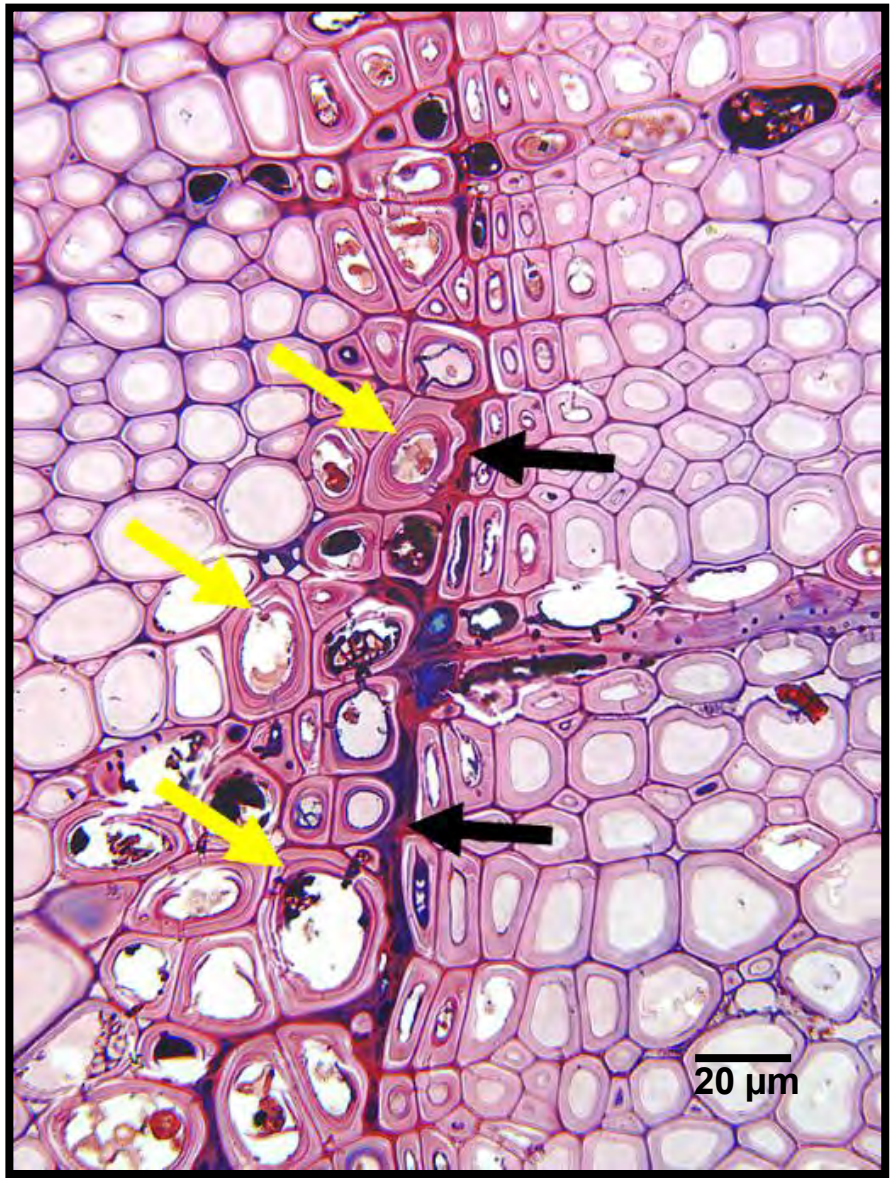


D. Rioux, SCF

3. Défense : érable piqué







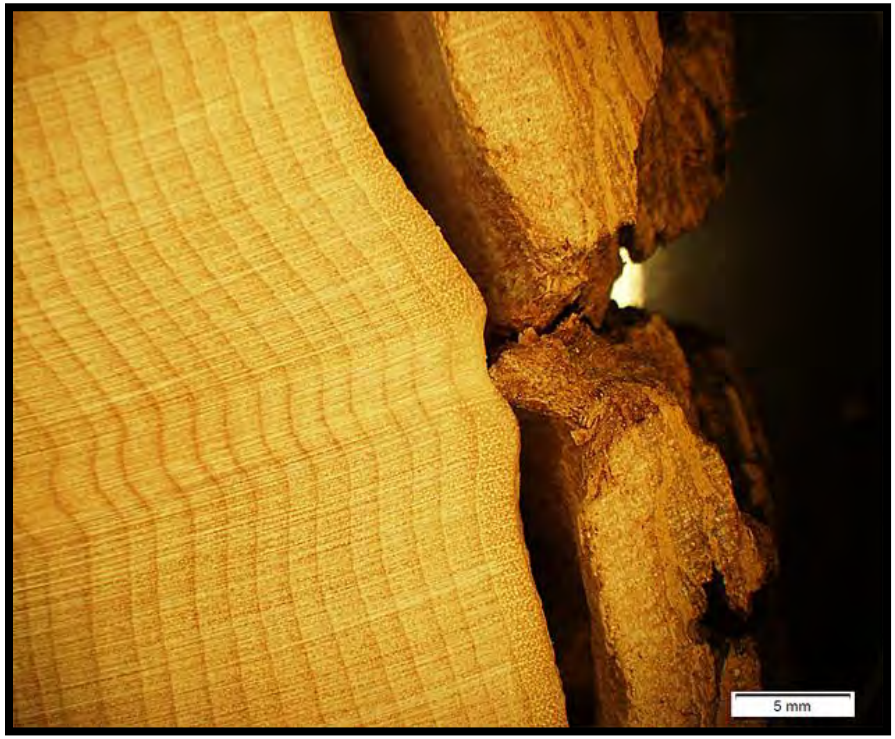
D. Rioux, SCF

Éthylène impliqué?

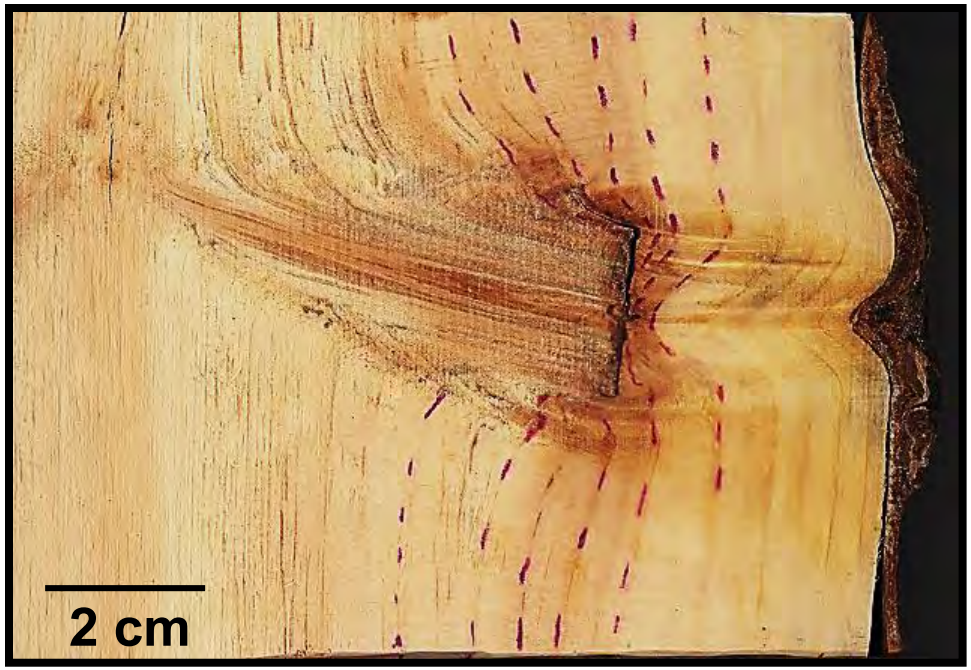
- Pression de l'écorce : l'hormone stimulerait le phellogène (Li et Cui 1985; Yamamoto et Kozlowski 1987)
- Diminuerait le diamètre des vaisseaux (Savidge 1988; Aloni et al. 1998)
- Induirait la formation de rayons (Lev-Yadun et Aloni 1995)
- Provoquerait la formation d'espaces entre les éléments du bois (Yamamoto et al. 1987)
- Produit en situation de stress

Rioux et al. 2003. CJFR 33 : 946-58

Érable à sucre

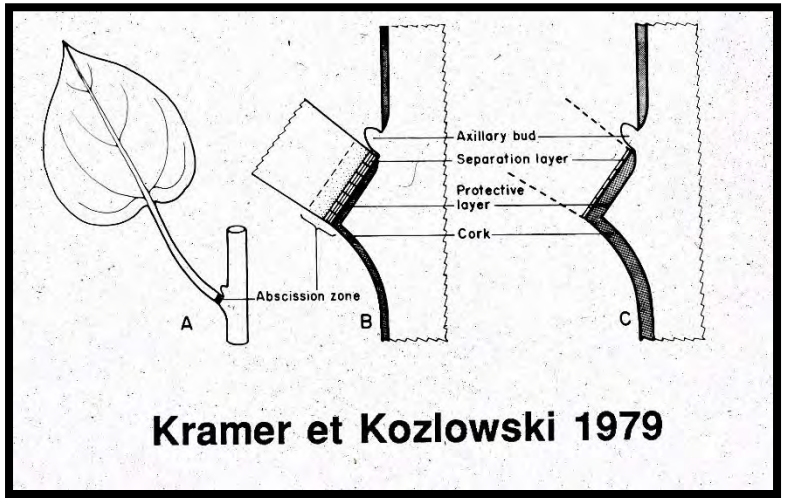


Pin blanc



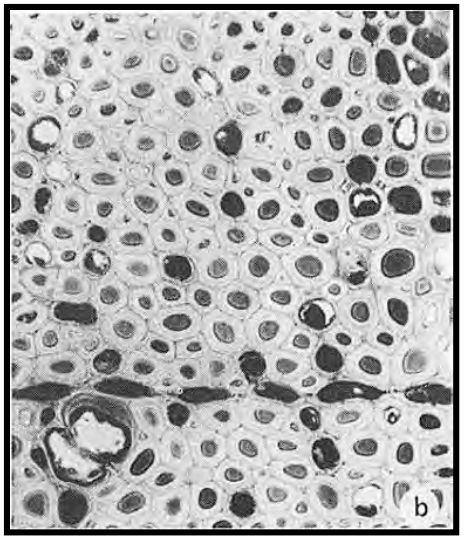
D. Rioux, SCF

Branches mortes = ~Abscission des feuilles?



Kramer et Kozlowski 1979

Dujesiefken et Stobbe 2002



von Aufsess 1984

Zone verte à la base des branches bien compartimentées chez l'érable rouge. Green et al. 1981

Noyer cendré

B. Marshall, Sault College

Noyer noir

Shigo 1989

TABLE 3.5 Variations in Natural Pruning of Lateral Branches of Various Species of Trees Growing in Dense Stands

Good natural pruners		Poor natural pruners	
Angiosperms	Gymnosperms	Angiosperms	Gymnosperms
Betula lenta	*Abies procera*	*Celtis laevigata*	*Abies balsamea*
Fagus grandifolia	*Larix laricina*	*Juglans nigra*	*Juniperus occidentalis*
Fraxinus americana	*Picea mariana*	*Quercus nigra*	*Juniperus virginiana*
Populus balsamifera	*Picea rubens*	*Quercus phellos*	*Larix occidentalis*
Populus tremuloides	*Pinus elliottii*	*Sequoia gigantea*	*Libocedrus decurrens*
Populus trichocarpa	*Pinus palustris*		*Picea engelmannii*
Prunus serotina	*Pinus resinosa*		*Pinus contorta*
Quercus alba	*Taxodium distichum*		*Pinus coulteri*
Quercus rubra			*Pinus monticola*
Salix nigra			*Pinus radiata*
			Pinus strobus
			Pinus virginiana
			Tsuga canadensis

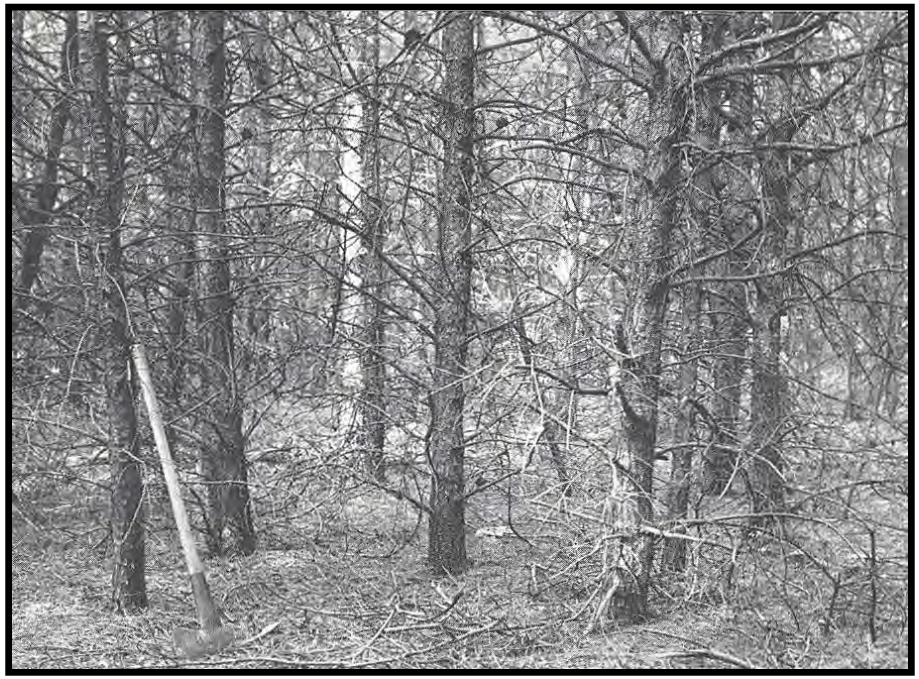
Kozlowski et Pallardy 1997

Élagage naturel

Pinus palustris

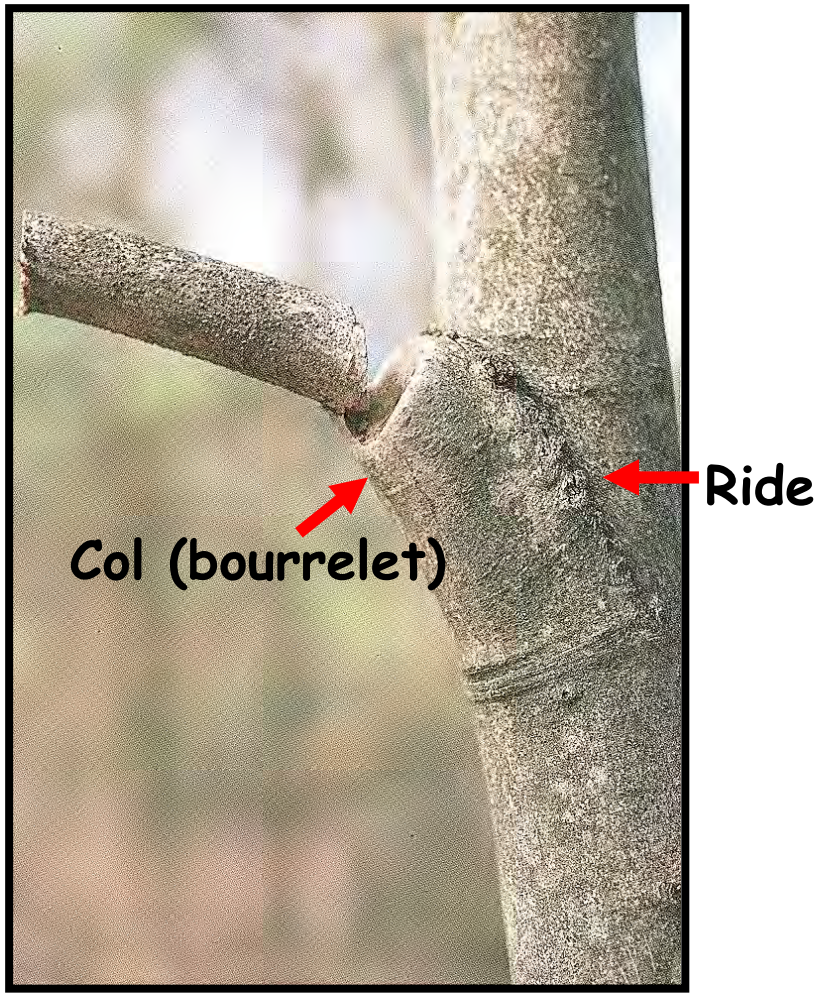
U.S.D.A. Forest Service

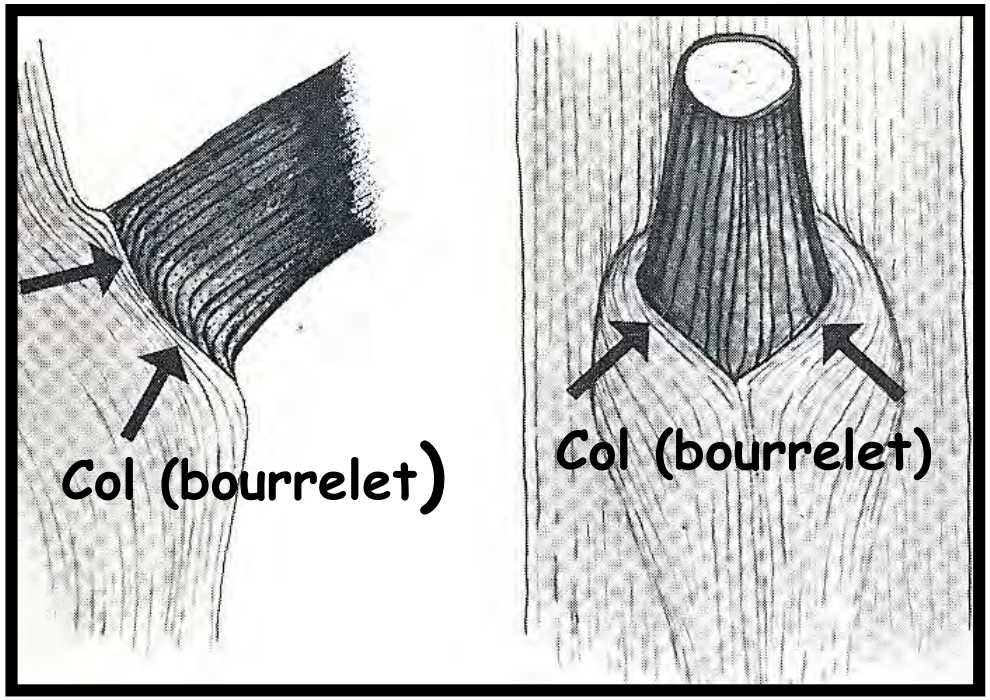
Pinus virginiana



Fenton et Bond 1964

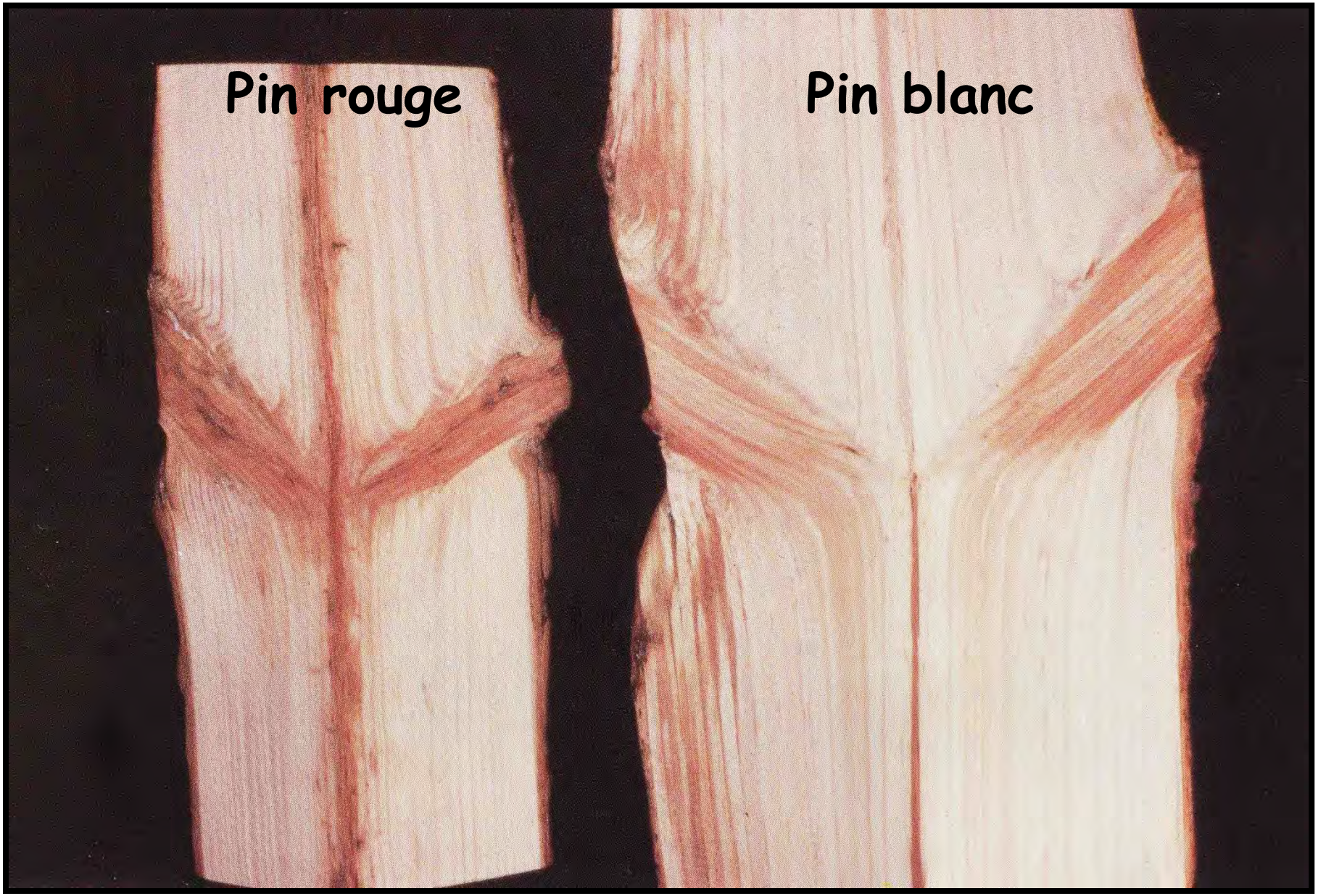
Élagage – Comment?





