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# Tree Anatomy: Periderm (Bark)

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Around tree roots, stems and branches is a complex set of tissues. These exterior layers are the environmental face of a tree open to all sorts of site vulgarities. This most exterior of tree tissue provides a measure of protection from a dry, oxidative, heat and cold extreme, sunlight drenched, injury ridden site. The exterior of a tree is both an ecological super highway and battle ground – comfort and terror. This exterior is unique in its attributes, development, and regeneration. Generically, these tree tissue layers surrounding a tree stem, branch and root is loosely called "bark."

Tissues of a tree, outside or more exterior to the xylem-containing core, are varied and complexly interwoven in a relatively small space. People tend to see and appreciate the volume and physical structure of tree wood and dismiss the remainder of stem, branch and root. In reality, tree life is focused within these more exterior thin tissue sets. Outside of the cambium are tissues which include transport cells, structural support cells, generation cells, and cells positioned to help, protect, and sustain other cells. All of this life is smeared over the circumference of a predominately dead physical structure.

## Outer Skin

Periderm (jargon and antiquated term = bark) is the most external of tree tissues providing protection, water conservation, insulation, and environmental sensing. Periderm is a protective tissue generated over and beyond live conducting and non-conducting cells of the food transport system (phloem). The dead cells and cell walls of the periderm can be filled with a variety of materials. With tree diameter growth (increase in circumference), multiple periderms may be generated and stacked beneath each other. Rhytidome is composed of dead layers of old periderms to the outside of current periderm, and can build up into thick layers.

Twigs are covered at first with a primary epidermis overlaying a primary cortex of simple cells. Once secondary growth (expansion in circumference or girth) begins, the epidermis growth may keep pace with expansion for a short time or for many growing seasons. Periderm is a secondary tissue of stems, roots and branches generated in a tree as the primary epidermis and primary cortex are crushed and pulled apart by secondary growth. Periderm is generated by a secondary meristem called phellogen.

## Embedded Parts

Periderm is generated by a phellogen which, like the vascular cambium, generates different tissues to either side (inside and outside). A secondary cortex under periderm (sometimes with a distinct color or with green chlorophyll present), is an area of interlaced cells (inactive phloem and phelloderm). These cells of the secondary cortex are derived from two different lateral meristems through formation and reformation of new phellogens. Cells of the secondary cortex closer to the vascular cambium can be photosynthetic. New periderms continue to form / reform inside as old periderm material sloughs off into the environment. Figure 1.

Conserved in the periderm over time are lenticels. Lenticels are loosely packed, less suberized cells in a localized area allowing for gas exchange across the periderm. In rough thick periderm, lenticels will be found in the bottom of periderm cracks and fissures. Lenticels allow for passive oxygen exchange with the atmosphere and carbon dioxide removal from tissues while minimizing water loss.

Cambial

At the beginning of tree life there are many living tissues derived from shoot and root tips, all called primary tissues. As tree parts begin to expand in circumference, initial primary tissues continue to grow at the tips but are ruptured, crushed, shed or grown-over as girth increases. Tissues generated to increase tree circumference are called secondary tissues. These secondary tissues include xylem, phloem, and periderm. Figure 2 shows a traditional cross-section of a mature tree stem.

Secondary tissues are derived from the cambium (i.e. vascular cambium), a mostly continuous zone of meristematic cells around the perimeter of stems, roots and branches. The cambium divides into xylem initials on one side (the inside) and phloem initials on the other side (the outside). Xylem and phloem are comprised of functional and nonfunctional living cells, dead cells, cell walls, and the spaces between. Farther to the outside / exterior, another meristematic zone may develop which generates a protective tissue called periderm.

Barking

Bark is a non-technical term for any tissue outside vascular cambium and surrounding a tree. This term is so general and non-precise that it should not be used in trees. In generic terms, bark includes: secondary phloem (both active and inactive) and associated tissues, secondary cortex, periderm and associated tissues, and dead tissues outside the periderm (including remains of primary epidermis and primary cortex). The term bark encompasses many living and dead tree tissues but defines none!

The traditional use of the word “bark” has a number of definitions which includes many tree tissues types. In its most inclusive and least descriptive form, bark can be any primary and secondary tree tissues existing outside the cambium. In this use, any tissue which can be peeled away leaving the wood cylinder behind is bark. In more precise use, the term bark has been used for all tissues outside phloem. Bark has also been a term used to describe just corky, dead tissues most exterior on stems, roots and branches. Bark is a nonscientific term used to describe many different tissue layers in a tree.

Layered

In some cases, bark has been divided into outer dead bark with no living tissue present, and inner bark with living tissue throughout. Because the secondary cortex has mutiple layers and cell types derived from both the vascular cambium and the phellogen, no clear visible dividing line exists between inner and outer bark. Figure 3

Another term used for dead outer layers of the bark is rhytidome. Rhytidome is all outer dead tissues beyond the current periderm (all old periderms and other enclosed / included tissues). Trees which generate and maintain a single initial periderm do not have a rhytidome.

In the past (and today with lay-people), many names and concepts have been used for periderm, secondary cortex, and phloem tissues with little recognition of tissue genesis and function. Because many different names have been used for the exterior portion of a mature tree, care is needed in defining tree tissues. Some terms are too broad, and many are imprecise and inaccurate.

Defining Better

Because bark is not an accurate and precise term, the term periderm should be used as the most exterior, circumferential area which still has living tree cells. All of a tree's visible periderm is a result of tree growth processes over time and environmental aging. Various tissue layer names have been used interchangeably and indiscriminately in many publications and conversations, like the level I term "bark." It is important to clearly define any use of the word "bark" to avoid misunderstandings. Professional tree health care providers should strive to always use level III (Figure 4) and IV (Figure 5) definitions for accuracy.

Peri...What?

The most exterior living tissue of a tree is usually associated with generation of a periderm. Periderm is a protective tissue produced over and beyond live cells of the food transport system. A periderm protects a tree from water loss, UV light impacts, heat loading, oxidation, and pest entry. Periderm contains many chemicals and crystals placed either as waste or for interference. Tannins, gums, resins, latex, and crystals (i.e. calcium oxalate or silicates) are all deposited by trees into periderm cells, cell walls, and intercellular spaces.

A periderm is usually generated in trees between active xylem / phloem tissues, and a stress-filled and damaging environment. Periderm is a combination of inactive, discarded, crushed, and new tissues concentrating protective functions into a thin, narrow space. Across its cross-section, periderm includes an inner layer containing a high concentration of living cells, and an outer layer of dead cells. These two layers, generated by a meristematic zone in the middle, comprise a periderm on a mature tree. Over time, multiple stacked periderms may be generated. The appearance of multiple periderms in cross-section do not represent annual increments.

Flow'em

Inside periderm is phloem. Periderm protects phloem tissues. Phloem in trees is generated by the vascular cambium. It is composed of various cells types including sieve transport elements, sieve transport helpers, phloem rays, phloem fibers, chemical containers, and latex producers. Not all trees have all these cell types. Phloem is responsible for food, nitrogen, and growth regulator transport vertically and horizontally within a tree. The active phloem involved with transport is very narrow and thin, usually less than 2 mm (~1/13 in) radial thickness, with a range of 0.3 - 14 mm thickness for active phloem across many temperate and tropical trees.

Tree phloem contains longitudinal transport cells called sieve elements. Sieve elements are stacked one upon another with openings in the top and bottom end walls. These sieve elements are managed in their transport function by surrounding live cells (companion or parenchyma cells). Phloem cells are generated by the cambium in an episodic process, layer after layer. Most layers are identical to those before and after. Sometimes there are changes in phloem tissue strength and color.

Go With The Flow

As phloem ages (i.e. new phloem is added behind) and becomes inactive, some cells are modified into thick walled, hard fibrous cells. The original phloem fibers (sclerenchyma), and these newly modified cells (sclereids or stone cells), within inactive phloem increments have been called bast (meaning binding). Bast fibers are and have been used for a variety of building and clothing fibers. Commercial fibers derived from various plant bast include flax, ramie, and hemp.

Inactive phloem sieve elements are blocked with callose. Neighboring parenchyma cells swell and crush sieve elements. Idioblasts (specialized inactive phloem cells) secrete materials such as resins, gums, mucilages, oils, and tannins. Cells also can develop sharp crystals which interfere with animal feeding. Lactifer cells generate latex which also interferes with animal caused injuries. All of this concentrated chemical production, secretion, and deposition tends to slow and halt pest advances. Inactive phloem cells also can have chloroplasts and store starch. Because periderms may eventually cover, enclose and incorporate inactive phloem tissues, periderms have a great diversity of appearances and other attributes.

Outer / Inner

Outer phloem can be contrasted with inner phloem. Inner phloem is a very thin layer containing active transport cells and associated cells immediately surrounding these vascular cells. Outer phloem contains inactive or nonconducting phloem cells, phloem ray cells, and phloem structural cells. The outer phloem cell types are greatly intermixed and intergraded, depending upon species. The structural components of these outer phloem cells can change with age. Outer phloem is derived from the vascular cambium and is difficult to delineate from the phelloderm cells derived from the most interior phellogen.

Surface Replacement

In new tree tissues, the outside is covered with an epidermis cell layer overlaying a primary cortex of simple cells. Once secondary growth (expansion in circumference or girth) begins, the epidermis may keep pace with tree growth. Figure 6. For example, species in the genera *Acacia, Eucalyptus*, and *Ilex* continue to divide and expand epidermal tissues for years. In most tree species, periderm is generated beneath, and eventually replaces, epidermis and primary cortex of young tree shoot and root tips. Figure 7 shows the expansion of a stem, root or branch with an already established periderm beneath the epidermis and primary cortex.

Secondary!

Periderm is a secondary tissue of stems and branches generated in a tree as the primary epidermis and cortex are pulled apart by secondary growth. Periderms are established below splits or breaks in the epidermis, or are formed below the epidermis all the way around a stem or branch. Periderm is made of specialized corky and/or flattened tissues. Perennial *Angiosperm* and *Gymnosperm* tree-forms generate the most visible, thick, and protective periderms. As mentioned, periderm is usually located exterior to stem, root and branch phloem. It can also be generated along the interior of shallow wounds occurring outside of the xylem core.

A Good Phellow

Periderm is composed of three tissue sets. The first is a meristematic zone called the cork cambium or phellogen (meaning cork producer). The phellogen generates a second tissue set called phelloderm (meaning cork skin) to the inside. Phelloderm cells can be produced in thin-walled or thick-walled varieties, which change periderm strength and associated periderm flaking, shedding or slipping patterns. Phelloderm may or may not be noticeable or present in some trees.

The phellogen also generates a third tissue set called phellem (meaning cork) to the outside. Mature phellem (cork cells) is composed of dead, tightly packed cells with walls impregnated with waxes and suberin, and with hollow cell centers which give some cork a low density. Tannins and resins of various types may fill cells providing a variety of colors and densities. Phellem is usually generated in much greater amounts than phelloderm. Figure 8.

Compound Origins

Periderms are classified into three forms. The first form is scale or arc periderms which are generated in localized small surface areas cutting off multiple overlapping volumes of tissues. For example, this form of periderm is found in species within the genera *Pinus, Pyrus, Quercus*, and *Tilia*. The second form of periderm is a ring periderm which are generated concentrically around an entire stem, root or branch as found in species of genera *Cryptomeria, Thuja,* and *Juniperus*. The third form of periderm is an intermediate form where very large scales and plates are generated (i.e. *Platanus*).
Figure 9.

Remember, the outward appearance of a tree is a product of two (lateral) meristems — the vascular cambium and cork cambium (phellogen). As new phellogens are formed inside inactive phloem tissues, phloem components are sealed off and incorporated into periderm tissues. The amount and type of tissues generated by phellogen give trees their distinctive base periderm color, form, and general appearance, as modified by the environment. In addition, various combinations of cell types incorporated within periderm, and various materials placed in and around these cells, add tremendous diversity to a tree's external appearance.

P...Gen

Phellogen (note the "-gen" suffix for tissue generation) has been called the bark cambium or cork cambium. The phellogen, and one to two cells beyond, which will form phellem, are the most exterior living cells in the tree (i.e. outermost edge of the symplast). Phellogen cells are thin-walled and active, forming side-by-side either as a complete cylinder around a stem, or as a localized saucer shaped arcs cupped toward the outside (concave to the outside).

