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SAPWOOD / HEARTWOOD

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Larger diameter and older branches and stems can be composed of one or two ages of xylem tissues, generally divided between sapwood and heartwood. Figure 1. Sapwood is xylem tissue containing living cells, usually around the outside circumference of a tree cross-section. Heartwood may or may not be present. Heartwood is xylem tissue without any living tree cells, usually occupying the center of stems and branches. For many temperate trees, there is a color difference between sapwood and heartwood.

Sapwood is the active component of xylem tissues. Less than 10% of sapwood cells are actually living. Most are dead but functional, concentrated in the last growth increment. Young sapwood transports water and materials from roots and is dead when functional. Young sapwood rays (radial parenchyma) and axial parenchyma are alive when functional in storing carbohydrate and defending xylem tissues. Because of the living tissues, carbohydrate stores, and lack of secondary defensive compounds and extratives, sapwood easily decays.

Callused

Around injuries and wounds, new tissue development can be seen as part of (or initiating) sapwood. On surfaces of a sapwood wound, meristatic tissue from the cambium zone or initiated by rays cells will push out onto the surface. These cells will limit oxidation, minimize water loss, and disrupt surface infection / colonization as part of beginning a compartmentalization process. The undifferentiated cell mass initially seen at a wound surface is termed "callus." As the tissues differentiate from callus into functional layers, the xylem tissue developed is termed "wound wood."

To The Heart

Heartwood is the passive, non-functional component of the xylem. It can have many materials deposited or generated at the sapwood / heartwood interface which can render it more decay resistant than sapwood. The transition zone between sapwood and heartwood can appear sharply defined, but on a cellular scale is wide and filled with unique processes of preparation and material conversions.

Heartwood transformation involves many steps including: programmed death of parenchyma (axial & radial); decrease in metabolic rate; starch depletion; accumulation of extractives and other compounds; and, tyloses are set. The transition area becomes less permeable to water and can cause changes in xylem moisture contents. The transition zone is irregular and does not follow one growth increment's boundary or remain in the same relative position from tree top to bottom.

The three cross-sectional transition patterns are usually categorized into:

1) distinct / sharp / abrupt;

2) semi-gradual; and,

3) gradual (thin transition zone <½").

Sand-Bags

Within cells of the sapwood / heartwood transition zone there is a gradual buildup of waste and specialized chemical precussors with a rapid accumulation / conversion at the boundary. These materials are remains of modified cell contents, including any carbohydrate (starch), chemically reduced into sometimes bio-toxic compounds generally called extractives. Deposition of extractives help set compartment boundaries and slow invading organisms, like decay and discoloration, and minimize oxidation of wood.

Heartwood Differences

There can be four primary types of heartwood or protection wood visible in a tree cross-section. In all types there are no living tree cells. Xylem tissue appearing like heartwood could include:

A) True heartwood is an age-altered wood, but it can become transformed into wetwood or discolored wood;

B) False heartwood is xylem tissue altered by tissue shedding and compartment development;

C) Discolored wood (i.e. pathological heartwood) is sapwood killed and altered by wounds, injury, infection, and sudden tissue death; and,

D) Wetwood is xylem tissue altered by microbes (primarily bacteria and yeast) which colonize a xylem area increasing pH, increasing water content, and lowering oxygen (O2). Wetwood usually begins as an infected sapwood compartment but will survive as true heartwood is generated around the site.

The xylem tissue types appearing to be, but not true heartwood (i.e B, C, & D above) are all associated with injury, compartmentalization, and tissue infection.

Heartwood usually begins to form 3-9 feet high in a stem and tapers like a cone down and up along stem center increments. Heartwood is usually found in roots only near the stem base. First formation age of heartwood ranges from 5 years old (example = *Eucalyptus* spp.) to >100 years old (example = *Fagus* spp. – beech), depending upon species. True heartwood expands with tree age if no other injury or infection occurs – expanding more rapidly under tree stress and expanding more slowly under better growth conditions.

Changing Formation Rates

The rate of sapwood area growth and diameter expansion is great during good growing conditions. During these same good conditions, heartwood area still expands but at a reduced rate. Sapwood area growth is reduced during environmental stress and site constraints. During these poor growth conditions, heartwood area accelerates at a greater rate. Figure 2.

