Forest based biorefineries.
The case of barks and the importance of chemical and structural features

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Network of conversion processes of different types, established in sequence and/or parallel flows, based on biomass as feedstock, for production of energy, chemicals and materials.

Biorefineries

- ✓ Diversity of processes
- ✓ Biomass

Underlying framework of full resource utilization and of environmental balance

Diversity of processes

Conversion based on physical, thermal, chemical, biotechnological processes and their combination

- ✓ Thermochemical
- ✓ Biotechnological & chemical
- ✓ Physical

- ✓ Energy and fuels
- ✓ Chemicals
- ✓ Materials

- Bark diversity and availability
- Bark structure and anatomy
- Bark chemical composition
- Bark-based biorefineries

- Bark has an external appearance that is species characteristic: it is part of the botanical description of the plant and often used for taxonomic purposes






- Bark varies with tree age and with growth conditions
- Bark makes up a considerable proportion of the stem e.g. >10%

Eucalyptus globulus (1-18 yrs)	11-22%
Acacia melanoxylon (40 yrs)	9%
Quercus faginea (40 yrs)	19%
Pseudotsuga menziesii (ca. 50 yrs)	10-17%
Pinus radiata (30 yrs)	9-12%

- Bark is removed during forest operations and tree processing: large amounts concentrate at the wood yards and pulp mills

Barks that we studied at CEF

Hardwoods

Albizia niopoides
Betula pendula
Copaifera langsdorffii
Eucalyptus sideroxylon
Eucalyptus globulus
Eucalyptus urophylla x E. grandis
Eucalyptus urophylla x E. camaldulensis
Goupia glabra
Kyelmeria coriacea
Plathymenia reticulata
Quercus cerris
Quercus variabilis
Quercus suber
Tectona grandis

