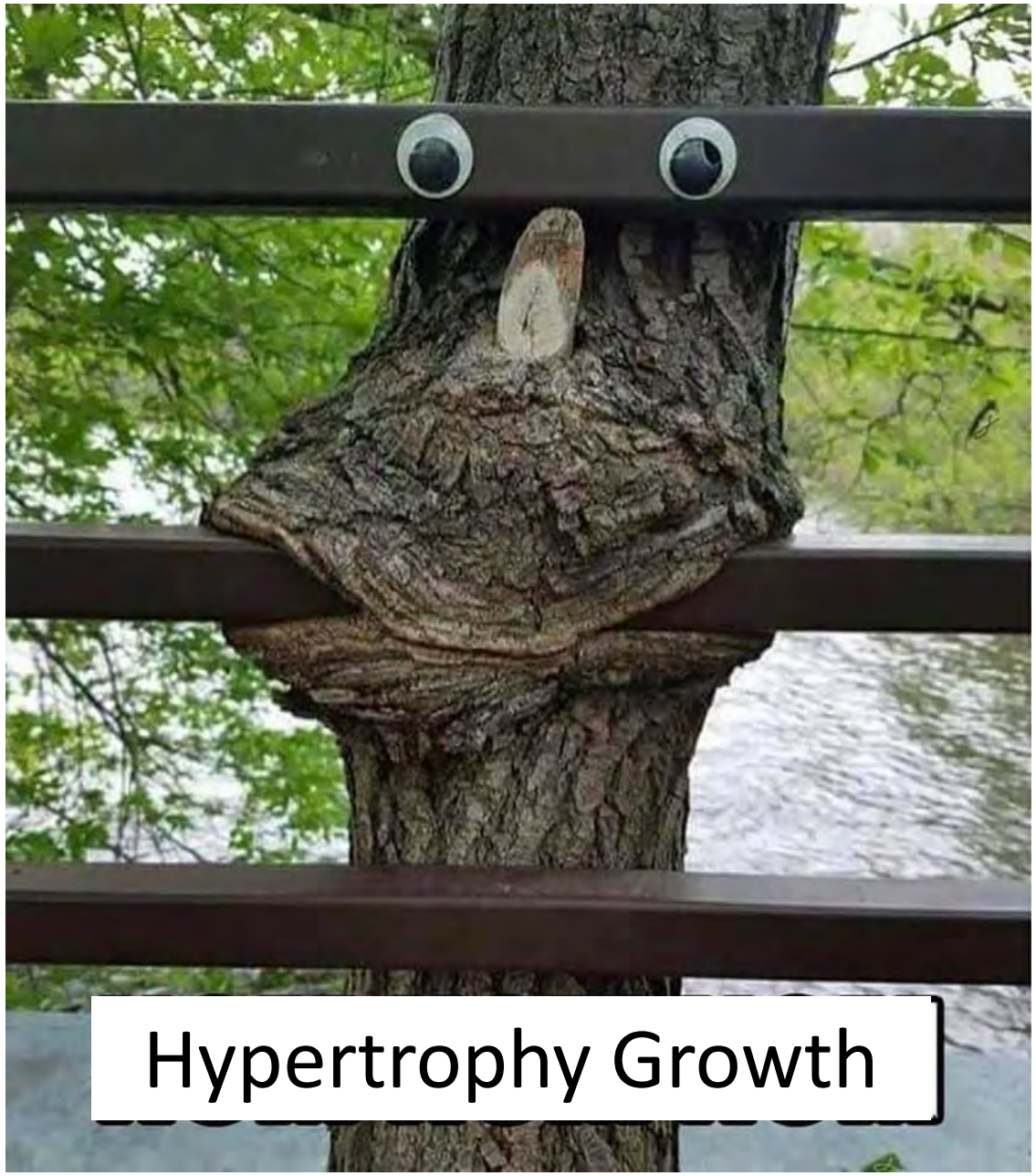
Forest Ecology and Management: How Does a Forest Grow

Prof. Jim Perry

WM/VIMS


Caught this tree trying to sneak out of the lake.
Original Soil Level
Soil Erosion!


Hypertrophy Growth

What is forest?

A large area covered chiefly with trees and undergrowth. A **Classified Forest** consists of 10 acres of more, supporting a growth of native or planted trees, which have been set aside for the production of timber and wildlife, the protection of watersheds, or the control of soil erosion.

What makes a forest a forest?

Forests are ecosystems in which the dominant vegetation is trees. They include biotic (people, squirrels, birds, trees, shrubs, flowers, and grass) and abiotic (sun, water, soil, buildings, and even cars) things interacting with each other.

General Types:

There are three general types of forest that exist.

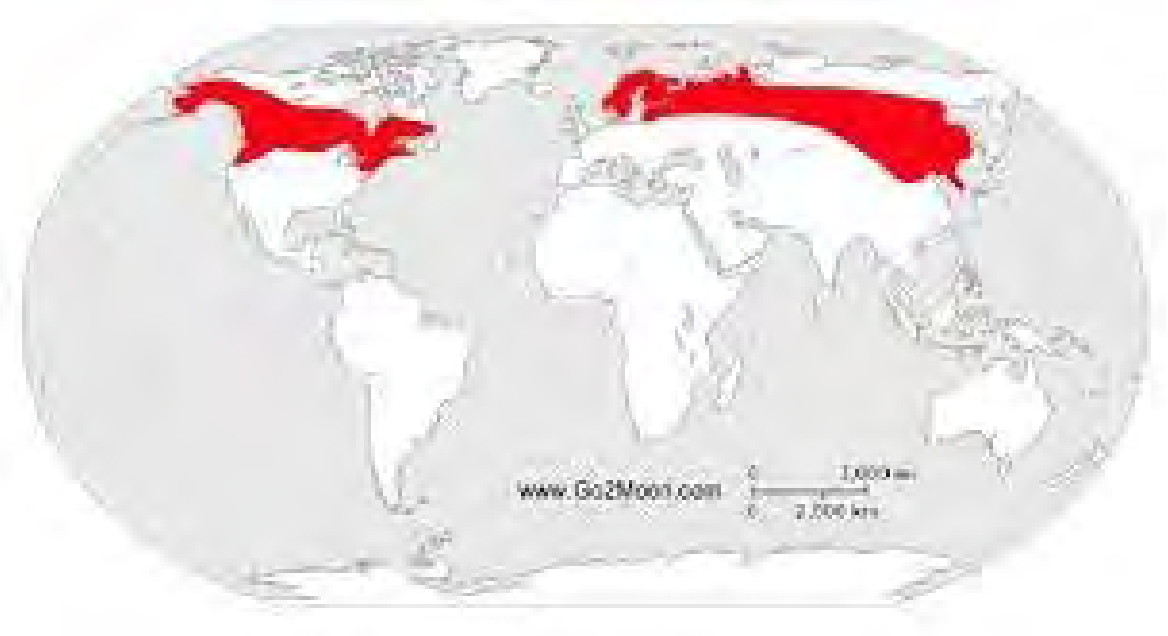
Boreal

Temperate

Tropical

Experts estimate that these forests cover approximately 1/3rd of Earth's surface.

Boreal Forest



The boreal forest corresponds with regions of **subarctic and cold continental climate**. Long, severe winters (up to six months with mean temperatures below freezing) and short summers (50 to 100 frost-free days) are characteristic, as is a wide range of temperatures between the lows of winter and highs of summer.

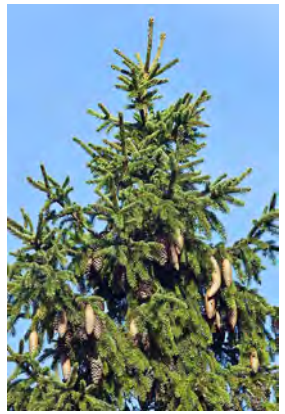
Boreal Forest

Needleleaf, coniferous (gymnosperm) trees, the dominant plants of the boreal biome. They are comprised of a few species in four main genera:

Spruce (*Picea*)

Fir (*Abies*)

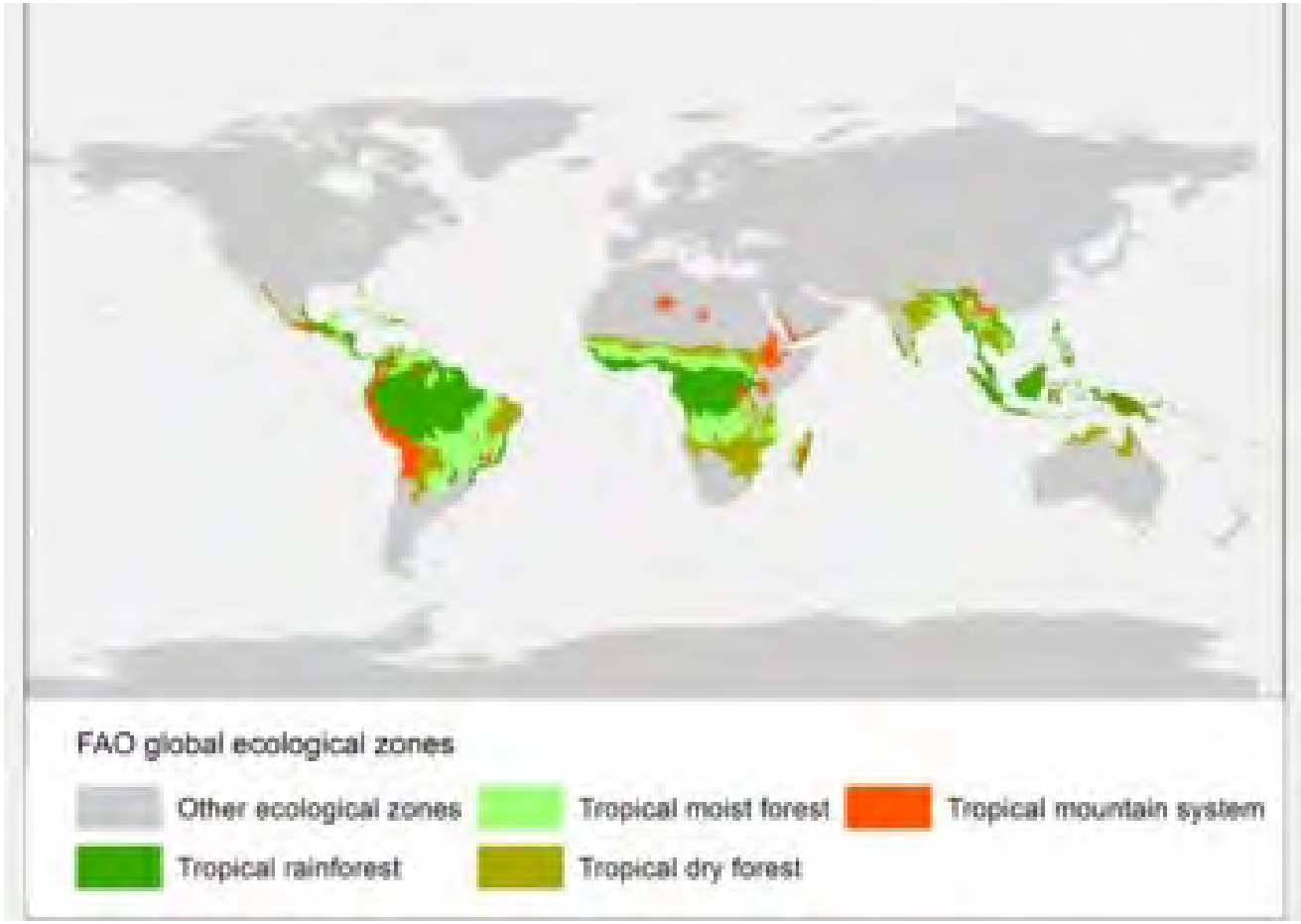
Pine (*Pinus*)



Larch or **tamarack** (***Larix, a deciduous member of the pine family***).