As trees grow in circumference, primary tissues split, break and peel away. Just before and during destruction of the epidermis, phellogen(s) are generated just below or at some depth beneath. A phellogen can develop, depending upon tree species, at various depths beneath the primary tissues (i.e. epidermis and primary cortex), or may develop within inactive phloem. Phellogen tend to be first generated beneath sites of residual stomates, which then develop lenticels.

Subceeding

A single initial phellogen may continue to divide in all directions to maintain a single meristematic surface around the circumference of a tree. Over time and aging in some species, this single phellogen may be "subceded" (grown beneath and cutoff) by newly generated phellogens of various lengths and depths. All cells beyond (exterior to) the most interior phellogen zone (plus one or two maturing phellem cells) are sealed off and die.

New phellogens are formed below existing phellogens as sloughing and environmental erosion decrease protective values. Eventually new phellogens are formed within the inactive phloem cells. This process of establishing new phellogens behind old phellogens lead to some living phelloderm and inactive phloem cells being sealed off, forming a visible layer of crushed, different colored cells between phellem layers. Figure 10.

Sealing Hatches

Periderm is initiated just below and to either side of lenticels, and beneath shallow injuries, splits, or breaks in the epidermis. Periderm can be formed below the epidermis all the way around a stem, root or branch. When too much oxidation (electron loss) or water loss is occuring, periderm is initiated beneath. Periderm is also generated along the interior of shallow wounds occurring outside of xylem core.

Any exposed living tree cell surface will attempt to generate a periderm. The tree side of all leaf or twig abscission points generate a protective periderm. Injured, infected, or dead tissues are sealed outside the living tree by a periderm called wound periderm. Wound periderms can also be called necrophylactic periderm, as compared with normal periderms which are termed exophylactic. The necrophylactic periderms have added chemical defenses infused inside cells and cell walls to minimize access by biotic agents. Exophylactic periderms are designed to minimize environmental stress.

Necro-derm

After injury to living tissues outside the xylem core, a wound phellogen may form to protect a tree from environmental (biotic / abiotic) stress and strain. Wound phellogen can follow the contours of an injury at some distance. Wound phellogens are formed after protective boundary setting has occurred. Deep injuries depend upon a compartmental response in the xylem-containing-core, as well as boundary setting around the wound edges in living phloem and periderm tissues. Boundary setting outside the cambium is less effective than xylem compartmentalization because of limited space and more intense environmental interactions.

Within seven minutes of an injury, a boundary layer of living cells are designated for protection. After several days a completed dead boundary layer has been established. These boundary layer cells use callose to plug-up and disconnect all connections with injured cells. Next, these boundary cells are lignified and then suberized, including any spaces between cells. Many antibiotic and anti-environmental chemicals can be deposited in and around these boundary layer cells. Wound periderm (necrophylactic periderm) is generated adjacent to boundary layer cells.

P...Em

Phellogen generates phellem to the outside (exterior). Phellem is a tissue layer of various thickness, depending upon tree species. Phellem is seen as the major component of stem, root and branch exteriors on almost all mature trees. In many trees, phellem is termed "cork" or "corky." Phellem is critical to a tree in minimizing water loss, minimizing oxidation of living cells (injury), and insulating live tissues from environmental stress. Phellem composition and structure is resistant to liquid and vapor movement, resilient to minor impacts and light abrasion, compressible, heat insulating, buoyant, low density compared to wood, and relatively unreactive to air, water, and soil pollutants and to most chemicals.

Tree phellem ranges from thick to thin, and corky to non-corky. Phellem has tightly packed (no intercellular spaces), suberized cells which can have a variety of wax, oil, resin, and tannin deposits. Many phellem cell walls are first lignified (phenolic supported) before they are suberized (polyester packed). Thick walled cells have additional lignin / cellulose layers deposited inside the cell over the suberin. Thick walled phellem cells can continue to have lignin / cellulose layers deposited and eventually become stone cells. At maturity, phellem cells are dead and filled with air, fluid or solid materials. The fillings of phellem cells provide for various coloration.

Diverse Layers & Cells

Phellem can be composed of alternating layers of thick and thin-walled cells, intermixed thick and thin walled cells, or different types of cells with unique defensive attributes. Among the phellem cells with various layers of cell wall thickening are unsuberized cells resembling normal phellem cells called phelloids. These cells can have either thick or thin cell walls and can develop into sclereids. The variety of cell wall thicknesses and types generate visible layers and islands of specific phellem cells.

For example, in species of the genera *Eucalyptus, Pinus, Picea, Larix, Betula*, and *Robinia,* alternating layers of cell wall thickness occur. In species of the genera *Abies, Cedrus*, and *Pseudotsuga*, the phellem is all thin walled cells.

Phloem tissue sealed off by a periderm and now part of phellem, can contain a number of different types of cells which lend unique characters to periderm. Interlocking phloem fibers and sclerified tissue (i.e. sclerenchyma) layers in old phloem provide strength and resilience to phellem. Depending upon number and orientation of incorporated phloem cells, periderm thickness, stringiness, and platiness will be modified.

Phellem Lost!

Over time, phellem is lost to the environment accidently through animal activities, climatic events, or structural failures. Phellem is also lost by design through weak zones (thin walled cells) giving way. Distinct layers visible in the phellem of most tree species are not annual or seasonal (i.e. can not be used in aging).

No discussion of phellem would be complete without mentioning periodical stripping of tree phellem for bottling corks. Commercial use of tree phellem is most known for making bottle corks from *Quercus suber* (cork oak) rhytidome. This oak generates massive phellem thickness of thin walled cells filled with air.

O2 Spots

Periderm is extremely impermeable to oxygen and water. A lenticel is a specialized area of periderm where phelloderm dominates over phellem. The phelloderm in this area has many intercellular air spaces. The phellogen also generates more loose filler cells as opposed to cork cells to the outside. Lenticels usually develop and are maintained beneath primary residual stomates. These points act as gas exchange ports for living tissues beneath. The phellogen continues to generate these unique localized areas of cells as it divides and new phellogens are produced.

Lenticels are most visible on the surface of some species of trees with smooth, thin periderms on twigs. For trees with thick and furrowed rhytidome, lenticels are at the bottom of fissures, valleys or crevasses. With expanding growth, lenticel areas are mechanically weaker than surrounding areas and continue to separate, maintaining gas exchange for living tissues beneath.

Gas Ports

There are three different types of lenticels in trees. The first is the simplest and is made of loose suberized filling cells (i.e. *Liriodendron, Magnolia, Malus, Persea, Populus, Pyrus, Salix*). The second type of lenticel is composed of masses of unsuberized filling tissue (i.e. *Fraxinus, Quercus, Tilia*). The third lenticel type has a closing layer formed over the top where alternating layers of suberized and unsuberized filling cells seal over the lenticel in the dormant season and new filling cell production in Spring burst the old closure (i.e. *Betula, Fagus, Prunus, Robinia, Picea*).

P...Derm

The phellogen in many trees divide and produce phelloderm cells to the inside (more interior). Phelloderm cells resemble phloem parenchyma generated by the vascular cambium. Phelloderm does not have suberized cell walls, but can develop into sclereids. Sclereids have layers of lignified and cellulose materials on cells walls. Layers or clusters of sclereids may be interspersed or alternate with thin walled unlignified cells.

Phelloderm may be very thin or thick. Ginkgo and many tropical trees have extremely thick phelloderms which provide most of the periderm protective function. Phelloderm cells may contain chloroplasts, process light, and fix carbon, especially noticeable in warm sunny periods of the dormant season. Phelloderm cells may store starch and can be stimulated to generate a new phellogen.

Which Cortex?

Phelloderm helps form, along with nonconducting (inactive) phloem area cells, a secondary cortex. In some trees this secondary cortex is a green photosynthetic layer just outside the active phloem and just inside the most interior phellogen. The secondary cortex is visible in some thin, smooth barked trees as a greenish tint just under the periderm and can be exposed with a light scrapping or abrasion. This photosynthetic tissue helps in the sense-and-respond system of a tree to initiate and release growing points, to initiate defensive and compartmentalization reactions, and to measure light resources and seasonal timing.

It must be noted, there remains much confusion between "primary cortex" and "secondary cortex." Primary cortex is an exterior, primary tissue just beneath the epidermis on young tree shoot and root tips which have not begun to grow in diameter. A "secondary cortex" is a mature tissue form derived from parenchyma and collenchyma of both vascular cambium and phellogen origins located just inside the innermost phellogen and outside the active or conducting phloem.

Understandings

Many textbooks which present both woody and non-woody plant anatomy can confuse readers with the term "cortex." Many use the term interchangeable (most unintentionally due to lack of careful definition) for both this secondary and primary tissue. In plant anatomy research, the cortex refers only to the primary tissue. In trees, "secondary cortex" should be used, remembering this tissue is not of a single origin, nor of a single cell type.

Growth Faults

Periderm is under tension from being pulled apart by tree circumference growth. These physical stresses initiate sclerification and wall thickening within inactive phloem. Trees with thinner periderms tend to have greater sclerification than thick periderm trees. As girth continues to increase, micro-tears constantly occur between cells. These faults are at first corrected by cell divisions pushing cells in between other cells. As tears and faults continue, new phellogens are initiated.

X-Section

In cross section, periderms can show light colored spots (stone cells), lenticel eruptions or openings, circumferential or radial bands of stone cells and phloem fibers, and/or light colored arcs of phloem fibers. Between the phelloderm and vascular cambium, phloem ray cells expand or dilate to fill in the expanded space and form conical shaped areas (wedge shaped in cross-section). Figure 11. In some species, phloem ray dilation occurs to its greatest extent just below surface cracks or fault lines. After phloem becomes inactive, cellular changes and mechanical forces push and collapse thin-walled cells and thicken some cell walls, all destroying radial order and symmetry of the expanding stem.

Figure 12 provides a cross-sectional view of a stem or branch with different tissues labeled. Note the progression of tissues generated from the two lateral meristems (i.e. vascular cambium and phellogen). Inactive phloem and phelloderm comprise the secondary cortex, which is not labeled. Everything seen in this cross-section was generated by two lateral meristems except the pith.

Time Passages

Periderms can be considered as two layers in time. The initial periderm-type layer is generated as primary tissues (i.e. epidermis and cortex) split over young tissues. This initial protective layer can last decades in some species, while in other species it is replaced later the same season. Over time, the initial periderm (epidermis and primary cortex) can be sealed off from living tissues by a new secondary periderm which forms inside (more interior) to the initial primary protective layer.

Being Second

The second periderm is generated by formation of a phellogen somewhere beneath the tissues of epidermis and primary cortex. Figure 13. This second periderm in trees usually forms by the end of the first year of growth or during the beginning of the second year of growth.

The depth below the exterior surface where periderms are generated varies by species. In most trees, the second periderm generated by a phellogen is established at or just below the epidermis. In some trees, the phellogen is established several layers into the primary cortex (i.e. *Quercus, Robinia, Gleditsia, Pinus,* and *Larix*). In a few trees, the phellogen is established within the inactive phloem (i.e. *Melaleuca*).

Areas first starting to generate phellogen(s) are usually under or near residual stomates or lenticels. Complete development encircling a stem or branch may take one growing season or as many as six years (i.e. *Acer negundo*). The phellogen may be formed around the entire circumference and continue to expand over time as a tree grows, forming a ring periderm. Second (and all subsequent) periderms may also form in local areas where needed, beginning an arc or scale periderm.

Subsequent Generations

All subsequent phellogens may be generated either around the entire circumference beneath the second periderm, or in many localized, overlapping arcs. The subsequent phellogens may develop quickly after the second periderm, may require years to form (i.e *Malus* & *Pyrus* < 8 years; *Pinus sylvestris* <10 years), or may not appear at all.

For example, the initial and second periderm is maintained for long periods (even over the entire life of a tree) in some species within the genera *Betula, Fagus, Abies, Carpinus,* and *Quercus*. In old *Fagus* genera individuals, the initial and second periderms and inactive phloem may be held on a tree for centuries.

Textures

Phellogen can generate phellem cells with alternating thick and thin walls, producing weak zones for periderm sloughing or separation. Periderms continue to form as a tree grows, cutting off and incorporating inactive phloem as layers within periderm. Concentric (ring) periderms peel away in strings, strips, or rings, like in species of the genera *Cryptomeria, Thuja,* and *Juniperus*. Scale (arc) periderms generate scaly or platey appearances as in most temperate tree species.