Softwoods

Picea abies
Pinus pinaster
Pinus pinea
Pinus sylvestris
Pseudotsuga menziesii

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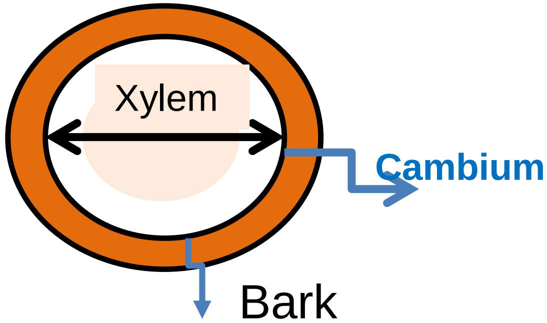
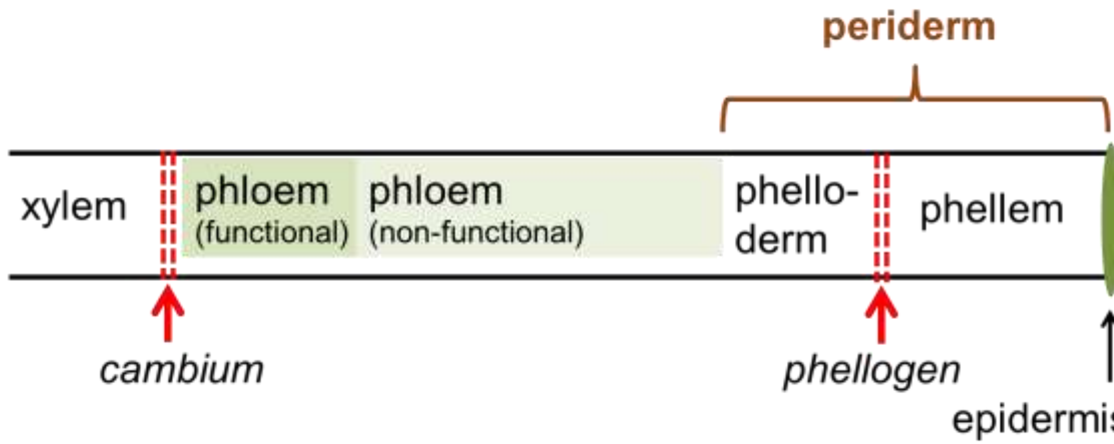
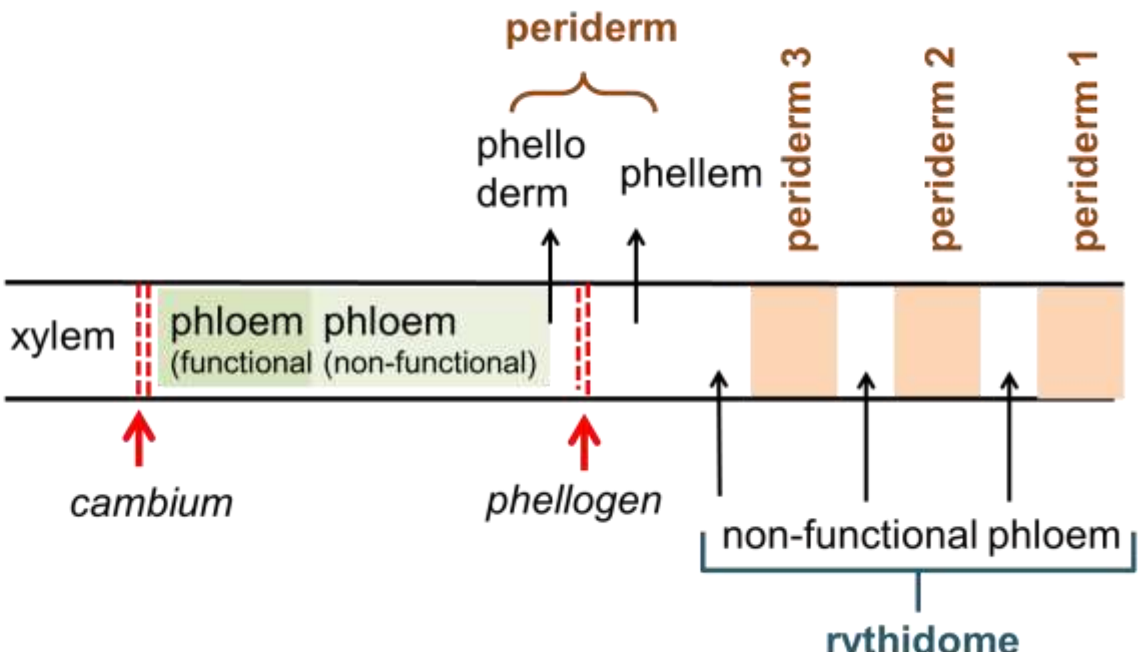
Bark results from
the activity of two meristems
and includes various tissues