There are less than 20 tree species found in Canadian boreal forest!

Tropical Forests



Tropical Forests

The world's tropical rainforests are likely home to **40,000 to 53,000 tree species** (Proceedings of the National Academy of Sciences (PNAS) Jun 1, 2015).

Incidentally, the most common tree species in Amazonia is the **mountain cabbage (aka heart-of-palm) palm species** (*Euterpe spp.).*

Kapok tree (*Ceiba pentandra*) in Madre de Dios, Peru
Photo credit: Mohsin Kazmi

Rubber tree (*Hevea brasiliensis*)
Photo credit: Mason Phillips

Coconut (*Cocos nucifera*)

Ipê (*Tabebuia spp*)
Photo credit: Forestal Santa Bárbara

Temperate Forests

Temperate forests are found in eastern **North America, northeastern Asia, central and western Europe, southwestern South America, southern Australia, and New Zealand**. In North America, the Eastern **Deciduous Forest** stretches from Florida to Quebec and Nova Scotia along the east coast and as far west as Texas and Minnesota.

1. High levels of precipitation
2. High humidity,
3. Variety of **deciduous** trees.

Deciduous trees are trees that lose their leaves in winter. Decreasing temperatures and shortened daylight hours in fall mean decreased photosynthesis for plants.

Virginia’s Forests

- Virginia has ~15.7 million acres of forestland. In 1940, Virginia's forest land base was only 14.3 million acres.

- 62% of Virginia is forested. In 1940, only 58% of Virginia was forested.

- Urbanization and development is the single biggest factor in loss of forestland acreage. Since 2001, ~500,000 acres of forested land has been lost to land use changes; 64% of this acreage were cleared for urban development; 30% to agricultural uses; and the balance to other land uses.

Partially offsetting this loss were reversions & afforestation efforts that returned ~350,000 non-forest acres to the forest land base.

Hardwood v. Softwood

Definition of Hardwood:

It is the wood from a woody **angiosperm** (flowering tree) as distinguished from that of **gymnosperm** (aka conifers). Examples of hardwood trees include **alder, beech, hickory, maple, oak, and walnut**. Most hardwoods have a higher density than most softwoods.

Definition of Softwood:

It is the wood that comes from **gymnosperm** trees (i.e. have needles and produce cones). Examples of softwood trees are **cedar, fir, juniper, pine, spruce, and yew**. Most softwoods have a lower density than most hardwoods.

- Hardwood forests make up 79% of all Virginia timberland; softwood forests make up 21%.

- In 1940, Virginia forestland was 57% in hardwood and 43% in softwood.

- In 1940 Virginia had 8.1 million acres in hardwood types; currently, Virginia has 12.5 million acres of hardwood.

- In 1940, Virginia had 6.2 million acres in softwood types; currently, Virginia has 3.2 million acres in softwood

	1940	2020
Hardwood	57% (8.1×10^6)	79% (12.5×10^6)
Softwood	43% (6.2×10^6)	21% (3.2×10^6)
Total	(14.3×10^6)	(15.7×10^6)

Forest Growth in Virginia:

•Net annual growth of hardwood timber volume is ~2.8% per year and annual removals average about 2.2% of total volume. VA's total hardwood volume has increased by 94% since 1940.

•Net annual growth of softwood timber volume is 5.4 % per year and annual removals average about 4.7% of total volume. VA's total softwood volume has increased by 20% since 1940.

•Virginia's forests are growing more timber than is being harvested. This is true in both hardwood and softwood forest types. The growth/removals ratio is 1.26 for hardwood and 1.16 for softwood in the 8th Survey of Virginia's forests (2008).

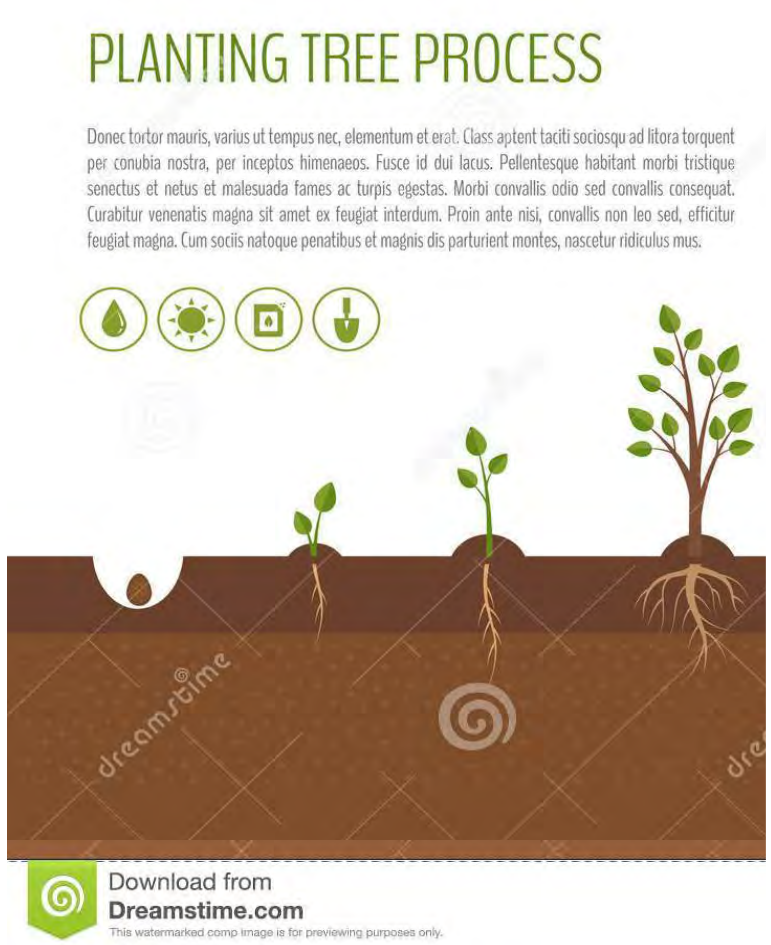
•Planted stands now make up about 15% of Virginia's timberland and 59% of all softwood acreage.

How Do Trees Grow?

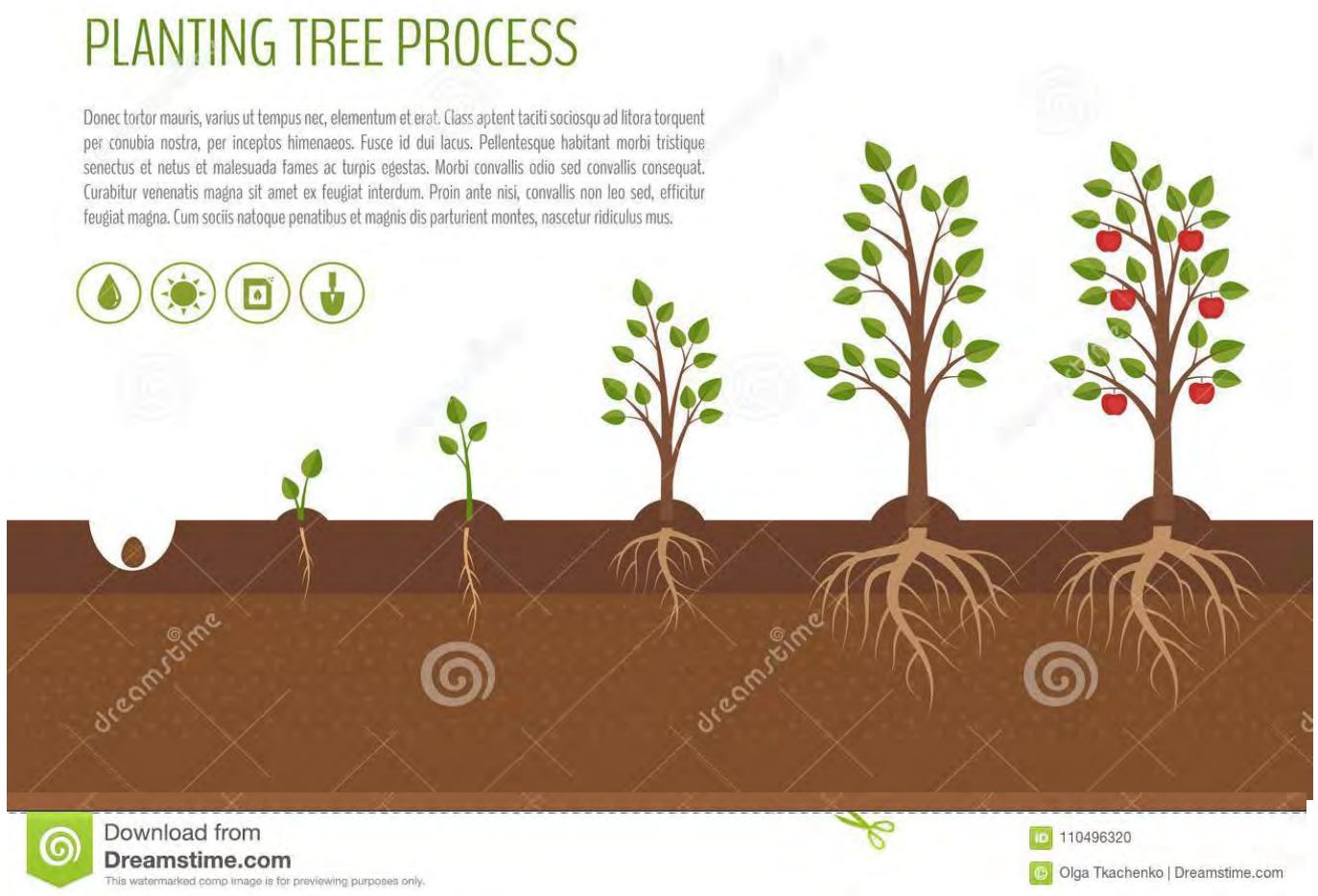
Whether planted or wild distributed, all trees start from seed.

PLANTING TREE PROCESS

Donec tortor mauris, varius ut tempus nec, elementum et erat. Class aptent taciti sociosqu ad litora torquent per conubia nostra, per inceptos himenaeos. Fusce id dui lacus. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Morbi convallis odio sed convallis consequat. Curabitur venenatis magna sit amet ex feugiat interdum. Proin ante nisi, convallis non leo sed, efficitur feugiat magna. Cum sociis natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus.



Sapling root-shoot ratio is 1:1



Sapling root-shoot ratio is 1:1
Mature root-shoot ratio is 1:5 to 1:6

Role of Leaves

Photosynthesis

the process by which green plants and some other organisms use sunlight to synthesize foods from carbon dioxide and water. Photosynthesis in plants generally involves the green pigment chlorophyll and generates oxygen as a byproduct.