If phloem fibers comprise a large percentage of the inactive phloem incorporated, periderm will be stringy and tends to produce a diamond shaped net of fissures as in species of the genera *Fraxinus* and *Tilia*. If periderms have few phloem fibers, the periderm will break into small scales as in species of the genera *Pinus* and *Acer*. Periderms composed almost entirely of corky phellem tend to stay connected together for long times such as in species in the genera *Pinus, Quercus, Robinia, Salix*, and *Sequoia*. These periderm layers tend to erode away over time, but not flake off.

Texture II

There are two commonly recognized subtypes under scale (arc) periderms: fibrous and flaky. Fibrous periderms pull away in long strips like in species of the genera *Carya, Tilia, Fraxinus*, and *Acer*. Flaky periderms have many sclereids which cause periderms to pull away in scales or flakes such as in species of the genera *Picea, Ostrya, Larix, Quercus*, and *Acer*. Rarely, species may continue to expand their second periderm and no other periderms ever form, as in some species of the genera *Fagus* and *Quercus*.

Scaly periderms derived from multiple periderm arcs have many different layers composed of tissue from old periderms and phloem, as in species in the genera *Pinus, Carya*, and *Acer*. Deep furrowed periderms are generated by incorporating phloem with many interlocking sclerenchyma fibers, such as in species of the genera *Ulmus, Salix, Quercus, Fraxinus,* and *Juglans*. Hard periderms contain many sclerified fibers while soft periderms contain mostly cork cells. Some stringy bark species like species in the *Eucalyptus* genus, have very fibrous periderms which are not well interlocked, or may be stuck tightly together with resins. Figure 14 provides a generic, stylized periderm / rhytidome surface texture matrix (i.e. Coder Tree Periderm Texture Matrix).

Classification

Periderms can be grouped into a variety of different texture classes and appearances. Some authors divide these periderm types into anywhere from 5 to 25 forms for identification. Remember each periderm surface texture is different for each individual, each species, and in each environment. Periderm is as unique as finger prints on humans. The most important components of how periderms appear are the different cells generated by the tree and their weathering over time. Periderm is a product of many years of aging coupled with erosion from the environment.

One simple way of classifying periderm surface types in trees depends upon four attributes:

1) periderms tightly affixed to the stem and branches;
2) periderms which peel away from stems and branches;
3) periderms with thorns, prickles, or spines; and,
4) total periderm / rhytidome thickness.

Figure 15 provides one example of a classification system used for differentiating genera and species based upon periderm / rhytidome characteristics.

Winged?

There are a number of unique surface structures which can develop within periderms. Phloem nodules arise from phloem tissues cutoff by a more interior periderm but still maintain water and growth regulator connections with the tree. These nodules usually have a significant volume of green (photosynthetic) tissue, but not always. Other surface periderm structures can include bumps, thorn or spur-like growths, or longitudinal corky fins called wings. Wings or cork bands running longitudinally along twigs and branchlets are generated by either local strips of periderms under and to either side of a cork ridge, or by localized excessive cork cell (phellem) production.

Shedding

Periderms, like other tree components are routinely shed. The adhesion between periderm and underlying phloem tissues on a tree depends upon species, season of the year, and past damage. *Angiosperm* periderms and phloem tissues usually require 2-3 times more force to remove than *Gymnosperms*. Commercially, mechanical tree stem debarking has placed species into “bark” removal categories.

Periderm shedding depends upon the radial position of where the second periderm was generated, formation pattern of subsequent periderms, phloem cell types, and age. Periderm shedding occurs along weak tissue lines. In *Populus* and *Fagus* genera, initial periderms can remain in position and functional for the life of a tree. Shedding rates are slow in smooth barked trees and usually occurs on a cell-by-cell basis or as small groups of phellem cells. In some species within genera *Betula*, layers of phellem tear loose in large thin sheets (papery).

Thickness?

Periderm becomes thicker with increasing tree diameter and thinner with increasing tree height above the ground, thinning greatly on branches. Over the entire height of a tree, periderm on the main stem can thin between 0 and 30%, compared to periderm thickness just above the soil. Periderm thickness on branches and over the stem flange at a branch base is significantly thinner than on the main stem. The top portion of a stem flange holding a branch (confluence area) is the thinnest periderm area in terms of live tree cells near the surface, although the apparent thickness is increased by roughness.

In some trees, periderm thickness on the basal portion of a main stem is great in order to minimize damage from fire. Species in the genera *Sequoia* and *Pinus* have thick rhytidome surrounding the tree base. Thermal insulation characteristics of these thick, low density periderms is great. Higher in the same trees, branches do not need (nor develop) periderm thickness increments for minimizing fire heat loads unless challenged in the past or near the ground.

Damaged Goods

Periderm damage from human activity, including from tree health care practices, can be severe. Periderm erosion, abrasion, and heating can all damage protective tissues, dead or alive. Figure 16 provides estimates of damage severity for a number of periderm atrtributes when a damaging agent is applied (i.e Coder Periderm Damage Assessment System).

Flange

In *Gymnosperm* and *Angiosperm* tree forms, branches are developed with, and supported by a stem flange. A stem flange represents a multiple layered, highly interconnected tissue area at the branch base where additional stem tissues are generated to provide structural support, defensive capabilities, and effective transport connectivity. Figure 17. This change in longitudinal fiber orientation from branch to stem disrupts normal cylindrical periderm generation.

Periderm thickness from a branch before a flange area, and periderm on a stem immediately above a flange area, can be quite different. Branch periderms can be more than 60% thinner than stem periderm around the flange site. Over a stem flange area, periderm must continually change orientation to protect living tissues. At the top of a stem-branch confluence, periderm can be especially close to the surface and is stimulated to generate additional phellem which can be seen as the production of a periderm chine or ridge.

Stem-Branch Unions

Two general types of periderm unions are found in trees, a chine or rimple. A periderm chine is composed of externally exposed layers of phellem at a stem-branch confluence. A periderm rimple results from the union of stem and branch periderms folding inward, sometime enclosing significant amounts of periderm / rhytidome tissues on the upper side of a stem-branch confluence. Figure 18.

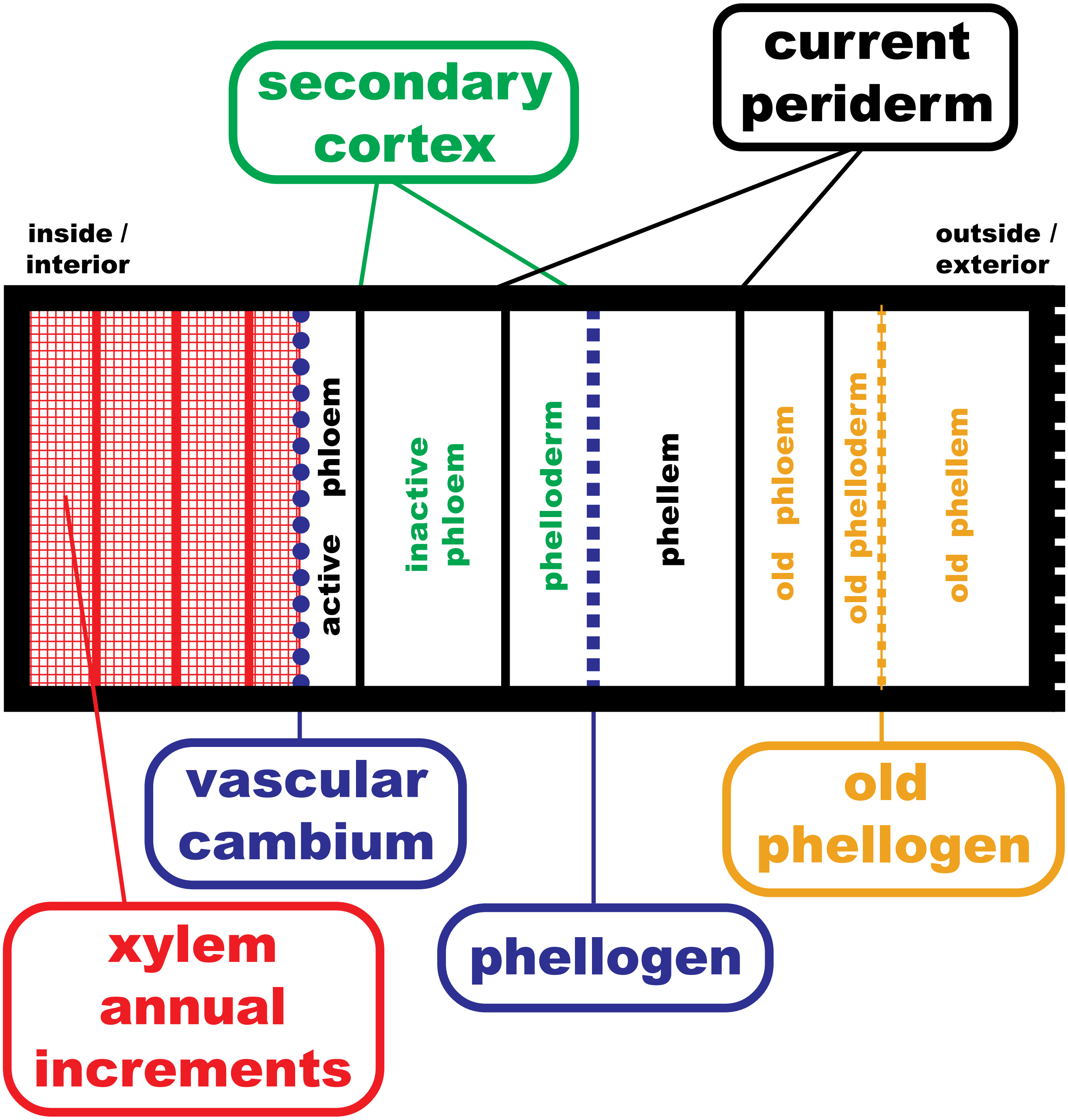


Figure 1: Diagram showing (from inside a tree to outside) the last few annual increments of xylem, vascular cambium, phloem, secondary cortex, current phellogen generating current periderm, and one older shed phellogen with generated periderm around the outside of a stem, large root or large branch.