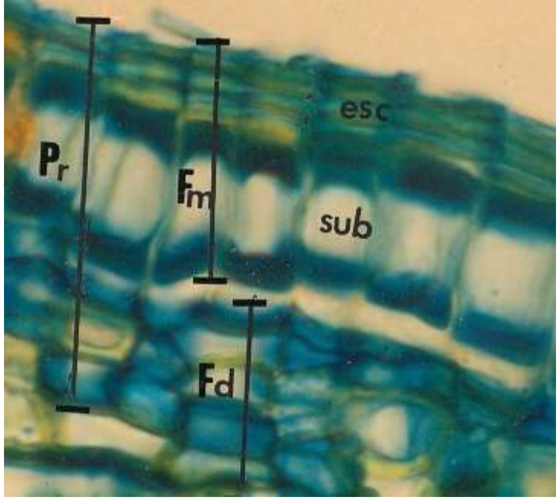


All tissues outside the cambium





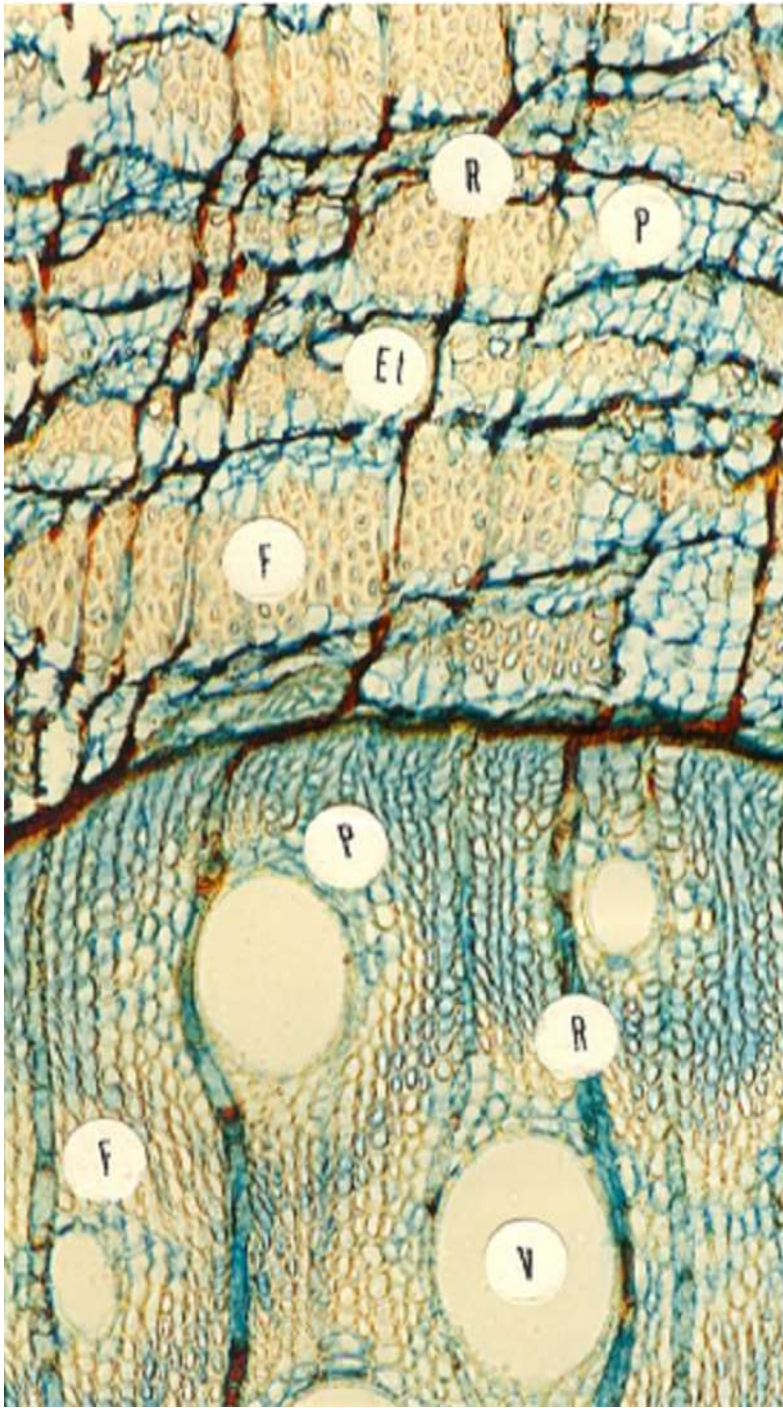
Eucalyptus globulus



Periderm

Phloem, non functional

Phloem, functional



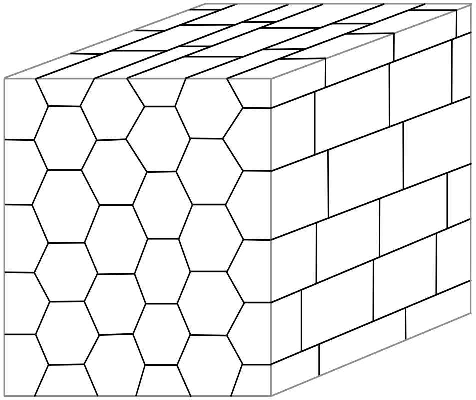
Quercus suber

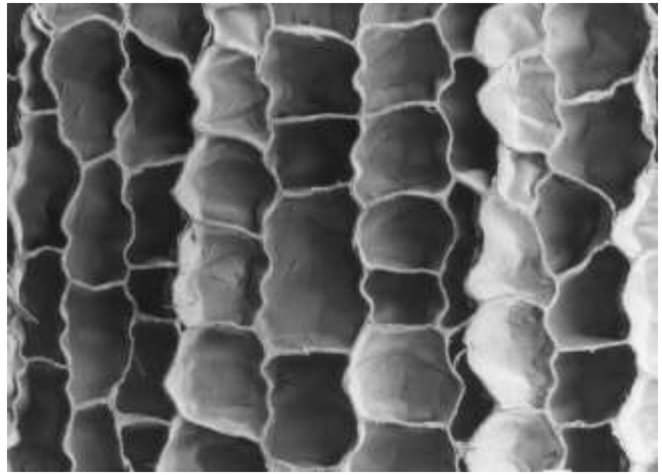
The bark is characterized by a thick layer of cork, forming