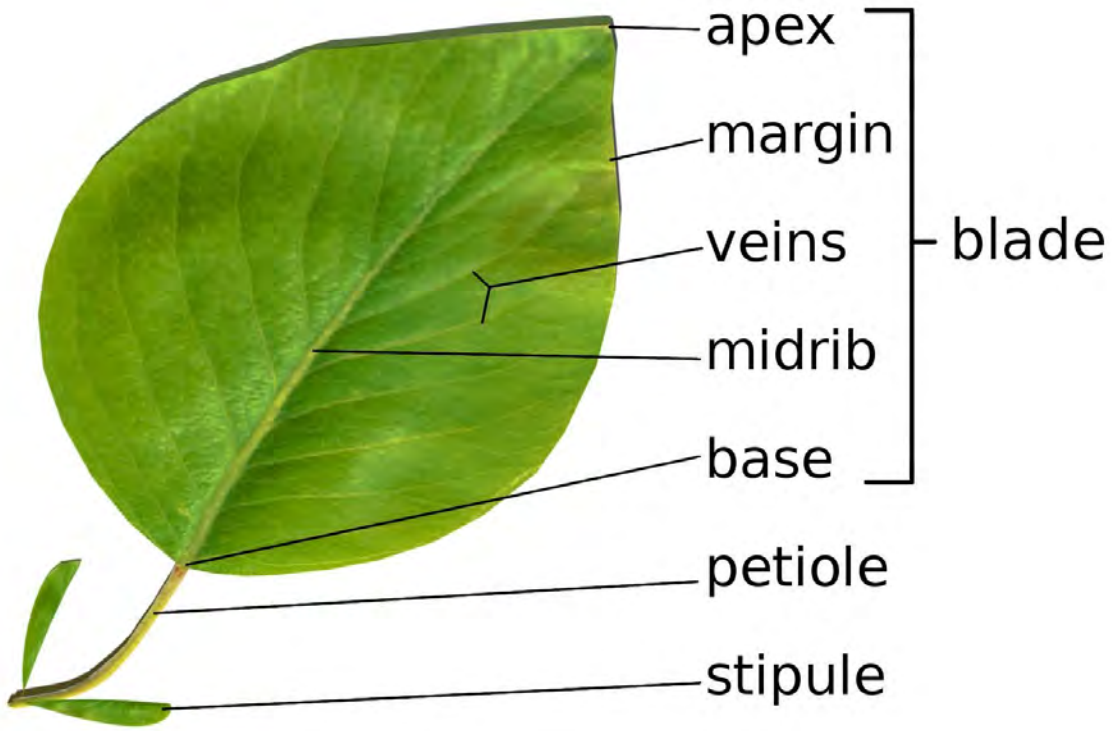
Manufacturing of sugars

Gaseous Transport

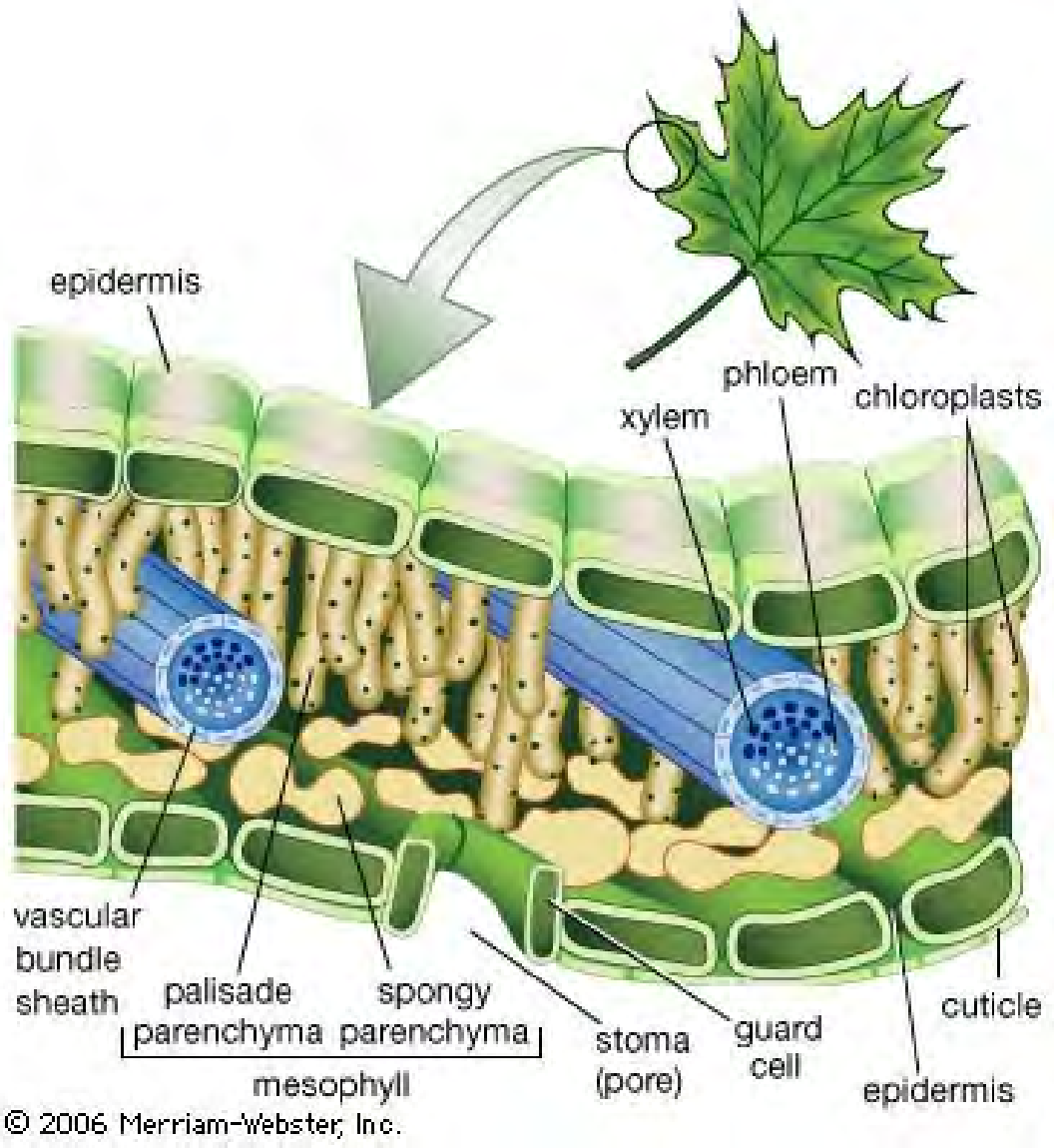
Uptake of CO_2 from atmosphere, removes toxic gases from soil.

Active in transport of sugars to roots (why?)

Roots donot have ability to produce sugar, i.e. they do not have capability of PS.



[Plant Leaves and Leaf (Anatomythoughtco.com)]

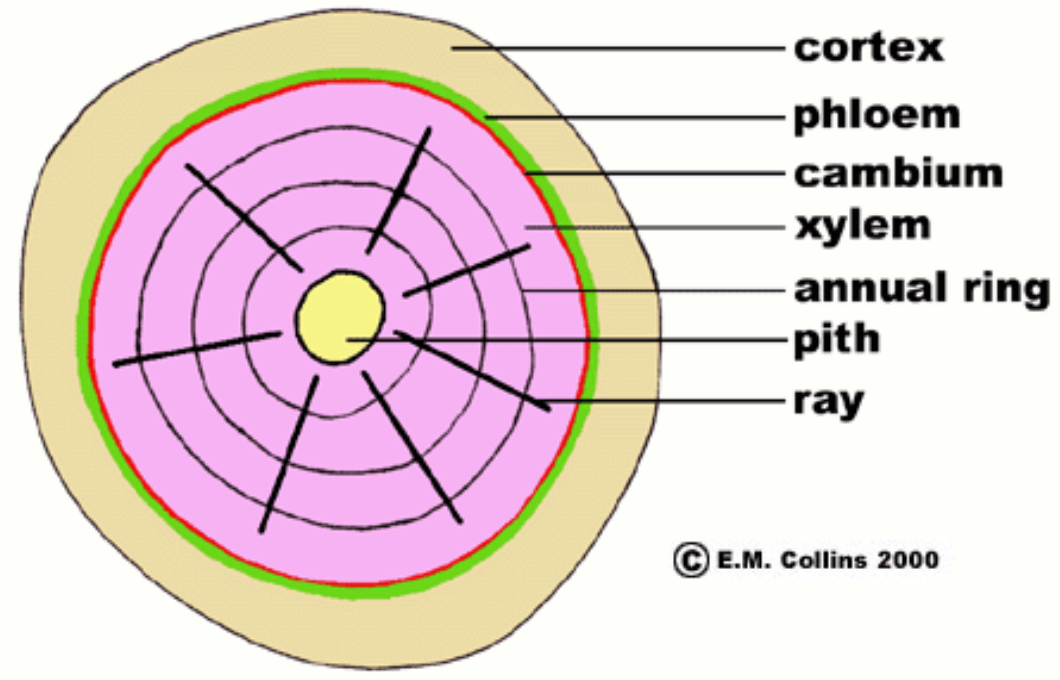


Stoma takes up CO_2 (and expels O_2),
Chloroplast fix CO_2,
Xylem transports water and nutrients to leaf,
Phloem transports sugars to roots.

Role of Woody Structure

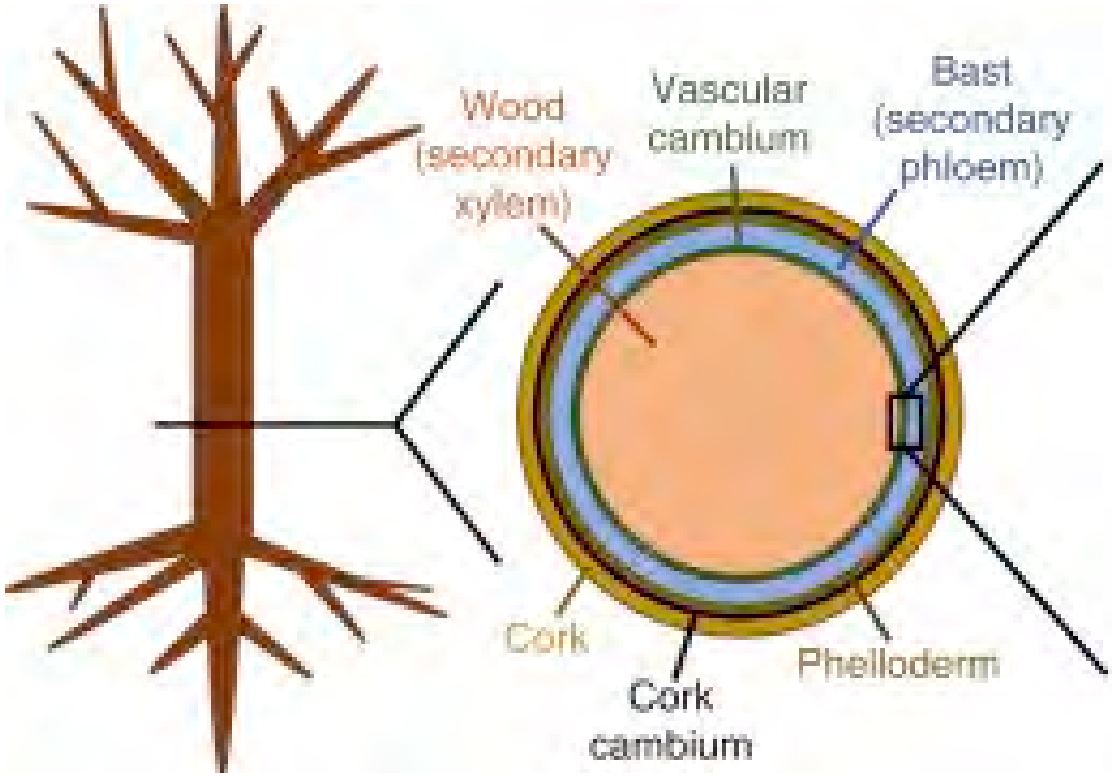
(twigs, branches, stem, roots)

Support structure,
Xylem and phloem for transport,
Cambium for growth,
Ray for gaseous exchange.