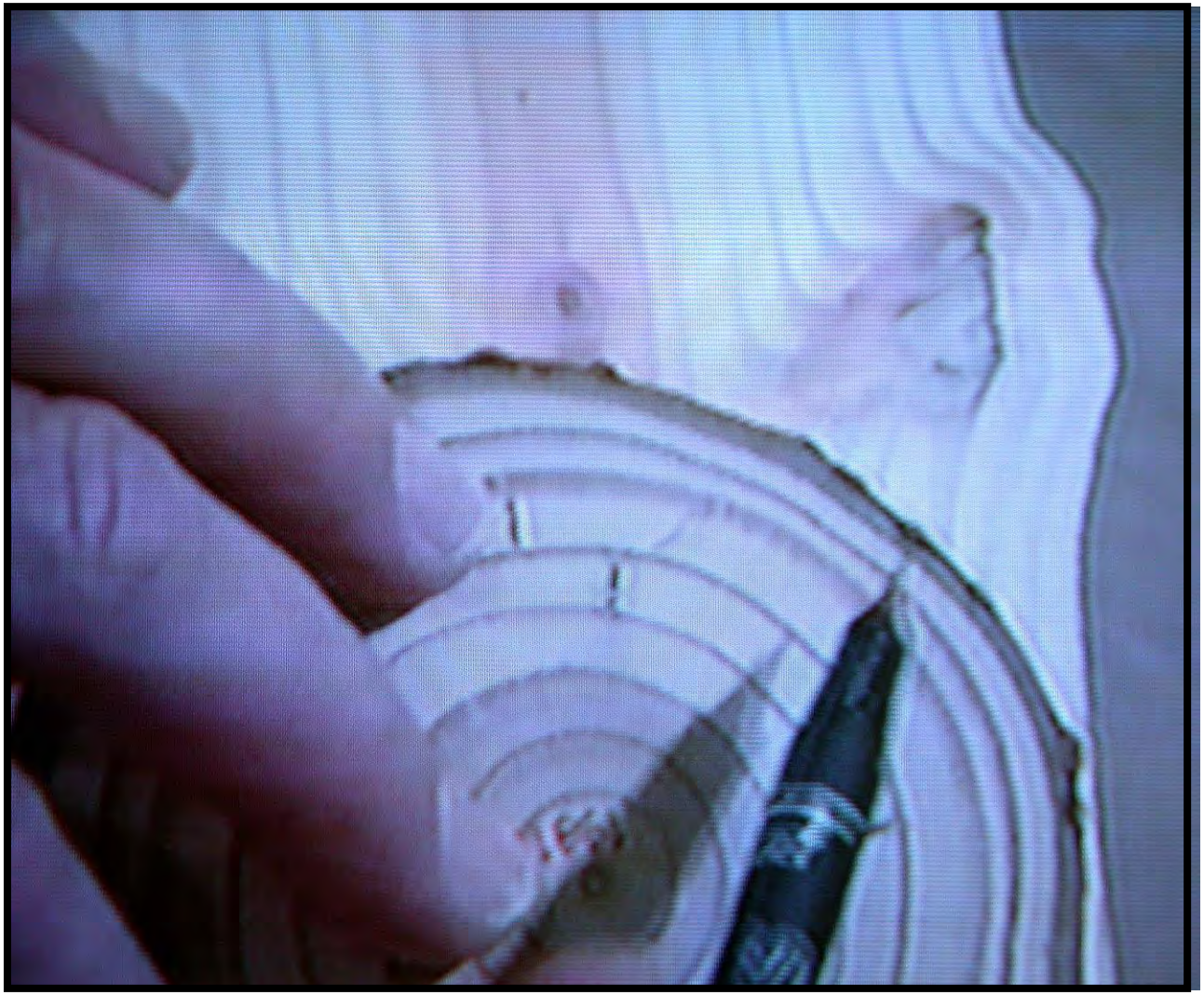
Shigo 1989

3. Défense : élagage



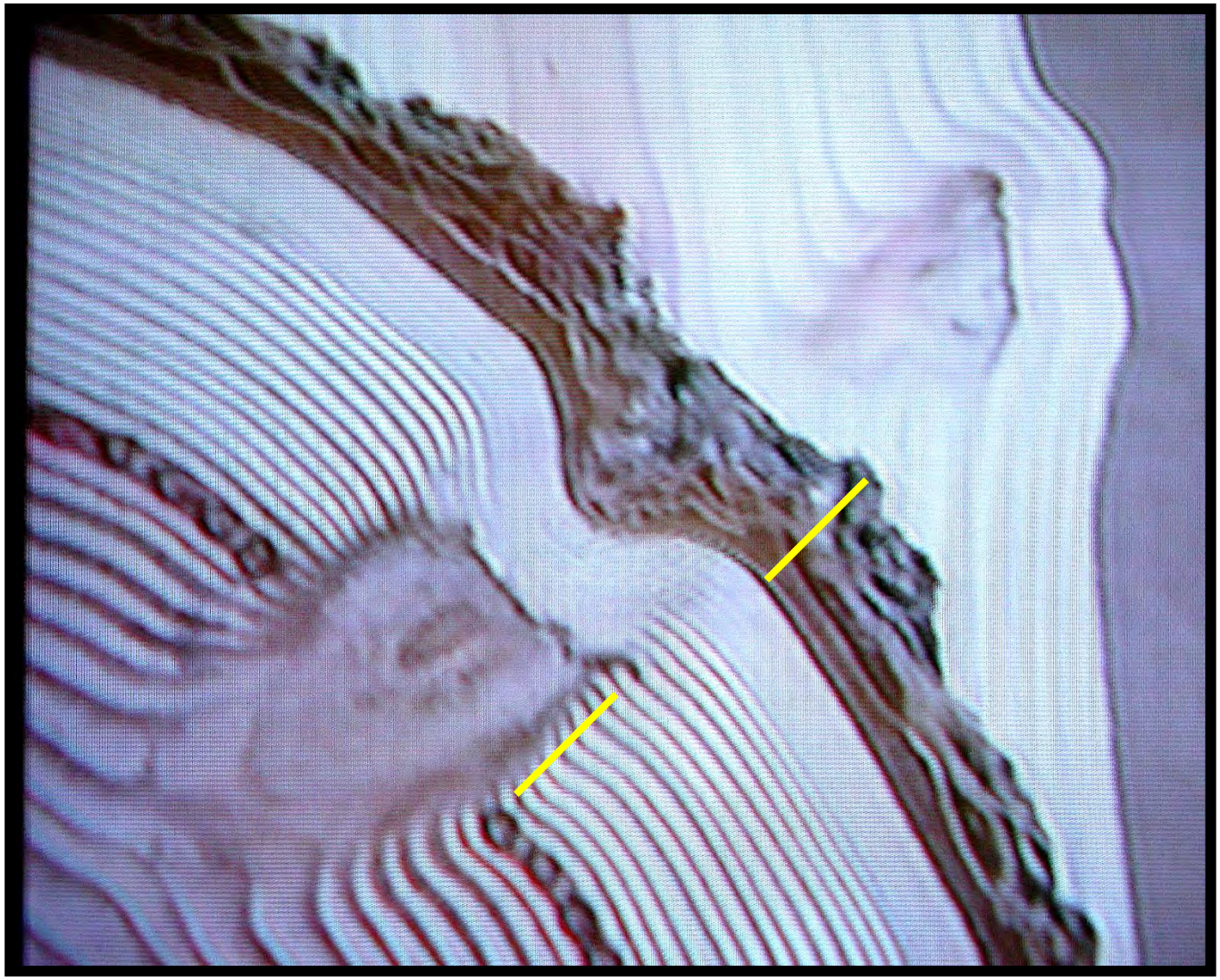
Shigo 1989

Écorce vs Fermeture



Service forestier C.-B. et L. Josza, Forintek

Écorce vs Fermeture

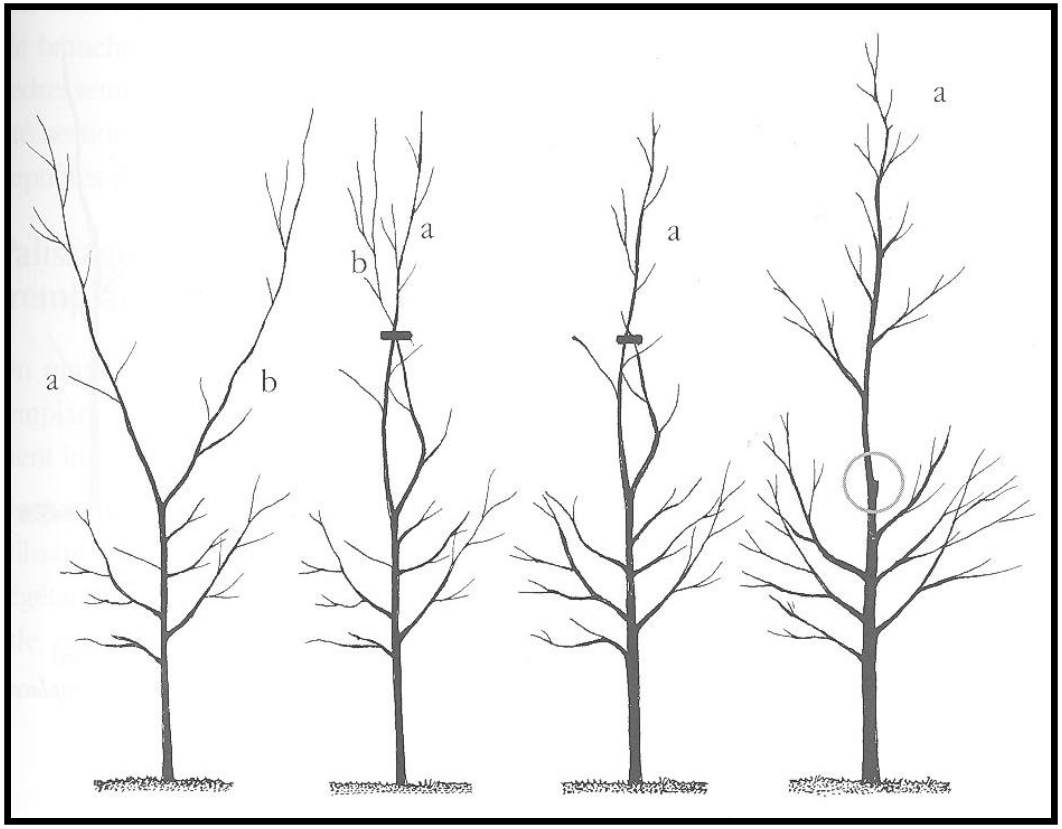


Service forestier C.-B. et L. Josza, Forintek

Taille de formation (fourche)

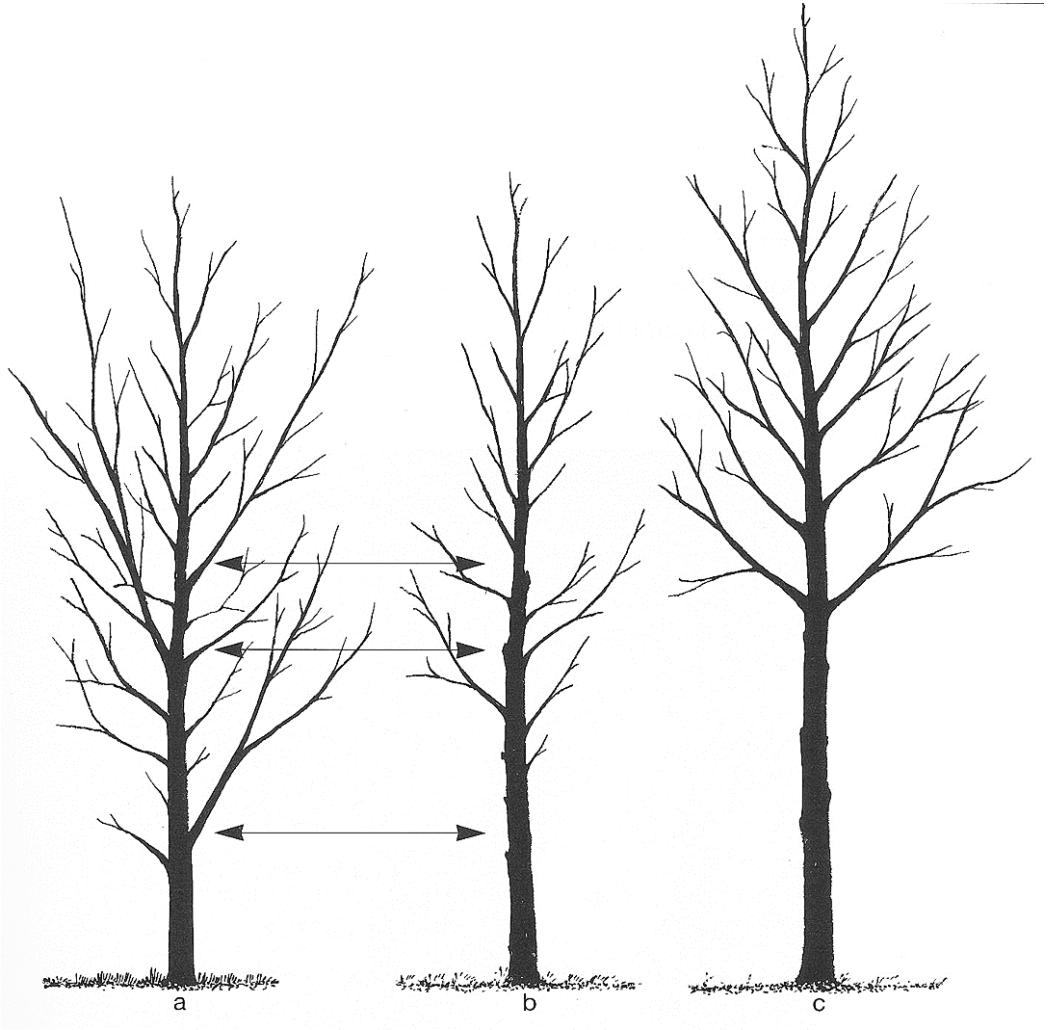
Taille de formation – Fourche – Grosse branche ou à angle aigu (< 30°)

http://www2.ville.montreal.qc.ca/jardin/info_verte/arbre/arbres.htm



Hubert et Courraud 2002

Taille de formation (de rattrapage)



Hubert et Courraud 1994

Greenhouse 2006

Table 2 : When to prune

J	F	M	A	M	J		J	A	S		O	N	D
☑	☒	☒	☒	☒	☒	☑	☑	☑	☑	☒	☒	☒	☑

☑ Optimum time to prune broadleaved trees
= Mid-June → Mid-September
(Cherry, Walnut, Sycamore, Oak, Ash, Poplar, Cricket Bat Willow etc)

☑ Ash, Oak and Poplar can also be pruned in **Jan / Dec**

☒ Avoid pruning trees in Spring and Autumn

- Conifères : dormance (hiver jusqu'à quelques semaines avant le débourrement)

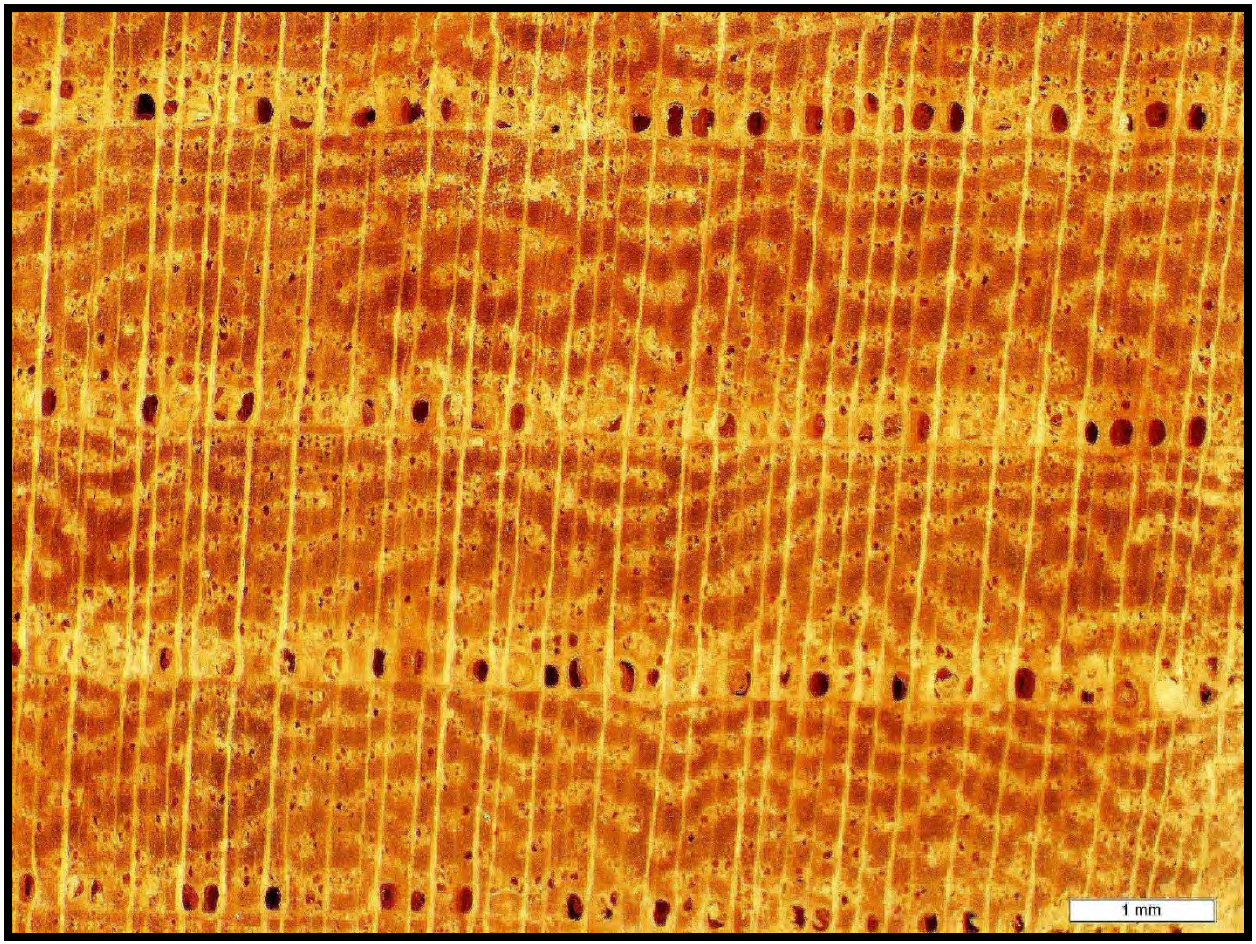
- De façon générale, pour la majorité des essences, si on enlève 10% et moins de branches de moins de 2 cm, n'importe quand (sauf ravageurs par exemple)

Chancre scléroderrien

Pomerleau et Ray 1957

G. Laflamme, SCF

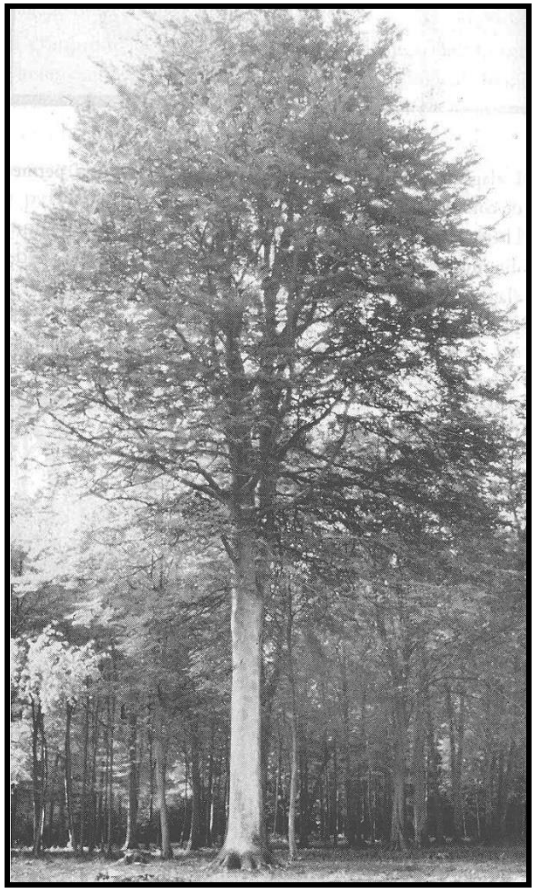
Maladie hollandaise de l'orme



D. Rioux, SCF

Élagage: tiges plus cylindriques

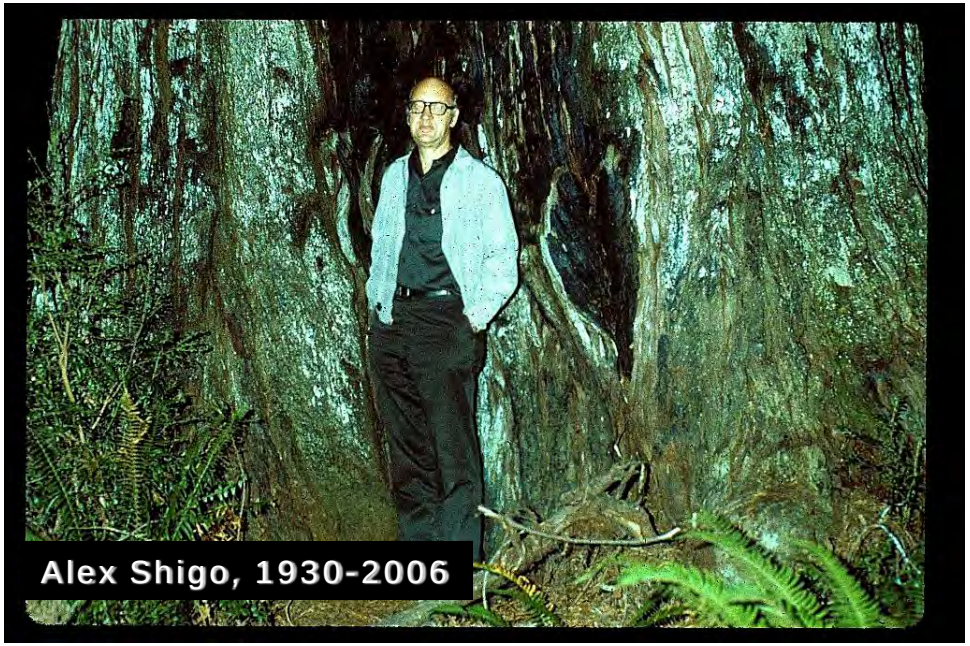
Farrar 1995

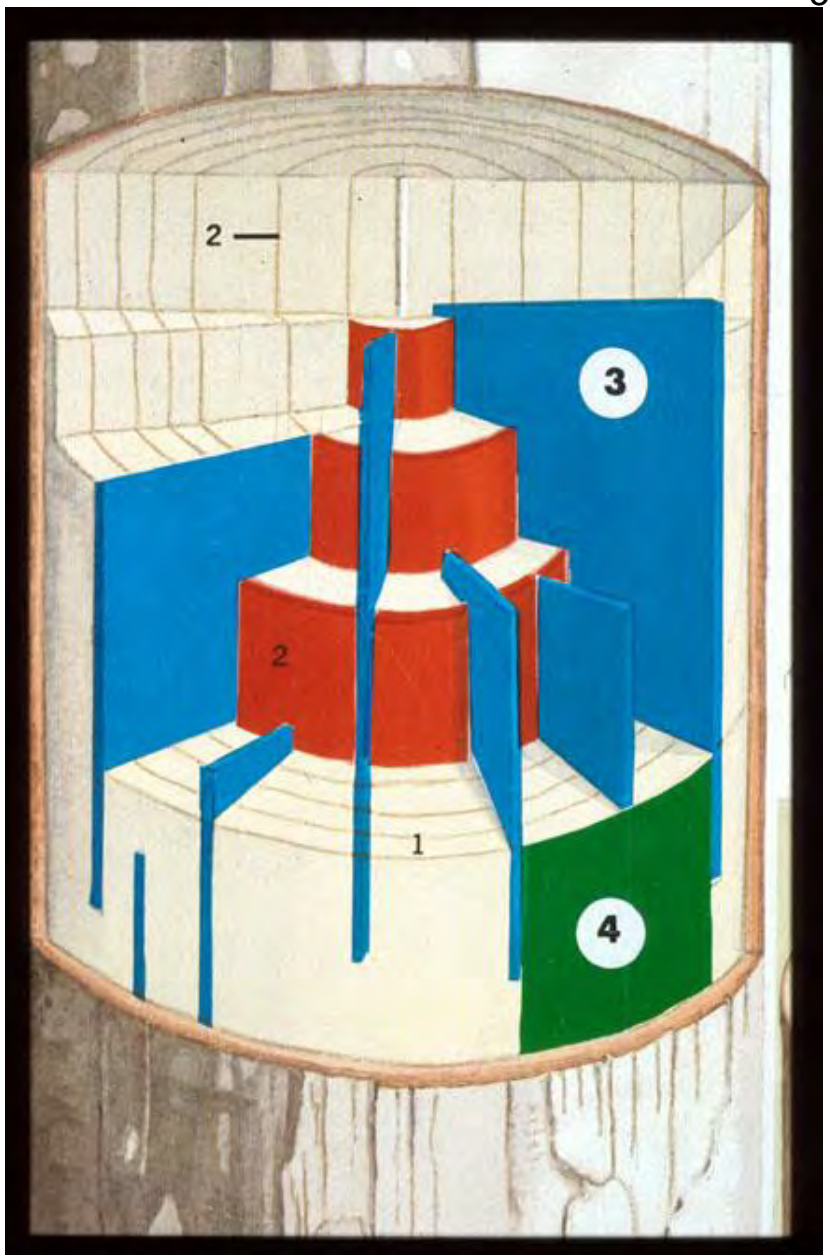


Hubert et Courraud 2002

Compartimentage

CODIT
(*Compartmentalization Of Decay In Trees*)