a continuous envelope around the stem i.e. the phellogen is tangentially and axially continuous

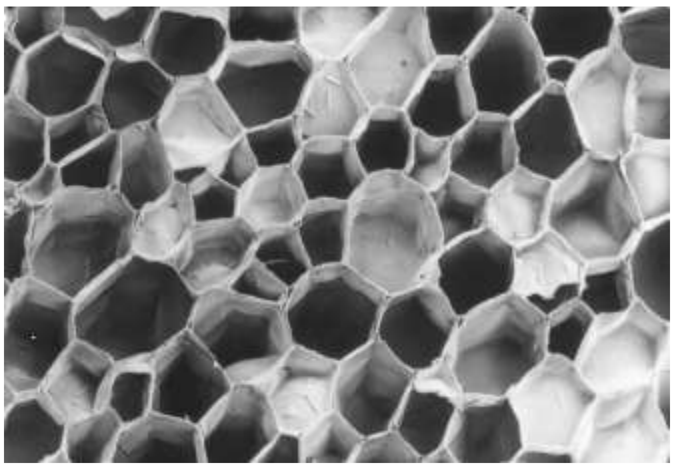
Few species have such periderm features e.g. *Quercus variabilis, Plathymenia reticulata, Kyelmeria coriacea*

CORK

Unique set of properties:
- light
- impermeable
- inert
- compressible
- elastic
- insulator
- durable