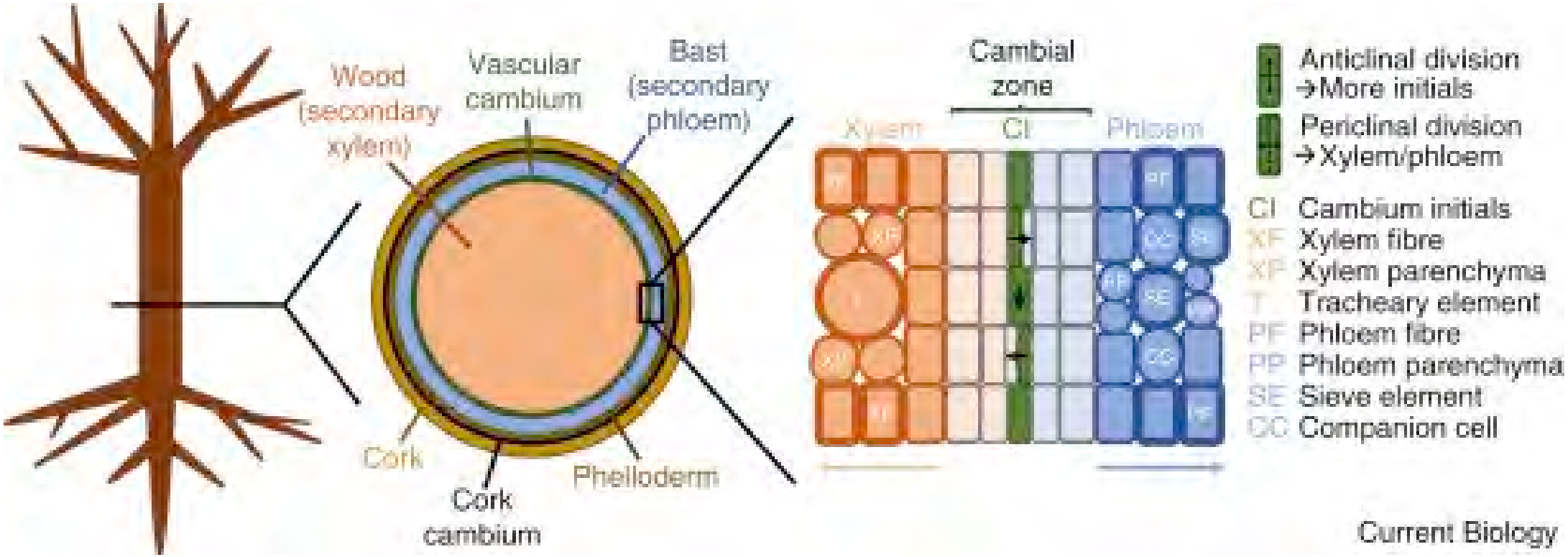


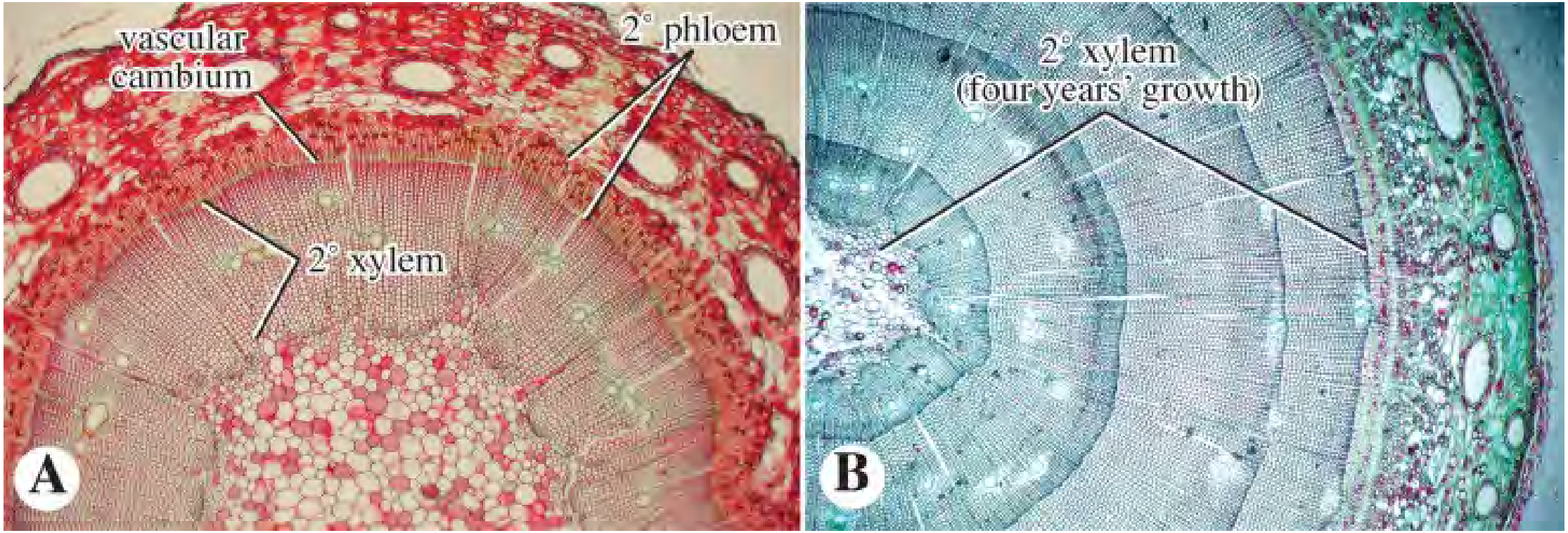
Cambial Growth

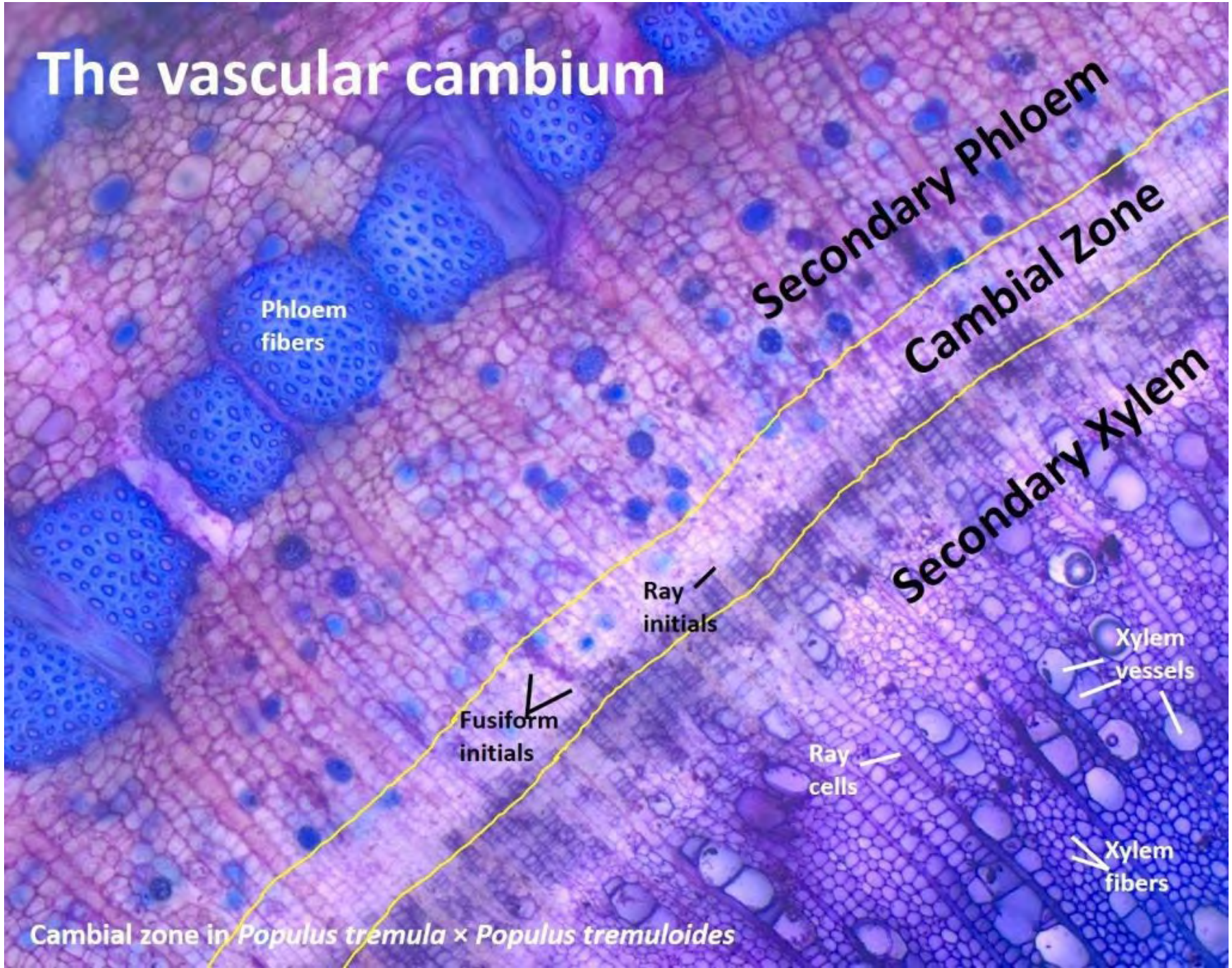
Two types: 1) vascular cambium and 2) cork cambium.