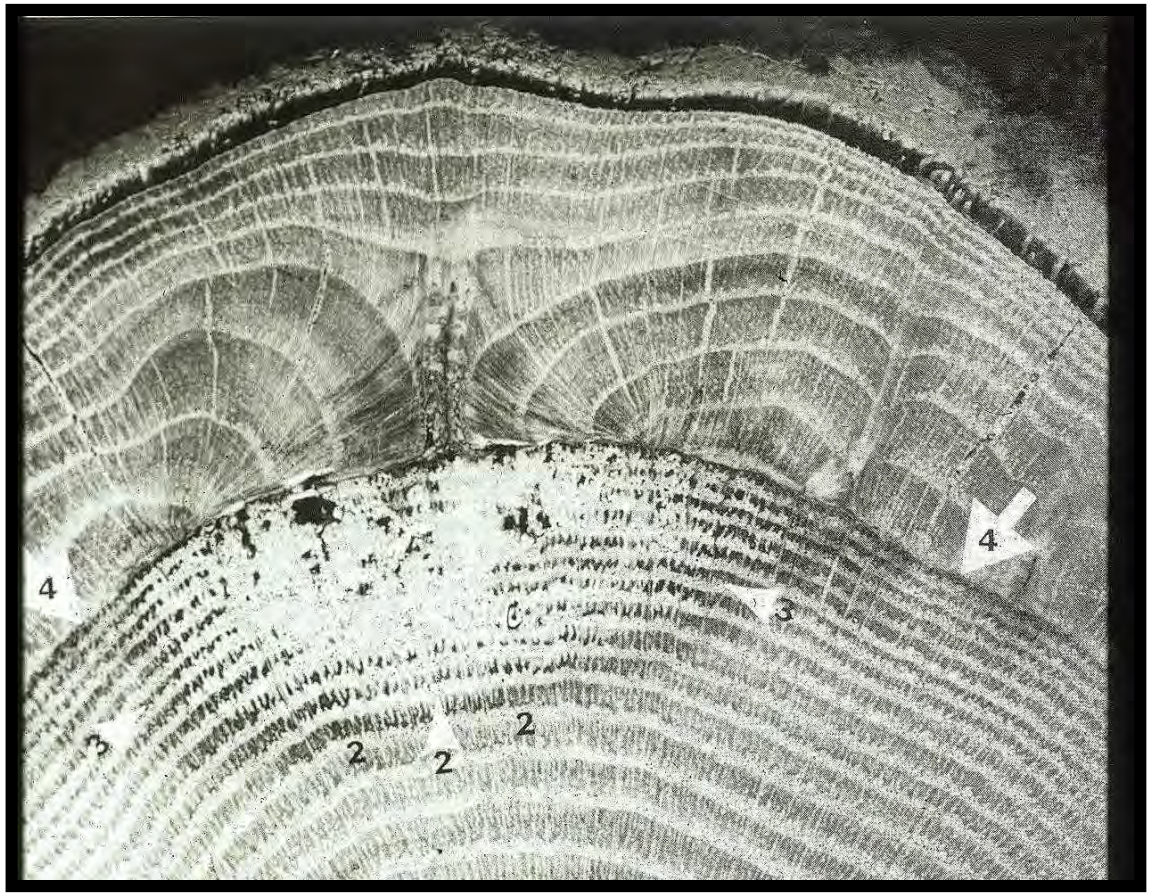


Adapté de Shigo et Marx 1977

Induits

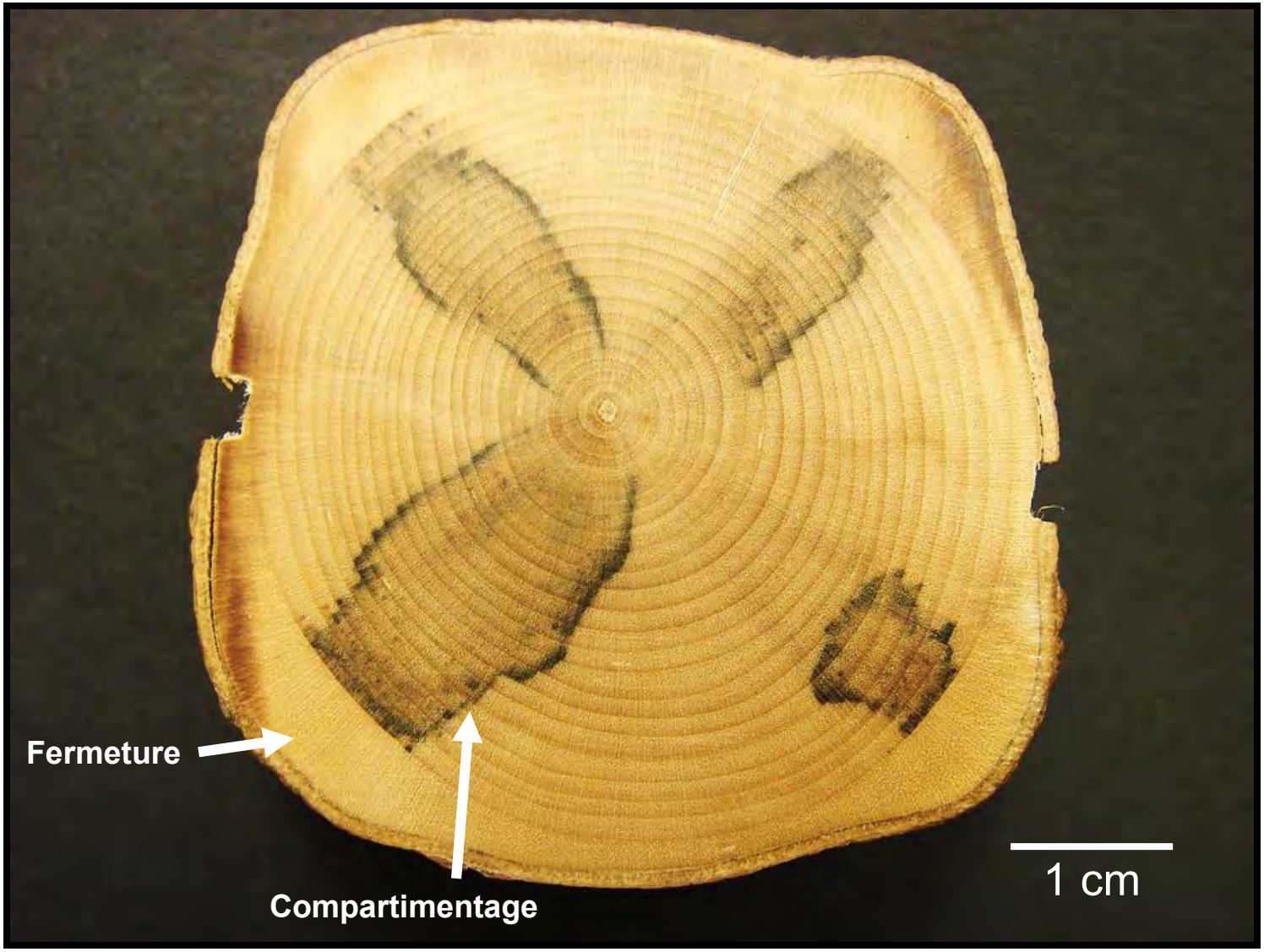
Fermeture des blessures et compartimentage

Shigo 1988



Shigo 1983

Érable à sucre entaillé



D. Rioux, SCF

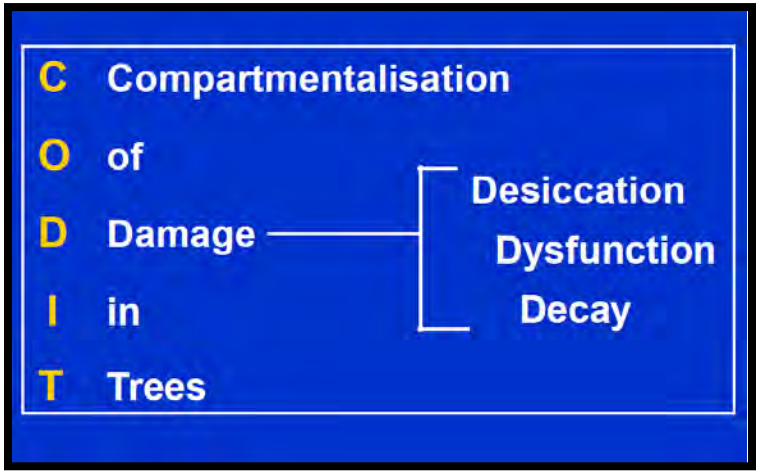
Facteur déclenchant : air (oxygène)

The CODIT-Principle

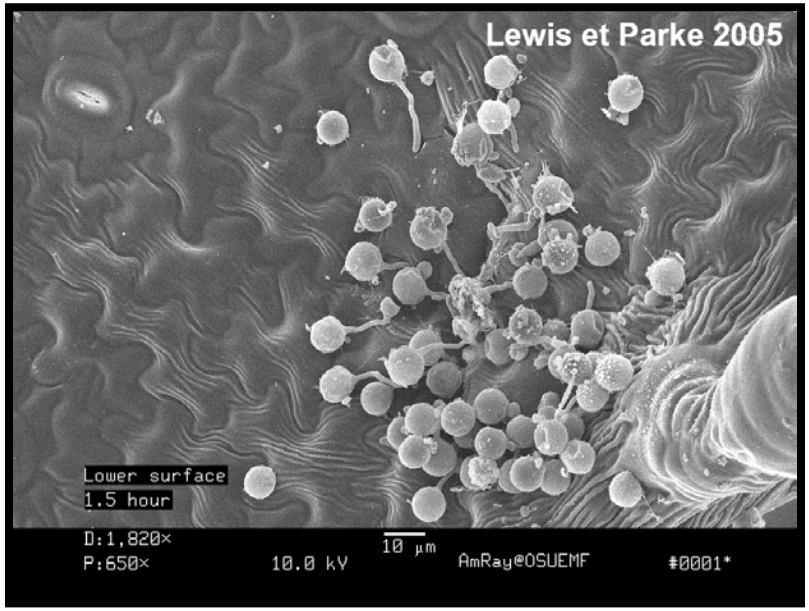
The four phases of defense after wounding:

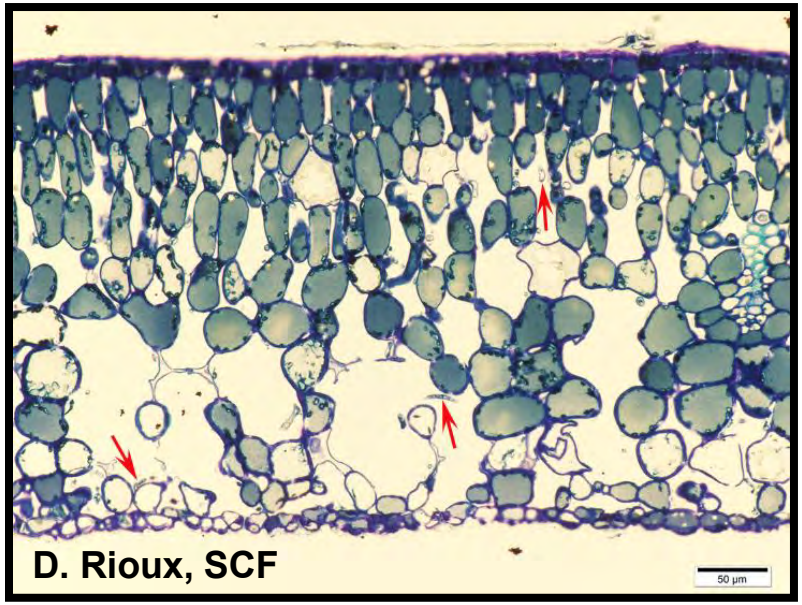
- Phase I - invading air and dessication
- Phase II - invading of microorganisms
- Phase III - spread of microorganisms within the wood
- Phase IV - wound closure (encapsulation of the decay)

(Dujesiefken/ Liese 2015: The CODIT Principle. ISA/US)



3. Défense : blessures → Air

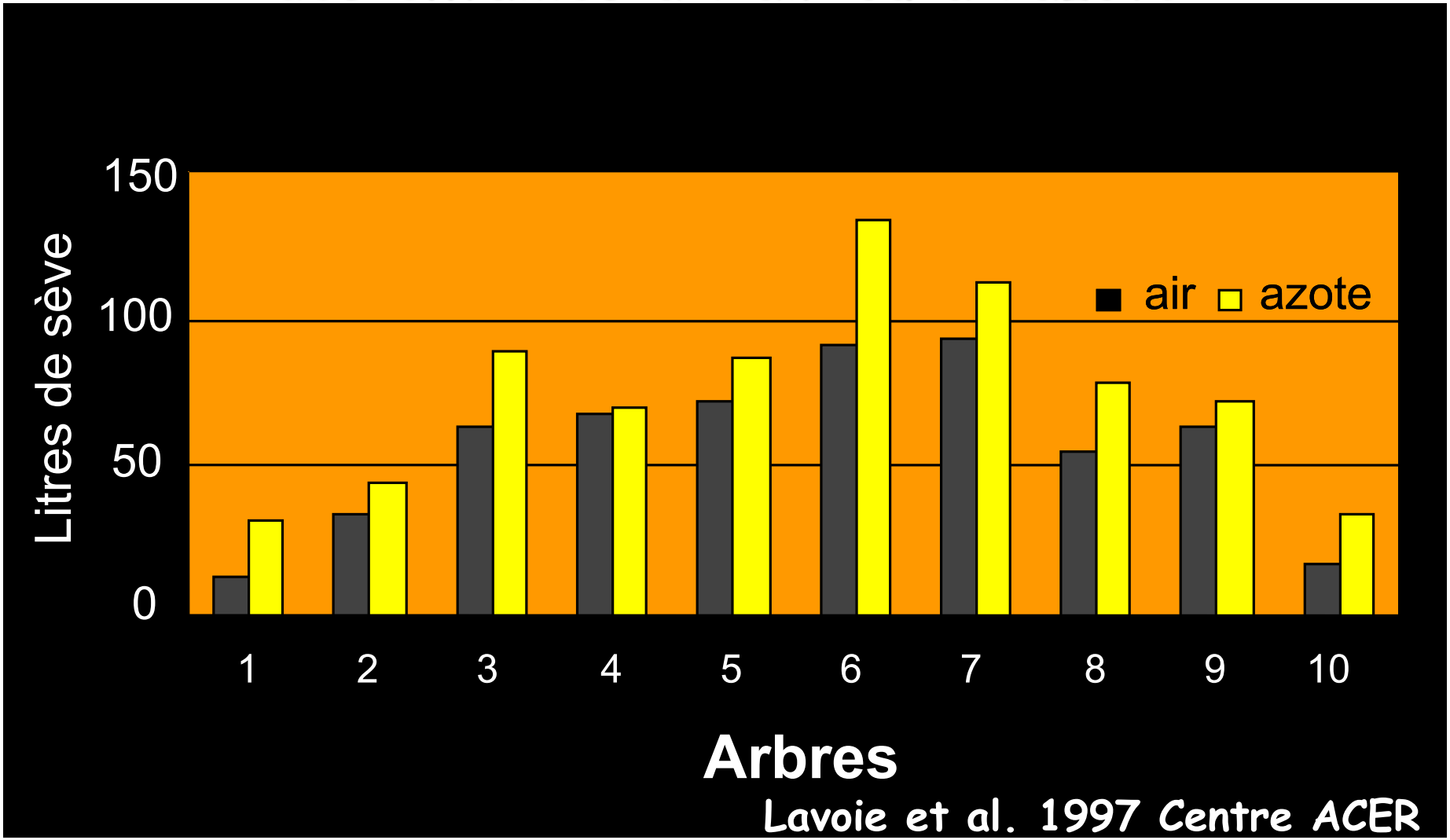




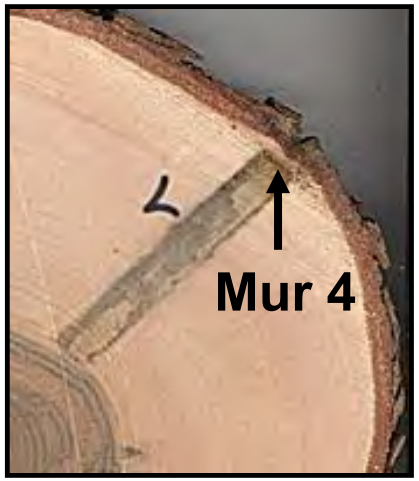
D. Zucchino, LA Times, 13-07-2014

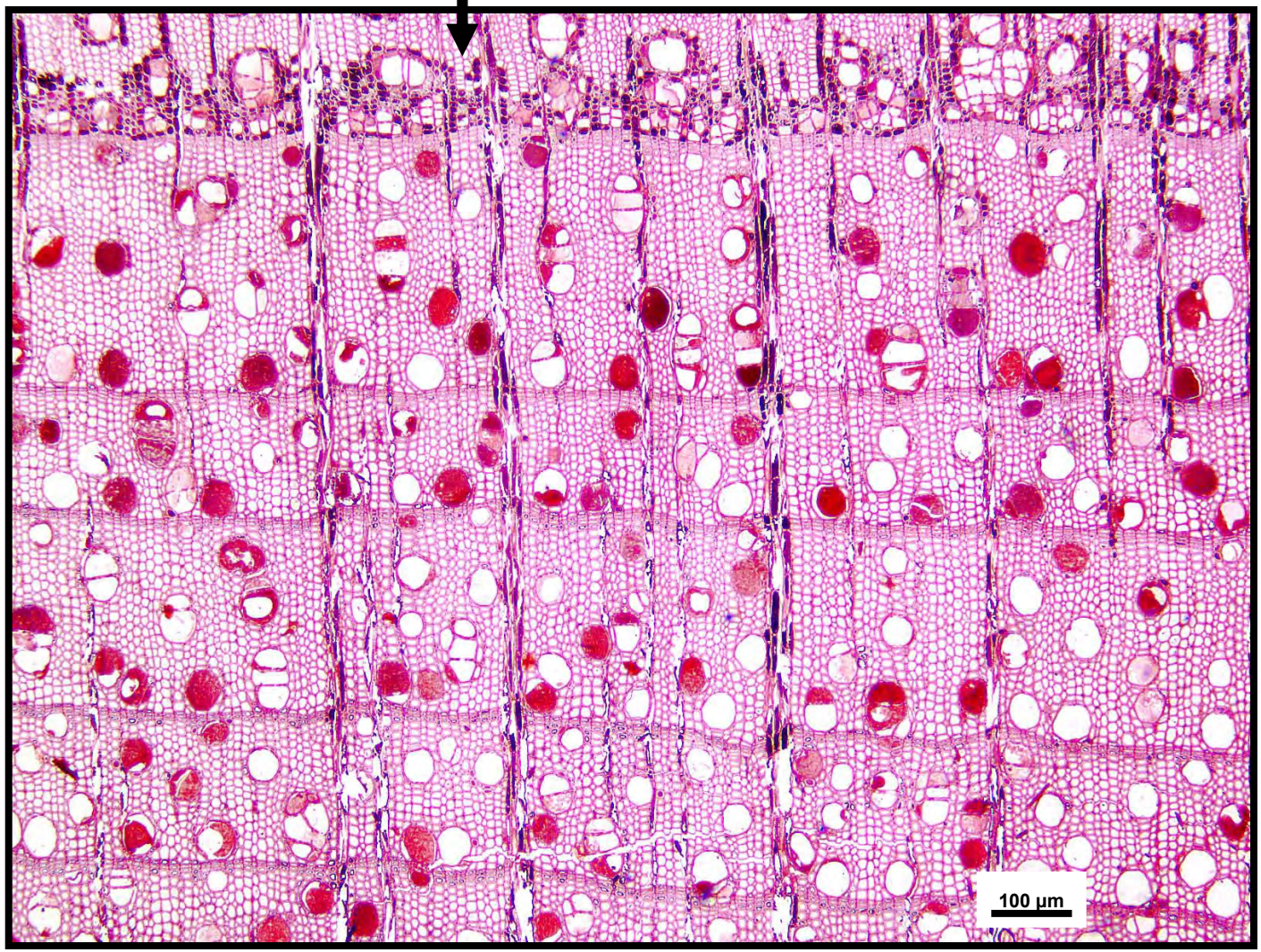
Palissades de Québec datant de 1693 découvertes fin octobre 2018

Rendement en fonction du traitement des entailles à l'air ou à l'azote



Murs 1 (gels) et 4 - Érable à sucre

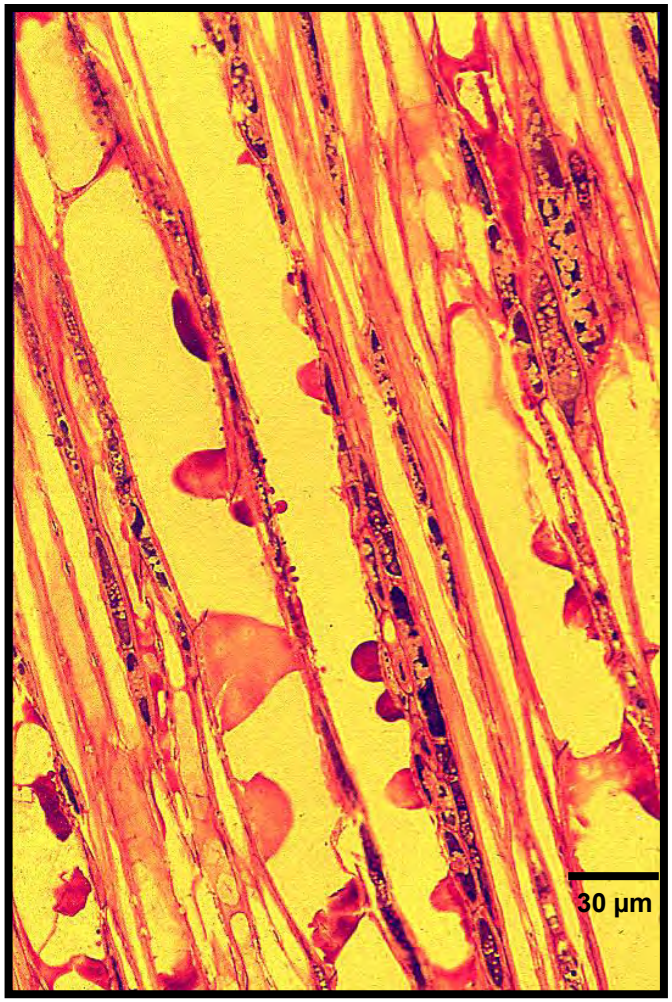




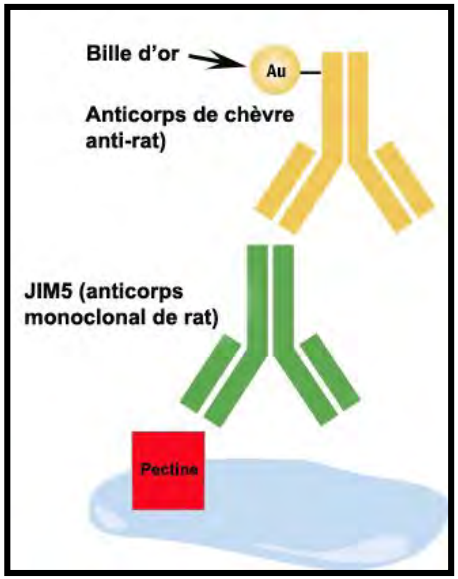
J. Grondin, SCF

Blocage des vaisseaux : gels

Cerisier de Pennsylvanie - Pectine

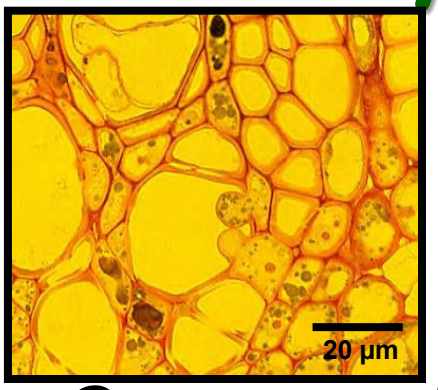


D. Rioux, SCF



D. Rioux, SCF

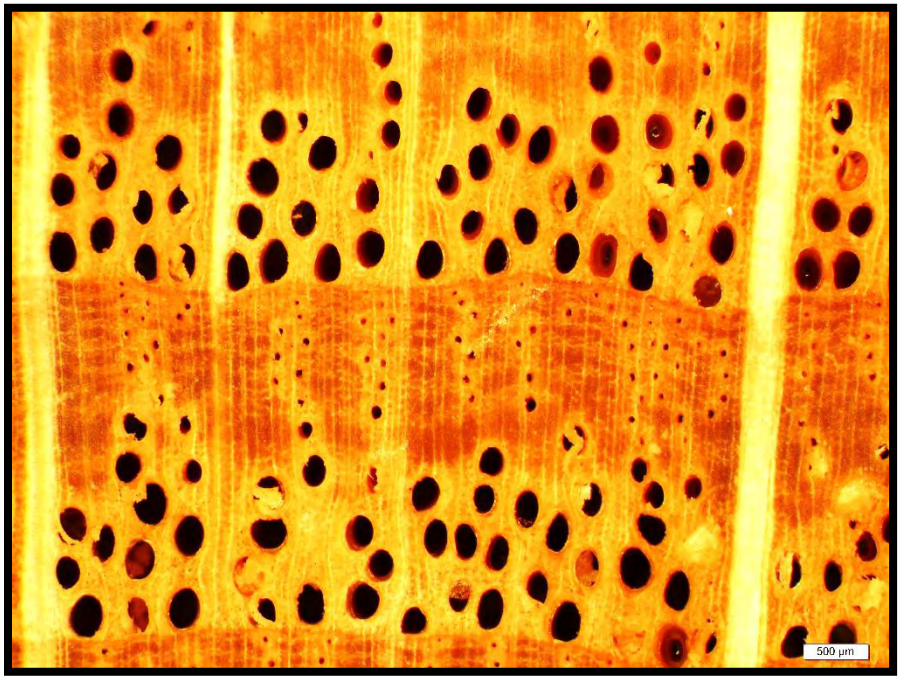
Blocage des vaisseaux : thylles



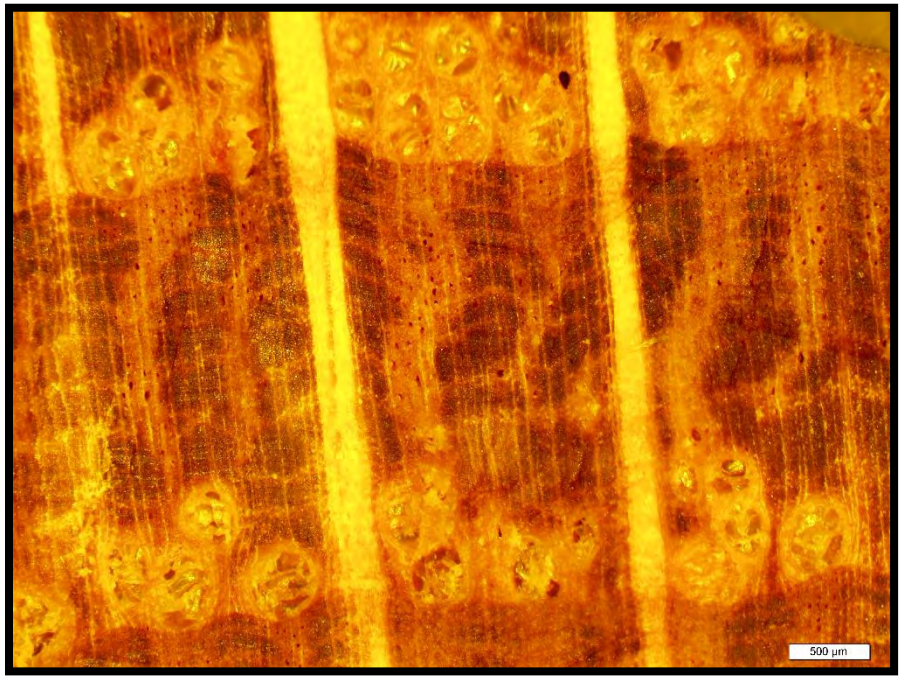
Peuplier baumier

D. Rioux, SCF

Quercus rubra



Quercus alba



D. Rioux, SCF

Chênes – *Quercus* spp.