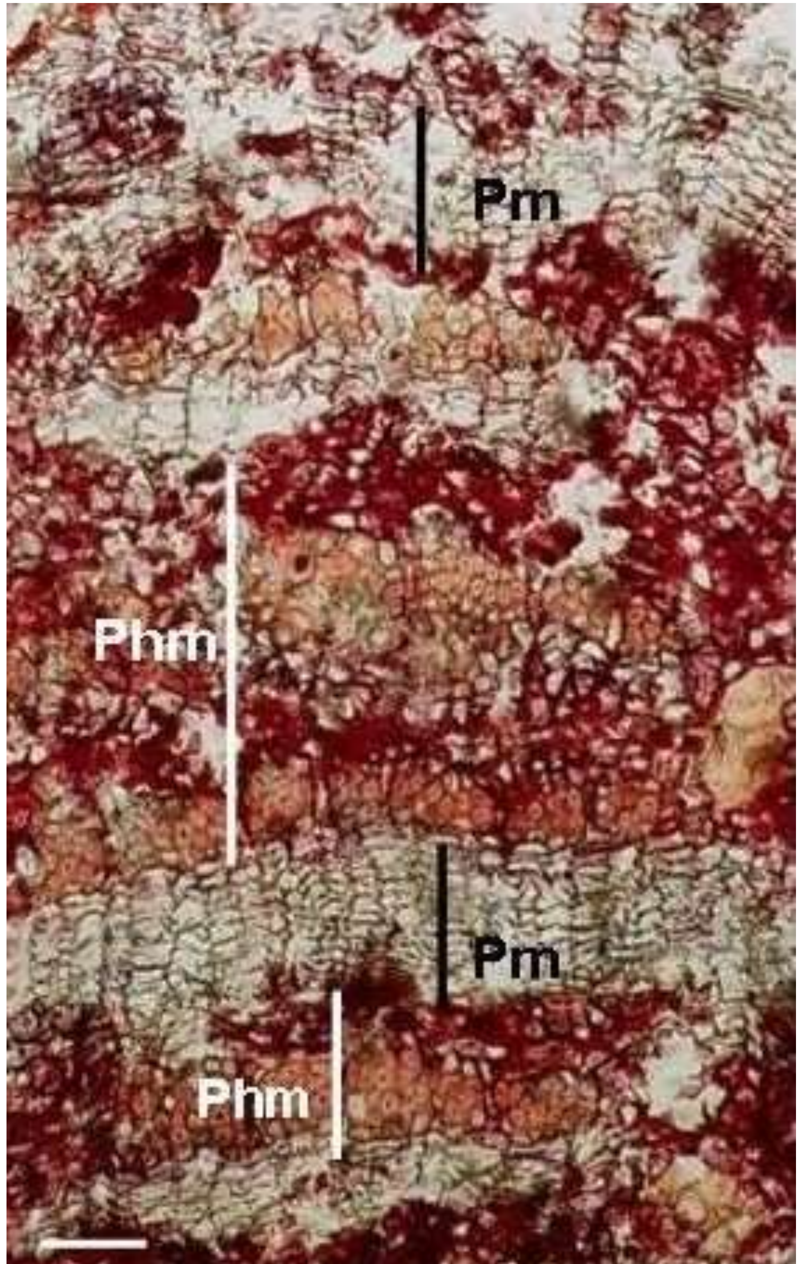




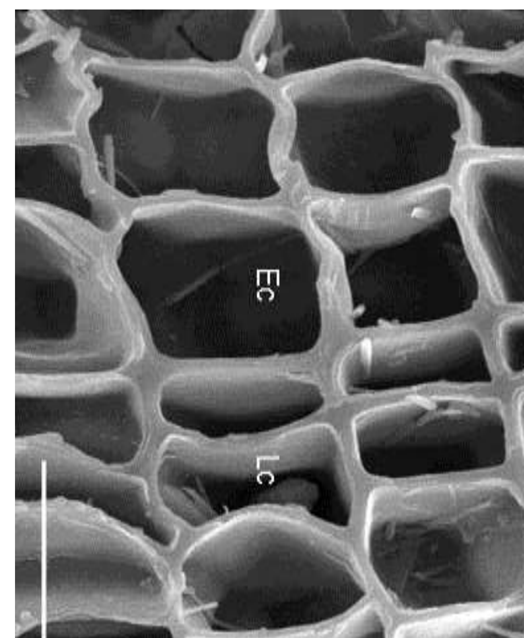


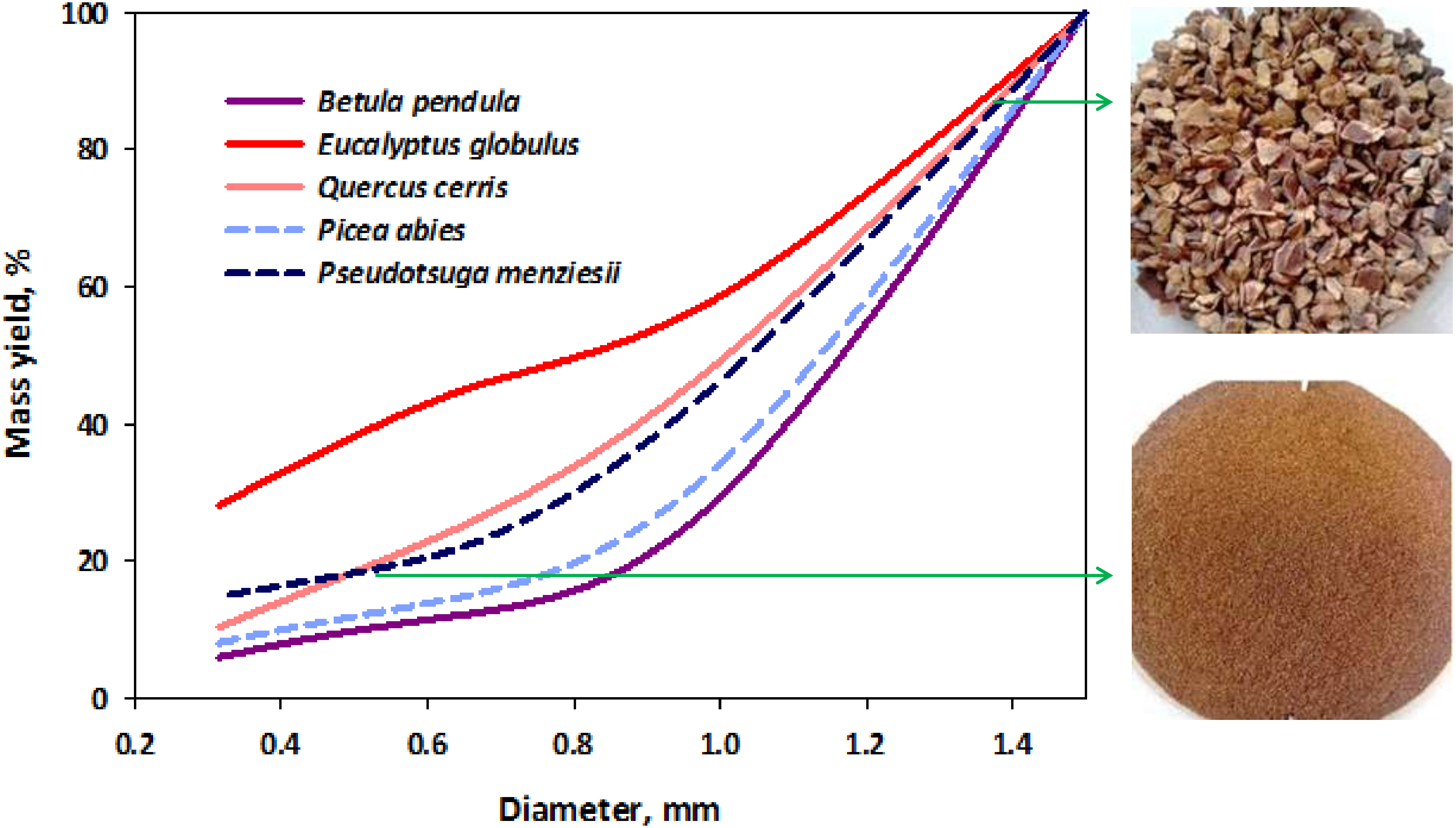
Regular and compact arrangement of closed, small and thin-walled cells

Quercus cerris



Thick bark with a large rhytidome with a high proportion of cork. The layers of cork are separated by phloem layers.





Grinding, separation of fines, fractioning by air and water flotation targeting specific fractions: e.g. cork enriched or fibre enriched