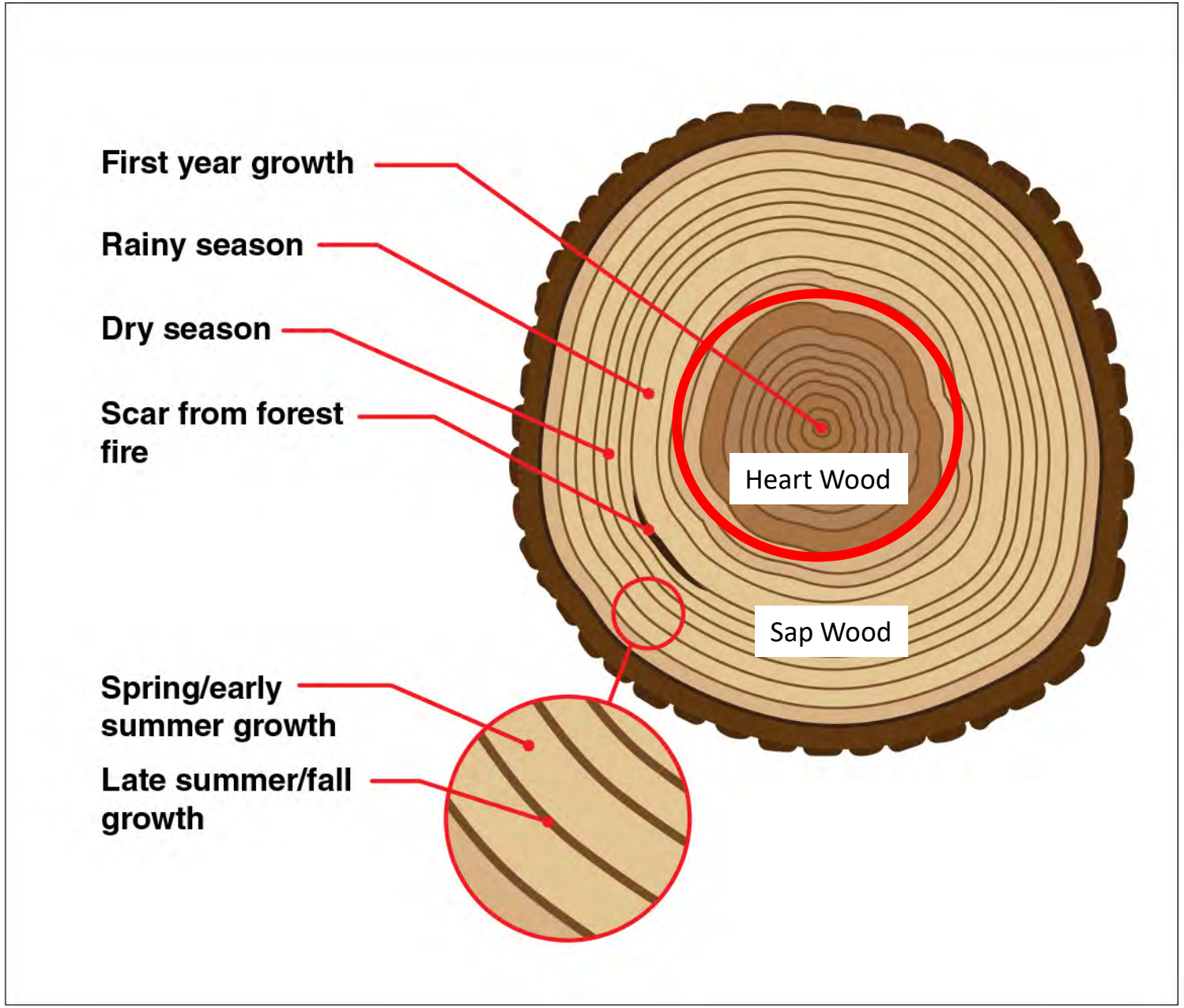


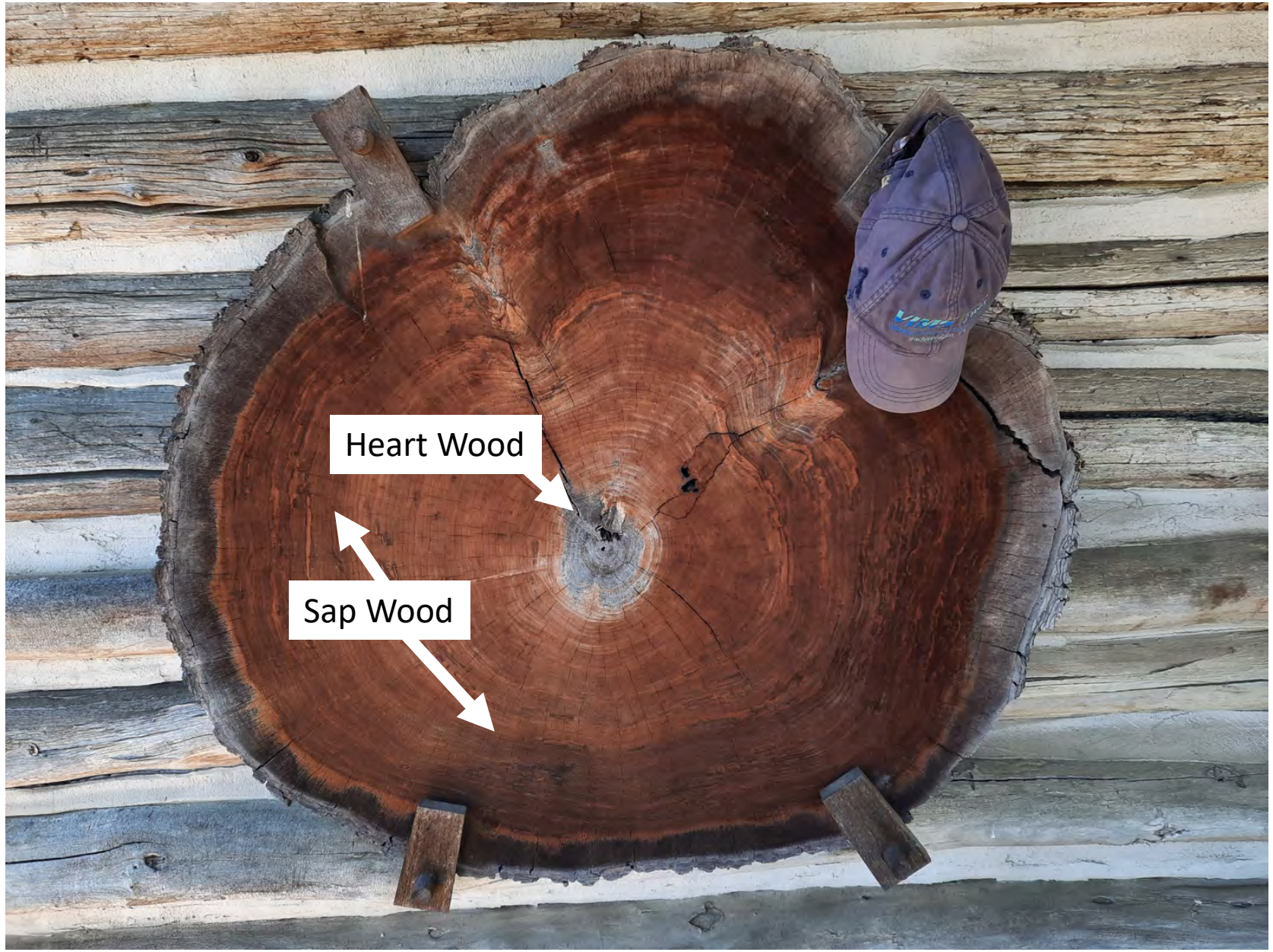
Cambial Growth



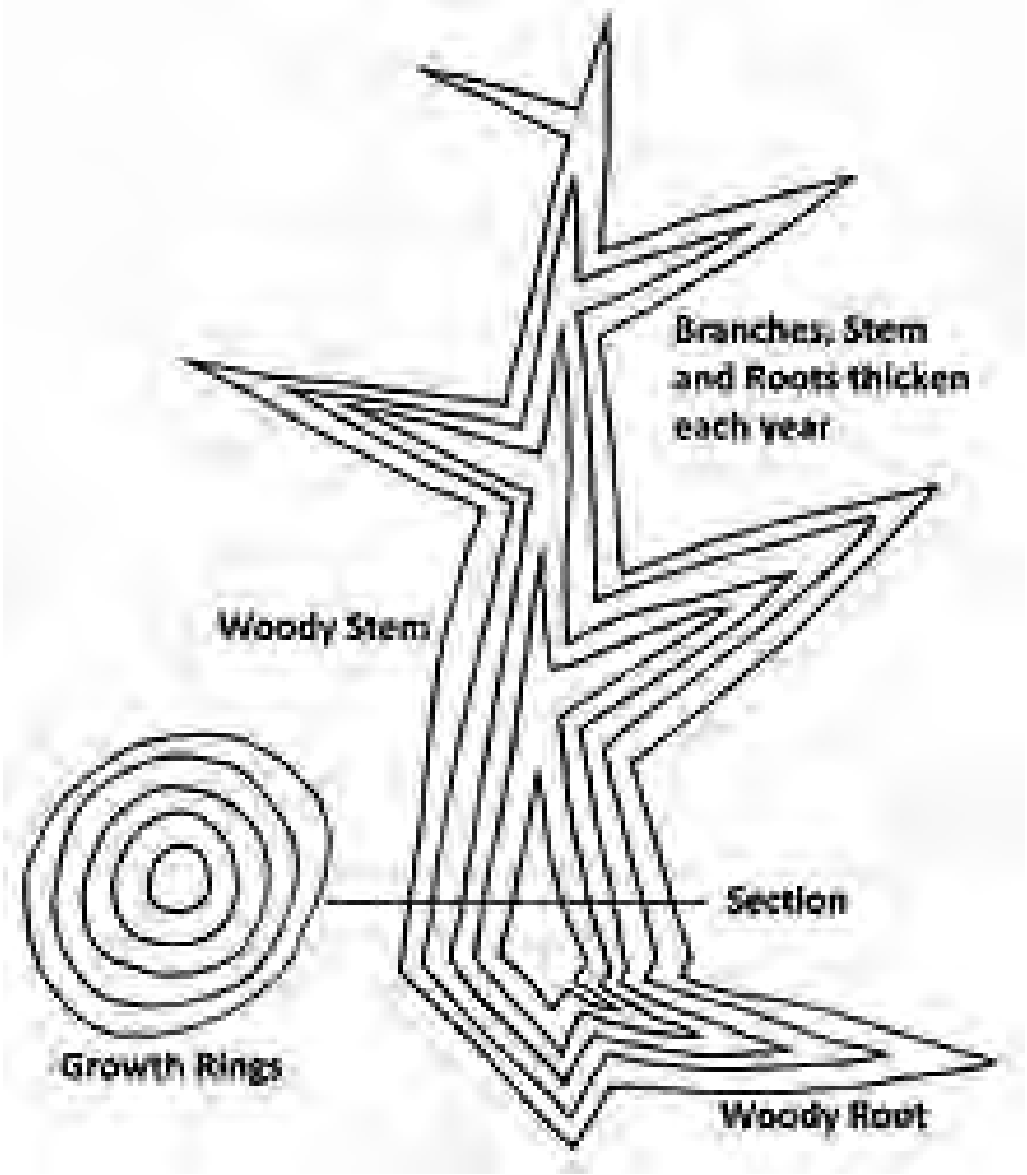

vascular cambium
2° phloem
2° xylem
A
2° xylem (four years' growth)
B

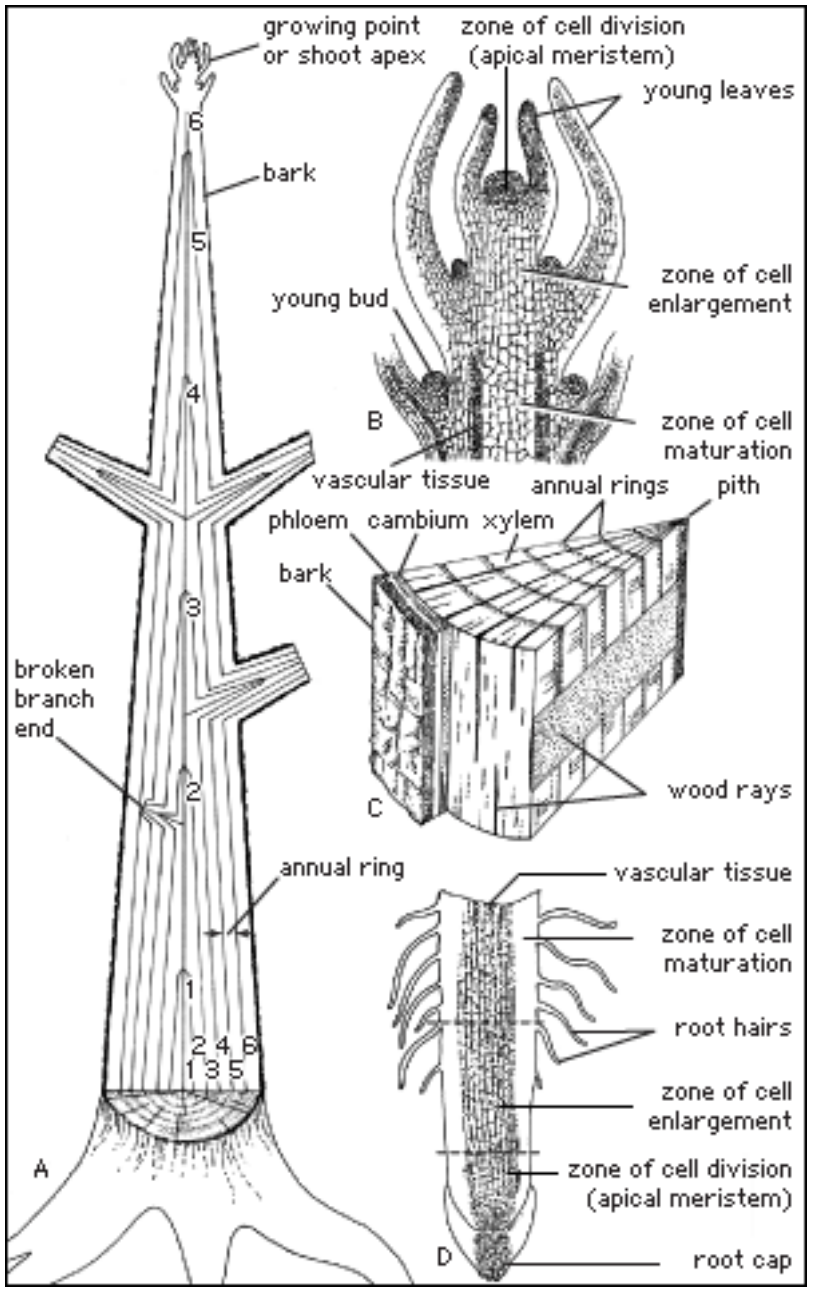

The vascular cambium
Secondary Phloem
Cambial Zone
Secondary Xylem
Phloem fibers
Ray initials
Fusiform initials
Xylem vessels
Ray cells
Xylem fibers
Cambial zone in *Populus tremula* × *Populus tremuloides*


First year growth
Rainy season
Dry season
Scar from forest fire
Heart Wood
Sap Wood
Spring/early summer growth
Late summer/fall growth


Heart Wood
Sap Wood

A tree has both Lateral, Root, and Apical growth!





Question: I drove a nail into a five year old tree at a height of five feet.

How high will it be in five years?

It will still be at FIVE FEET! WHY???

Lateral growth!

Aging a Tree

1. Counting limbs: very difficult.