Chênes rouges

Q. rubra (rouge)

Q. velutina (noir)

Q. falcata (rouge falciforme)

Q. palustris (des marais)

Q. agrifolia (de Californie)

Q. kelloggii (de Kellogg)

↓

Flétrissement du chêne

Encre des chênes rouges

Chênes blancs

Q. alba (blanc)

Q. macrocarpa (à gros fruits)

Q. bicolor (bicolore)

Q. robur (pédonculé)

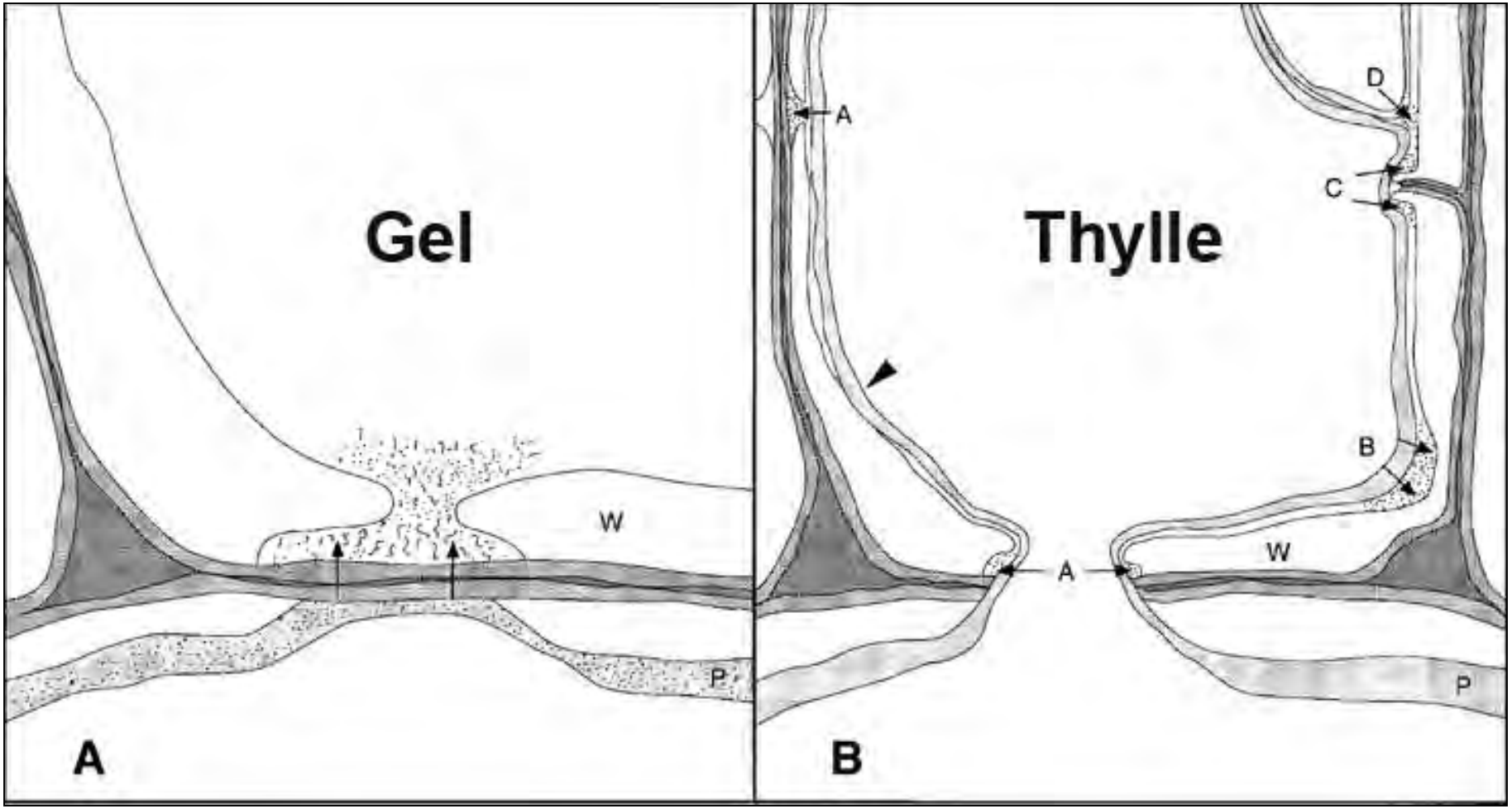
Q. garryana (de Garry)

Q. montana (châtaignier)

Occlusion des vaisseaux
Thylles : sécrétion de pectine

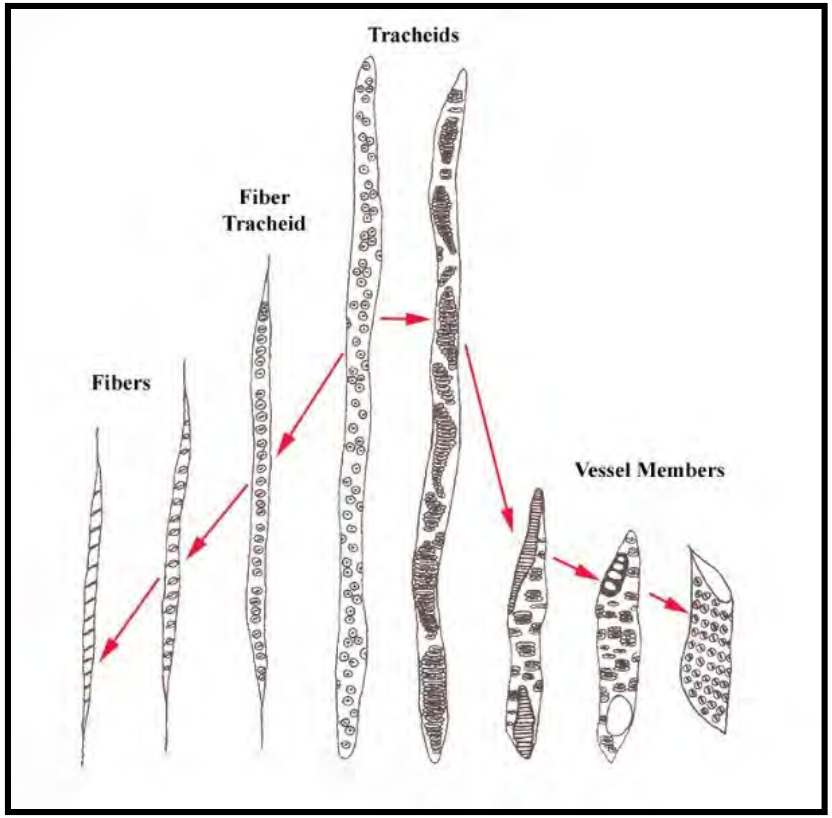
D. Rioux, SCF

Blocage des vaisseaux - Pectine

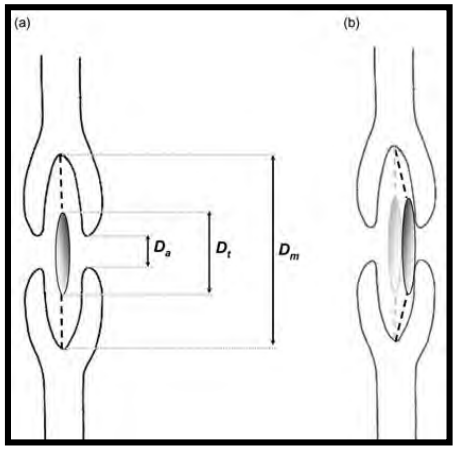


Rioux et al. 1998. Phytopathology 88 : 494-505

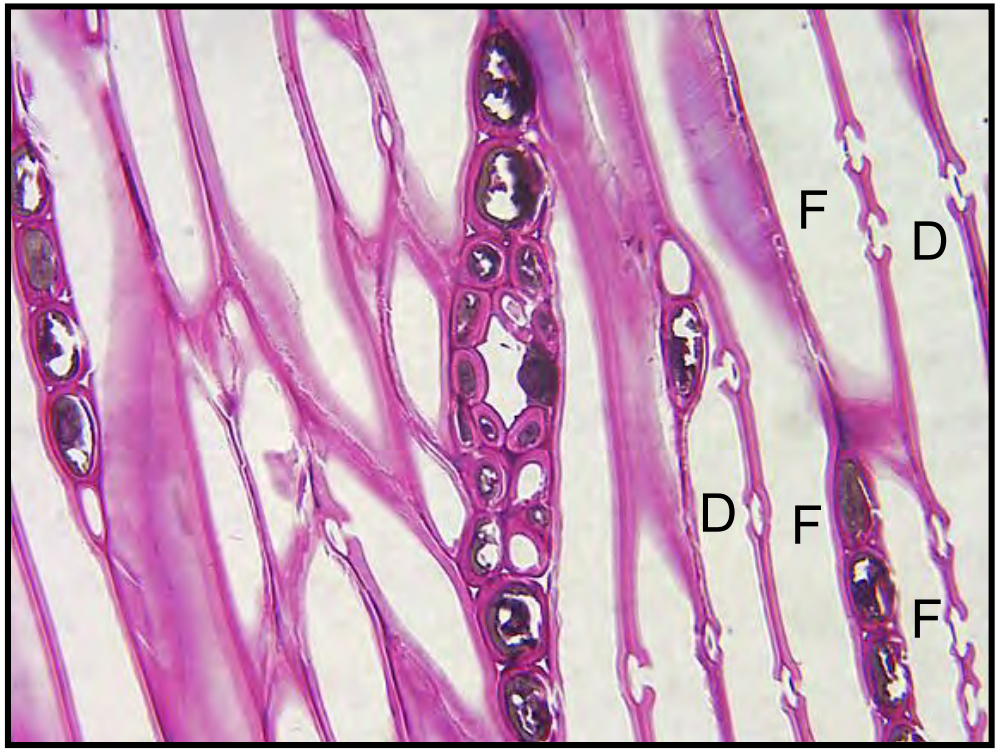
Conifères



JefPat.org

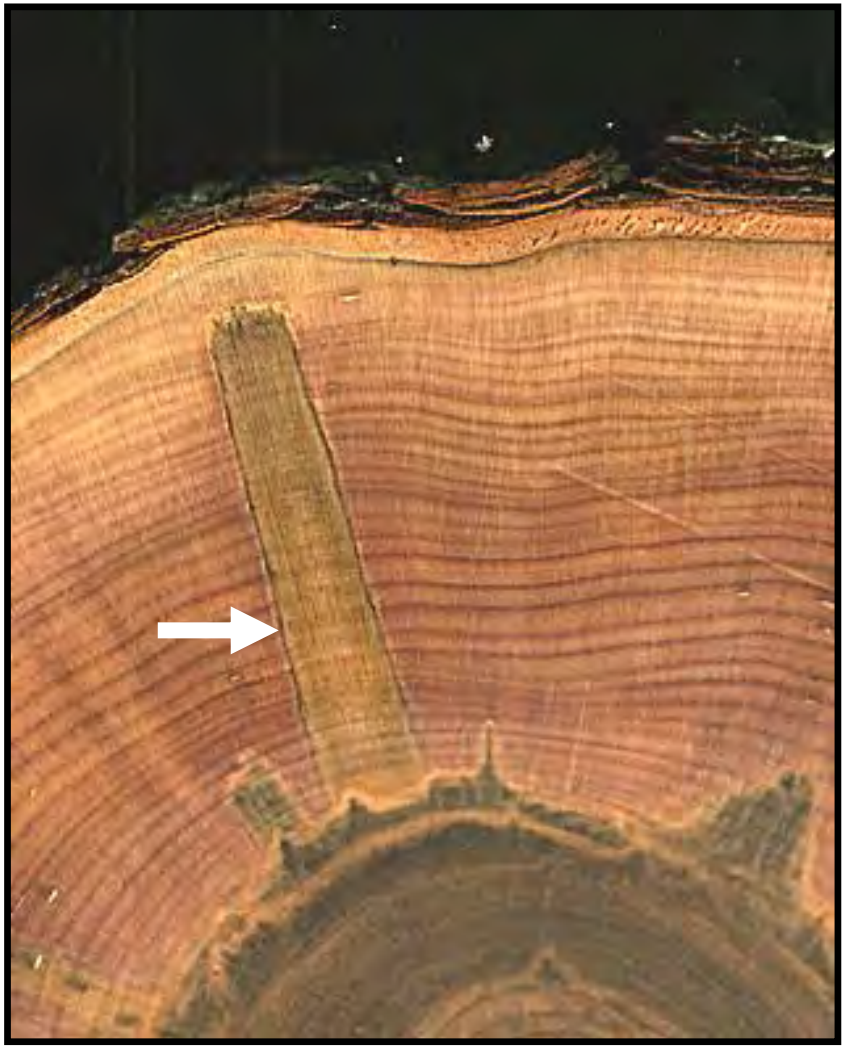


Delzin et al. 2010

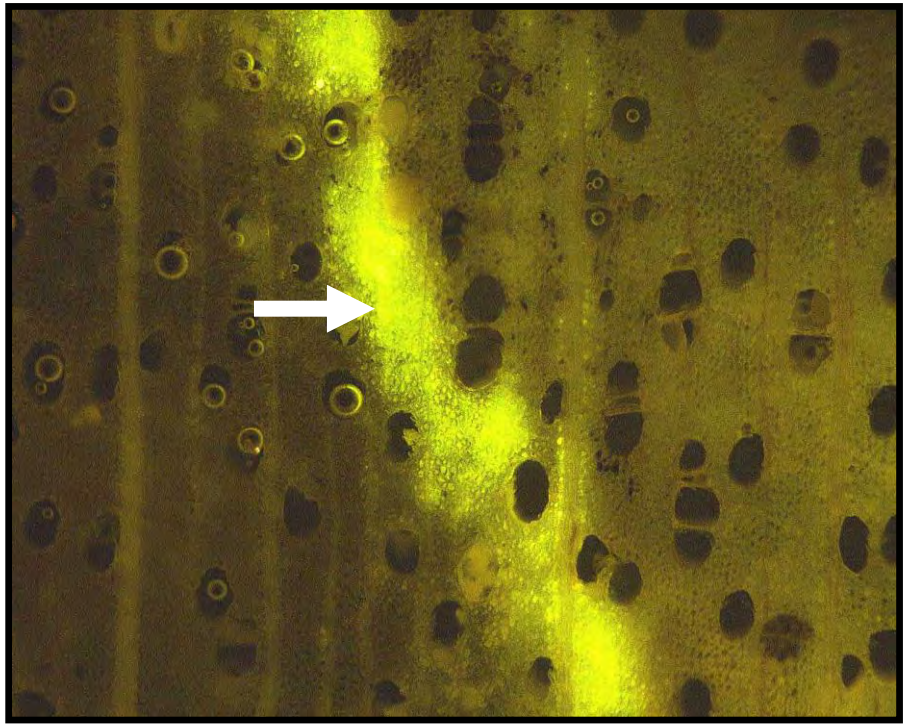


D. Rioux, SCF

Entaillage – Érable à sucre

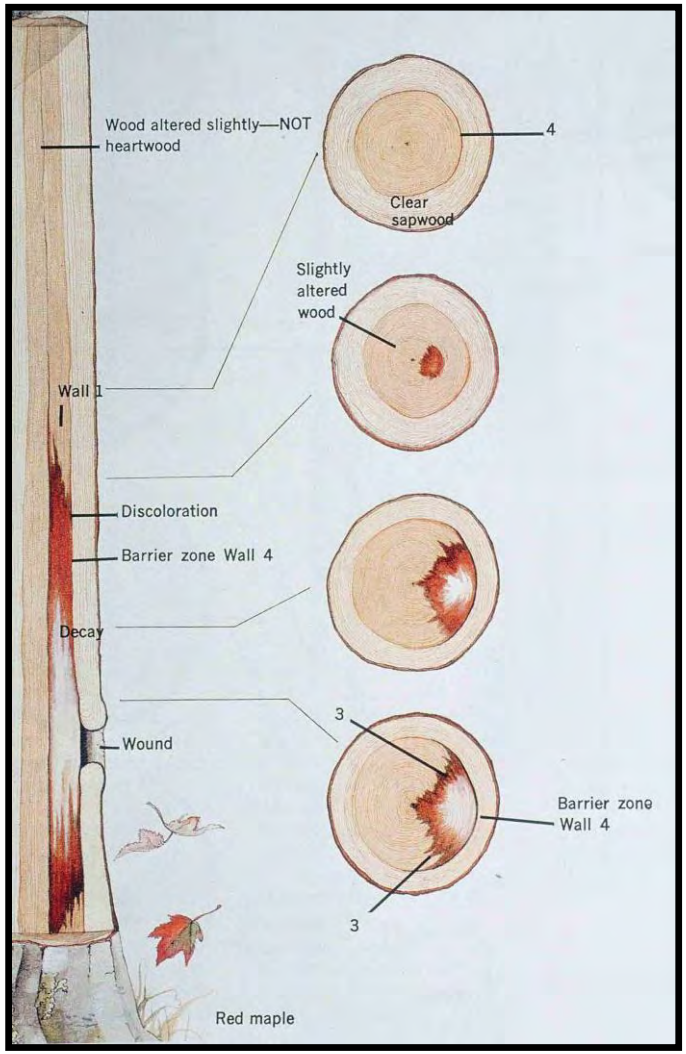


Centre ACER



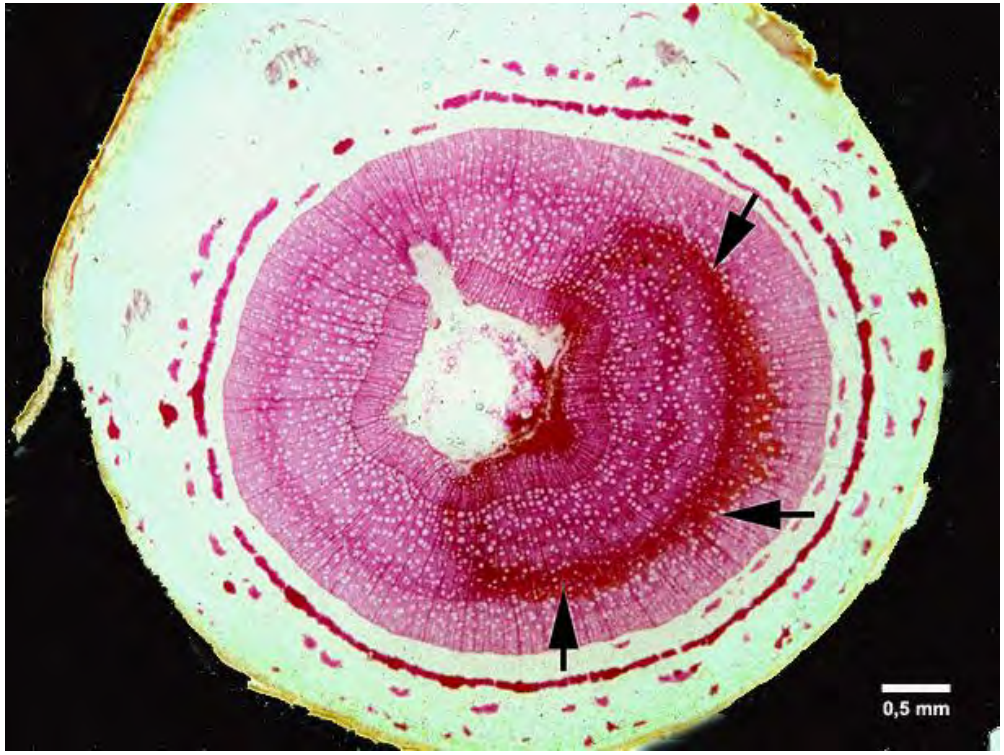
D. Rioux, SCF

3. Défense : compartimentage



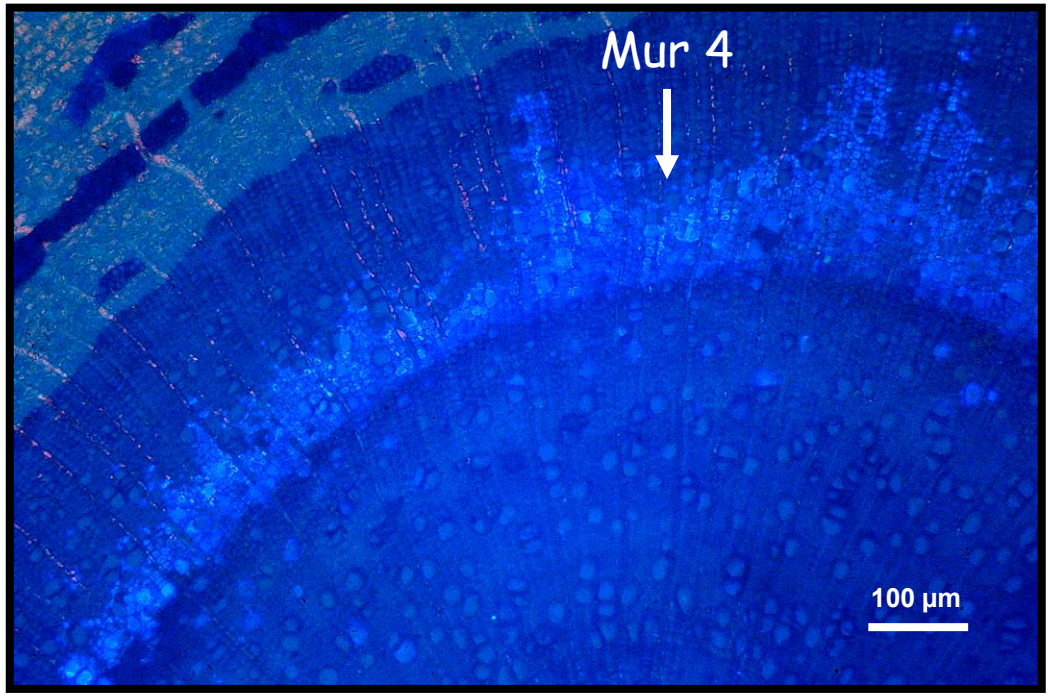
USDA Forest Service

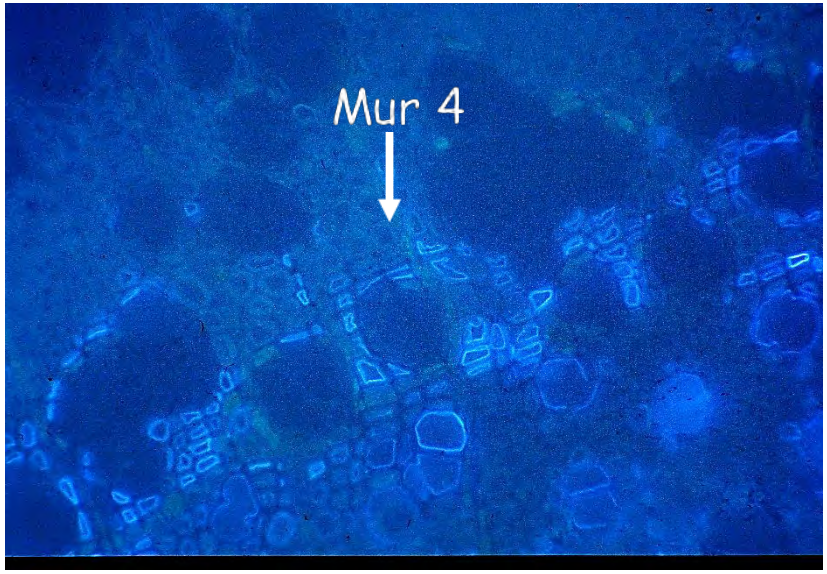
Peuplier baumier (lignine)



Rioux et Ouellette 1991

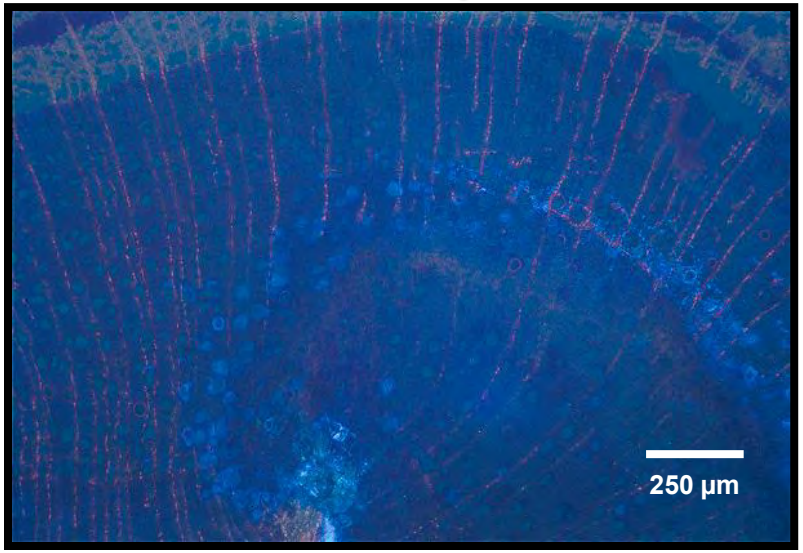
Peuplier baumier (subérine)