- Bark chemical composition is complex, diverse and different from wood

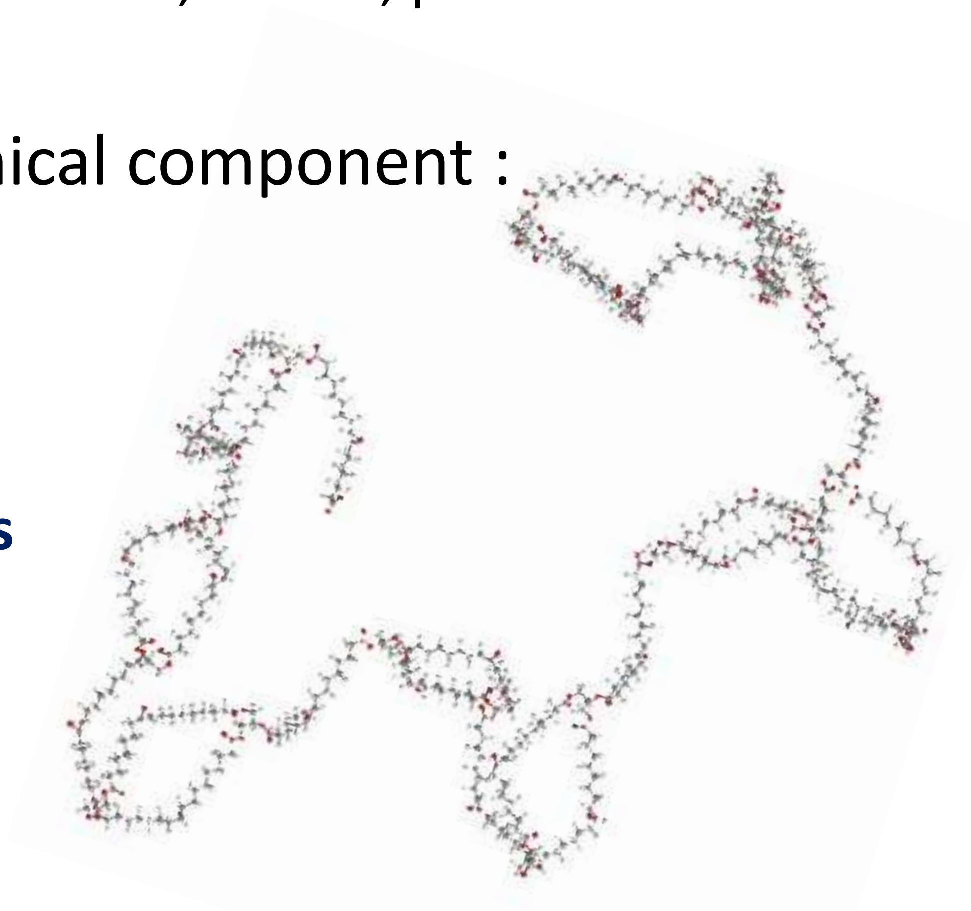
  higher ash content

  more extractives and with large diversity

  e.g. lipids, terpenoids, sterols, phenolics

- A specific structural chemical component : suberin in cork cells

A macromolecule of ester linked long chain fatty acids and alcohols to glycerol



- Proportion of structural components depends on the different tissues and cellular types

Chemical composition of whole barks or industrial barks

	Extractives	Suberin	Lignin
Albizzia niopoides	14.5%	0.5%	37.1%
Betula pendula	17.6%	5.9%	27.9%
Copaifera langsdorfii	21.3%	0.8%	36.6%
Eucalyptus globulus	8.5%	0.9%	34.1%
Eucalyptus sideroxylon	55.7%	1.9%	13.1%
Goupia glabra	24.6%	1.1%	43.8%
Tectona grandis	10.7%	1.9%	20.0%
Pinus sylvestris	18.8%	1.6%	33.7%
Pinus pinaster	11.4%	1.5%	43.7%
Pinus pinea	19.9%	2.3%	40.1%
Picea abies	21.6%	1.3%	27.0%
Pseudtotsuga menziesii	26.7%	22.0%	29,5%

Chemical composition differs between phloem and cork

Chemical composition of phloem and cork separated from the bark

	Quercus cerris		***Betula pendula***		***Pseudotsuga***	
	Phloem	Cork	Phloem	Cork	Phloem	Cork
Ash	13.0%	2.6%	3.6%	2.1%	3.0%	0.9%
Extractives	6.5%	16.7%	8.1%	32.2%	28.4%	29.2%
DCM	(1.7%)	(10.9%)	(6.1%)	(31.1%)	(1.1%)	(5.6%)
EtOH	(3.6%)	(3.4%)	(1.0%)	(0.6%)	(24.1%)	(21.1%)
H2O	(1.3%)	(2.4%)	(1.0%)	(0.6%)	(3.2%)	(2.4%)
Suberin	5.5%	28.5%	3.2%	36.2%	3.8%	36.2%
Lignin	35.4%	28.1%	32.2%	14.3%	35.1%	16.8%
Polysacch,	30.6%	16.5%	43.0%	10.3%	31.8%	16.9%

