CHAPTER 7: COMPARATIVE ANATOMY of PITH in BRANCHES and RAMETS of COMMON SPECIES of DICOTYLEDONOUS and CONIFEROUS TREES and, WOODY SHRUBS.

7.1 Introduction

7.1.1 The goal

In identification of genus or species of branches, using the established keys to identify heartwood may help, but not always, because branch tissue is mainly sapwood not heartwood. Sapwood and heartwood are anatomically different as reviewed in Chapter 6. The anatomy of sapwood in branches is living tissue that varies with age. In small branches it may never reach heartwood formation.

In the structure of stem and branches there is a central core called the pith (Fig. 7.1). It is also called medulla and ground tissue. There are anatomical features of the pith that maybe unique to specific genus or species that may assist in identification. Thus a comparative anatomy was undertaken of the pith in branches and ramets of a group of common NW Coast North America dicotyledonous (dicot) and coniferous trees and woody shrubs that would have been used in ethnographic artifacts. The goal was to determine if by comparative anatomy of the pith anatomy can the samples be identified at least to genera.

Ramets are stems of woody shrubs that are produced annually from buried rhizomes or surface stolons of a clone. They may live for one or several years depending on a species. For example, Gaultheria (Salal) and Rubrus spectabilis (Salmon berry) are woody shrubs that produce each year new stems (ramets) that grow from a clump of buried rhizomes (underground stems). These ramets can eventually become independent plants and are genetically the same as the parent. Ramets are stem in origin thus their root is an adventitious root that may show some stem anatomical characteristics.

Ramets may live for one or many years. For example ramets of Salal may live up to twenty years and produces annual growth rings of 2\textsuperscript{nd} xylem, where as Salmon berry lives up to only 5 years +/-, and produces only one 2\textsuperscript{nd} xylem growth ring but the pith increases in size with age. With woody tree dicots the branches may live for years and will show their age by the number of growth rings of 2\textsuperscript{nd} xylem.

7.1.2 Pith characteristics Fig.7.1

7.1.2.1 Development of pith
Fig. 7.1 Pith development in the growth of an angiosperm, dicotyledonous woody shrub branch. With permission Kantharal gowda gkraj-bg@yahoo.co.in

The general anatomy of pith development and variable characteristics are similar for dicotyledonous and coniferous branches. Fig. 7.1 shows the apical meristem at the tip that produces the embryonic tissues: the protoderm that produces the bark; the ground meristem that produces the outer cortex and central pith; and the procambium that produces primary xylem and primary phloem.

The primary xylem tissues during its growth may further differentiate and forms small thin walled primary protoxylem and large thick walled primary metaxylem cells. These primary xylem cells make small bundles around the outer margin of the pith. The amount and size of these cells in the vascular bundles and because of its contact to the pith, may assist in pith species identification. This is shown in Fig. 7.1 in the one and three year old stem diagrams.
7.1.2.2 Characteristics of central pith

The primary tissue groups, called primary vascular bundles, take different shapes and sizes and appear as enlargements around the margin of the pith ring giving it it’s unique shapes. This is shown in Fig.7.1. in the three year old stem. Thus they are diagnostic features for identification of different species. In Fig.7.1, the pith has a shape called a polyarch-meaning it has many arches. These arches are caused by the position of the primary vascular bundles. This is just one example of the pith shapes. Some are elliptical, elongated, or irregular as will be seen in the following section.

As already mentioned, the ground meristem produces the central pith. As the stem ages the central pith (Fig.7.1) is present and shows a constant shape and little change in size. On examination of the anatomy of branches from a number of different species it was noted that the central pith cells had different shapes and sizes that may be useful for species or genus identification. In most branches with at least one year’s 2nd xylem growth the pith size and shape is constant. In a few species, after a certain number of years growth the pith may enlarge, or may go through disintegration by autolysis--self hydrolysis- leaving a partial or complete hole (lacuna) thus it is a species specific feature and may aid in species identification.