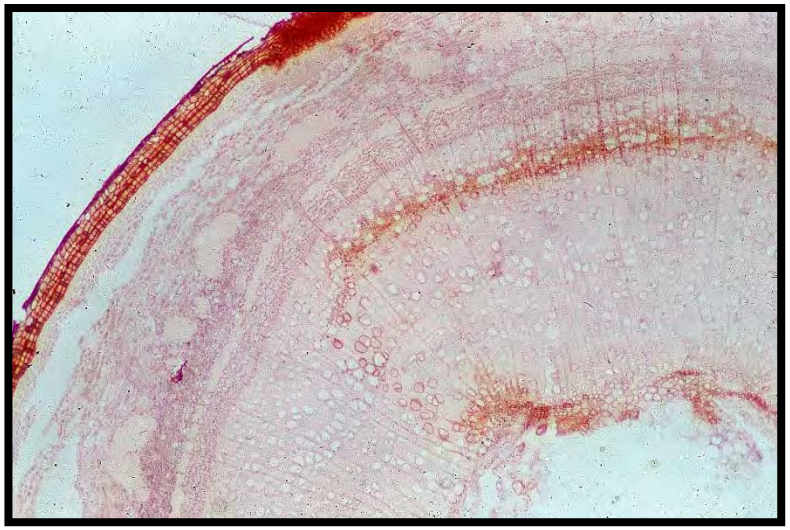


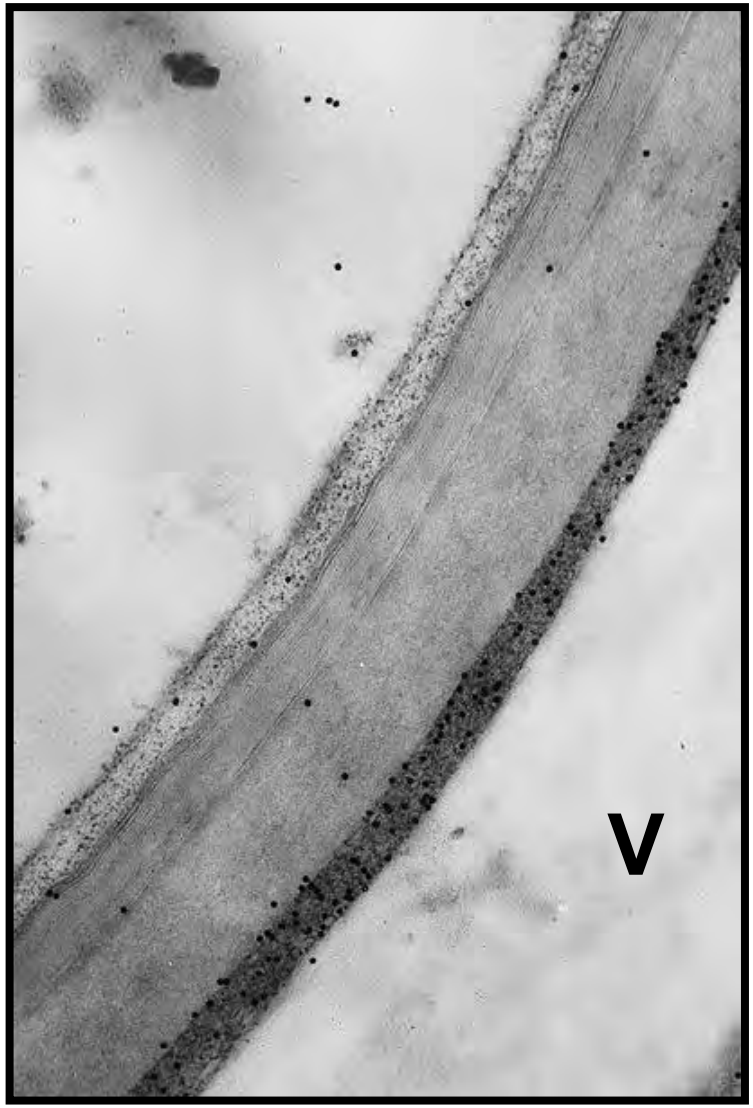
Rioux et Ouellette 1991

Peuplier baumier (subérine)



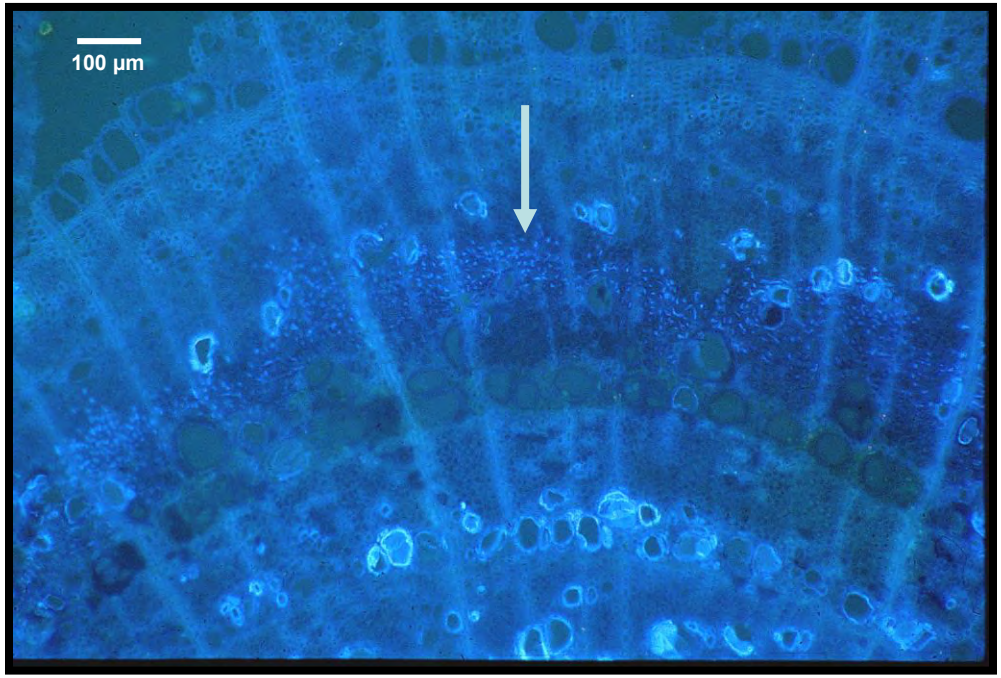
Rioux et Ouellette 1991

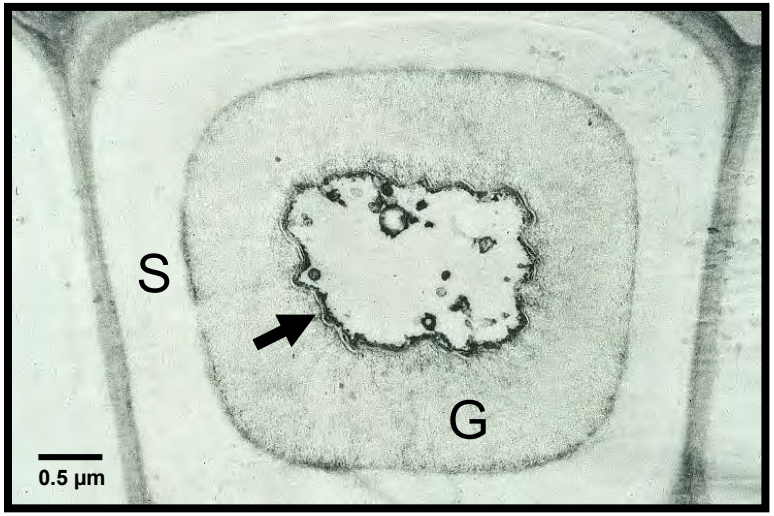




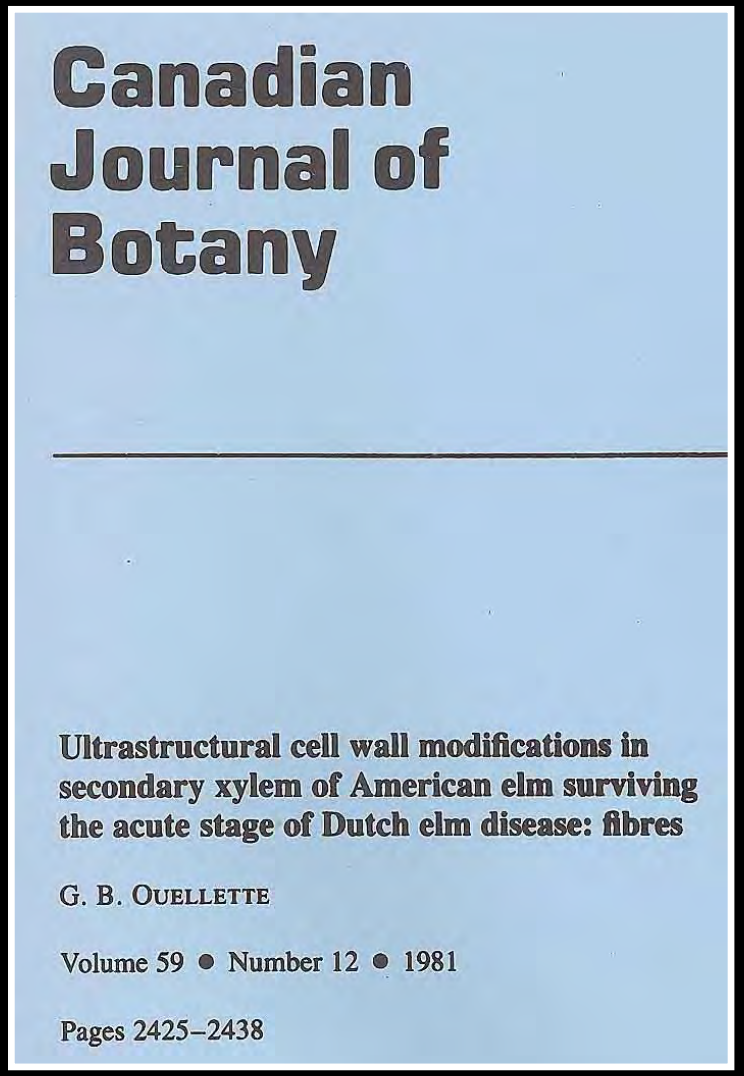
Rioux et al. 1995

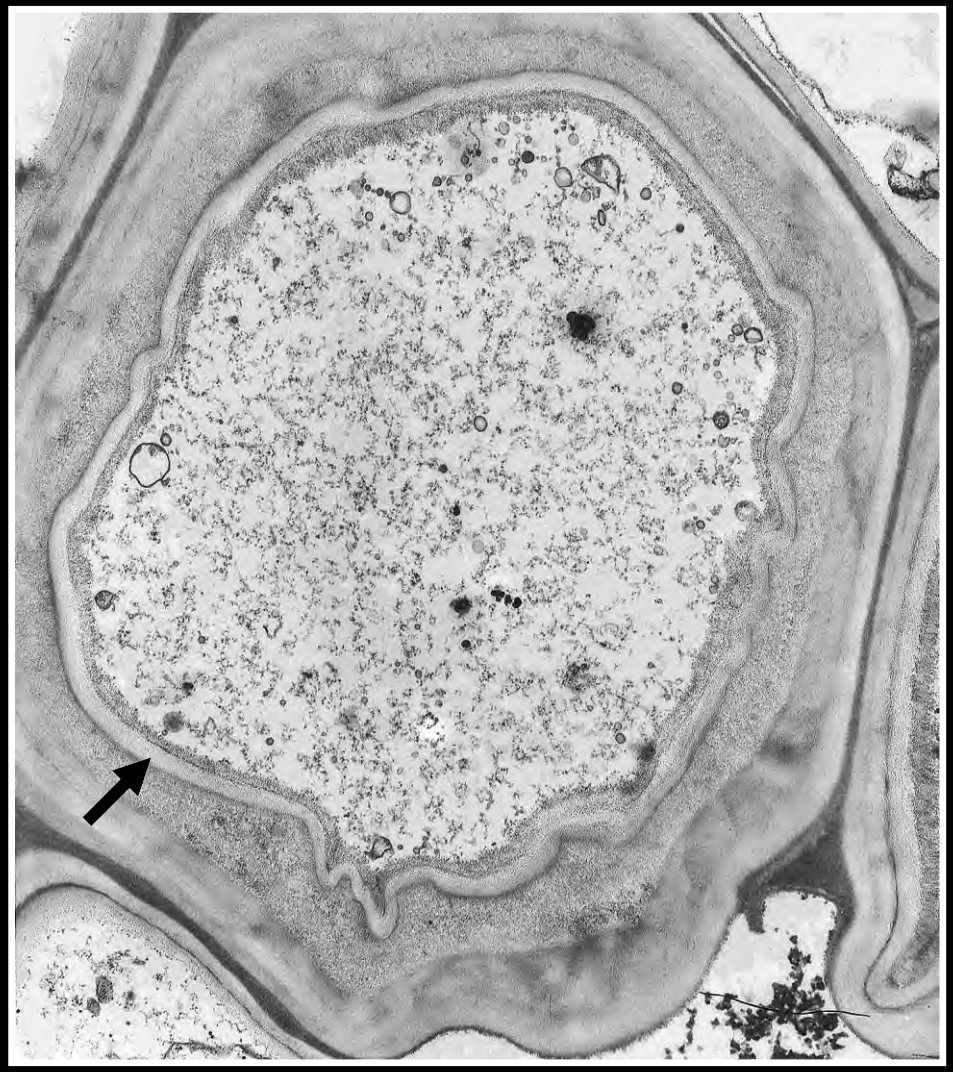
Orme - Résistance





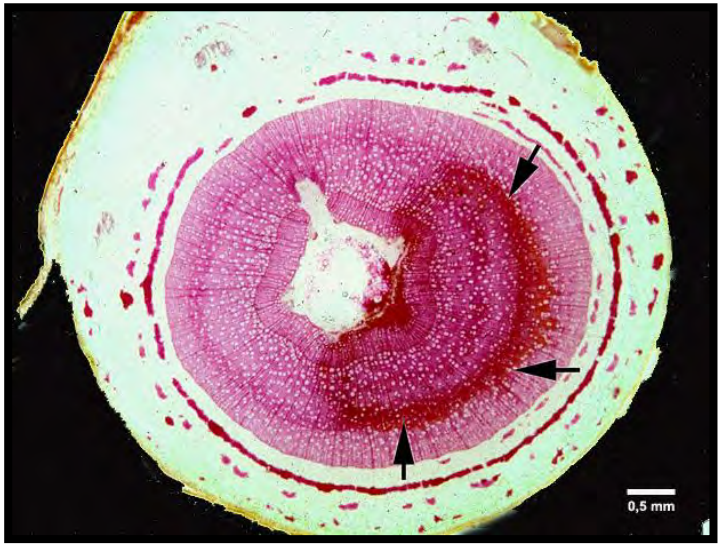
D. Rioux, SCF

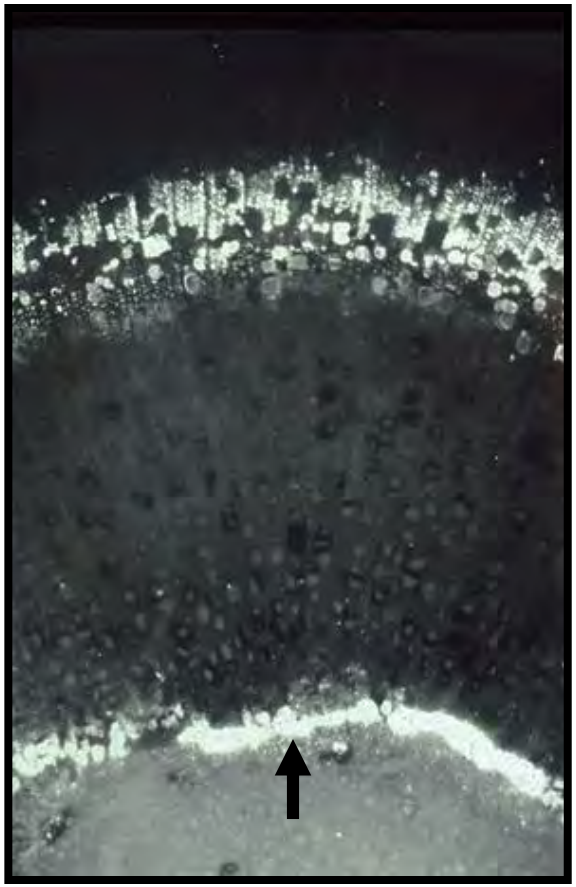


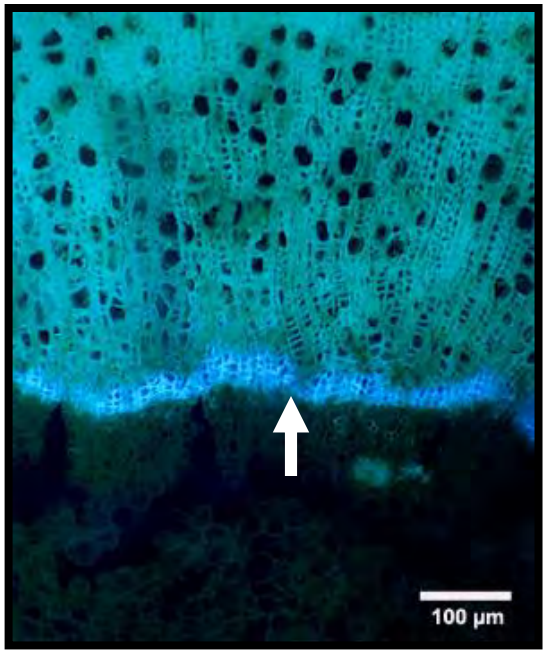


"…are reminiscent of suberin layers observed in other normal or diseased plants"

Peuplier baumier : nouveau mur 2







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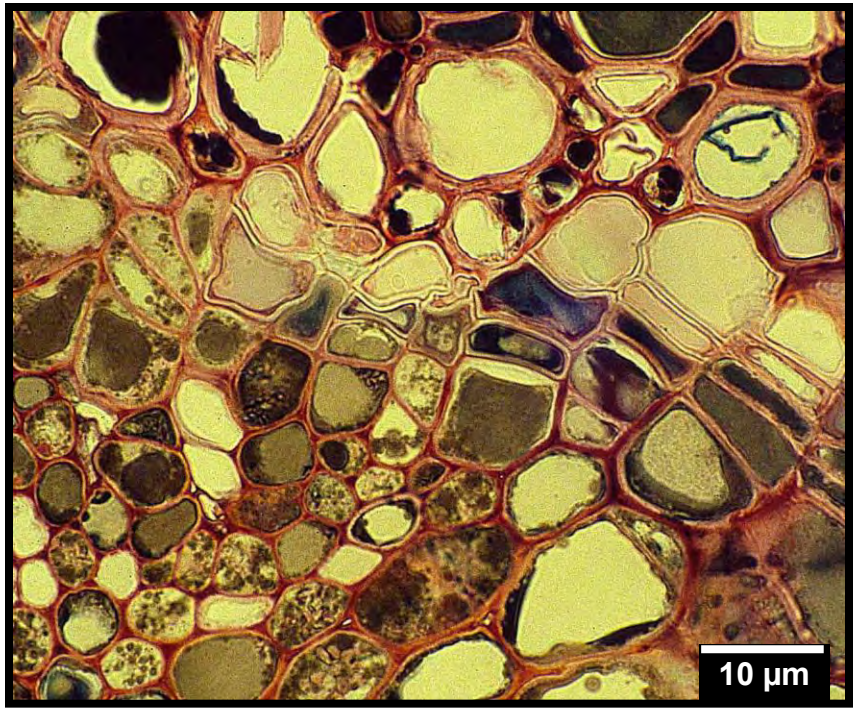
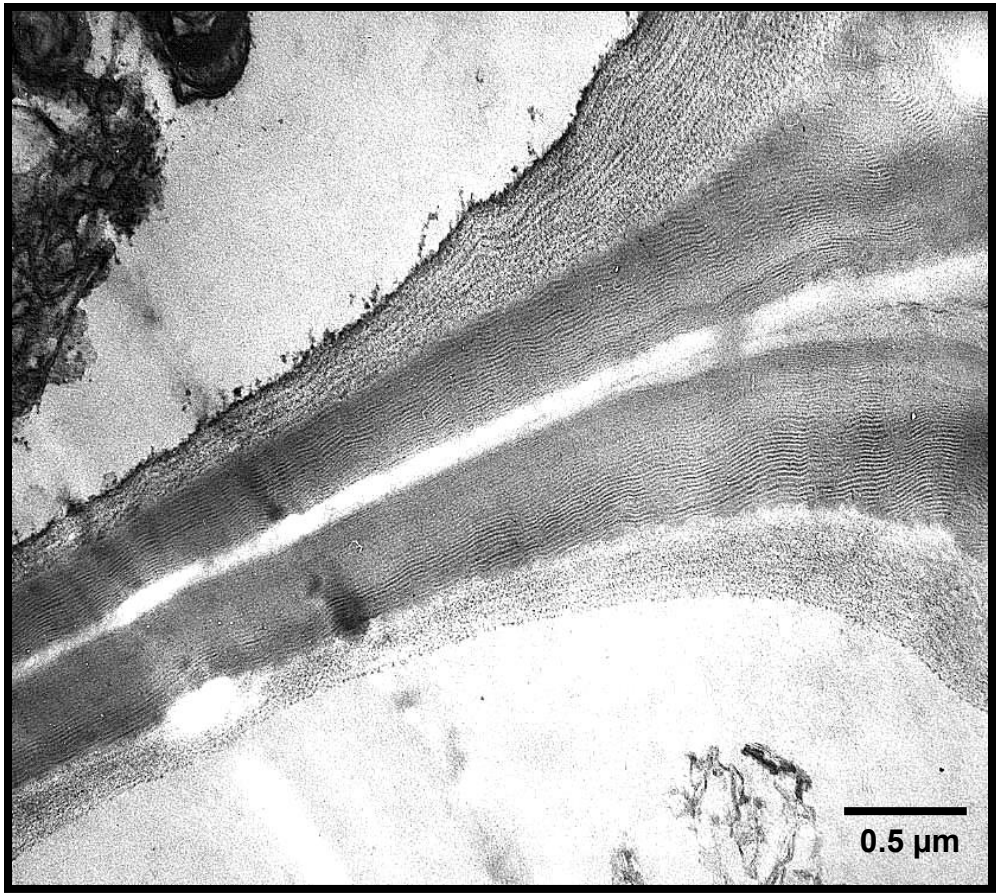
Peuplier baumier : nouveau mur 2





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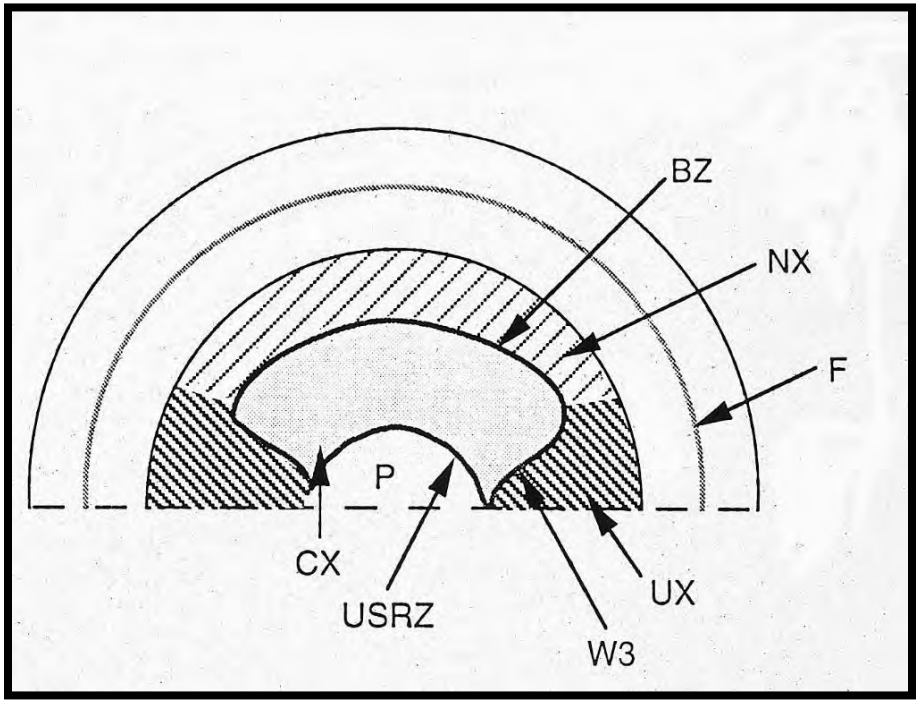
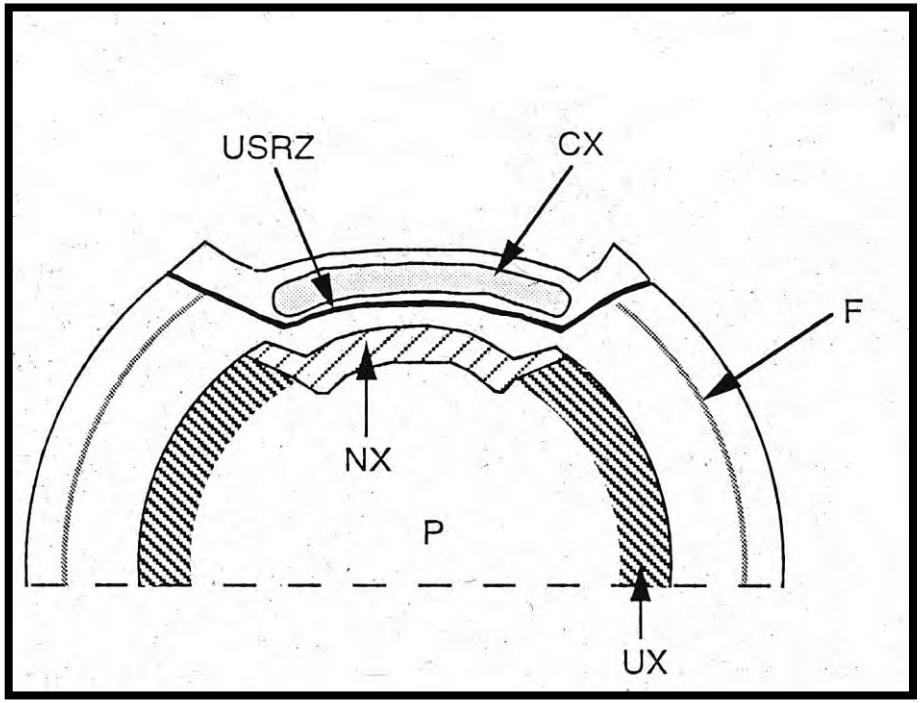
Peuplier baumier