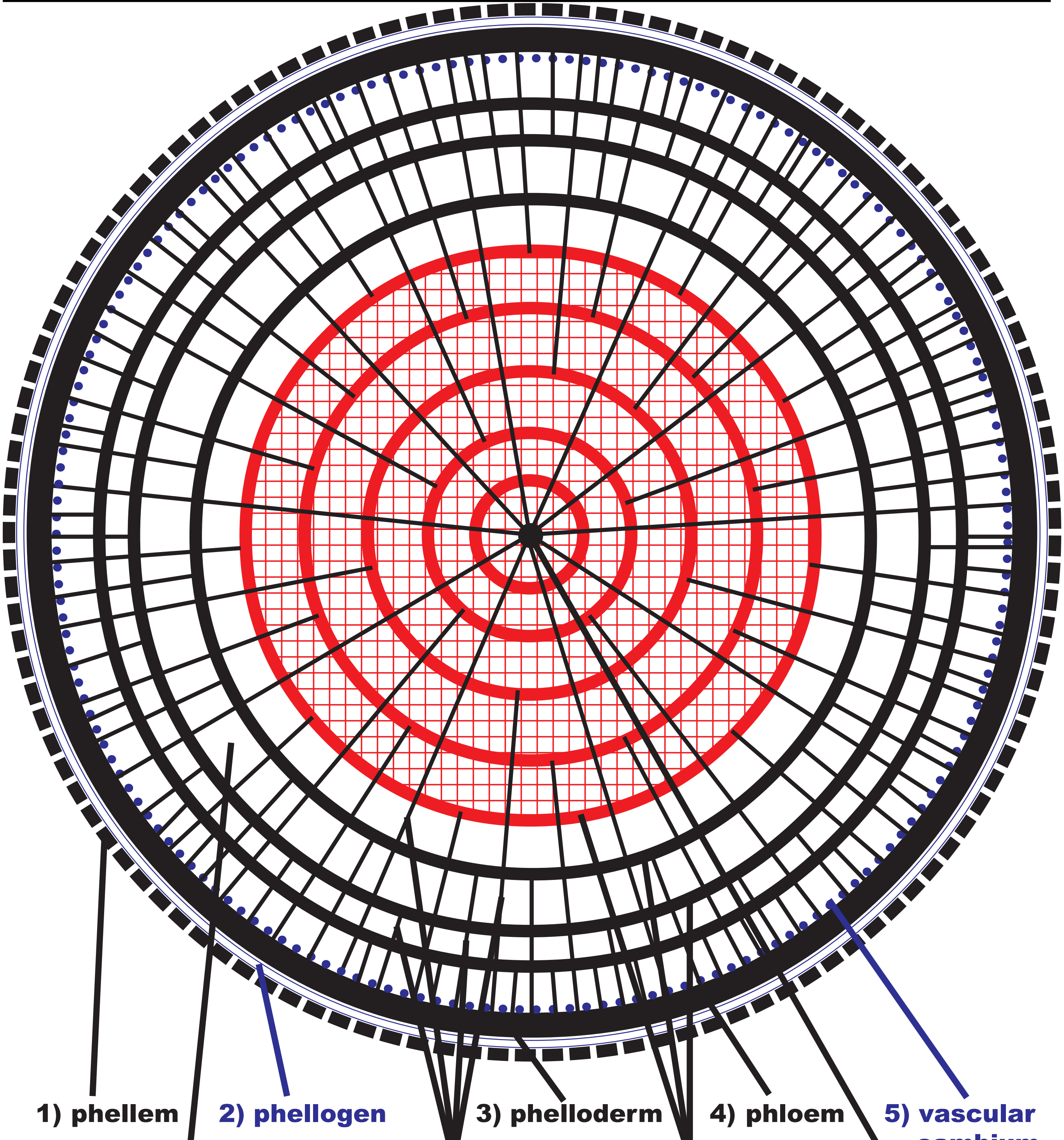


Figure 2: Diagram of specific stem or branch tissue cross-section (no pith in root). Number 1-3 are periderm.

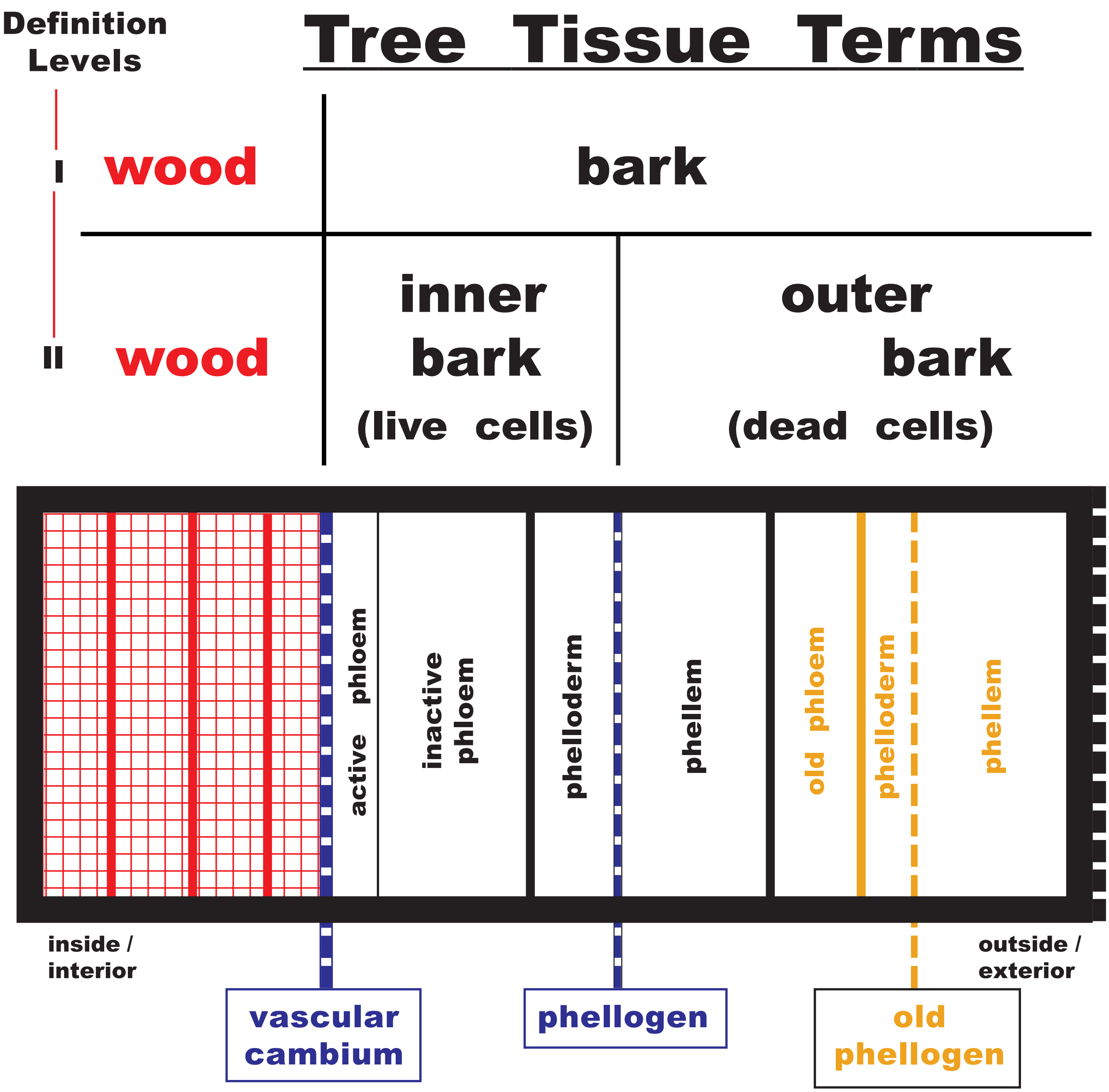


Figure 3: Diagram representing a segment of a mature tree cross-section showing various old and simple terms (i.e. definition levels I & II) traditionally used for various stem, root and branch tissue layers. These terms are considered non-technical.
(Note this diagram does not show radial components.)

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Definition Level III

# Tree Tissue Terms

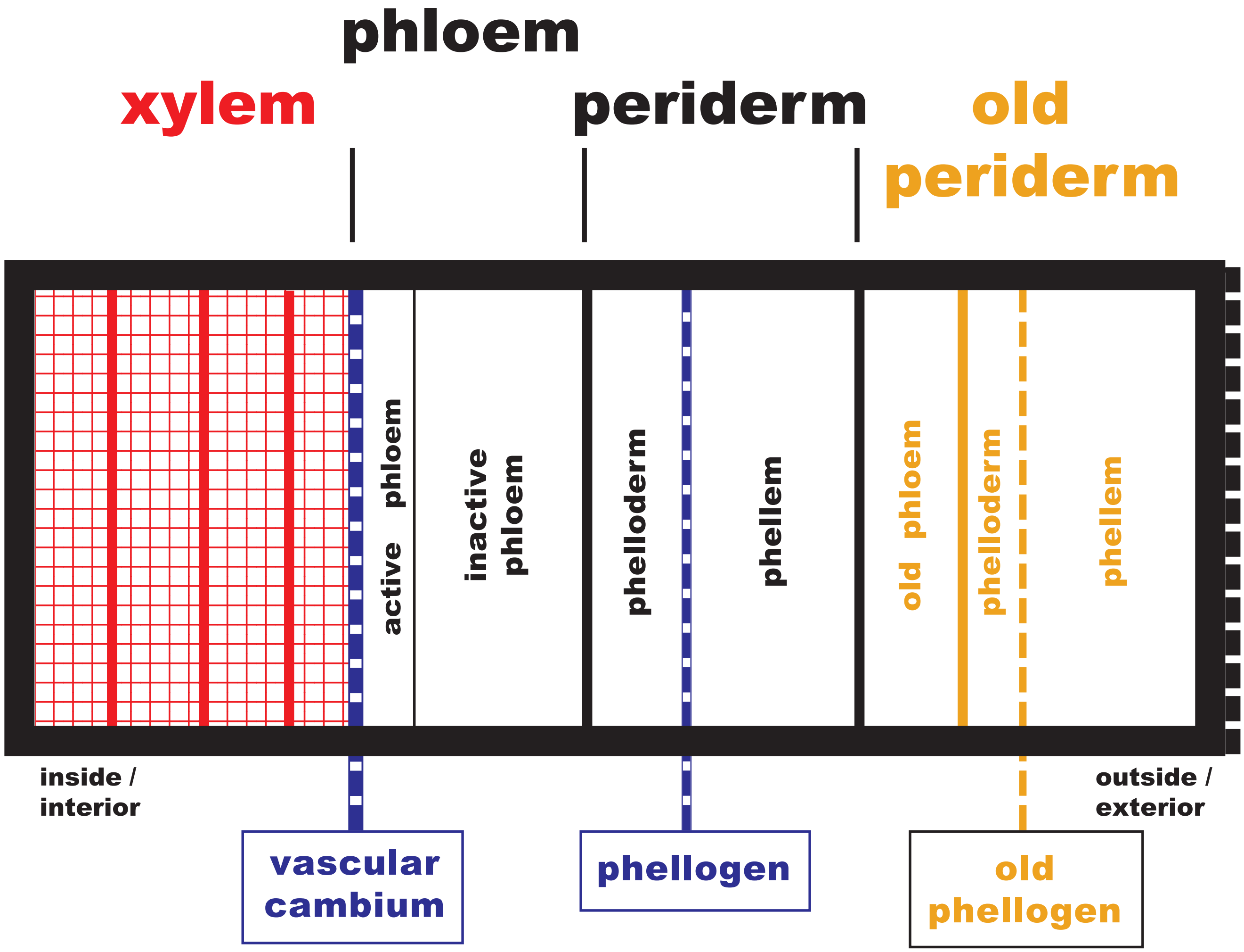


Figure 4: Diagram representing a segment of a mature tree stem or branch cross-section showing terms (i.e. definition level III) traditionally used for various stem & branch tissue layers. (Note this diagram does not show radial components.)