If sapwood area accumulation (not diameter inches or circumference) remains constant over several growing seasons, this equates to steady growth rate and tree productivity. If heartwood area accumulation is accelerating and sapwood area is declining, the tree has a declining growth rate and decreasing productivity. If heartwood area accumulation is decelerating and sapwood area is accelerating, the tree has an expansive growth rate and increasing productivity.

Heartwood Exposure

Shallow injury and damage to sapwood is usually sealed off quickly and effectively. Shallow wounds are defined by being within a 100% sapwood area. Wound depth is not critical as long as the wound is surrounded by 100% sapwood. These type of shallow wounds stimulate the strongest compartmentalization and defense process because of the presence of living cells and stored carbohydrate (i.e. fuel for compartmentalization.) Figure 3.

A deep wound (regardless of the actual depth of damage into xylem tissue) is any wound penetrating into heartwood. A small branchlet or huge stem could both have heartwood, and cutting into the heartwood area of xylem tissue in either represents a deep wound. A deep wound is more difficult to defend against because all the cells are dead and can not respond, and the chemical residue positioned in heartwood has a limited defense capability. Figure 4 provides a heartwood exposure assessment for branch wounds or pruning cuts.

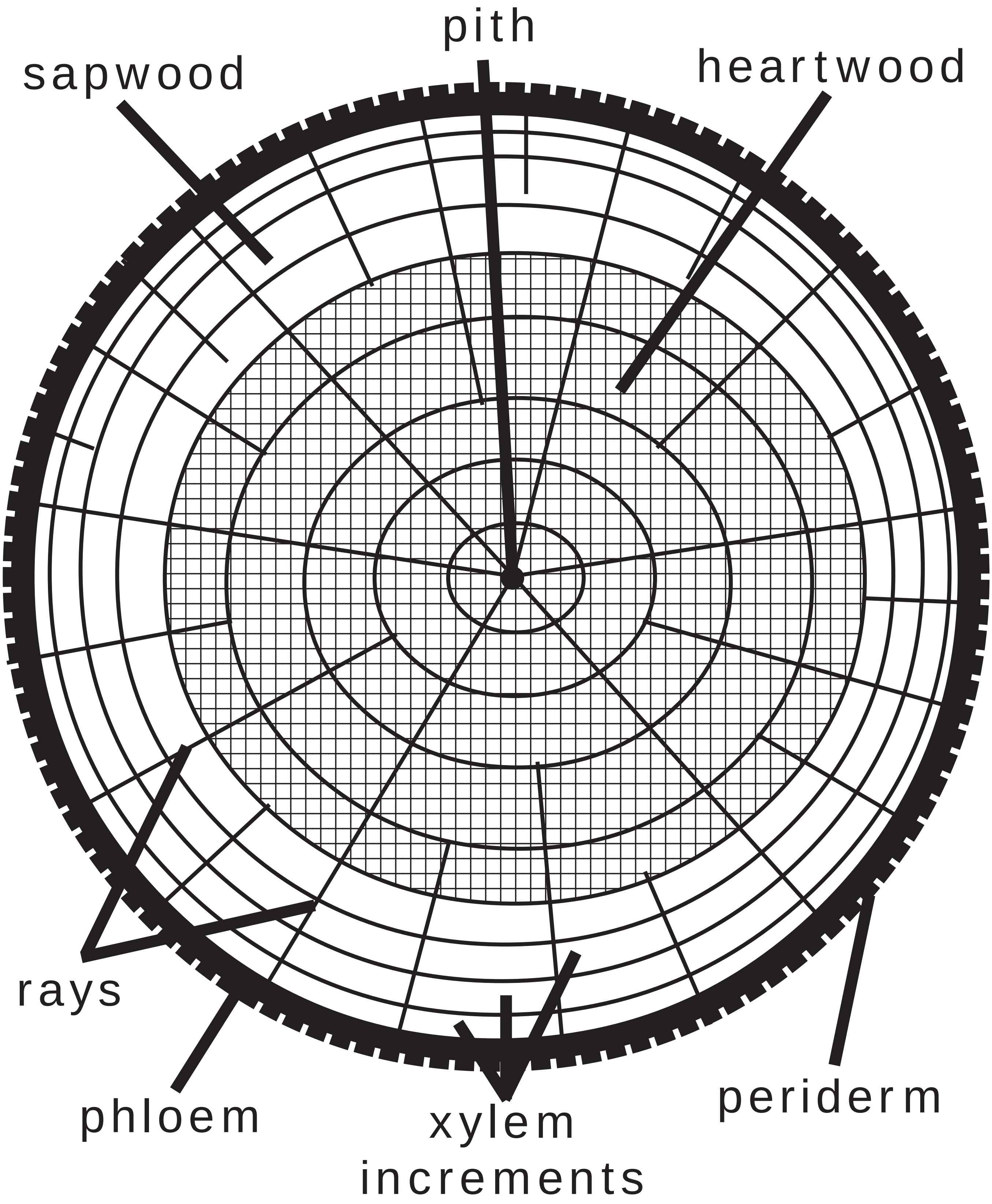

Figure 1: Diagram of stem cross-section.

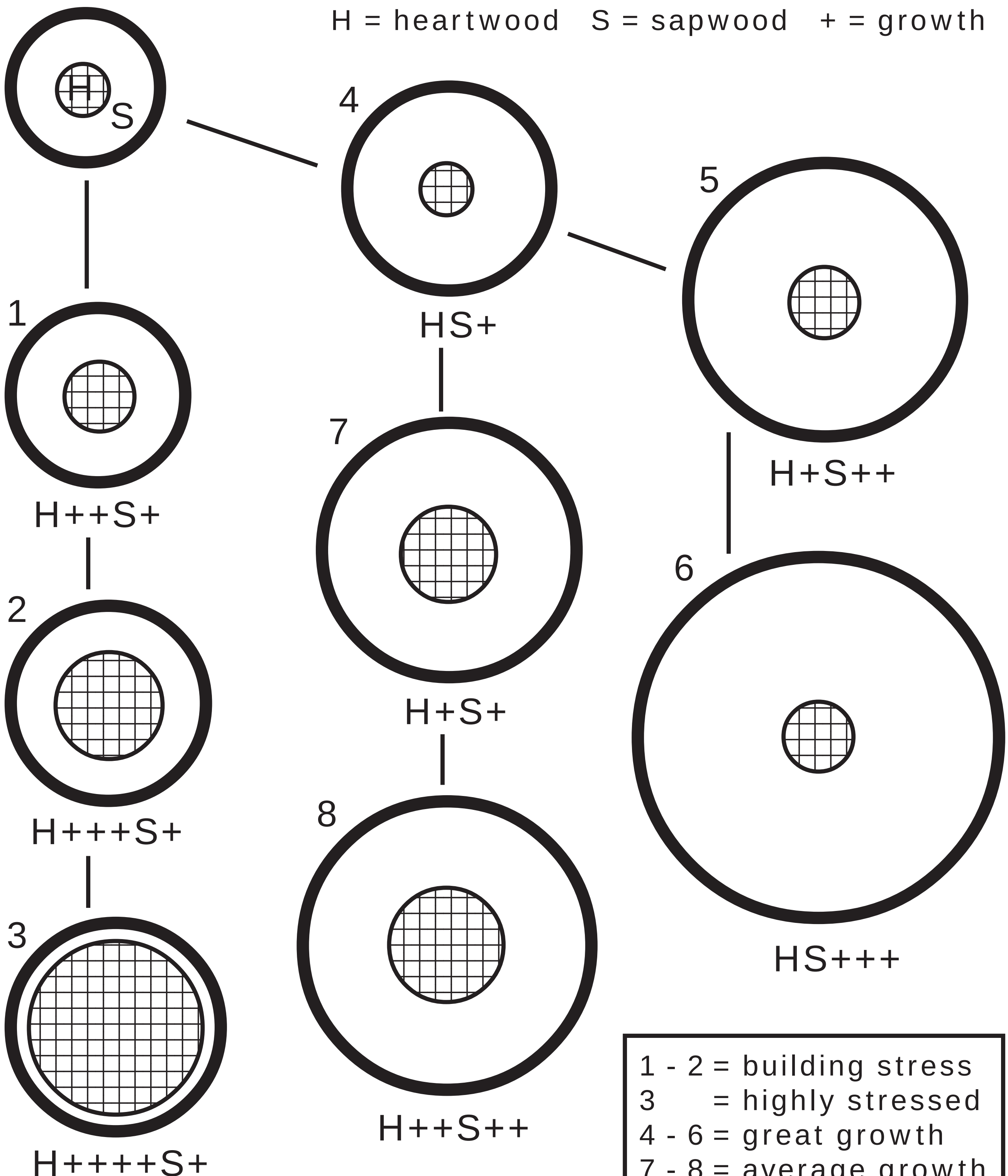

Figure 2: Diagram showing various cross-sectional sapwood / heartwood expansion and growth combinations representing different environmental constraints on trees.