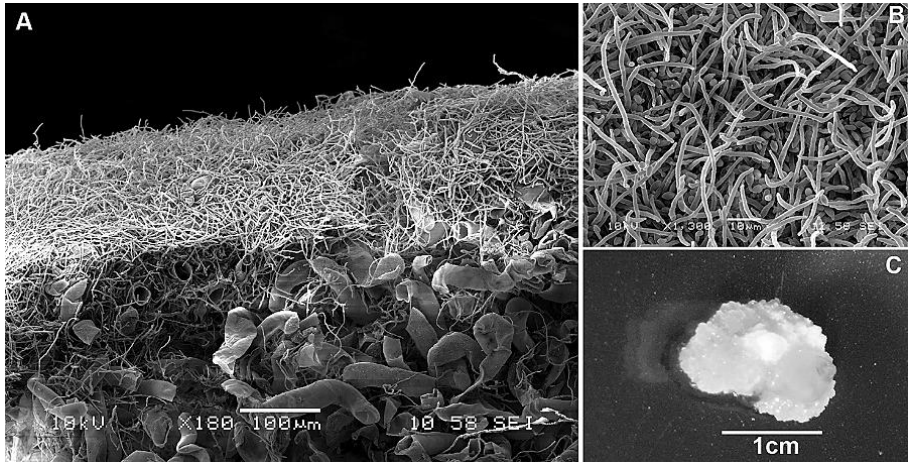
Oeillet

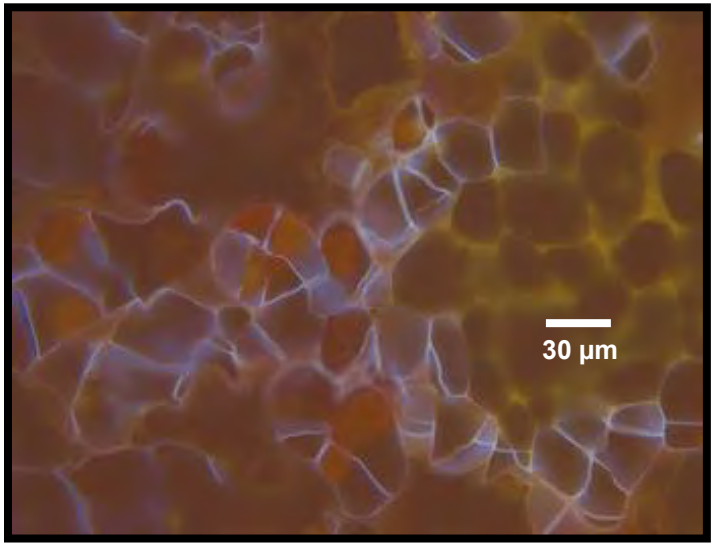


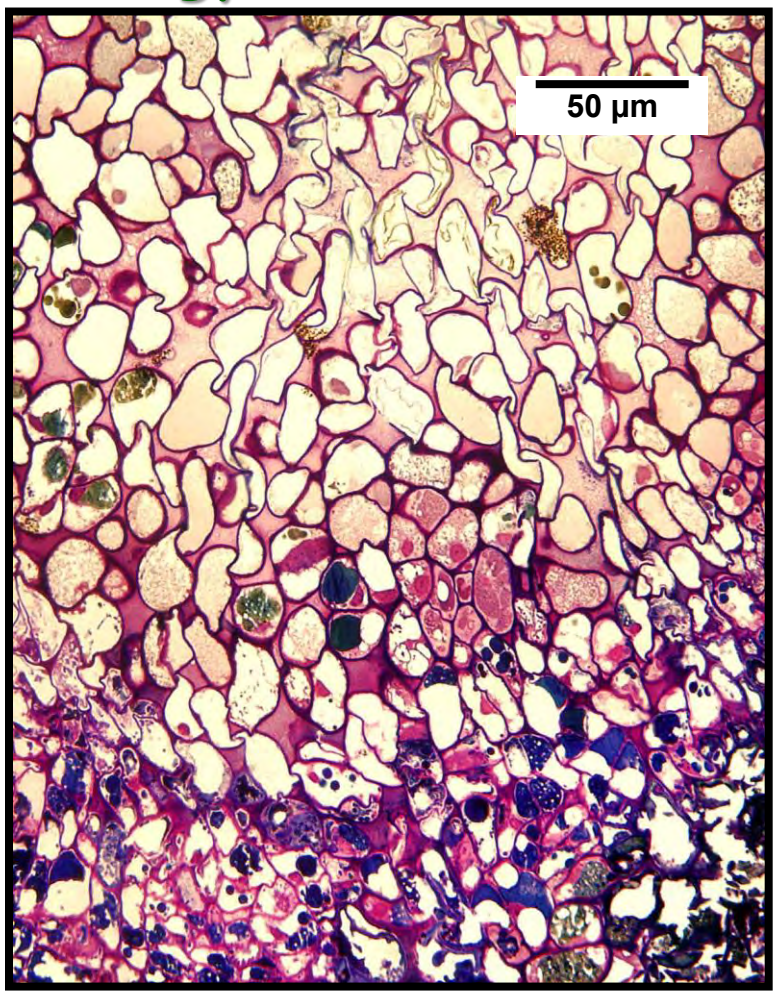
Baayen et al. 1996. Phytopathology 86 : 1018-31
Rioux et Baayen 1997. Trees 11 : 389-403

Cals d'orme américain inoculés avec *Ophiostoma novo-ulmi*

Aoun et al. 2009. Phytopathology 99 : 642-50

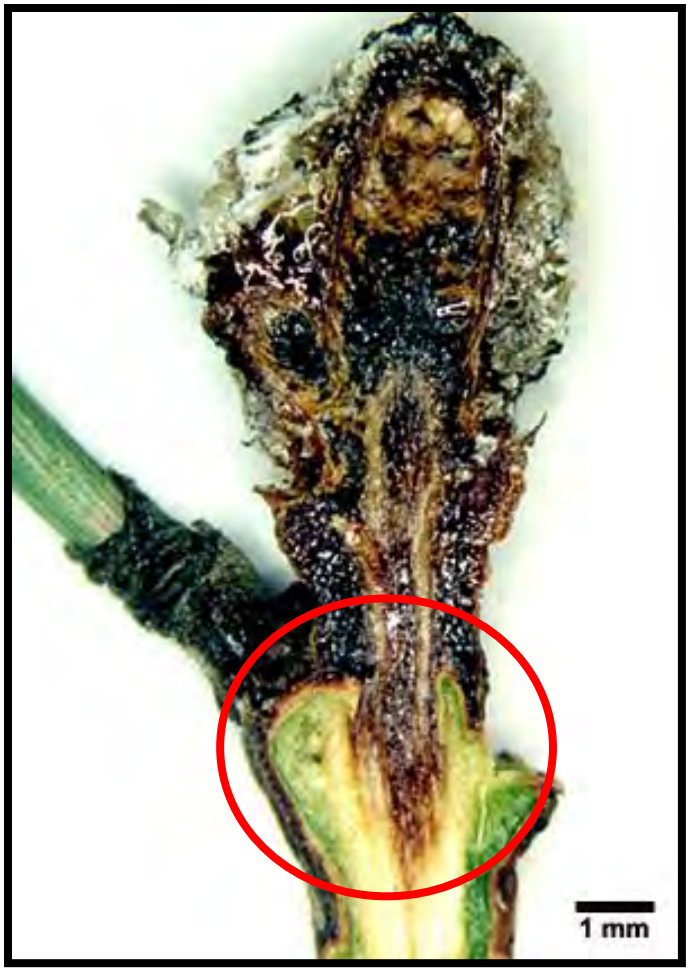






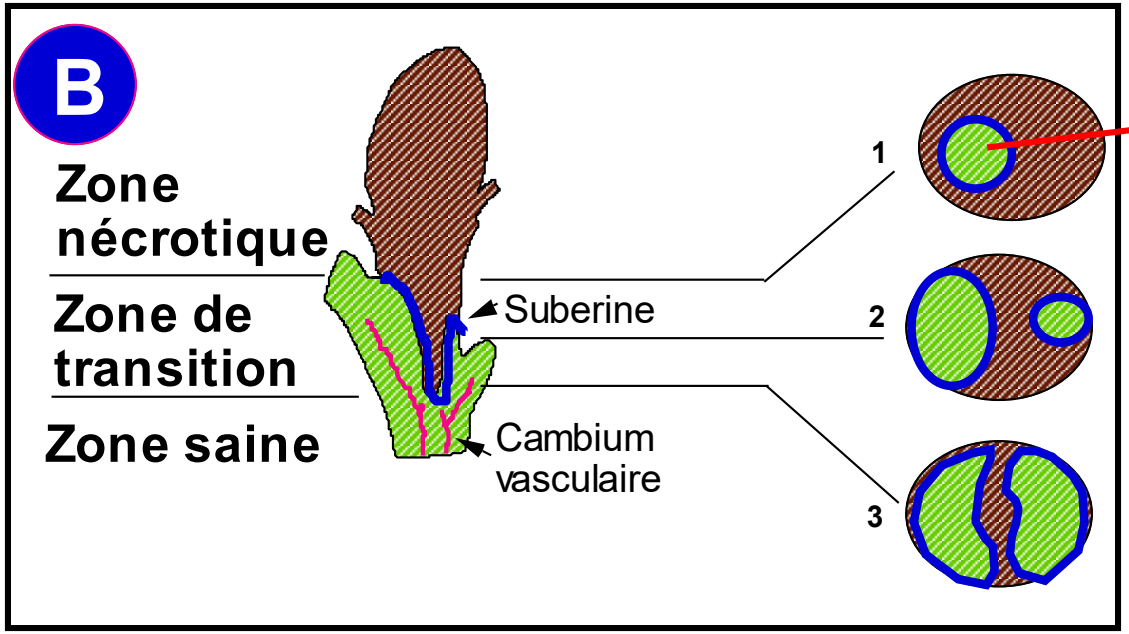
Chancre scléroderrien
Race européenne vs Pin gris

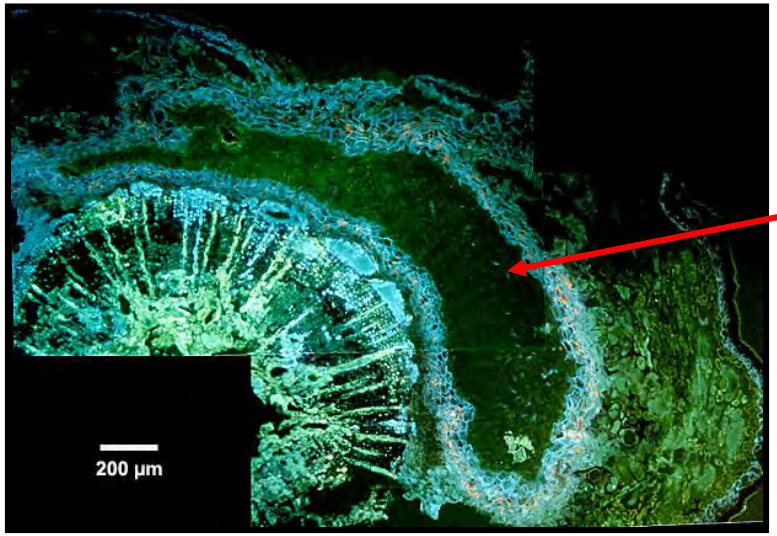
G. Laflamme, SCF



M. Simard, SCF

3. Mécanismes de défense

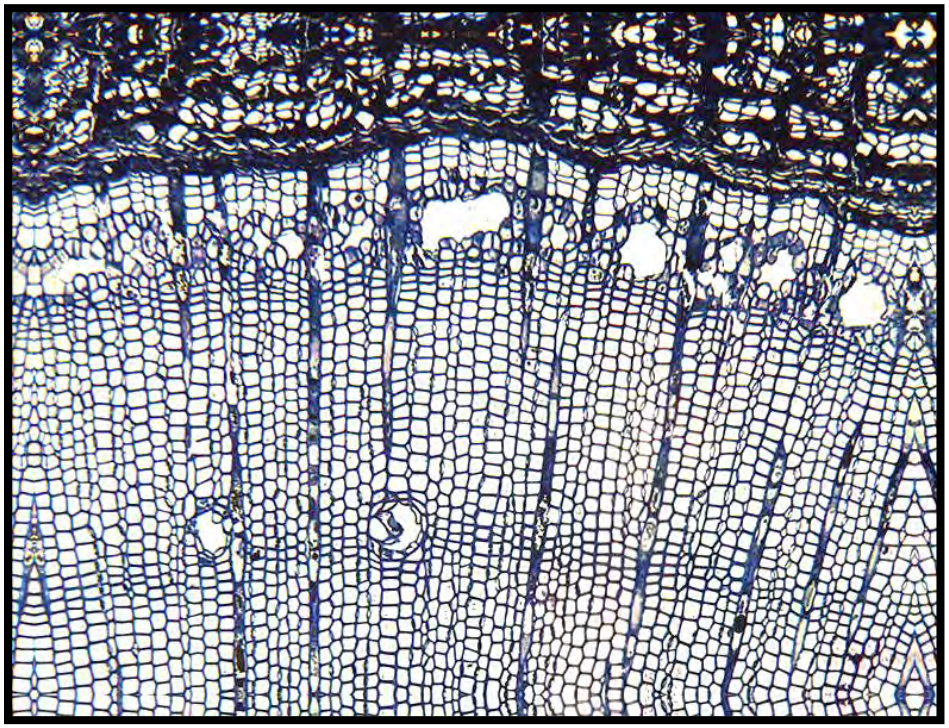




Simard et al. 2001. Phytopathology 91 : 1128-40

Canaux résinifères

Tige – Mélèze
Encre des chênes rouges



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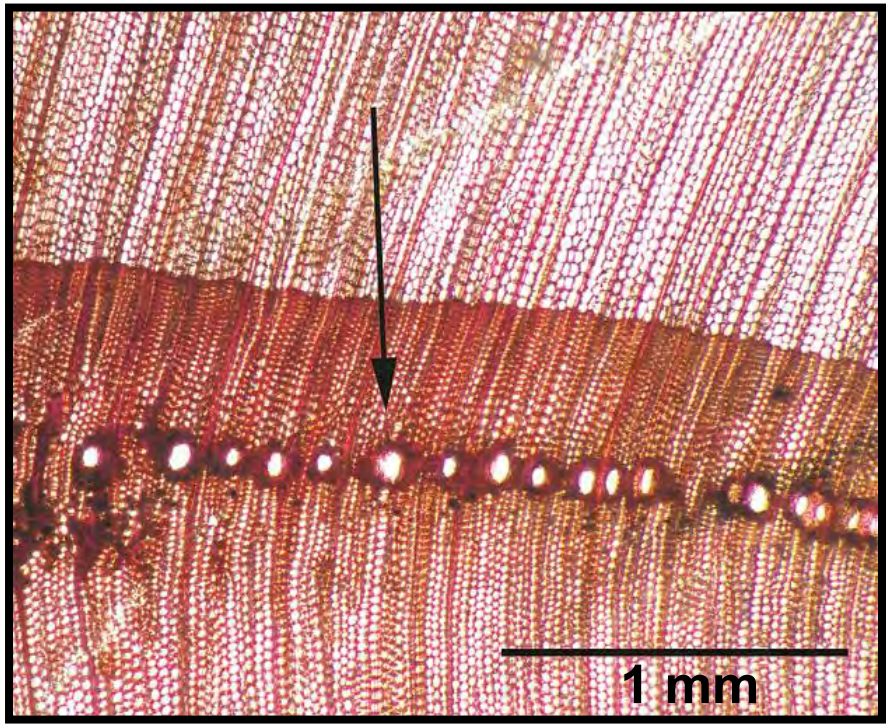
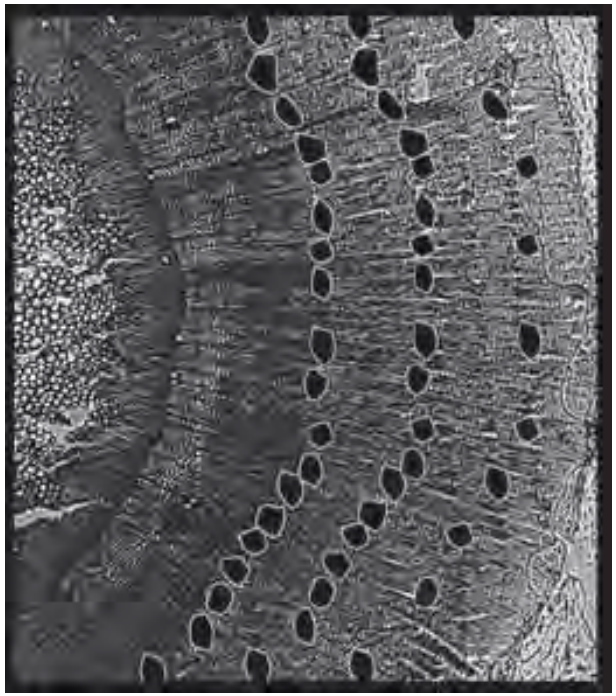
Racine – Sapin de Douglas
Armillaire

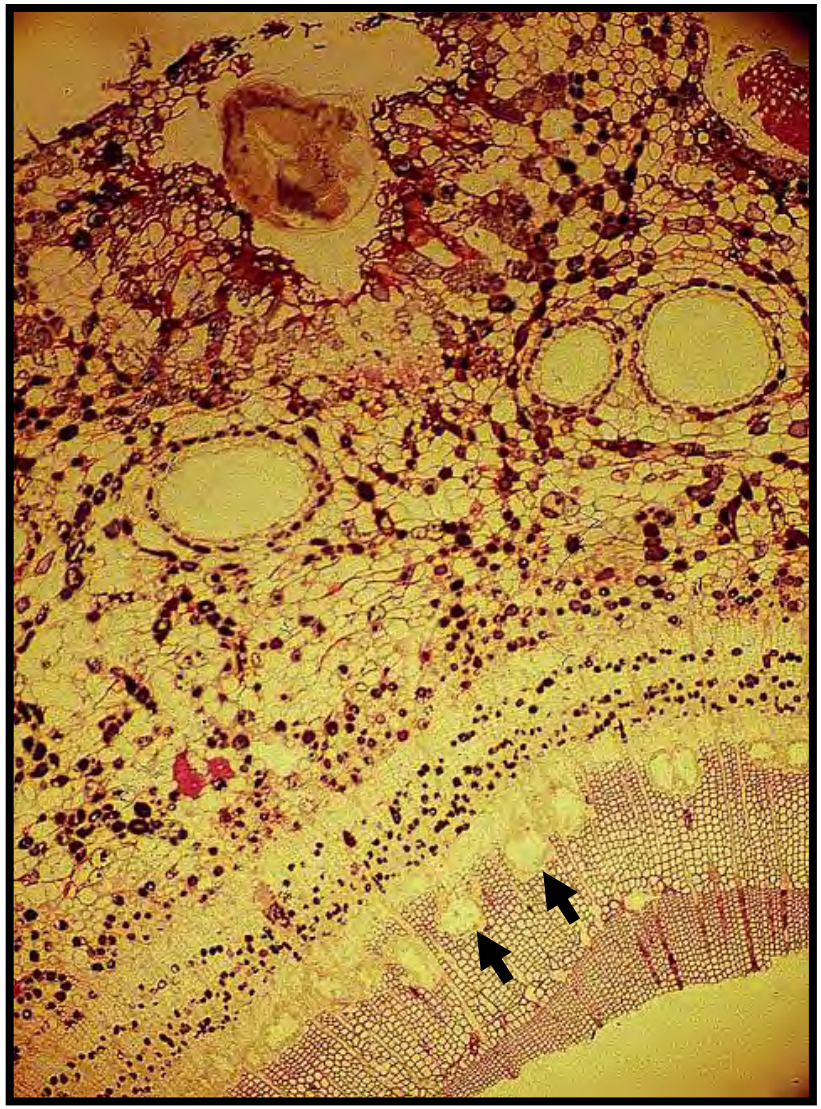


Cruickshank et al. 2006

Charançon du pin blanc



Poulin et al. 2006



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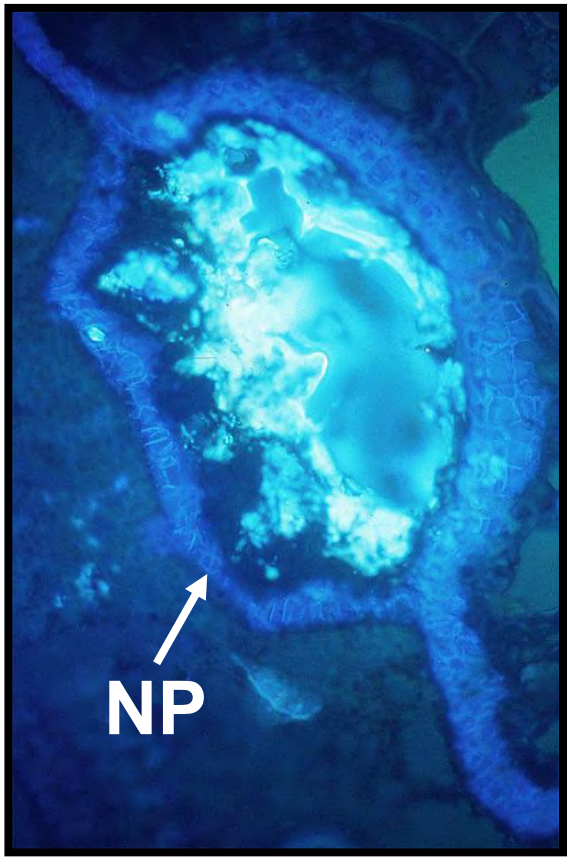
???