2. You can estimate the age of a tree by using the formula: GF x D where GF is the growth factor and D is diameter of tree in inches at 54in (chest height) . For Shumard or pin oak, the growth factor is three; red oak, four; white oak, five; and shingle oak, six. If you have a different variety of oak or were unable to identify the oak, obtain a rough age estimate by using four.

GF for some other species:
- Red Maple Species - 4.5 **Growth Factor** X diameter.
- Silver Maple Species - 3.0 **Growth Factor** X diameter.
- Sugar Maple Species - 5.0 **Growth Factor** X diameter.
- River Birch Species - 3.5 **Growth Factor** X diameter.
- White Birch Species - 5.0 **Growth Factor** X diameter.

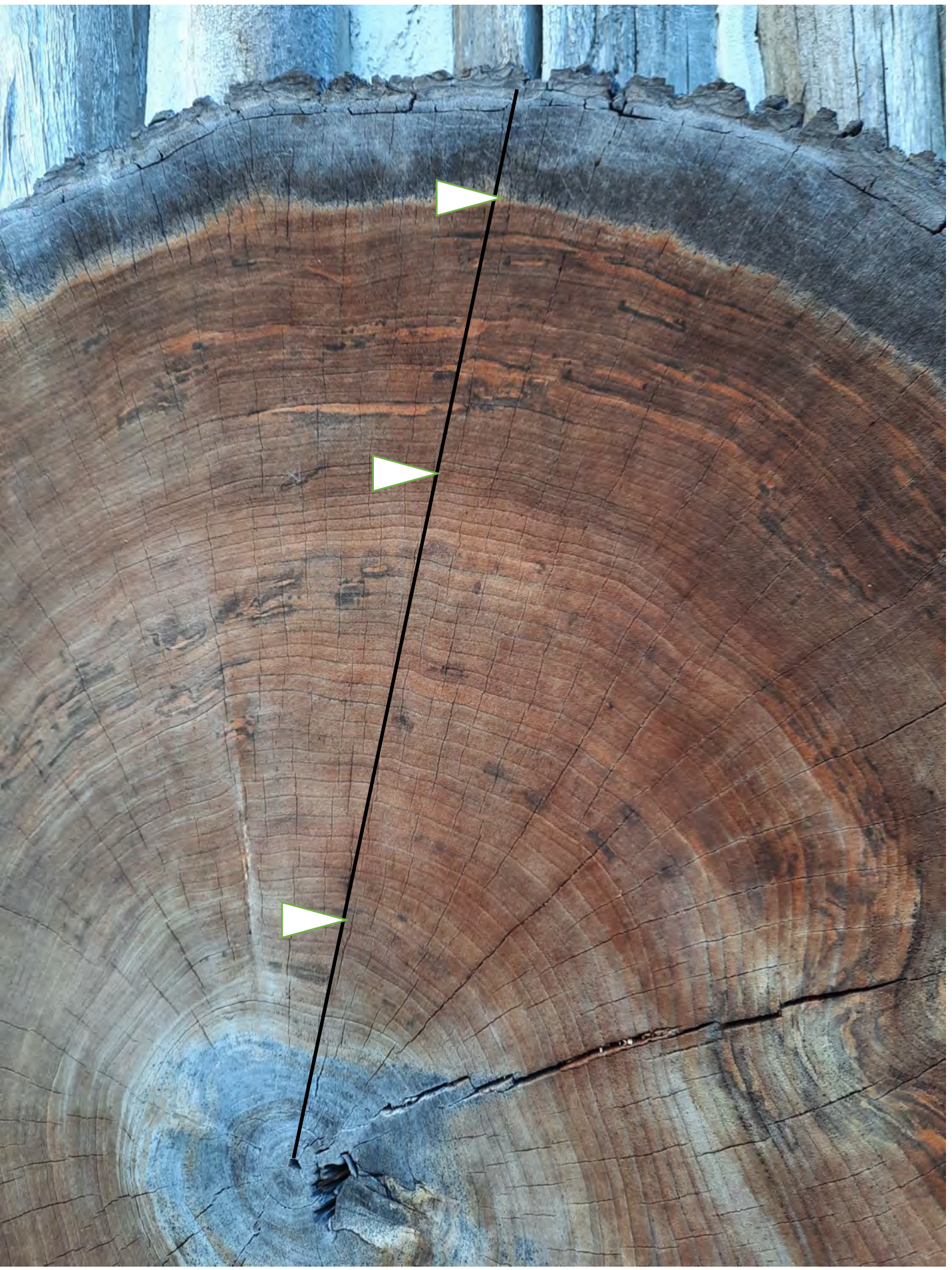
For example, a red maple with a 10 inch diameter would have an estimated age of 4.5 x 10 = 45YO

3. Counting annual rings.

Loblolly Pine GF = 2.0

Diameter = 36in

2.0 X 36 = 72YO



~17 YO

+28
+17

~45 YO

+20

+45

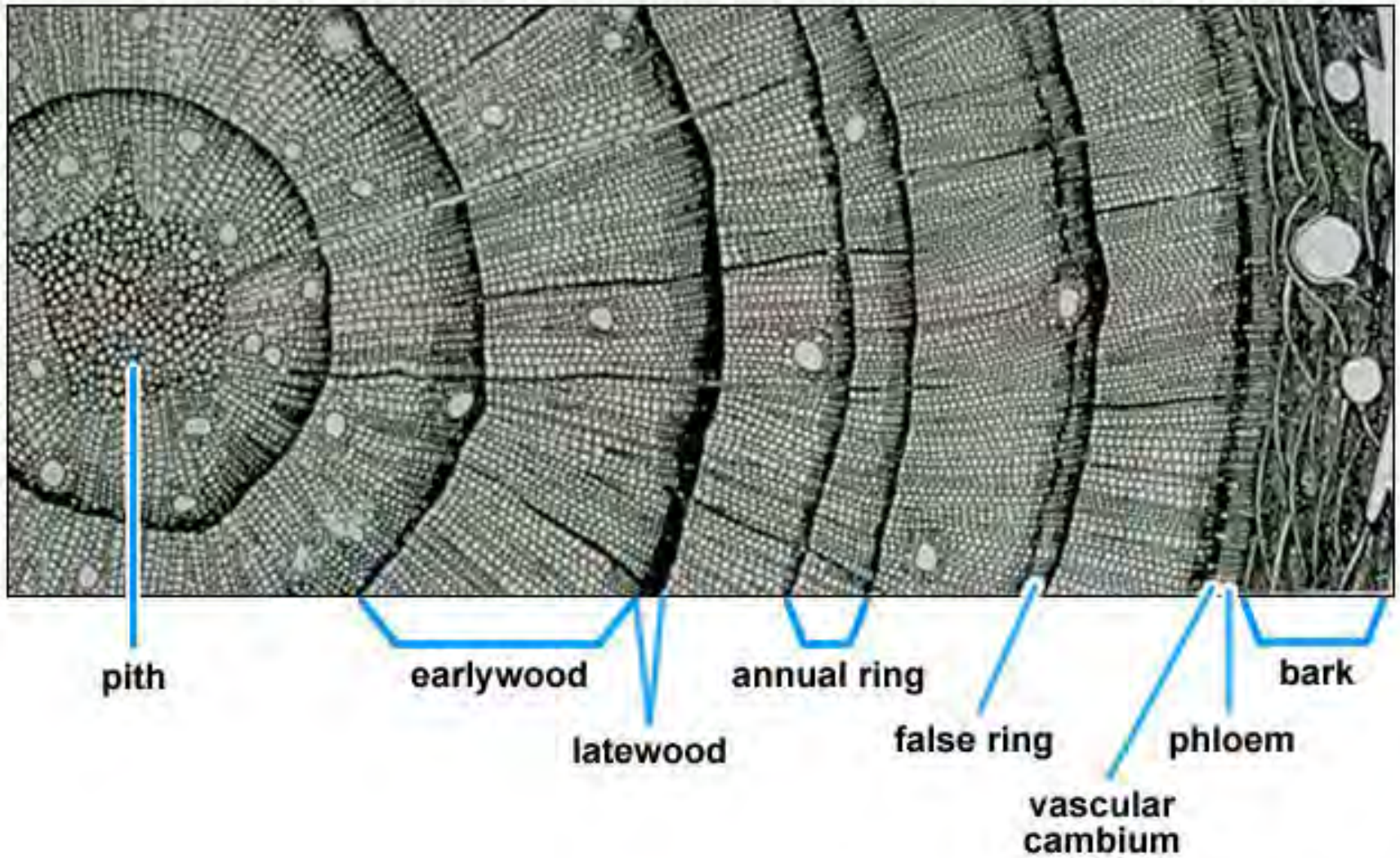
65 YO

~+10
+65

~70 YO


We estimated this “cookie” to be 72 YO using GF and 70 counting rings!