Definition
Level IV

# Tree Tissue Terms

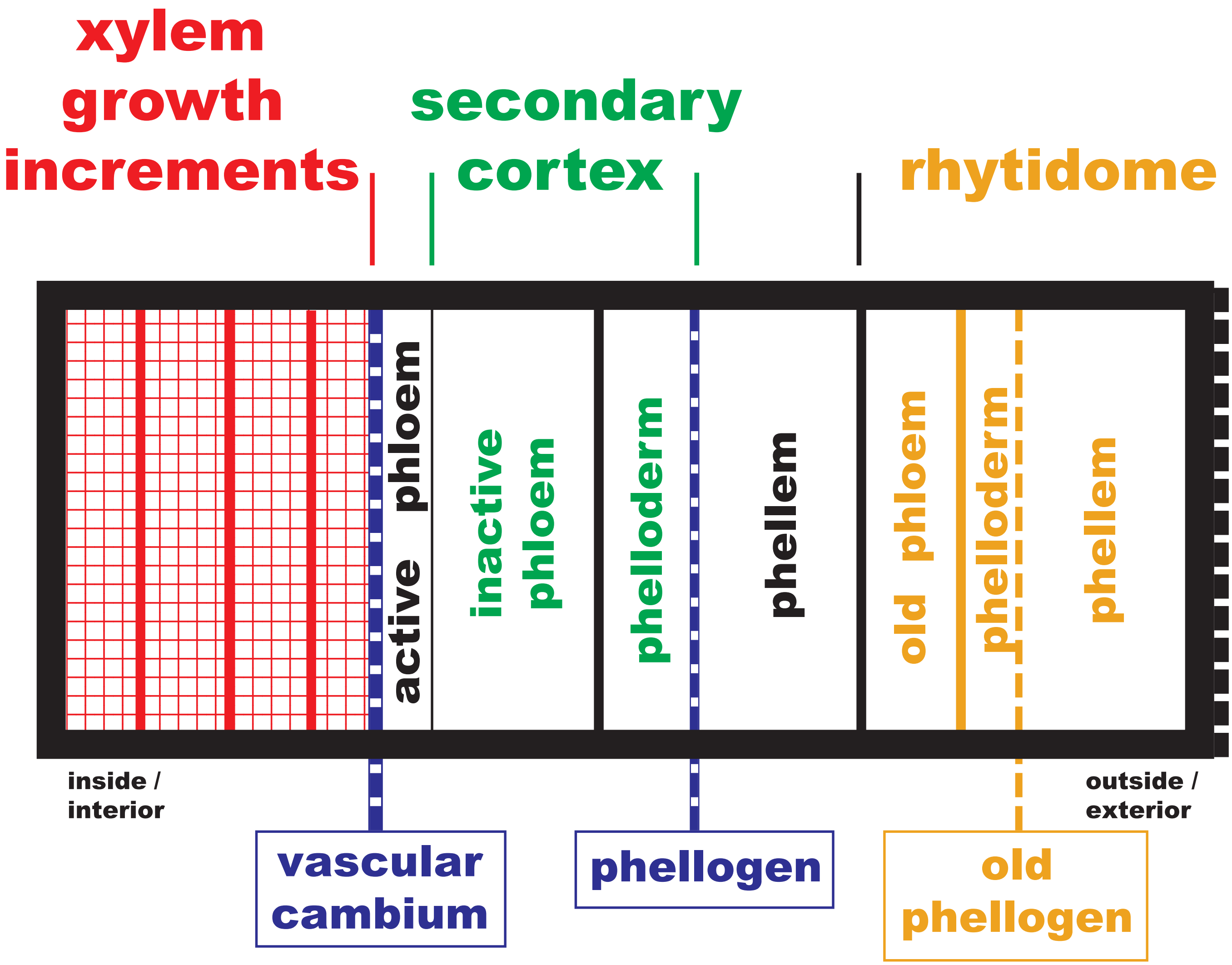


Figure 5: Diagram representing a segment of a mature tree stem, root and branch cross-section showing \ technical terms (i.e. definition level IV) used for various tissue layers. Secondary cortex is a combination of tissue types from two different lateral meristems. Rhytidome is composed of from one to many shed periderms beyond current active periderm generation.
(Note this diagram does not show radial components.)

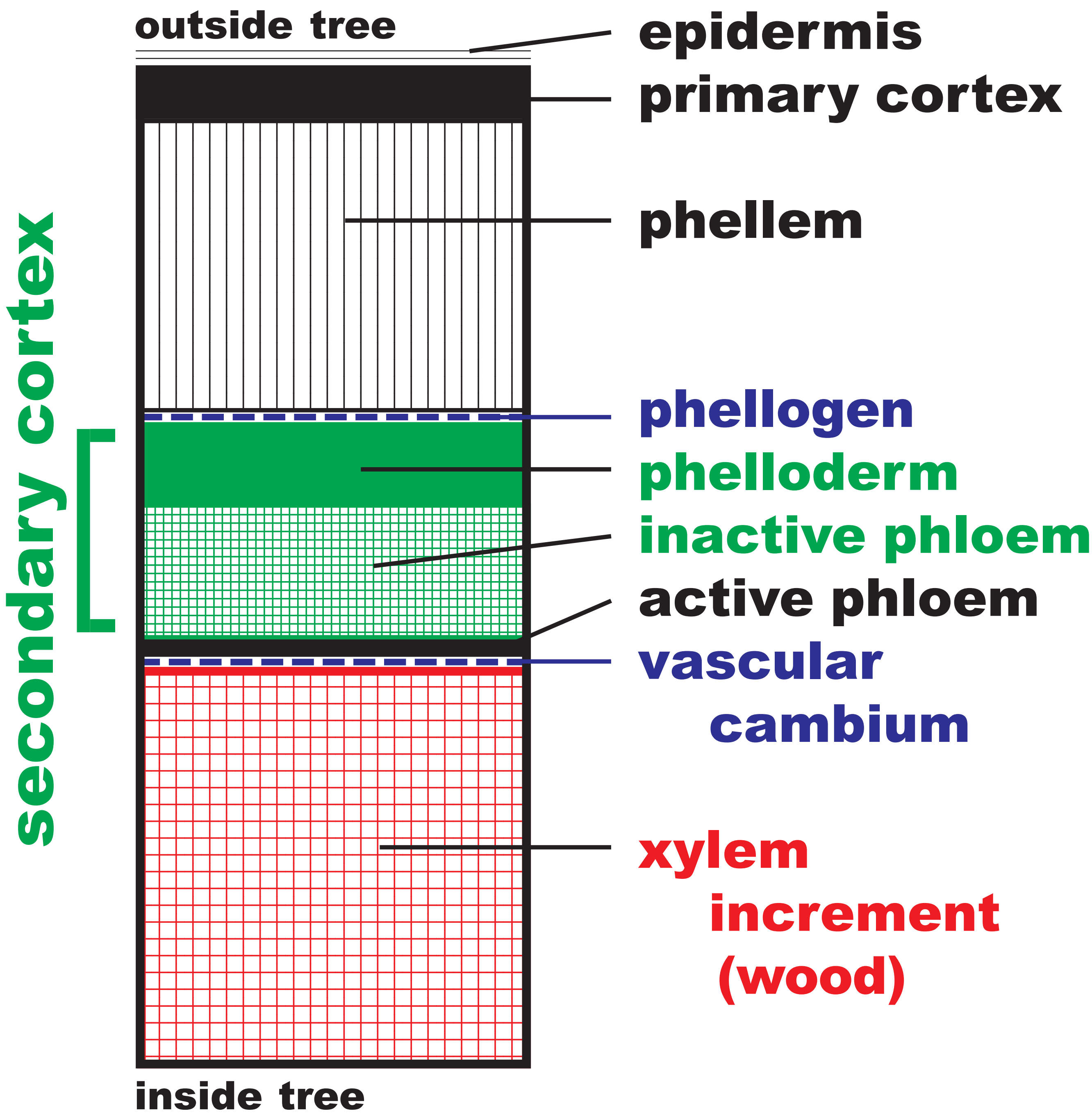


Figure 6: Diagram of a narrow cross-section of a tree stem, root or branch. As secondary growth from the vascular cambium is generated, a phellogen (lateral meristem) is generated and produces phellem to the outside (exterior) and phelloderm to the inside (interior). Phelloderm and inactive phloem comprise a secondary cortex.

(Dotted lines are the two lateral meristems.)

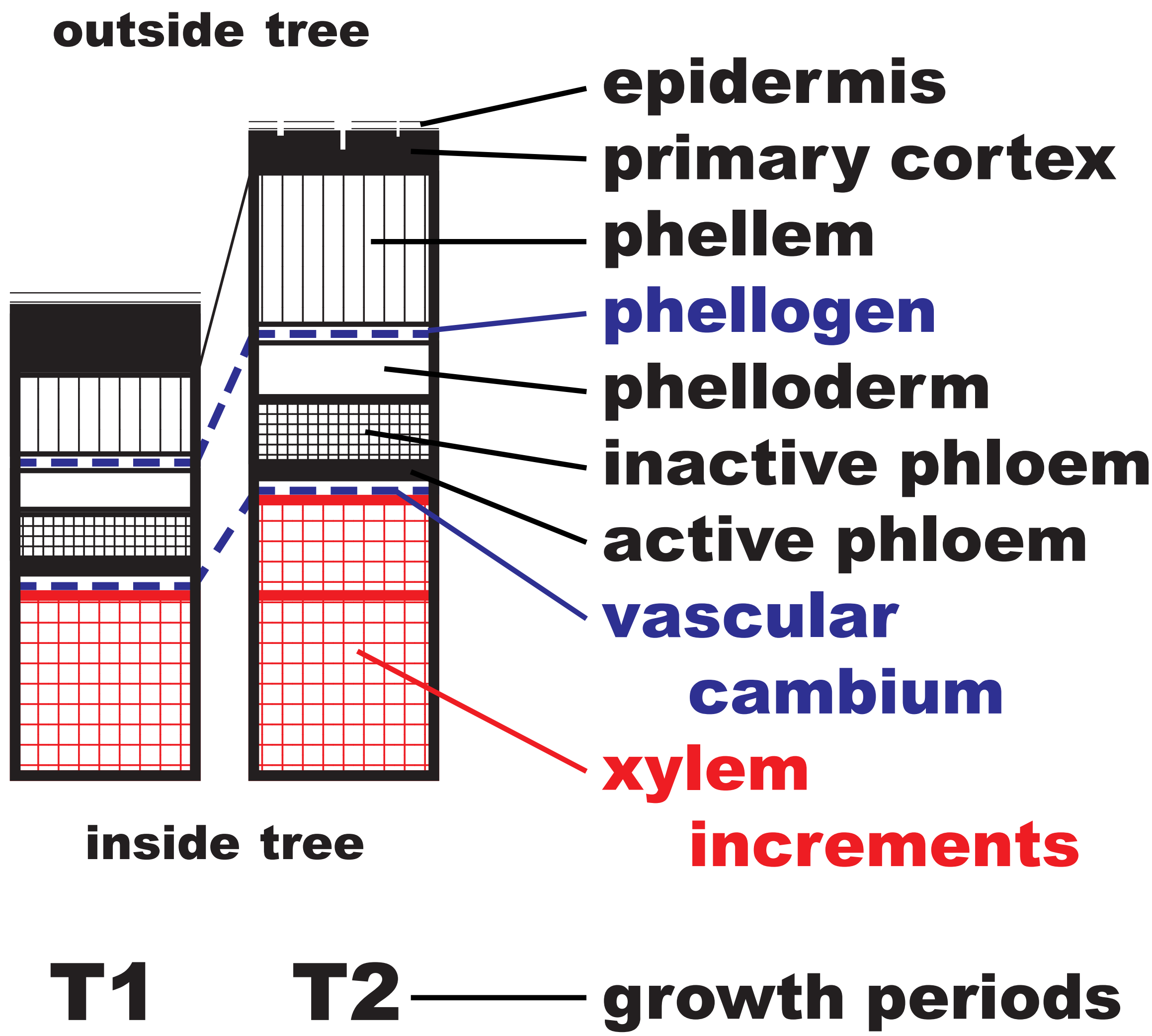


Figure 7: Diagram of tree stem, root or branch cross-section. With secondary growth over time, the epidermis and primary cortex are usually crushed and torn, leaving a phellogen which generates phellem and phelloderm. Phelloderm and inactive phloem comprise the secondary cortex.
(Dotted lines are the two lateral meristems.)