D. Rioux, SCF

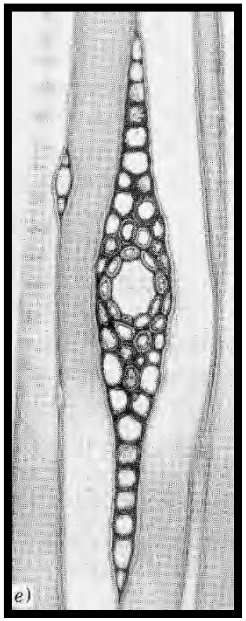
IAWA Bulletin n.s., Vol. 11 (3), 1990: 227–238

RESIN CANALS IN PINUS TAEDA

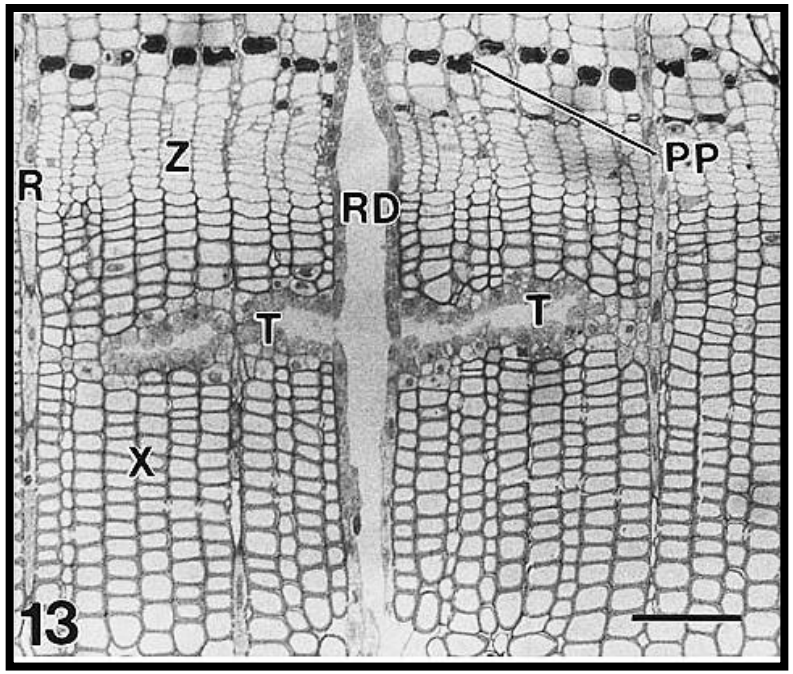
LONGITUDINAL CANAL LENGTHS AND INTERCONNECTIONS BETWEEN LONGITUDINAL AND RADIAL CANALS*

by

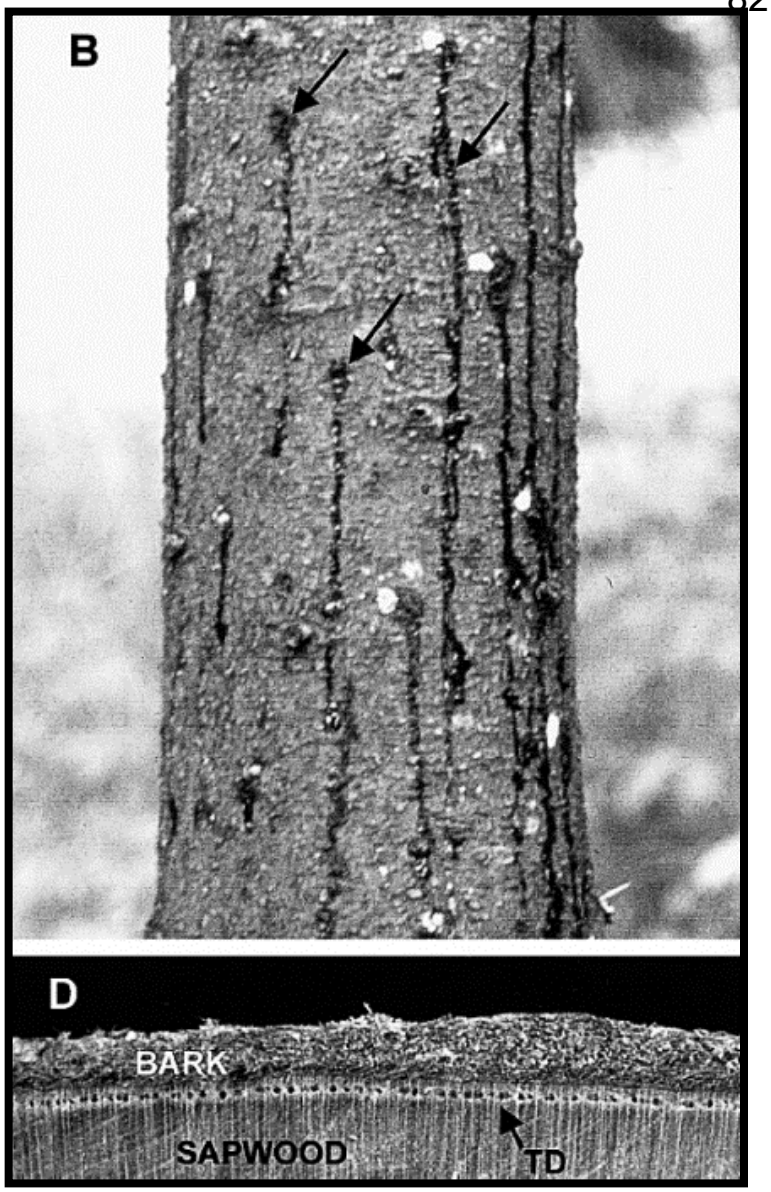
C.A. LaPasha and **E.A. Wheeler**
Department of Wood and Paper Science, Box 8005, North Carolina State University, Raleigh, N.C. 27695-8005, U.S.A



Panshin et de Zeeuw 1980

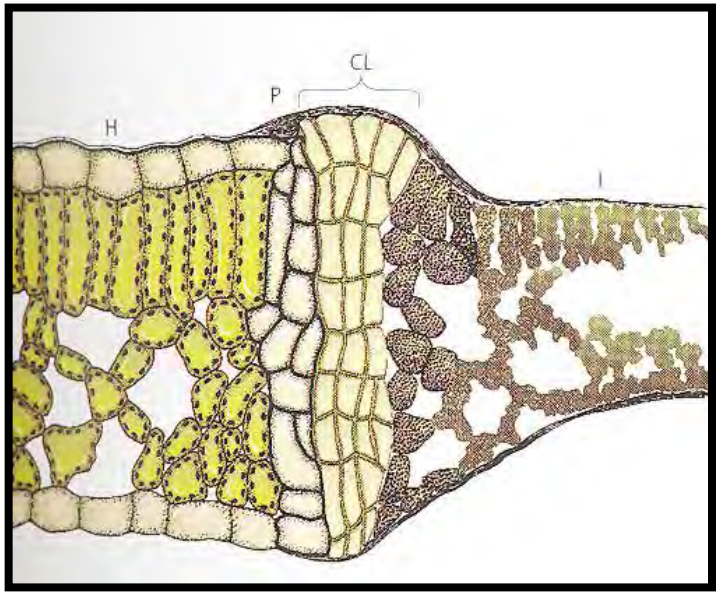


Nagy et al. 2000

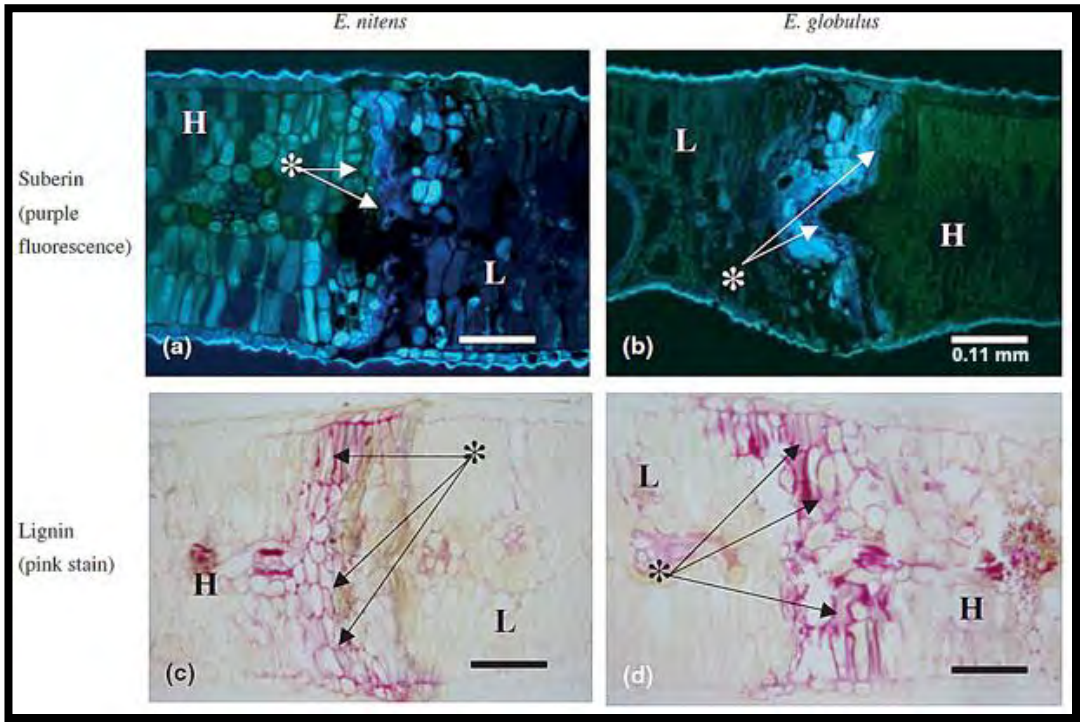


Franceschi et al. 2002

Subérine et lignine

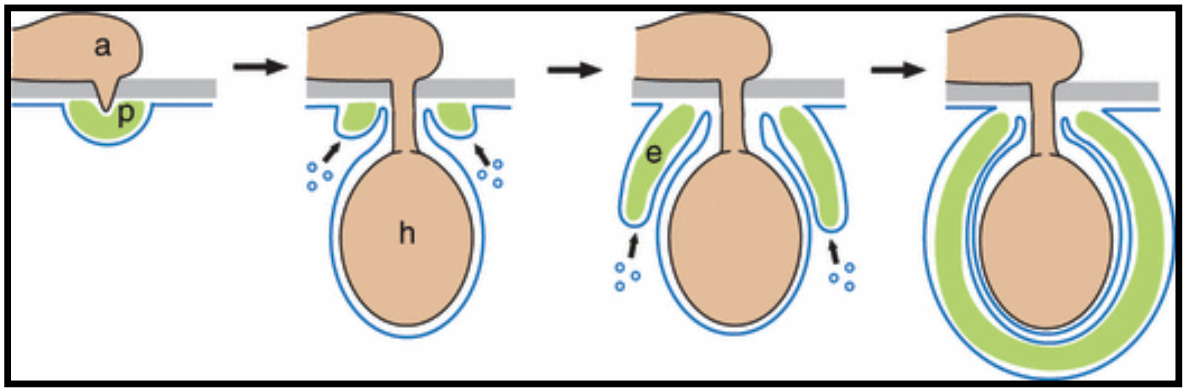


Cunningham 1928 *in* Agrios 2005

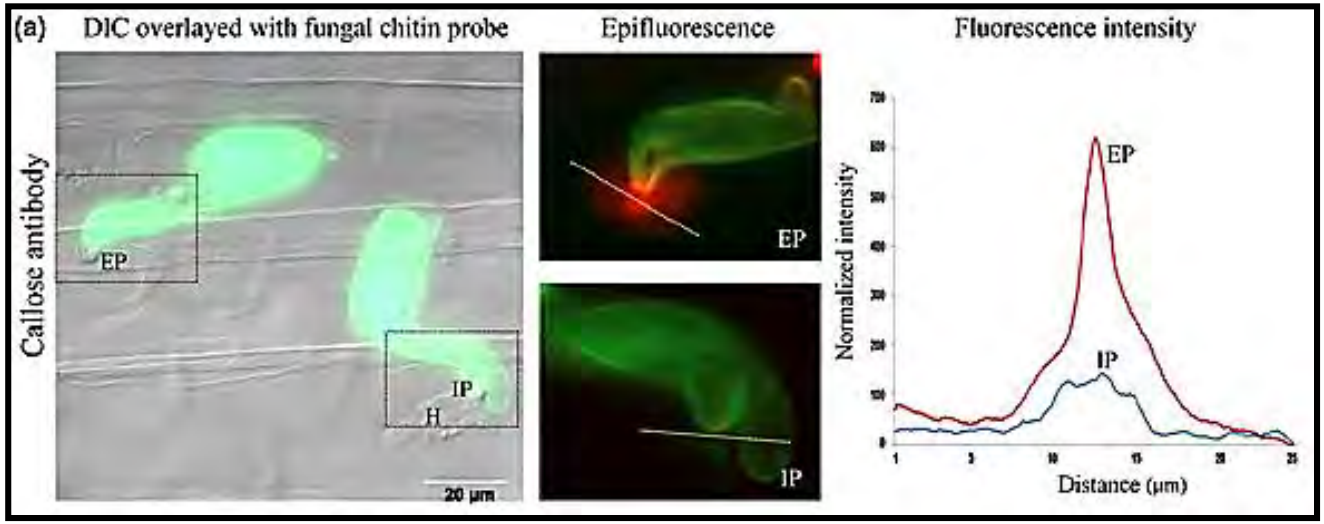


Smith et al. 2006

Papilles



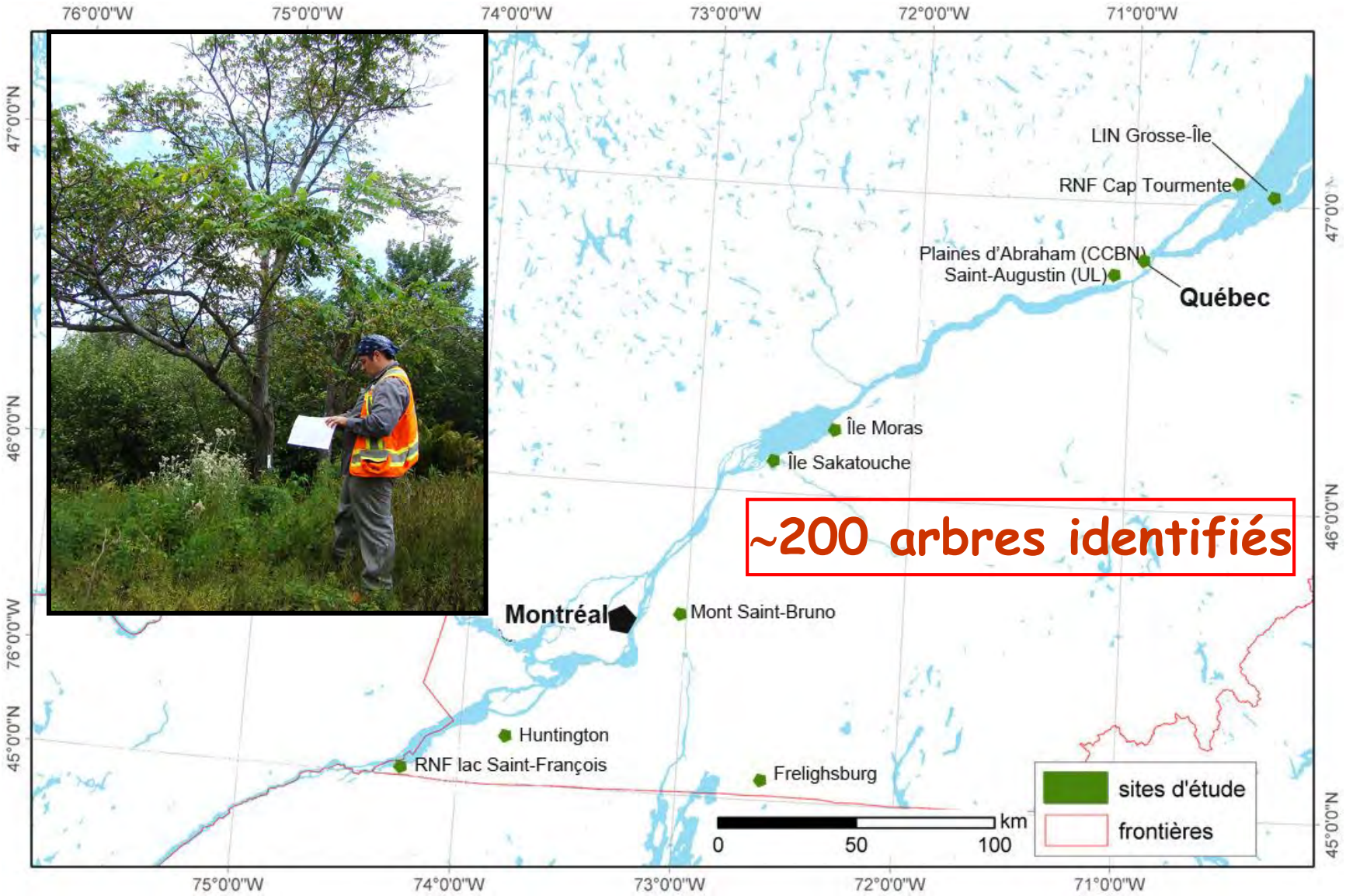
Meyer et al. 2009



Chowdhury et al. 2014

P.-M. Charest (U. Laval)

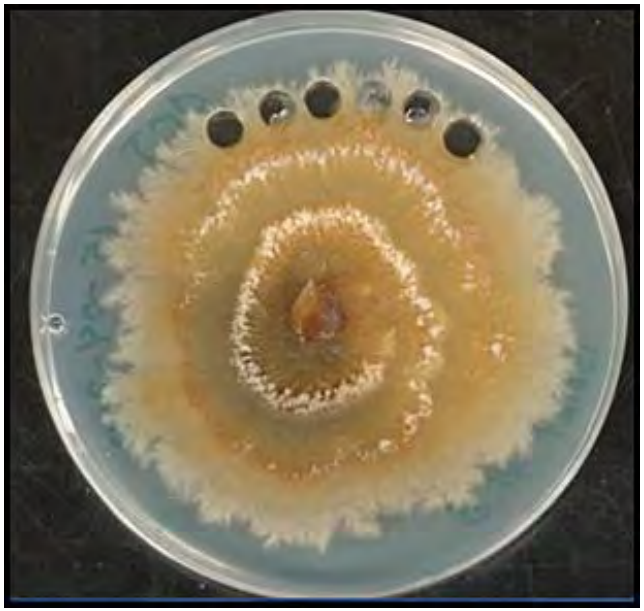
Protection et rétablissement du noyer cendré



Multiplication avec noix

N. Nadeau-Thibodeau, SCF

Chancre du noyer cendré
Inoculation



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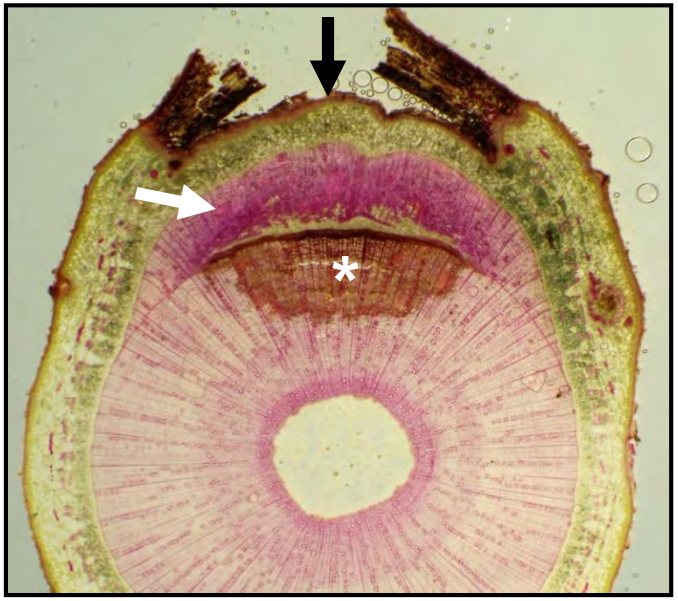
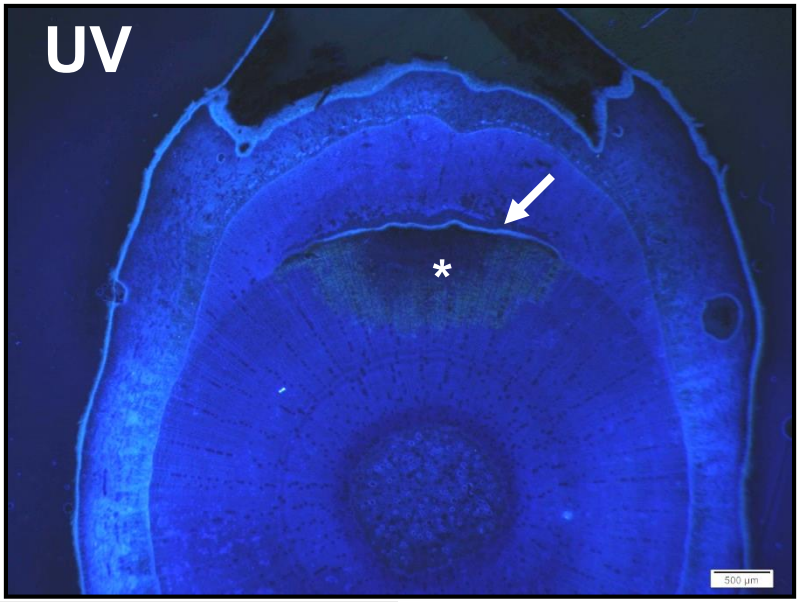
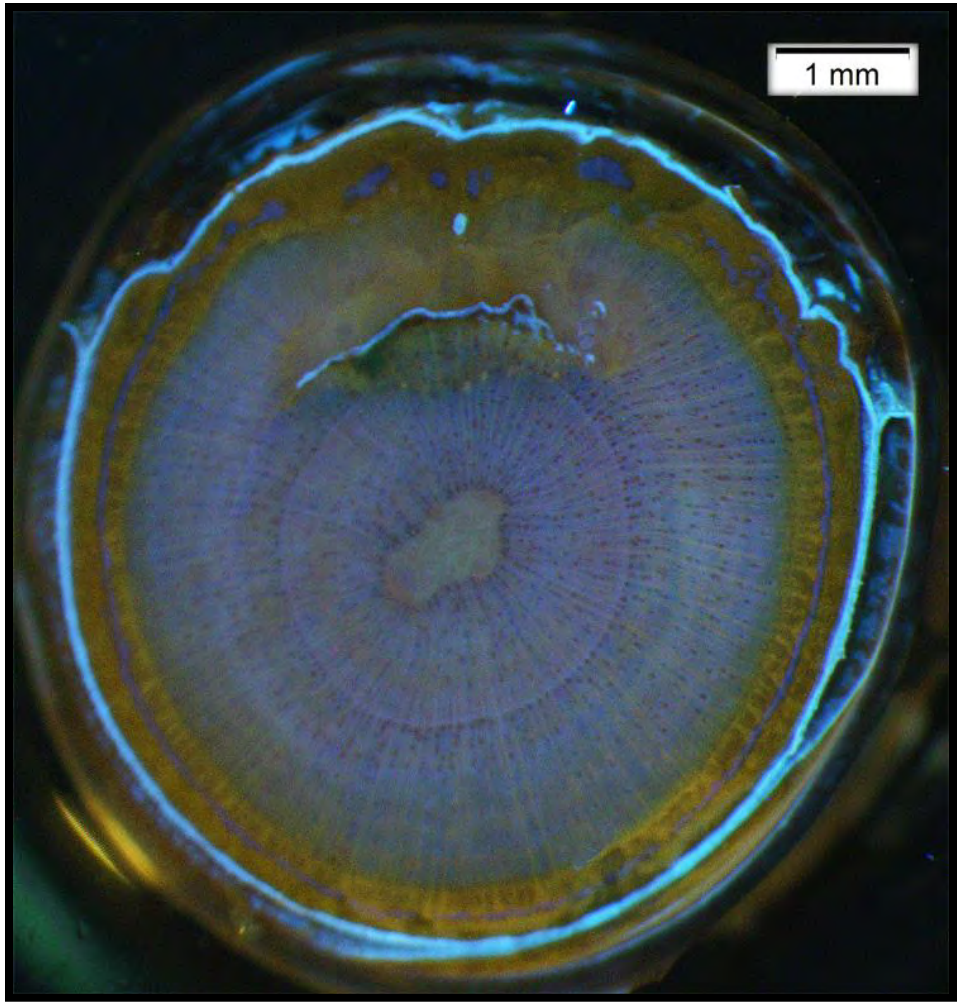
Avant dormance

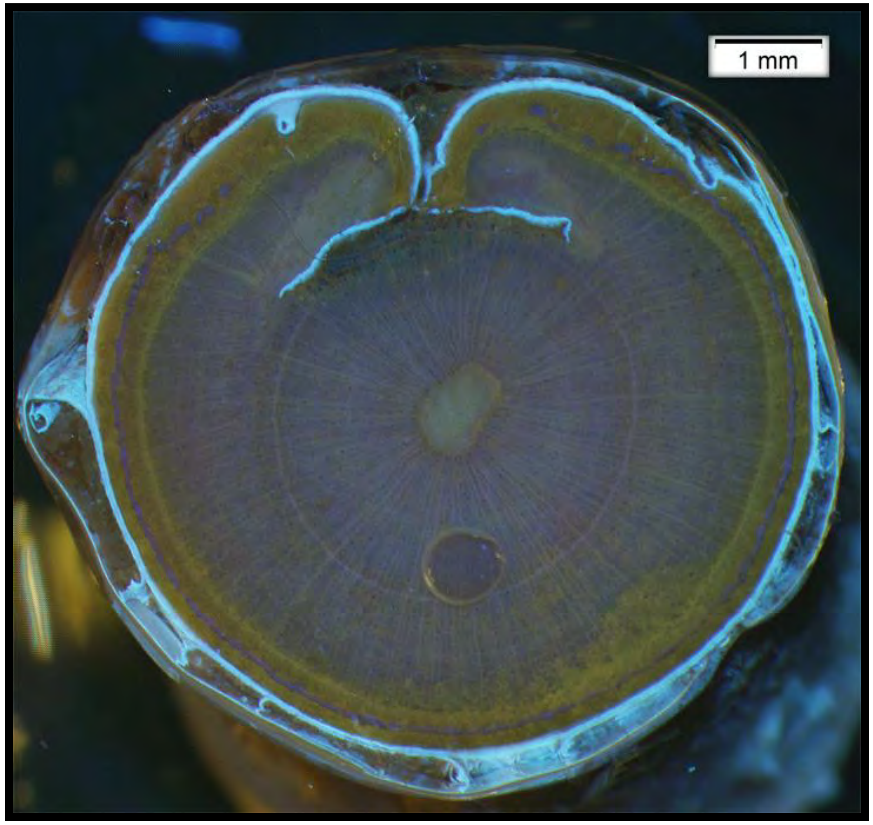




M. Lagacé et M. Blais, SCF

Inoculation tiges - Bouleau jaune





Après dormance (290 jai)

N. Nadeau-Thibodeau, SCF

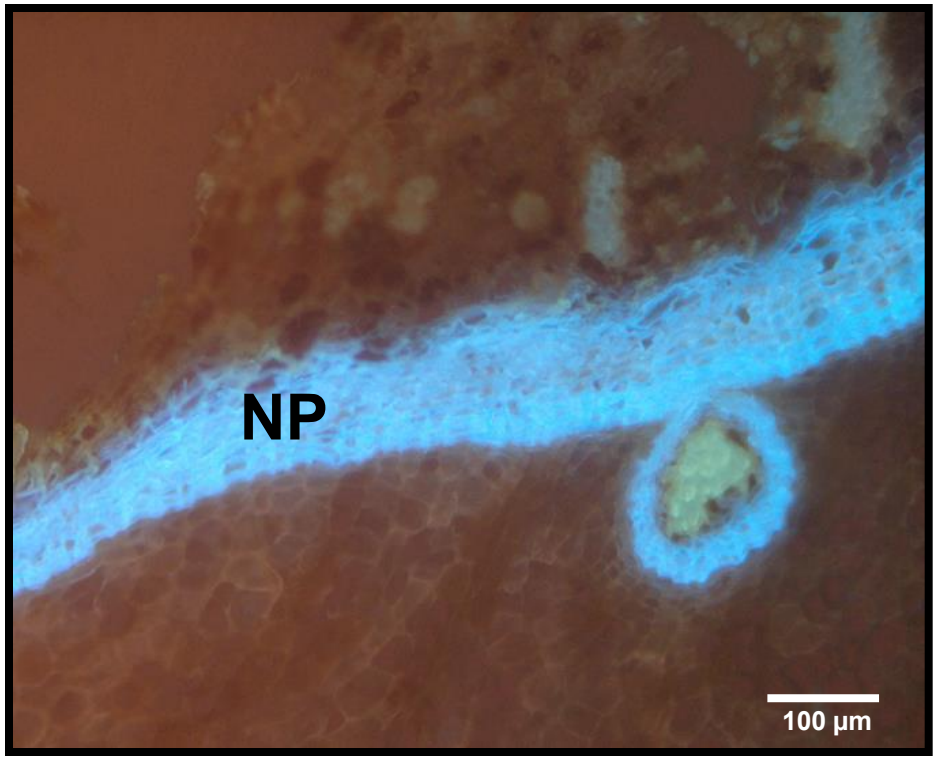
Noyer semblant résistant après dormance

N. Nadeau-Thibodeau,

SCF

SCF

Conventionnel (UV)