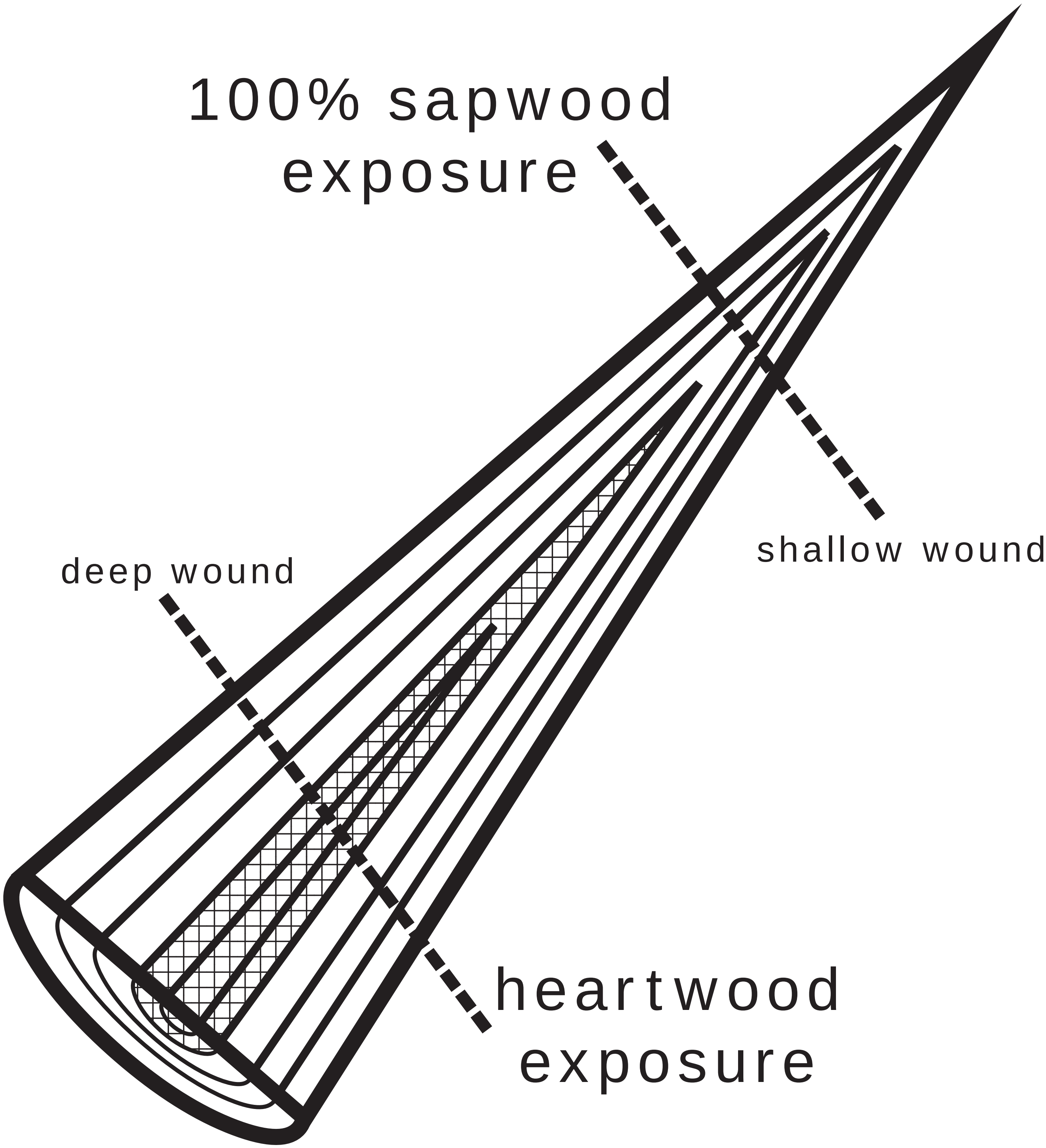

Figure 3: Diagram of a deep cut and a shallow cut using heartwood exposure to gauge relative wound depth.