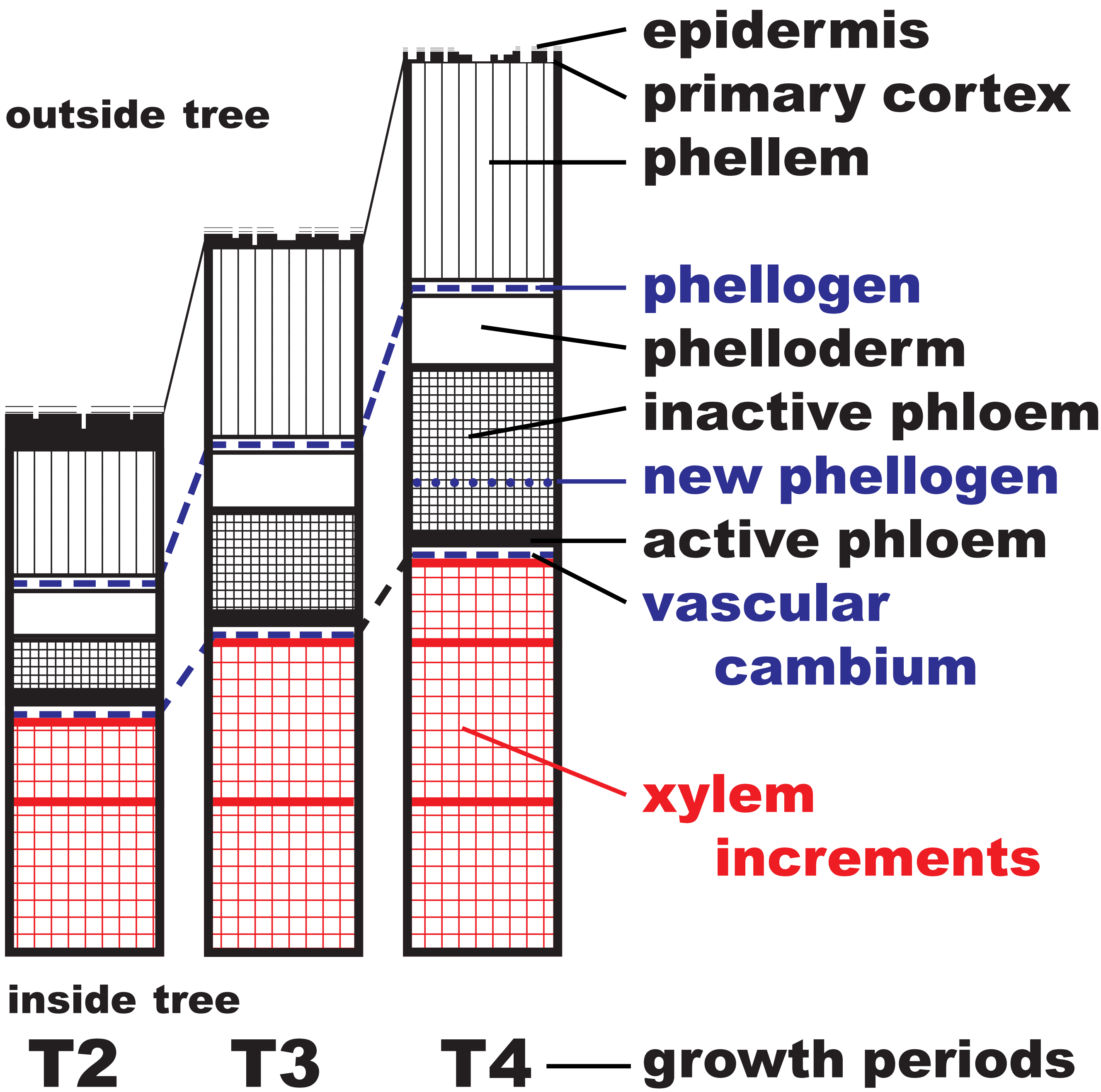


Figure 8: Diagram of tree stem, root or branch cross-section. As secondary growth proceeds, a phellogen (lateral meristem) generates phellem and phelloderm. Phelloderm and inactive phloem comprise a secondary cortex. A new phellogen will be generated in the secondary cortex behind the current periderm as it is shed. (Dotted lines are the two lateral meristems.)

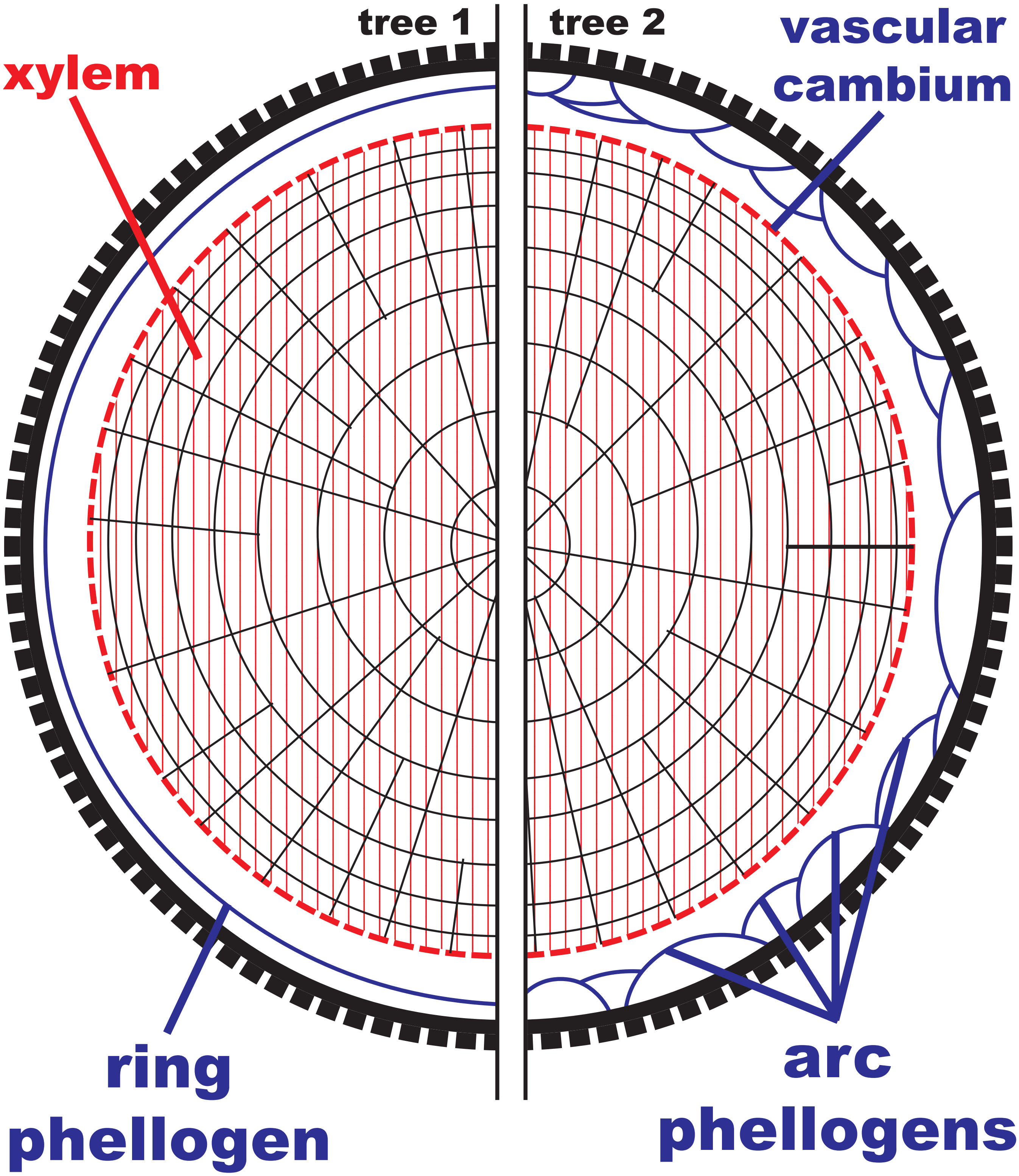


Figure 9: Diagram representing the two primary types of phellogens in trees -- a circular, ring, entire, or circumferential type; or, a crescent, scale, or arc type.

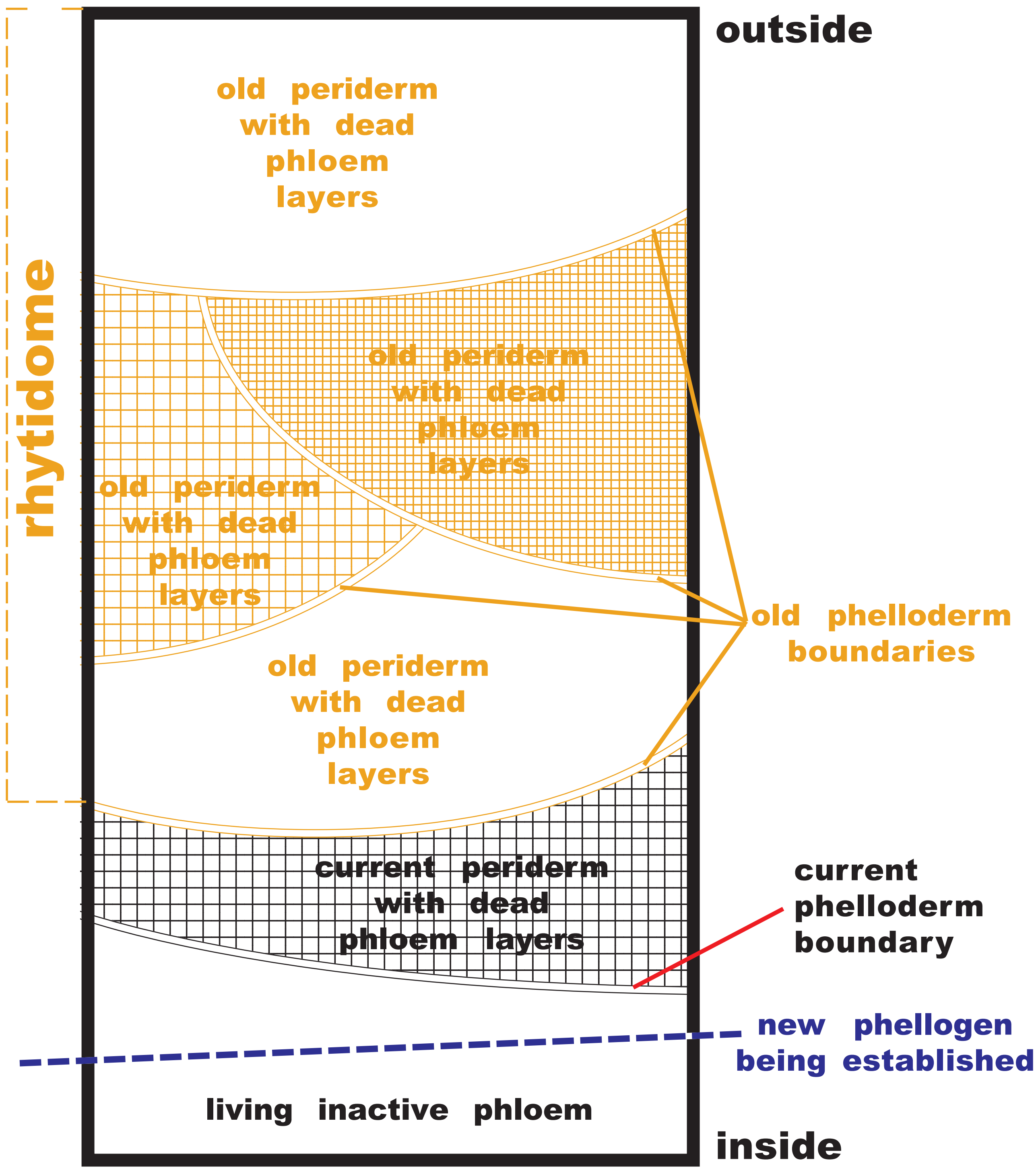


Figure 10: Layered pattern of old arc periderms (rhytidome) beyond a new periderm being established within inactive phloem.

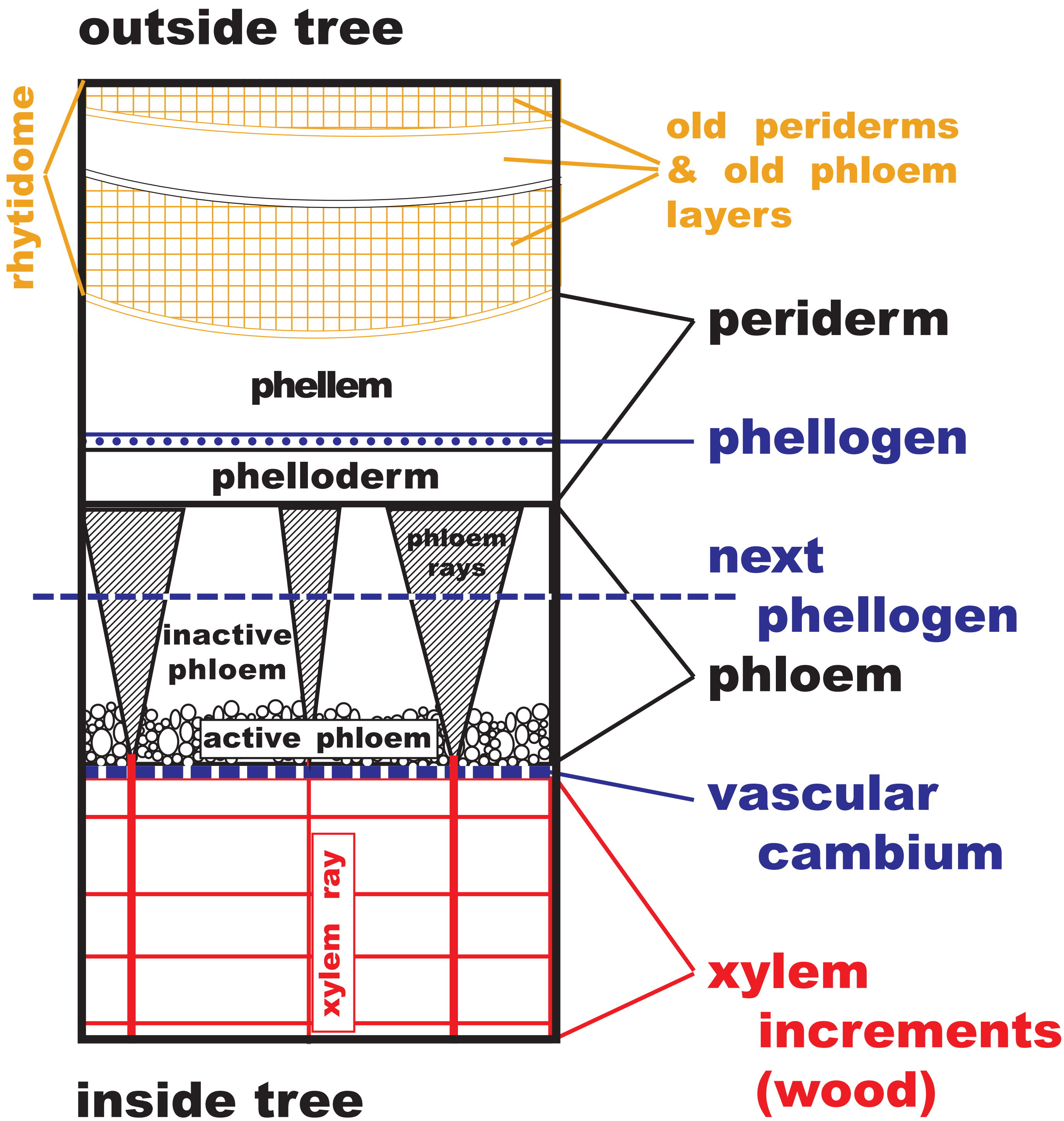


Figure 11: Segment of tree stem, root or branch cross-section showing tissue layers from outside to inside including old arc periderms.