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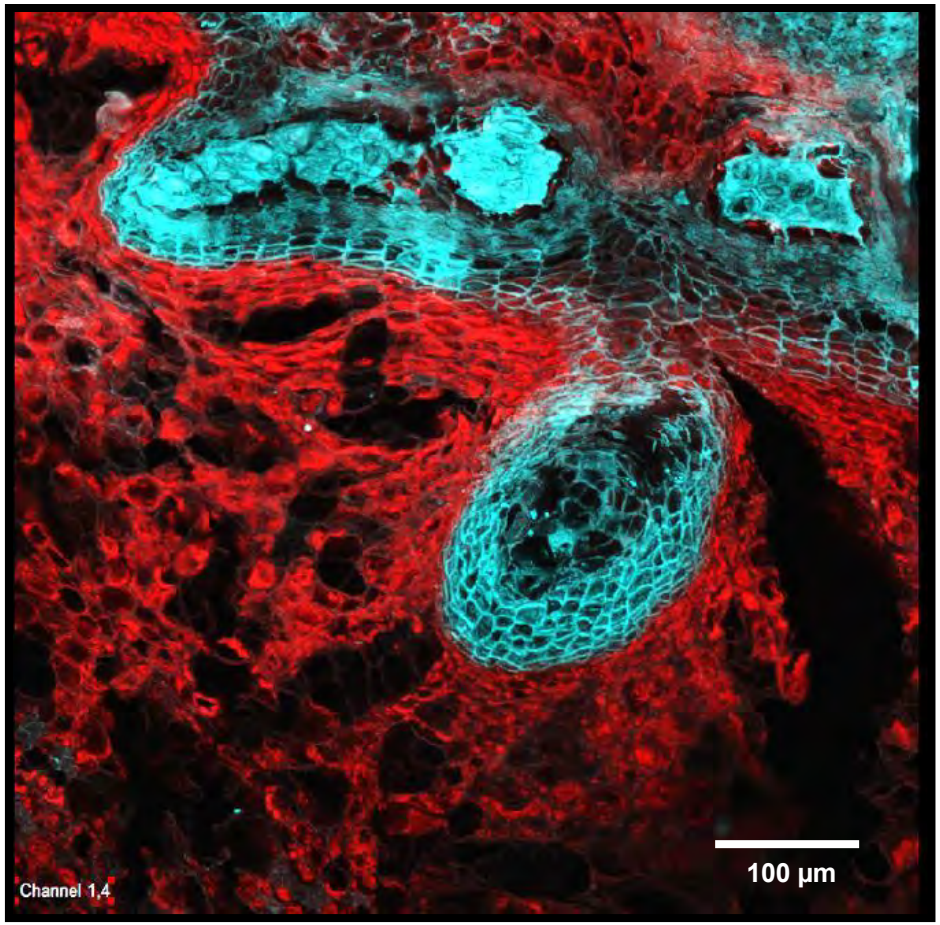
Confocal



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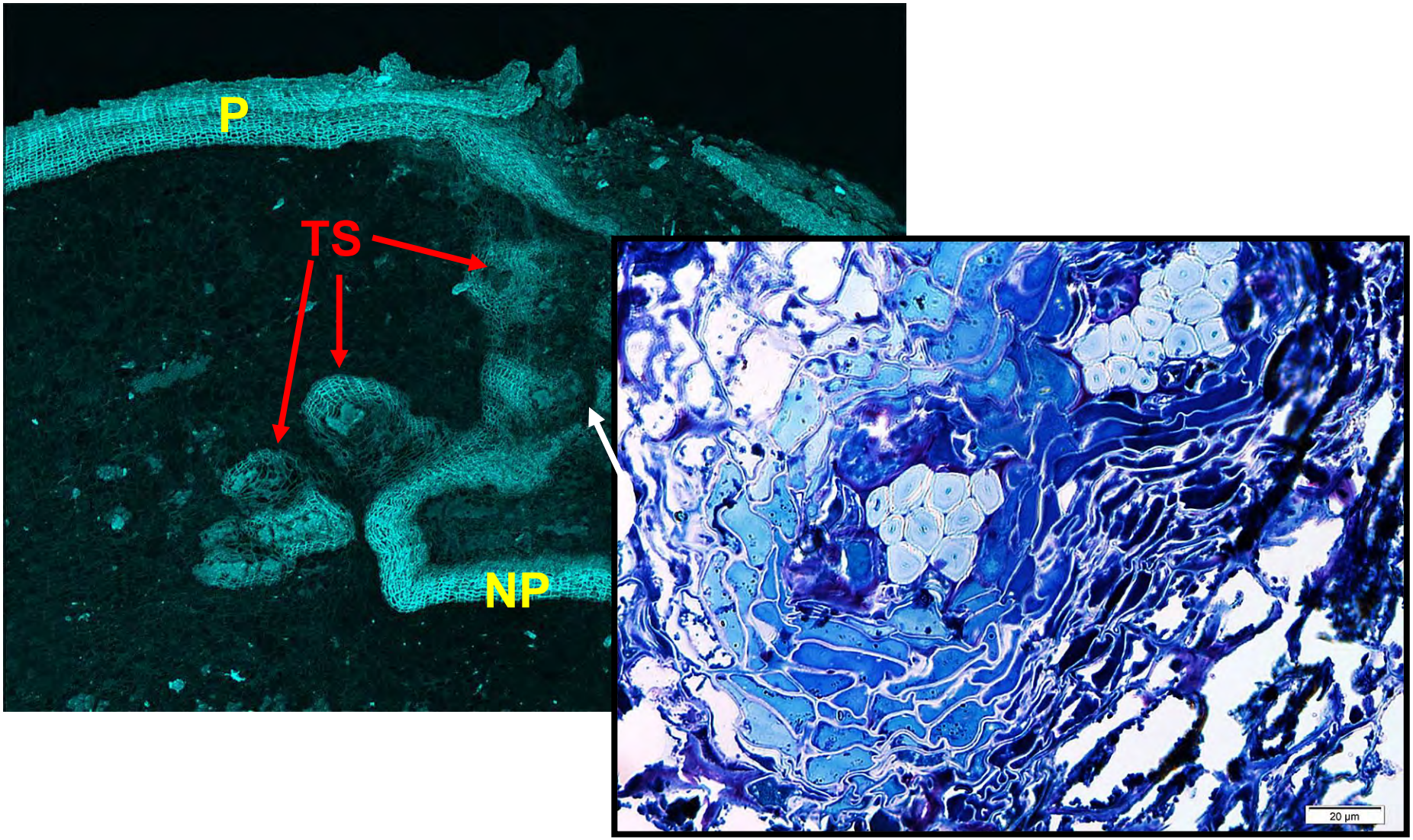
3. Mécanismes de défense



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  Danny Rioux, Martine Blais, Nicolas Nadeau-Thibodeau, Marie Lagacé, Pierre DesRochers, Krystyna Klimaszewska, and Louis Bernier

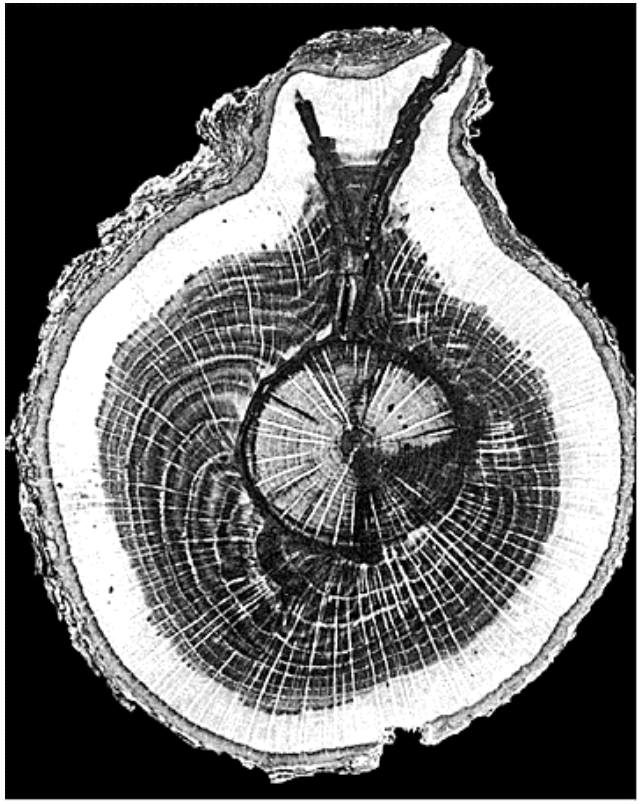
Phytopathology 108: 1237-1252

Défense = Faiblesse structurale

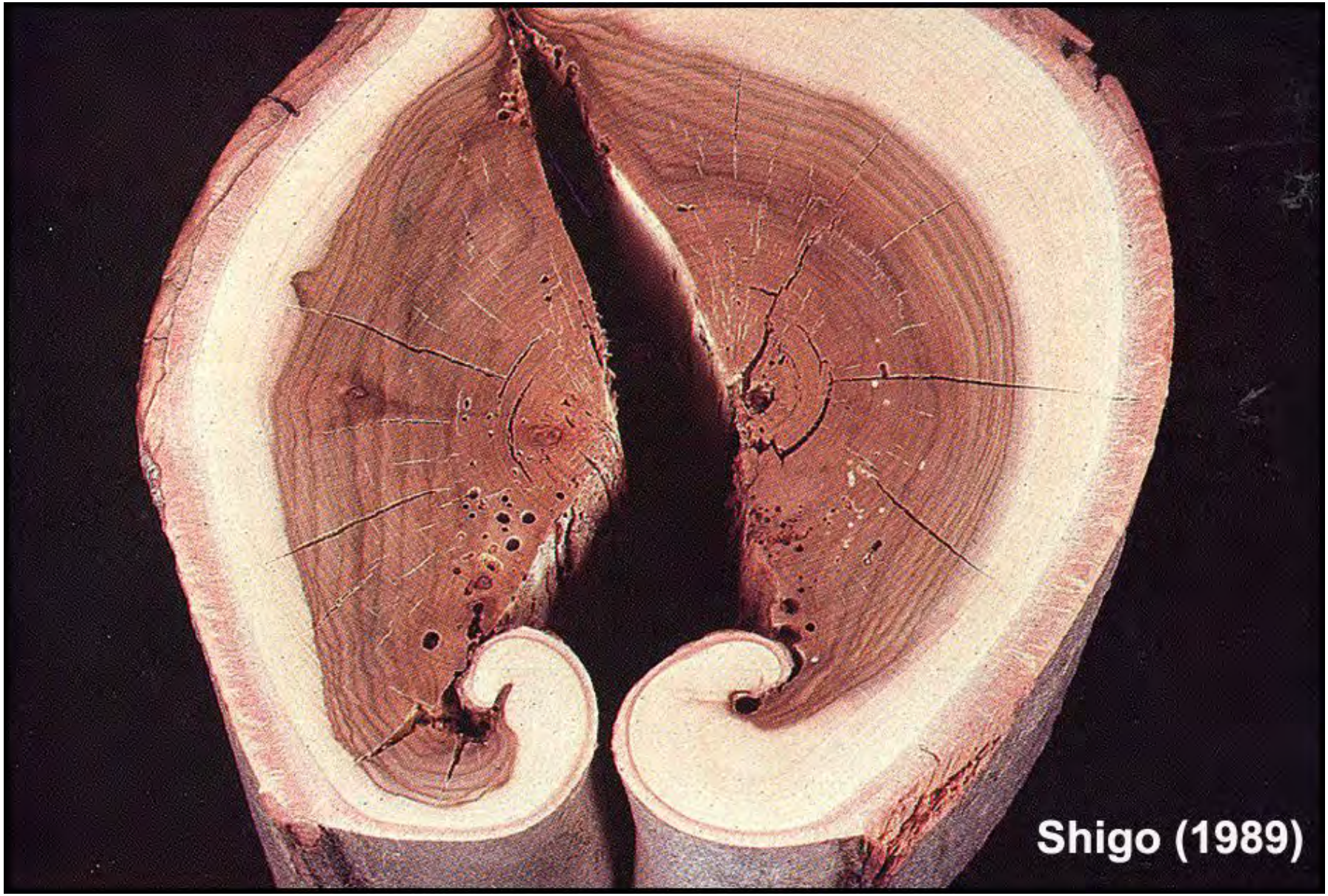
United States
Department of
Agriculture
Forest Service
Research
Paper NE-478
1981

Radial Shakes and "Frost Cracks" in Living Oak Trees

by Heinz Butin
and Alex L. Shigo



Défense = Faiblesse structurale

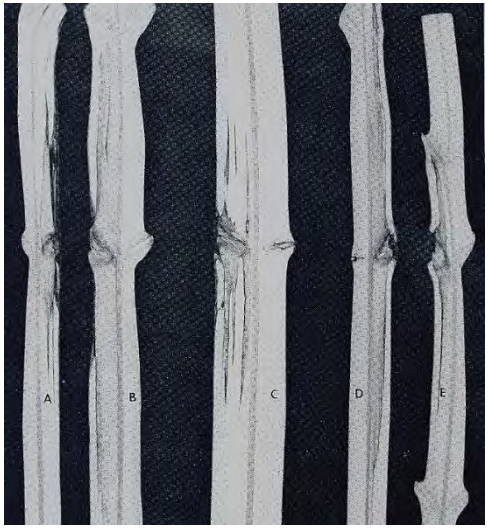


Stimulation des mécanismes de défense (MD)

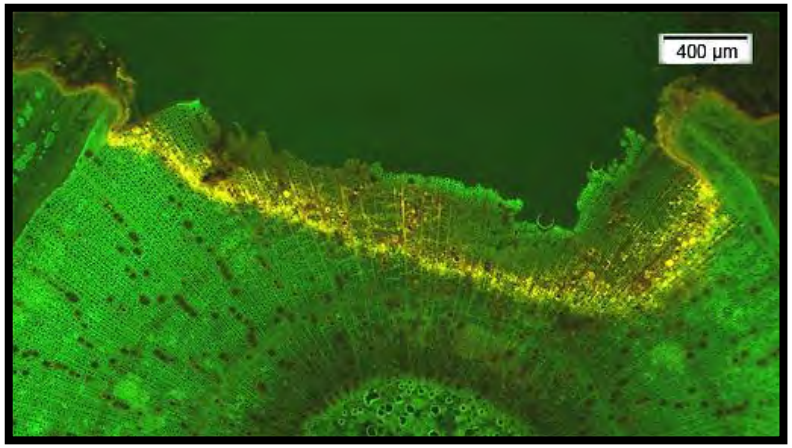
220 Santamour: Inheritance of Wound Compartmentalization

INHERITANCE OF WOUND COMPARTMENTALIZATION IN SOFT MAPLES

by Frank S. Santamour, Jr.



Shigo 1988



M. Lagacé et M. Blais, SCF

JOURNAL OF
ARBORICULTURE

May 1977
Vol. 3, No. 5

WOUND DRESSINGS ON RED MAPLE AND AMERICAN ELM: EFFECTIVENESS AFTER FIVE YEARS

by Alex L. Shigo and Charles L. Wilson [1]

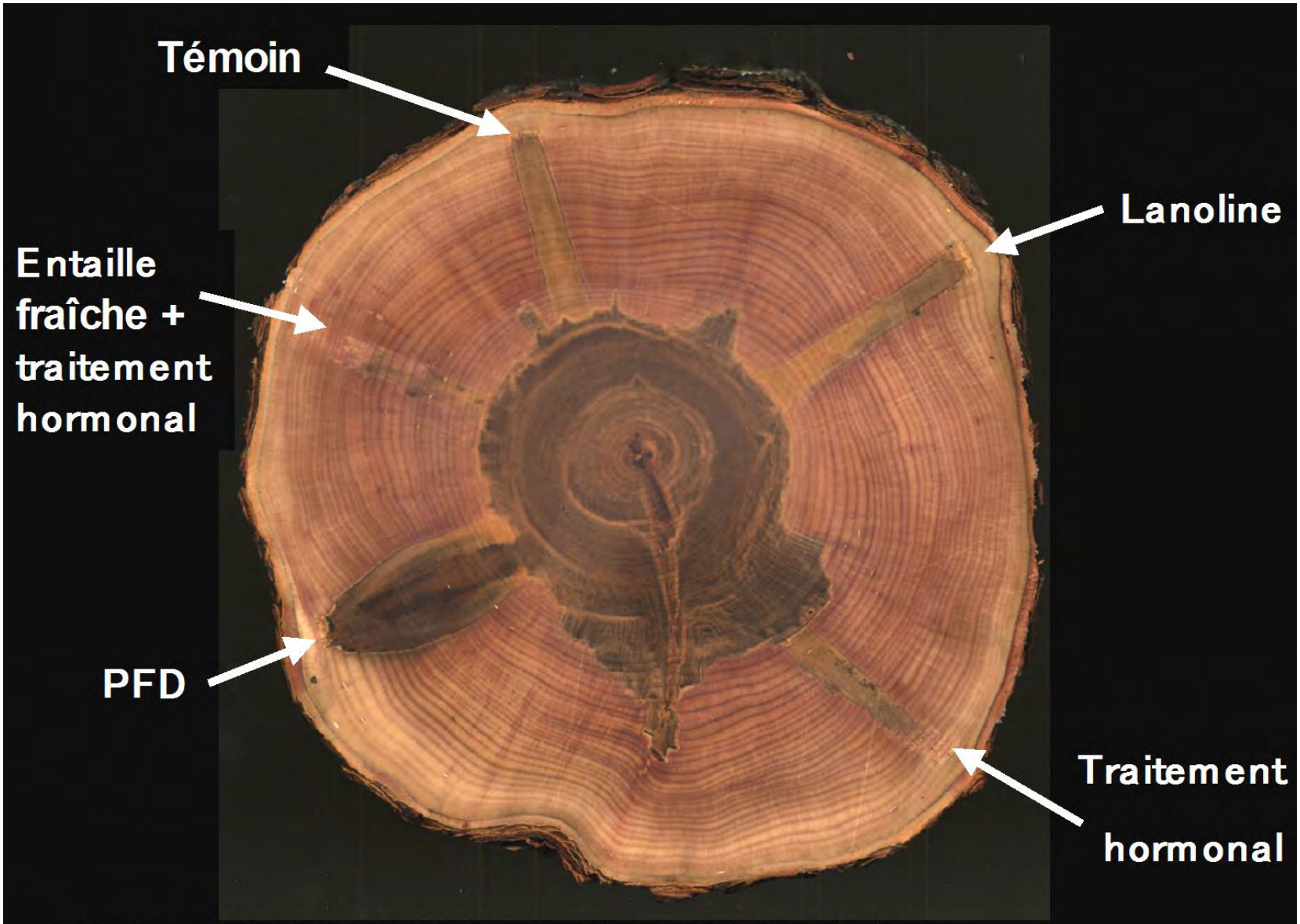
Abstract. Closure and internal compartmentalization of wounds on red maple and American elm were not stimulated by dressings of an asphalt-based material, orange shellac, or polyurethane varnish. After 5 years, decay fungi had infected many treated and control wounds. Some trees closed wounds rapidly; others closed wounds slowly regardless of the treatments.

exhibited beneficial properties against specific diseases (Dye 1971).

Few studies have been done on the internal effects of the dressings. Houston (1971) conducted a study on the effect of some chemicals on the development of discoloration and decay in

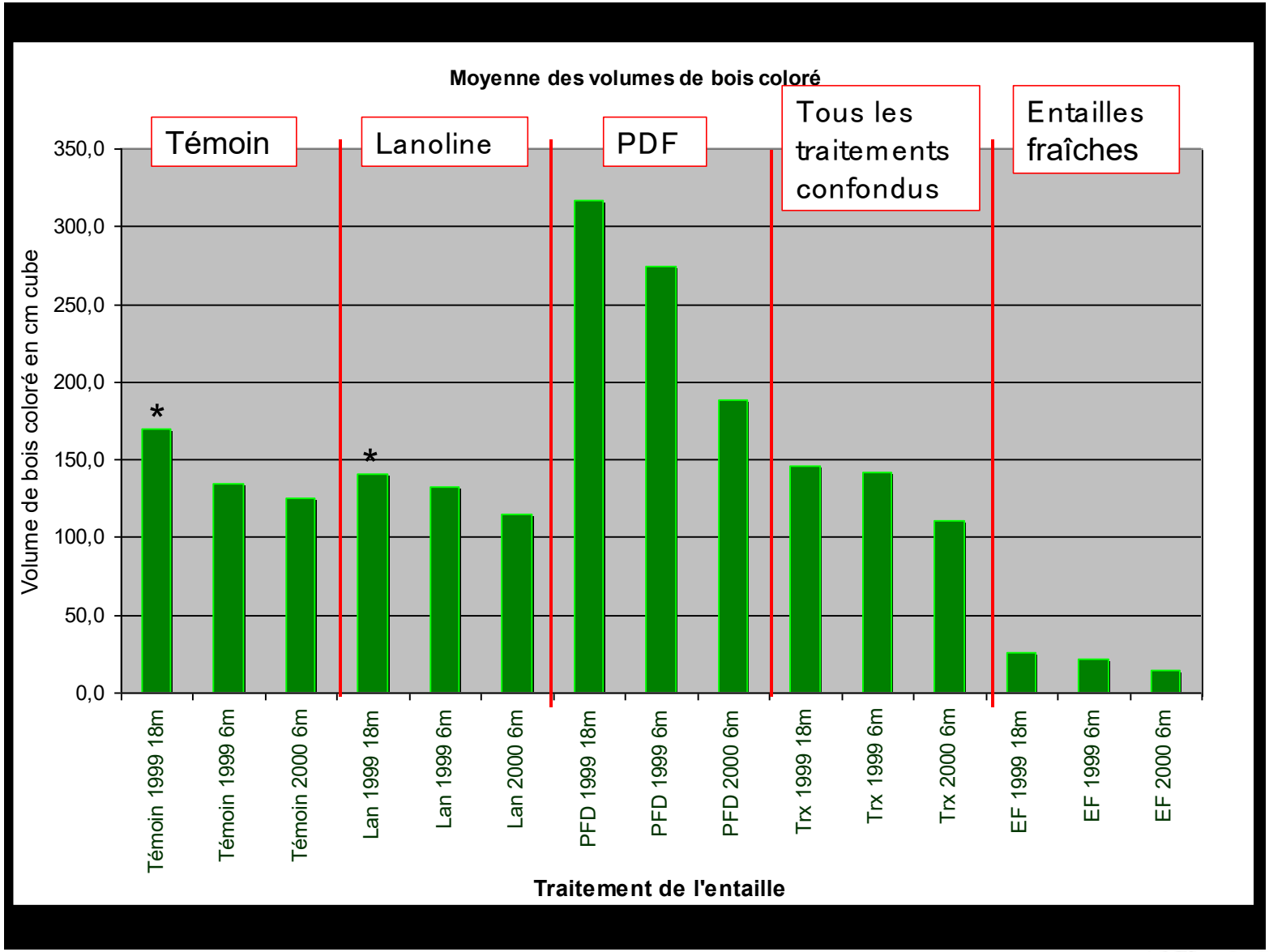
Hormones (AJ, Eth, AAB, AS, Bét, Cyt) - Lanoline

Stimulation des MD



Découpe de tige pour la mesure du volume de bois coloré.

J. Grondin (2004)



J. Arboriculture 1996, 22(5): 206-210

206 McDougall and Blanchette: U

POLYETHYLENE PLASTIC WRAP FOR T
WOUNDS: A PROMOTER OF WOUND C
ON FRESH WOUNDS

by Dennis N. McDougall and Robert A. Blanchette

- Immédiatement après blessures : f de
- Une semaine après blessures : aucu

RNCan, SCF

G. Allard 2003 (Centre ACER)

Été 1998 10 % de cime restante

Été 2002

À retenir

- Agents pathogènes pénètrent l'arbre par des blessures ou ouvertures naturelles
- L'arbre répond d'abord à la présence d'air
- Un arbre vigoureux se défend bien
- Fermeture des blessures ≠ Compartimentage
- Compartimentage (tissus) : imperméables et anti-microbiens (ex. subérine)
- Aspects pratiques : structure du bois; liège; élagage; sélection-résistance; traitements pour stimuler les MDs

Remerciements

Marie Simard

Marie Lagacé

Martine Blais

- Louis Bernier et Guy Bussières (U. Laval)
- Sylvia Greifenhagen (OMNRF)
- Stéphane Guay et Jean-Pierre Renaud (Centre ACER)
- Michel Nicole (IFRSDC)
- Pierre DesRochers, Gaston Laflamme, Robert Lavallée, Guillemond Ouellette, Armand Séguin et Philippe Tanguay (SCF)

MERCI!

QUESTIONS?