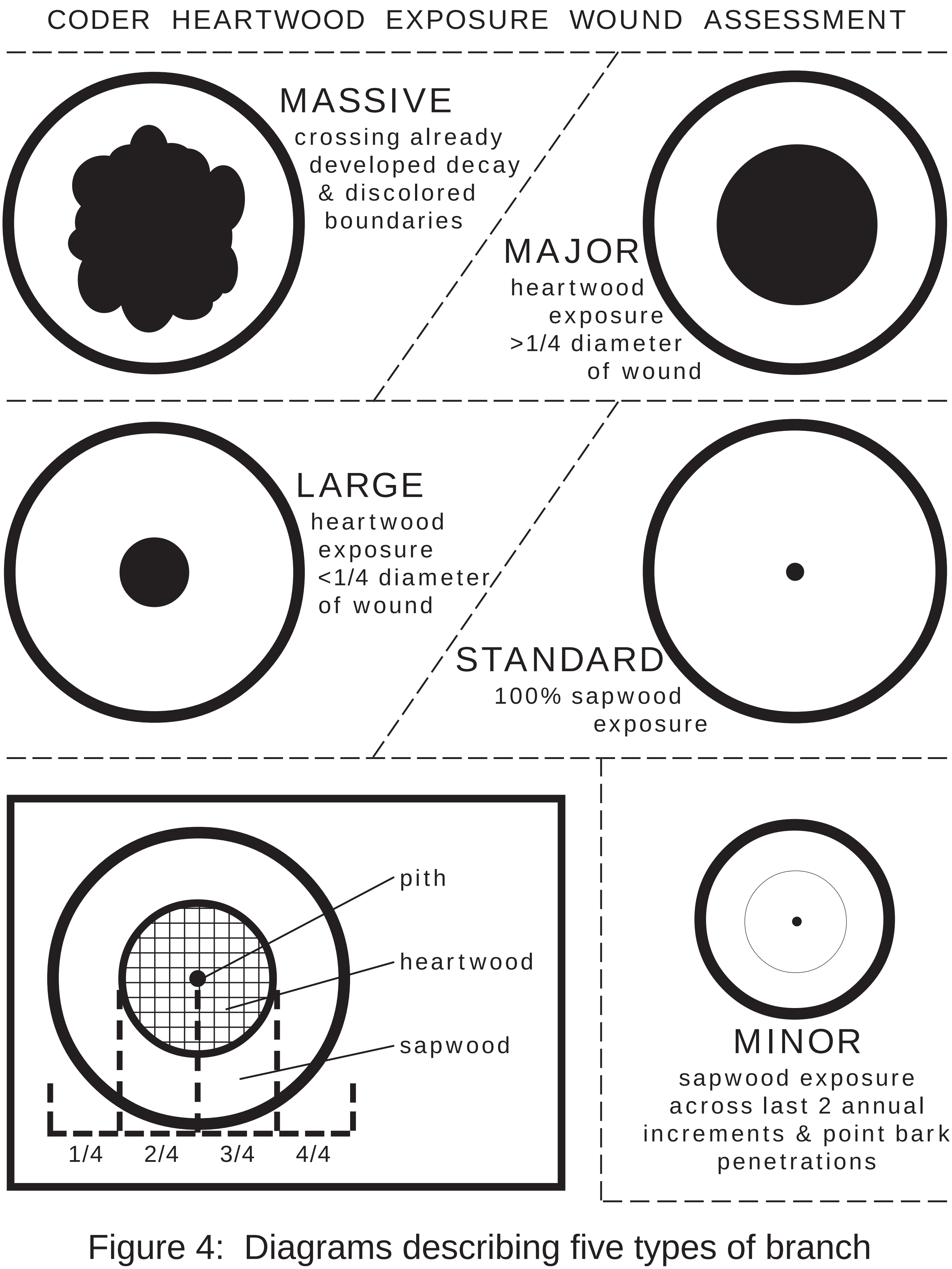

Figure 4: Diagrams describing five types of branch wounds using heartwood exposures on wound face.