Cross Section of a CONIFER



NOAA Paleoclimatology Program

What is maximum life span of North American trees?

Depends on:

1. Climate;
2. Available nutrients;
3. Disturbance;
4. Species

Common Name	Scientific Name	Average Lifespan	Maximum Lifespan
Ash, Green	*Fraxinus pennsylvanicum*	120	175
Beech, American	*Fagus grandifolia*	300	400
Cedar, Eastern red	*Juniperus virginiana*	150	300
Cherry, Black	*Prunus serotina*	100	250
Cypress, Bald	*Taxodium distichum*	600	1800
Dogwood, Flowering	*Cornus florida*	125	?
Hickory, Mockernut	*Carya tomentosa*	200	300
Sweetgum	*Liquidambar styraciflua*	200	300
Magnolia, Southern	*Magnolia grandiflora*	80	120
Maple, Red	*Acer rubrum*	130	300
Maple, Silver	*Acer saccarinum*	100	125

See also Appendix 1.

: Loehle, C. (1988). "Tree life history strategies: the role of defenses." Canadian Journal of Forest Research 18(2): 209-222.

What does a tree need to survive and grow?

Sunlight

Water

CO_2

Nutrients

Macronutrients: C HOPKNS CaFe, Mg

TABLE 1: Form, source, mode of uptake and major functions of the 16 plant essential nutrients.

Nutrient family	Nutrient	Percentage of plant	Form taken up by plants (ion)	Mode of uptake	Major functions in plants
Primary	Carbon	45	Carbon dioxide (CO_2), bicarbonate (HCO_3^-)	Open somates	Plant structures
	Oxygen	45	Water (H_2O)	Mass flow	Respiration, energy production, plant structures
	Hydrogen	6.0	Water (H_2O)	Mass flow	pH regulation, water retention, synthesis of carbohydrates
	Nitrogen	1.75	Nitrate (NO_3^-), ammonium (NH_4^+)	Mass flow	Protein/amino acids, chlorophyll, cell formation
	Phosphorus	0.25	Dihydrogen phosphate ($H_2PO_4^-$, HPO_4^{2-}), phosphate (PO_4^{3-})	Root interception	Cell formation, protein syntheses, fat and carbohydrate metabolism
	Potassium	1.5	Potassium ion (K+)	Mass flow	Water regulation, enzyme activity
Secondary	Calcium	0.50	Calcium ion (Ca^{2+})	Mass flow	Root permeability, enzyme acitivity
	Magnesium	0.20	Magnesium ion (Mg^{2+})	Mass flow	Chlorophyll, fat formation and metabolism
	Sulfur	0.03	Sulfate (SO_4^{2-})	Mass flow	Protein, amino acid, vitamin and oil formation
Micro	Chlorine	0.01	Chloride (Cl^-)	Root interception	Chlorophyll formation, enzyme activity, cellular development
	Iron	0.01	Iron ion (Fe^{2+}, Fe^{3+})	Root interception	Enzyme development and activity
	Zinc	0.002	Zinc ion (Zn^{2+})	Root interception	Enzyme activity
	Manganese	0.005	Manganese ion (Mn^{2+})	Root interception	Enzyme activity and pigmentation
	Boron	0.0001	Boric acid (H_3BO_3), borate (BO_3^{3-}), tetraborate (B_4O_7)	Root interception	Enzyme activity
	Copper	0.0001	Copper ion (Cu^{2+})	Mass flow	Enzyme activity
	Molybdenum	0.00001	Molybdenum ions ($HMoO^{4-}$, MoO_4^{2-})	Mass flow	Enzyme activity and nitrogen fixation in legumes

Macronutrients: C HOPKNS CaFe, Mg

What kills a tree?

Disease

Fire and lightning

Storms (blowdowns)

Timbering

Diseases of Virginia Trees

Beech Bark Disease

- Wooly, white tufts appear on the tree
- Yellow or white eggs appear on the crooks of the trees
- Red clusters appear on the bark once the fungus has taken over

Beech Bark Disease afflicts beech trees more than any other disease on the east coast of the United States and throughout Europe. It occurs when the beech scale insect attacks the bark. It chews on the outer bark, making a wound. In that wound, two different forms of fungi can move in and invade the rest of the tree.

Oak Wilt

- Leaves discolor and eventually wilt
- Leaf margin browning
- Sap may be discolored

Oak Wilt hits oak trees, but it hits other types of trees as well. This is a fungal disease that impacts the leafy parts of the tree. Insects transmit the fungus from tree to tree, hitting even healthy trees. While all areas are struck, urban areas seem to have even more trouble with Oak Wilt than other parts of Virginia.

Thousand Cankers

- Black cankers appear on the knots of the wood
- Tree starts to die quickly
- Visible tunnels in the dark of the wood

Up until about 2010, the disease never even crossed onto the east coast, but now it has taken off after an outbreak in Knoxville. It attacks mostly black walnut trees, and can hit all walnut trees, but has been showing signs that it can extend to other trees as well.

Sudden Oak Death (caused by **Phytophthora ramorum,** a water mold pathogen)

•Dying leaves that are clustered together
•Spotty leaves toward the tips and near the stem
•Some trunk cankers may form

Attacks more than just oak trees too, which makes it very scary. In fact, it has been known to attack over 100 species of trees, ferns, shrubs, vines, and other plants. What it attacks is different on each type of plan, sometimes it will go for the leaves, sometimes the trunk, and may even go after the roots.

Note that it is believed that Sudden Oak Death has been eliminated in Virginia.

Powdery Mildew Disease

•White or gray powdery talcum powder substance of leaves
•Fungus growing along the root system of the trees

If you have chokeberry, crabapple, linden, or catalpa trees in your yard, you need to be on the lookout for Powdery Mildew Disease. While this disease attacks those trees in particular, it can attack any weak trees. These are the trees that have other diseases, have wounds on the trunk (from pest infestations) or those who are nutrient deficient.

Powdery mildew is most commonly found in areas where there is full sunlight and the tree has the chance to dry out. That being said, the climate in Virginia isn't always the best for this disease.

Role of Fire

What does fire do to trees?

In general, trees are killed outright by crown fires and high intensity fires.

- Lower intensity fires may leave damaged strands or cause partial tree kill.
- Degree of crown scorch, foliage consumption, bud mortality, and stem damage to the bark and cambium layer (just under the bark) determine whether trees will survive.

What happens to trees after a fire?

- It may take several years for trees to die from fire-related injury.
- Trees that survive direct injuries from fire often have increased vulnerability to secondary factors including insects and drought stress.

Certain species are fire tolerant, i.e. fire cherry, slash pine, pond pine.

Role of Lightning

Lightning or electrical current passes from the trunk of the tree through the roots and dissipates in the ground.

Major root damage from electricity may cause the tree to decline and die without significant aboveground damage.

If the tree is in leaf, the leaves wilt and the tree will probably die within a few days.

As soon as lightning strikes the tree, water in its cells can start to boil causing steam to form.

The expanding steam can explode, cracking bark or even stripping it off the tree.

If the lightning strikes deep within the tree, the whole tree can blow up!

Storms

High winds and saturated soil conditions typical of summer **storms can** cause **tree** roots **to** fail and branches **to** weaken.

During winter, the weight of ice and snow accumulation **can** be equally damaging, resulting in failure of branches and entire **trees**.

Timbering

The Coastal Plain of Virginia has the most mechanized and highest production logging operations in the state.

(Barrett et al., 2012. Forest Harvesting in Virginia. Dept. Forest Resources and Environmental Conservation, VT, Blacksburg, Va.)

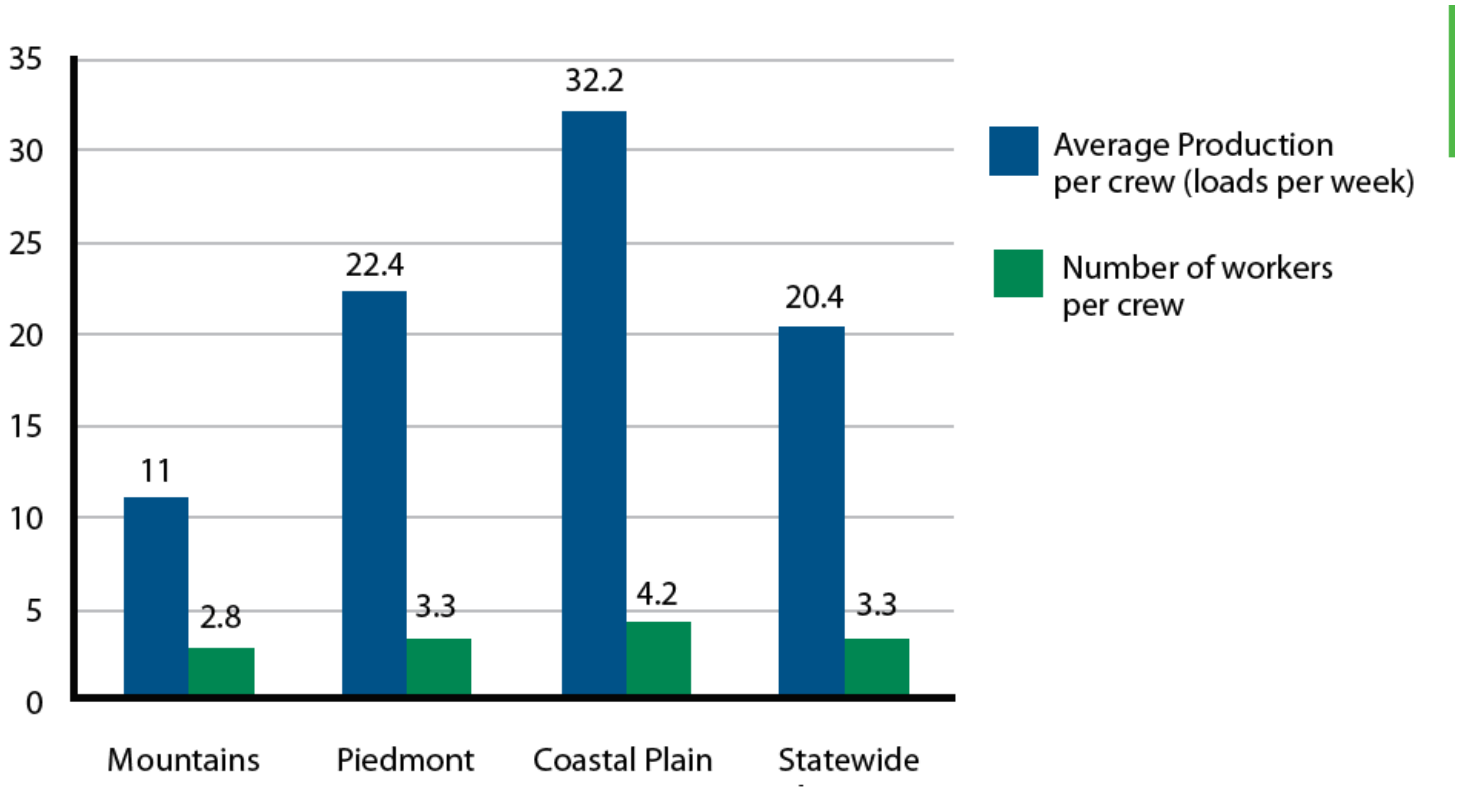


Fig. 12. Average logging business production in loads per crew, per week.