The bark based biorefinery

Use for energy
- bioenergy
- bio-oils

Use for materials
- pulp
- fibre composites
- cork products

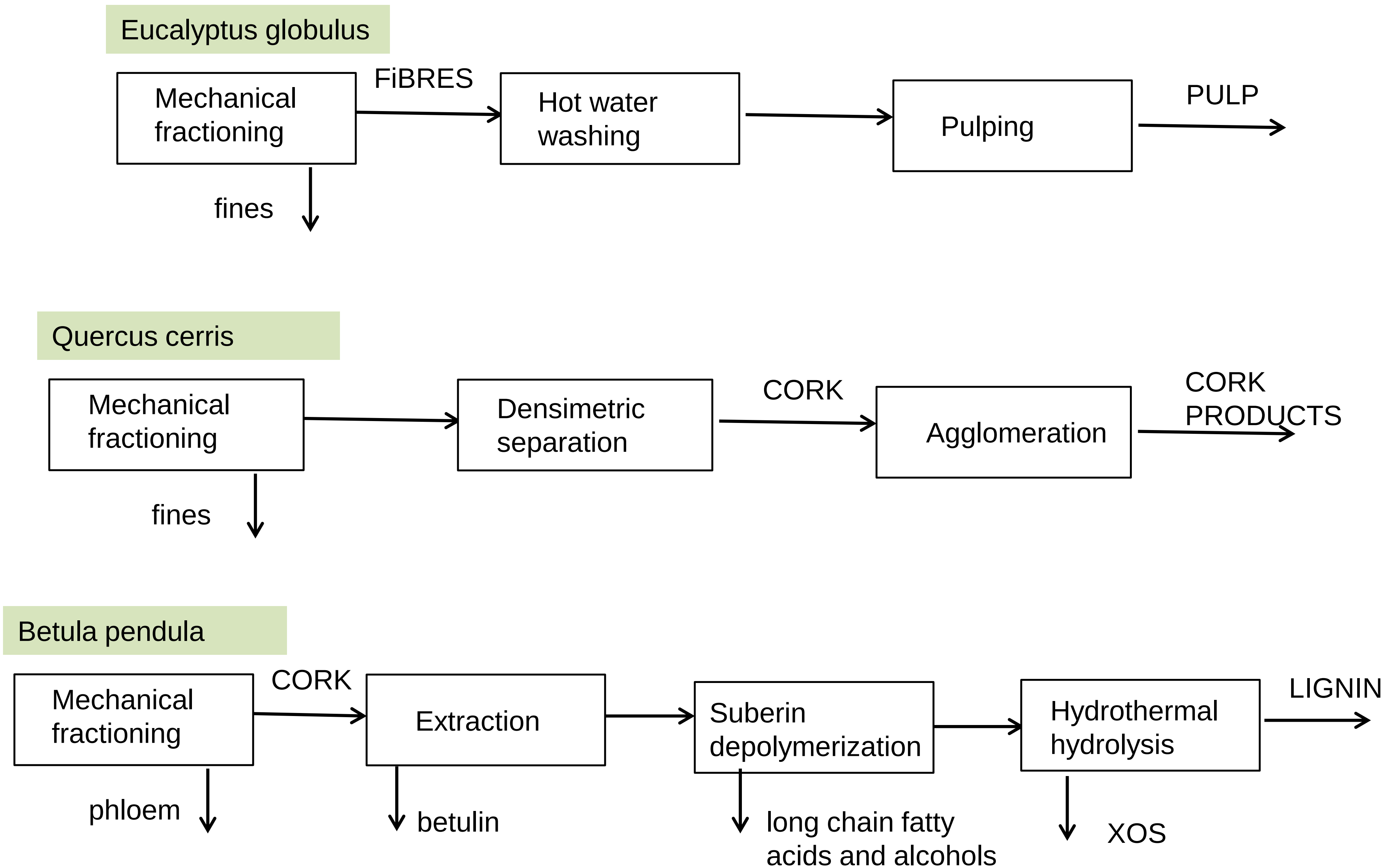
The structural and cellular features are the driving factors
- % of fibres & biometry
- % of cork & celll features

Use for chemicals
- pharmaceutical
- nutraceutical
- polymers
- adhesives

The chemical composition and chemical features are the driving factors
- extractives & composition
- suberin & composition

Integrated use

Bark based biorefinery depends on structure and chemistry



CONCLUSIONS

Bark is an important tree component that should be considered in the overall wood supply chain

Barks are available and interesting resources for added value processing

There is enormous variability in structure and chemical composition of barks

Knowledge on bark structural and chemical features is essential for processing design and valorization

Thank you

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