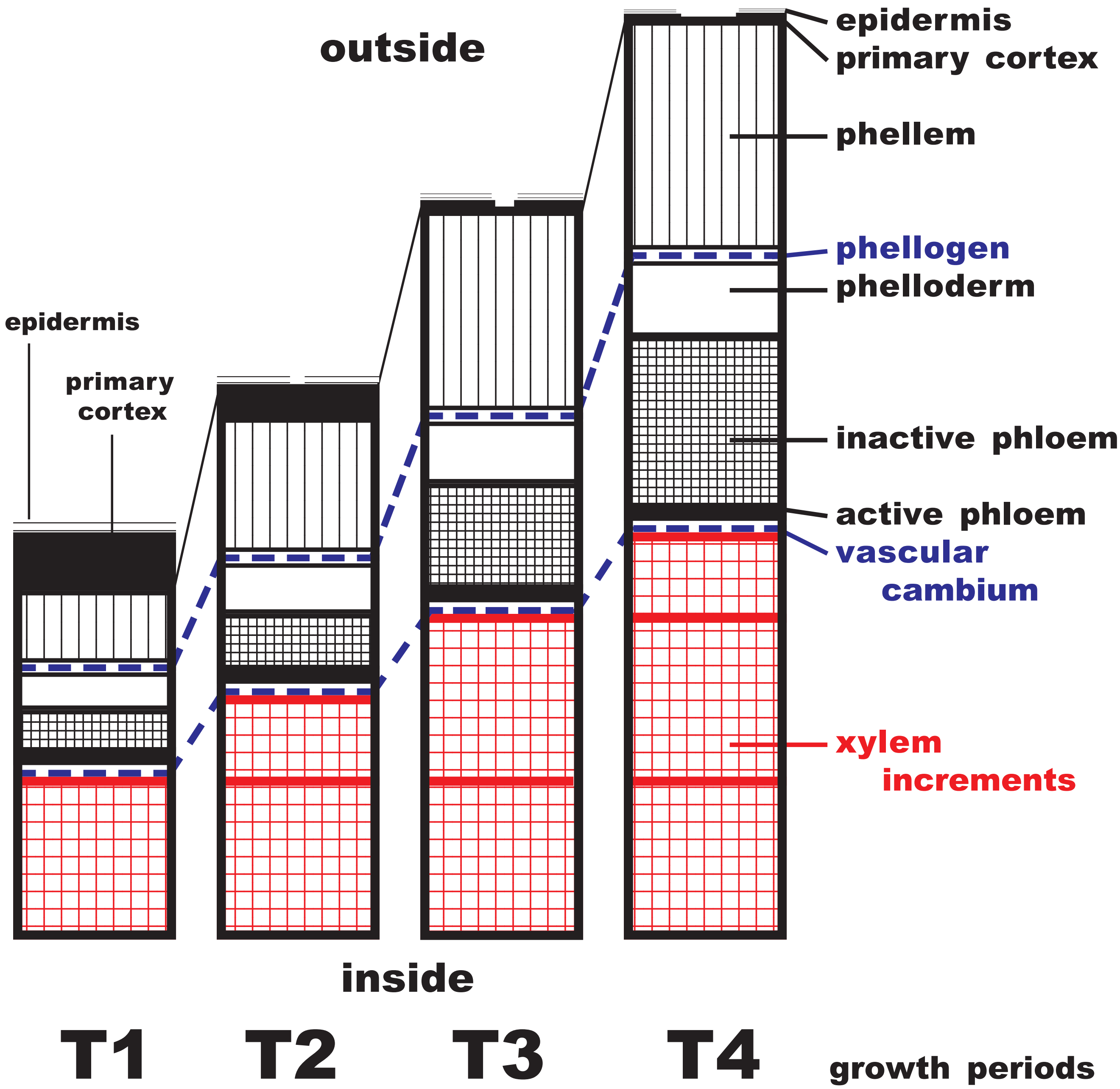


Figure 12: With secondary growth over time (T1 through T4), the epidermis and primary cortex are crushed and torn, leaving a phellogen generating phellem and phelloderm. Phelloderm and inactive phloem comprise the secondary cortex. (Dotted lines are lateral meristems.)

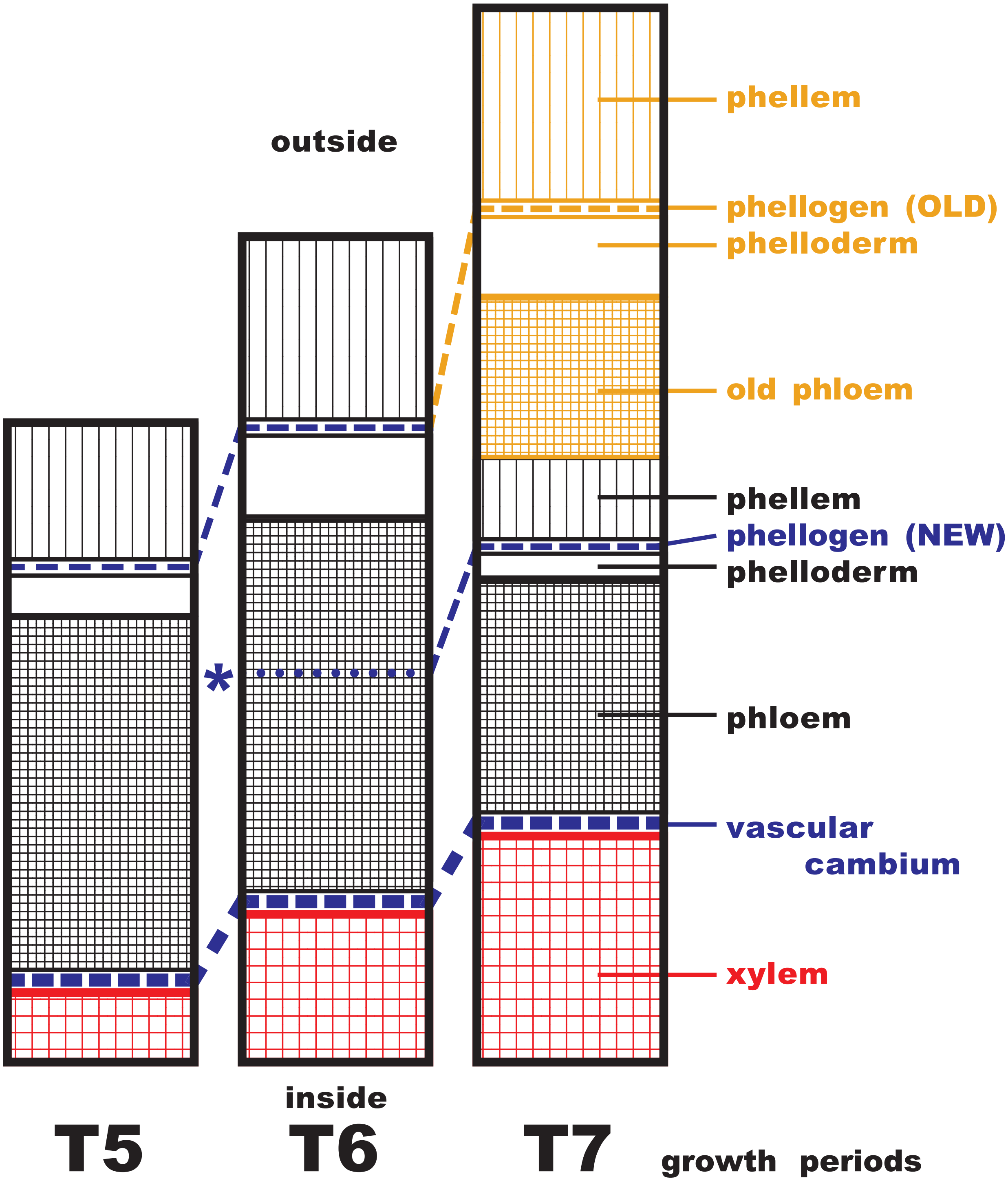


Figure 13: Initiation of a new periderm (*) behind the initial protective layers with secondary tree growth. Note initial protective layers and some phloem are outside living sheath of tree in the T3 growth period. (Dotted lines are lateral meristems.)

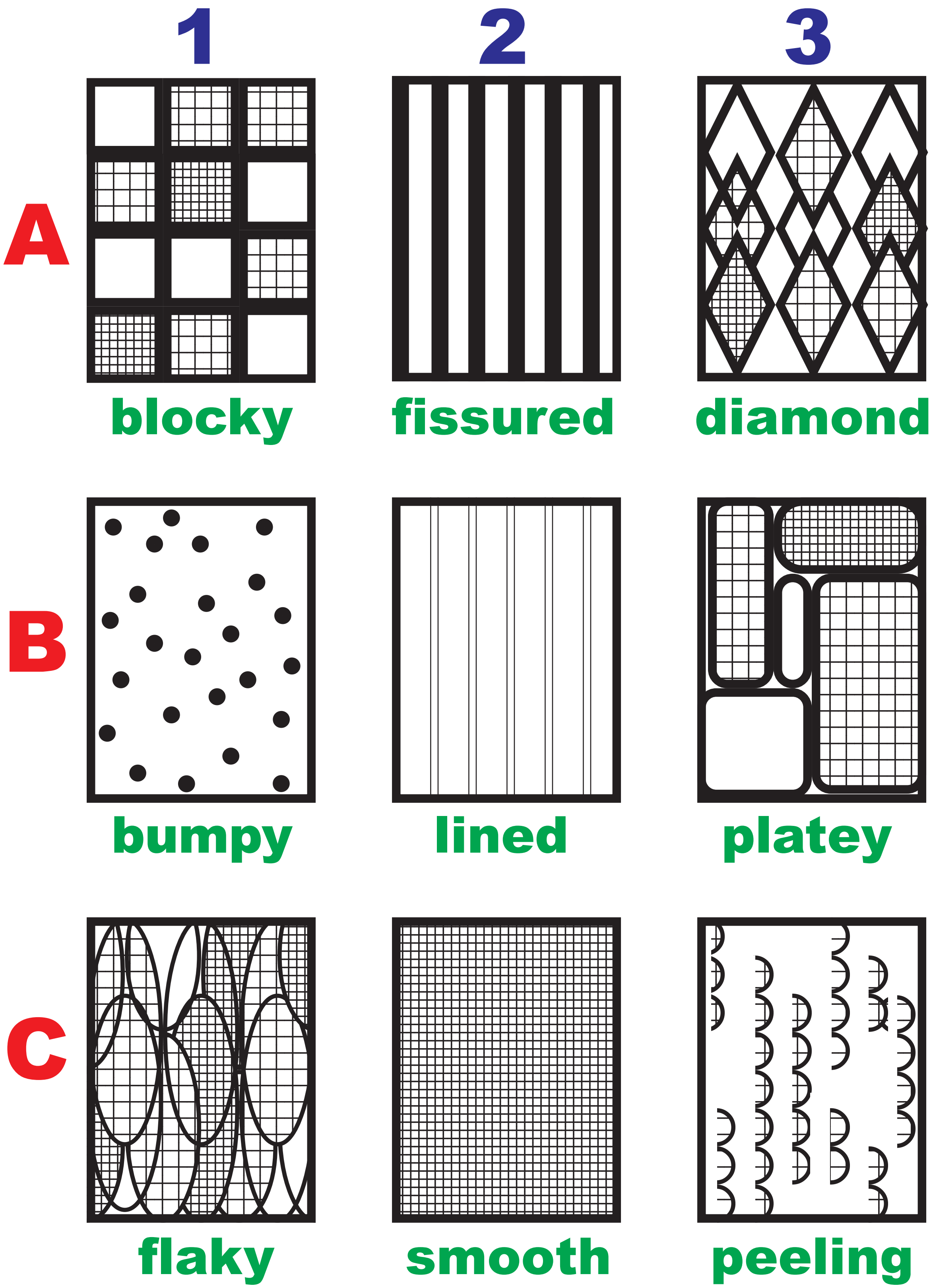


Figure 14: Generic stylized tree periderm / rhytidome surface textures. (Coder Tree Periderm Texture Matrix)