Nearly all of the virgin forest in Virginia have been harvested several times over the past centuries.

The only know remaining virgin forest is located in the George Washington and Jefferson National Forest (~250,000 acre) and a 40 acre tract on the Nottaway River.

Therefore, nearly all the forests that you see are secondary growth.

Impact of Logging

When cut, the trees roots often survive;

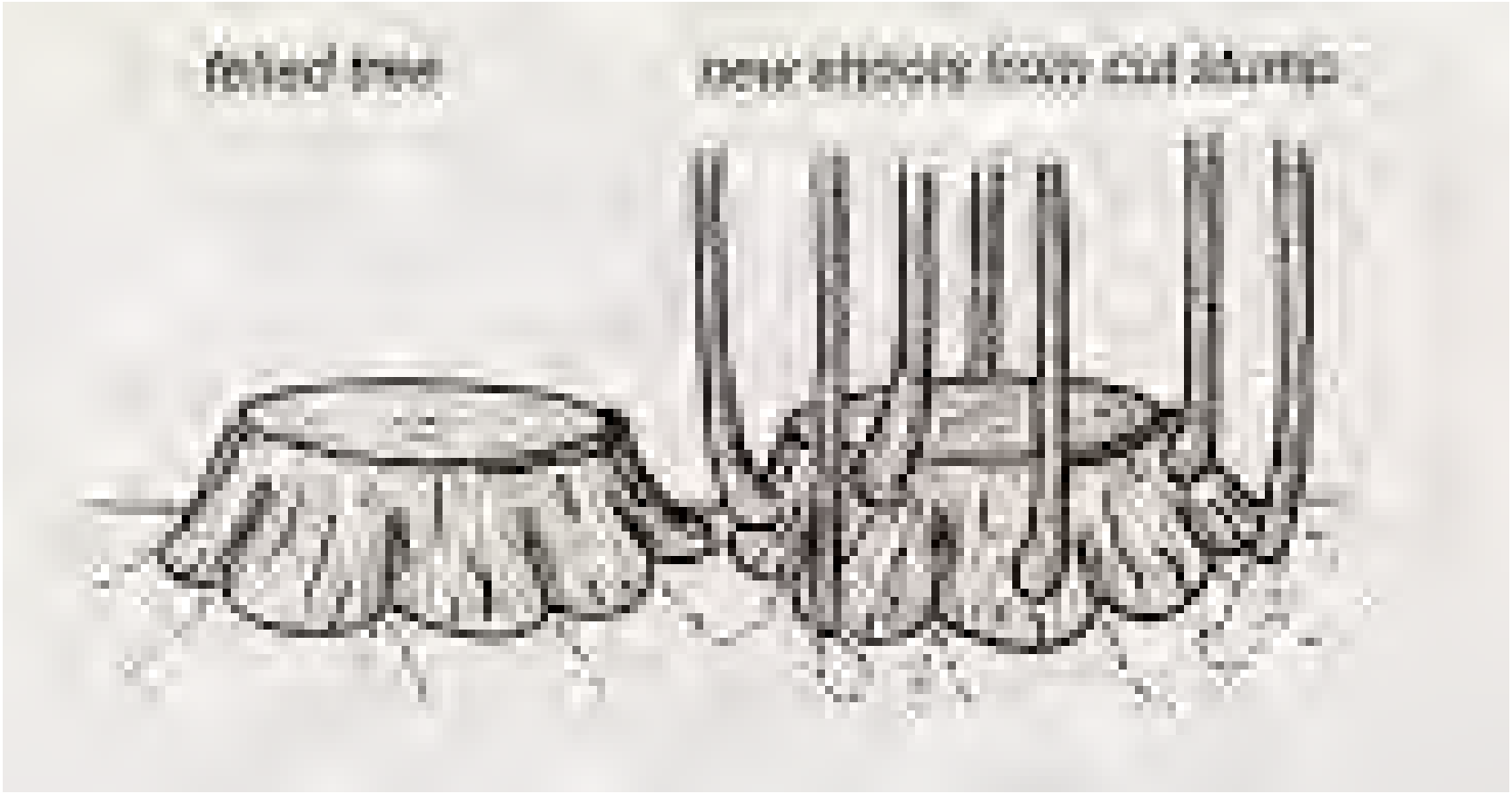
New “shoots” grow from the stump. These are called “Coppices”;

These are usually numerous and will compete with each other;

Dominant ones will survive and dominate secondary forest.

Removing the trees also produce an open canopy in which light can now penetrate.

Saplings that were in the understory are now “released” and grow to maturity.


felled tree
new shoots from cut stump

Conclusions:

1. Trees have both apical and lateral growth.

2. Many have long life expectancies.

3. There are several ways to determine a trees age (branches, growth factor, rings).

4. Most of our coastal plain forest have ben logged several times in the past.

OLD GROWTH FORESTS OF VIRGINIA

COUNTY	AREA NAME	BRIEF DESCRIPTION
Albemarle	Fernbrook Natural Area	63ac HF evolving to resemble pre-Colonial forest.
Arlington	Glencarlyn Park	Includes examples of 100YO mature native forests
King and Queen	Eagles Nest on the Dragon Run	39 acres of bald cypress wetlands and forest.
Lancaster	Hickory Hollow Natural Area Preserve	254 acres of mixed forest, ravines, and swamps.
Madison	Whiteoak Canyon - Shenandoah National Park	200,000 acres old growth.
Middlesex	Big Island on the Dragon Run	203 acres bald cypress wetlands and forest
Orange	James Madison Landmark Forest	200 acres HF
Richmond City	James River Park System	562 acres
Stafford	Crow's Nest Natural Area Preserve	2,200 acres mature HF (upland calcarious and TFS)
Westmoreland	Voorhees Nature Preserve	729ac mature HF


Caught this tree trying
to sneak out of the lake.


NOM NOM NOM

A 4852 year old Bristlecone Pine located in Inyo National Forest in Eastern California, USA.

Scientists recently found bald cypress trees along the Black River in North Carolina that are over 2,000 years old - including one that is at least 2,624 years old.

Analysis of these tree rings help us understand the role of a severe drought that started in 1587 and lasted two years, coinciding with the first attempts to settle in Roanoke in North Carolina - possibly shedding some light on why the settlers of Roanoke Colony disappeared sometime between 1587 and 1590!

https://www.sciencealert.com/a-2-624-year-old-tree-has-just-been-found-growing-in-a-swamp-in-america

A tree stump and
a human fingerprint.

We are nature.

| TheMindsJournal

If your problems are plenty and your rewards are few, remember the mighty oak was once a nut like you!

Appendix 1. Life expectancy of North American Trees.

Common Name	Scientific Name	Average Lifespan	Maximum Lifespan
Ash, Green	*Fraxinus pennsylvanicum*	120	175
Beech, American	*Fagus grandifolia*	300	400
Cedar, Eastern red	*Juniperus virginiana*	150	300
Cherry, Black	*Prunus serotina*	100	250
Cypress, Bald	*Taxodium distichum*	600	1800
Dogwood, Flowering	*Cornus florida*	125	?
Hickory, Mockernut	*Carya tomentosa*	200	300
Sweetgum	*Liquidambar styraciflua*	200	300
Magnolia, Southern	*Magnolia grandiflora*	80	120
Maple, Red	*Acer rubrum*	130	300
Maple, Silver	*Acer saccarinum*	100	125

Oak, Black	*Quercus velutina*	100	225
Oak, Blackjack	*Quercus marilandica*	100	?
Oak, Chestnut	*Quercus prinus*	300	400
Oak, Live	*Quercus virginiana*	200	300
Oak, Northern Red	*Quercus rubra*	200	400
Oak, Overcup	*Quercus lyrata*	300	400
Oak, Pin	*Quercus palustris*	100	150
Oak, Post	*Quercus stellata*	250	450
Oak, Scarlet	*Quercus coccinea*	80	180
Oak, Southern Red	*Quercus falcata*	200	275
Oak, Water	*Quercus nigra*	175	175
Oak, White	*Quercus alba*	300	600
Pecan	*Carya illinoensis*	300	?
Pine, Loblolly	*Pinus taeda*	100	300
Pine, Virginia	*Pinus virginiana*	100	200
Tupelo, Black	*Nyssa sylvatica*	250	600
Walnut, Black	*Juglans nigra*	150	250

: Loehle, C. (1988). "Tree life history strategies: the role of defenses." Canadian Journal of Forest Research 18(2): 209-222.

Appendix 2. Growth Factors for North American Trees

- Red Maple Species - 4.5 Growth Factor X diameter
- Silver Maple Species - 3.0 Growth Factor X diameter
- Sugar Maple Species - 5.0 Growth Factor X diameter
- River Birch Species - 3.5 Growth Factor X diameter
- White Birch Species - 5.0 Growth Factor X diameter
- Shagbark Hickory Species - 7.5 Growth Factor X diameter
- Green Ash Species - 4.0 Growth Factor X diameter
- Black Walnut Species - 4.5 Growth Factor X diameter
- Black Cherry Species - 5.0 Growth Factor X diameter
- Red Oak Species - 4.0 Growth Factor X diameter
- White Oak Species - 5.0 Growth Factor X diameter
- Pin Oak Species - 3.0 Growth Factor X diameter
- Basswood Species - 3.0 Growth Factor X diameter
- American Elm Species - 4.0 Growth Factor X diameter
- Ironwood Species - 7.0 Growth Factor X diameter
- Cottonwood Species - 2.0 Growth Factor X diameter
- Redbud Species - 7.0 Growth Factor
- Dogwood Species - 7.0 Growth Factor X diameter
- Aspen Species - 2.0 Growth Factor X diameter