| # | bark thickness | bark stem attachment | texture & topography | (genera examples) |
|---|---|---|---|---|
| 1 | thin | attached | smooth / flat | (Carpinus, Fagus, Ilex) |
| 2 | thin | attached | shallow longitudinal fissures / ridges | (Acer, Cercis, Liriodendron) |
| 3 | thin | attached | shallow irregular scales | (Abies, Cedrus, Pinus) |
| 4 | thin | peeling | thin strips / rolls | (Acer, Betula, Platanus) |
| 5 | thin | peeling | smooth large flaking patches | (Pinus, Platanus) |
| 6 | thin | attached | smooth bark with thorns / spines | (Aralia, Gleditsia) |
| 7 | intermediate | attached | shallow small / medium scales | (Ostrya, Picea, Prunus) |
| 8 | intermediate | peeling | fibrous flexible strips | (Cupressus, Juniperus, Thuja) |
| 9 | intermediate | peeling | heavy fibrous rigid plates | (Carya, Chamaecyparis) |
| 10 | thick | attached | deep longitudinal fissures / ridges | (Castanea, Liquidambar, Quercus) |
| 11 | thick | attached | hard interlaced ridges | (Fraxinus, Juglans, Populus, Tilia) |
| 12 | thick | attached | hard blocky with deep fissures | (Cornus, Diospyros, Quercus) |
| 13 | thick | attached | hard corky bark | (Casuarina, Quercus) |
| 14 | thick | attached | large scaly / platey | (Pinus) |
| 15 | thick | peeling /attached | soft fibrous longitudinal ridges | (Eucalyptus, Pseudotsuga, Sequoia, Taxodium) |

Figure 15: One type of stem bark appearance classification. (derived from Vaucher, 2003)

10 9 8 7 6 5 4 3 2 1

| | most potential damage → least potential damage |
|---|---|
| A | Twig · Root · Branch · Stem |
| B | Initial Periderm · Subsequent Periderms · Many Periderms |
| C | Thin / Smooth · Thick / Deeply Furrowed |
| D | Peeling / Soft Periderm · Solid / Hard Periderm |
| E | Spring (Leaf Expansion) · Summer (Wood Formation) · Fall · Dormant |
| F | Weather: Hot · Warm · Cool · Cold |
| G | Continually Wet · Periodically Wet · Normal Moisture |
| H | **Predisposing Conditions Present:**<br>1. Area Already With Periderm Damage.<br>2. Area Around Hardware Anchors / Attachments.<br>3. Area in Contact with Heat Source (light / lantern).<br>4. Area Continually Abraded / Eroded / Injured.<br>5. Area in Drainage Path of Cavity / Infection.<br>6. Area Damaged / Charred by Fire. |

Figure 16: Potential damage assessment (Coder Periderm Damage Assessment System) for tree periderm / rhytidome caused by ropes, metal and other agents.
Each line lists potential damage from greatest potential (10) to least (1).
If enough force (energy) is applied for a greater duration, periderm will be damaged regardless of conditions.

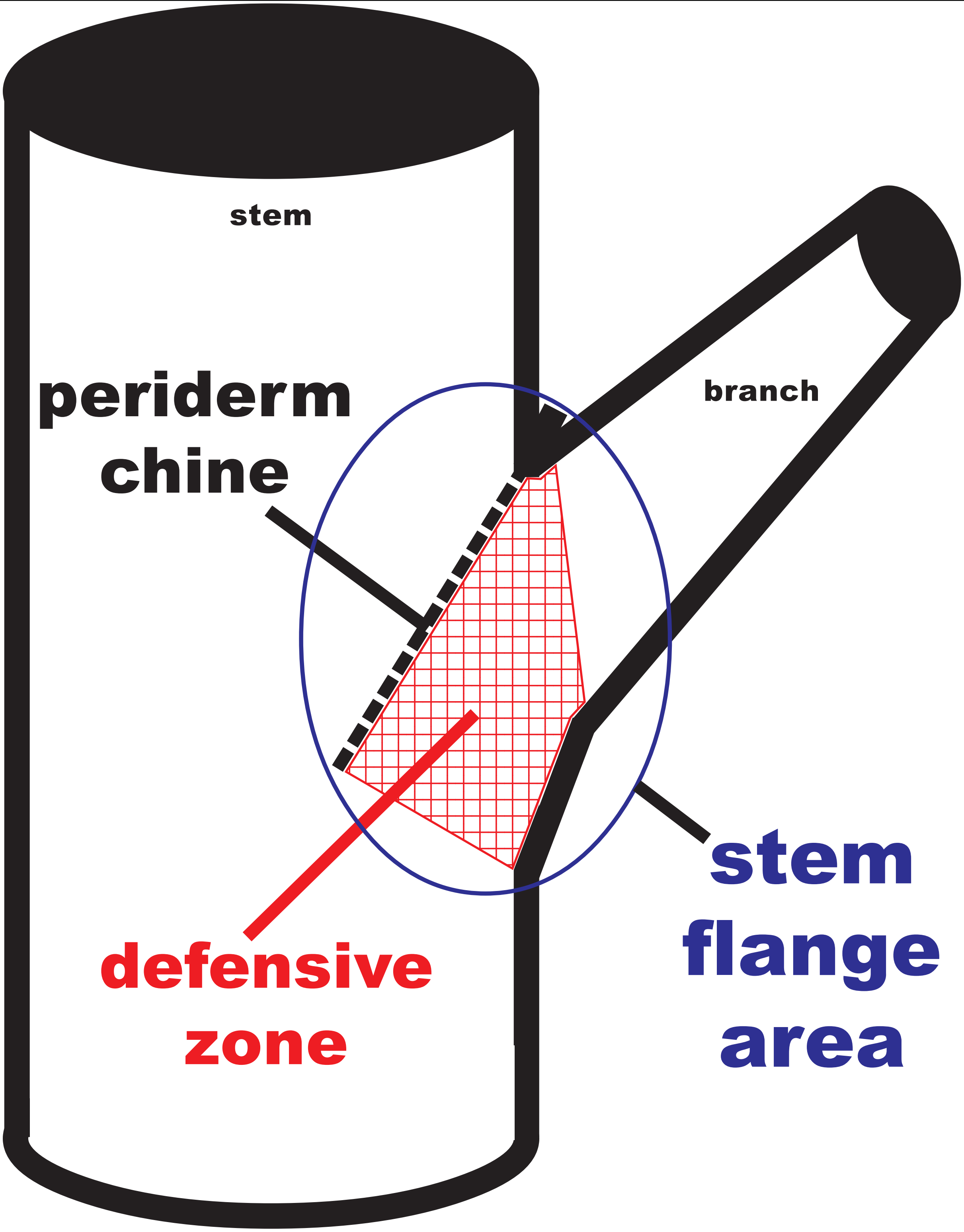


Figure 17: Stem-branch confluence area showing periderm chine (periderm ridge), stem flange area, and defensive zone (shaded).

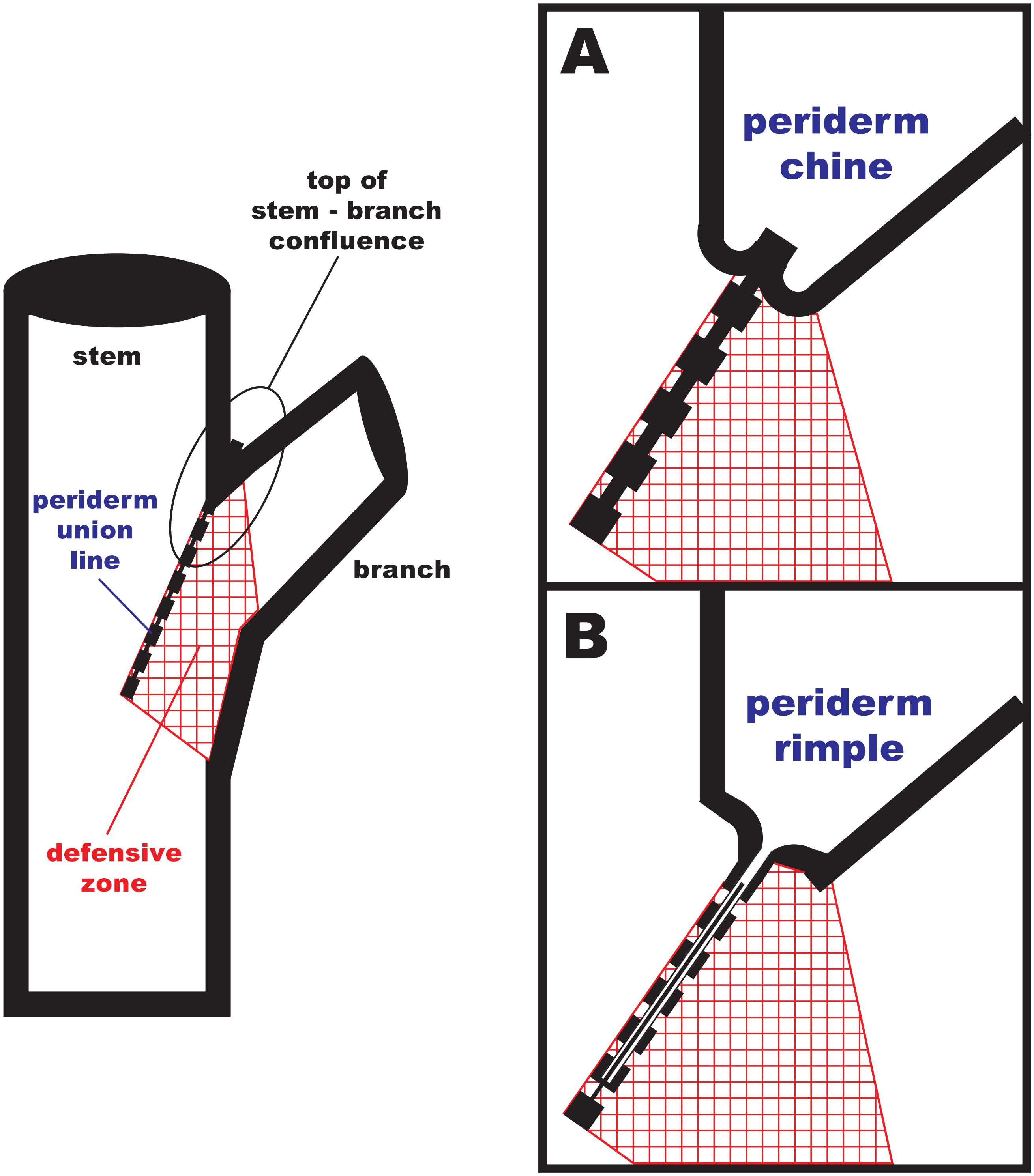


Figure 18: Graphical representation of two types of stem / branch periderm unions: A) periderm chine (ridge or crest); B) periderm rimple (fold or wrinkle). The rimple union can contain periderm folded within.

Citation:

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