Pith is mainly made up of spongy, flexible, thin walled parenchyma cells. These are composed solely of cellulose cell walls and are joined together with hemicelllose and pectin. Some pith cells may become lignified, usually due to stem injury. In specific species the pith cell size and shape varies, i.e., circular, elongate, etc., and the cells may show different relationships to adjacent cells, i.e. closely packed or free.

There are many different functions of pith parenchyma cells. Some cells are filled with air giving stems lightness and bending ability. Its light weight allows long stems to bend without breaking. Some pith cells are involved in starch storage. In stem tissue injury the pith cells, because they are living cells, can regenerate.

In early development the pith cell walls are commonly white but some may become brown because of the presence of polyphenolics for biocidal protection, and some have species specific colors. Commonly in species with young small branches chlorophyll is present and functions in normal photosynthesis.

In review, all growth stages of the branch, the central pith, shown in Fig.7.1. retains a constant specific shape once formed and undergoes little change in size over the three years. On examination of the anatomy of branches from a number of different species it was noted that the central pith of the different species had different anatomical shapes due to the arrangement of the procambium bundles and that these may be useful for species or genus identification. Some appeared as tetrarchs, star shaped, circular, elongate etc. In most dicot trees, the piths are very small. In the case of ramets it is characteristically very large and takes at least half the width of the ramet.
7.1.3 Ethnographic use of pith

Ethnographic use of pith has been mainly for paper using specific plants species. The pith of the plant Tetrapanax papyrifera – rice paper plant – was used to make Chinese rice paper for paintings and artificial flowers. The stems contained pith that was 25-50mm in diameter. The pith was removed and cut in small length. These are called rods. With a special sharp knife the pith is pared of around the rod to make a continuous thin sheet of paper. The paper sizes were approximately 3.5 inches square or 10x12 inch. It was used in China for paintings etc and making decorative small plant stems.

The original pith helmets were made from sola, Aeschynomene aspera, an Indian swamp plant, or A. paludosa, but it is the secondary xylem that is used, not the pith. The common name is balsa wood.

Within ethnographic groups, pith has been reported to be used in fishing gear as a buoyant assistance and in making games.

Any ethnographic object that has branches, as a part of its structure, it may still have the pith with it. Knowing the anatomy of pith cell, because of its thin walls, mechanical features and water adsorbancy, it is necessary to in making logical conservation care.

7.1.4 Methods of analyses

For photography of dicot samples anatomical features, free hand transverse (cross) sections of the samples were made with a single edged razor blade. Sectioning from an artifact requires permission from the owner and a conservator. Only a very small sample is required and it should not destroy any significant ethnographic or culturally information or important. The sections are mounted in water. After use the slide with the sample should be appropriately labelled, packages, and stored with the artifact for future research if necessary.

The cut sample commonly has fractures, due to cutting, but it does not interfere with tissue anatomy interpretation. These unstained free hand sections are presented in preference to histologically stained preparations, because they have enough inherent color for contrast of tissue and cell details needed for identification. The natural color is often an identifying feature. In this method it is much less time consuming than histological preparations and it does not involve any chemicals and is much less expensive. The present method is a chemical free, green approach. Only in a few cases have the fresh tissue been stained with dilute saffranin for lignin presence.

Preferably, hydrated samples are the easiest to use. The dicot samples were of living tissue that is normally hydrated. Archaeological samples from wet sites are commonly hydrated. The gymnosperm photographs used in this research are of histologically prepared slides - and a few of fresh tissue. They are used to verify some of fine details of the cells etc. In perusing the research of the detailed anatomy, histological preparations of samples were necessary. In using artifact samples one is looking for salient feature for identification.

The plant family name as well as genus and species is used because in some cases the pith characteristics are family specific. The samples are presented alphabetically according to family for ease of finding information.
7.1.5 The samples and families

In this study the anatomy of the pith of branches of seven conifers and 13 dicot trees, woody shrubs and ramets is presented. The family name is given because species in the same family commonly show similar pith characteristics and are grouped together and thus are presented alphabetically according to family.

**Dicots Samples: in order of family**

*Acer circinatum*- vine maple tree branch. Aceraceae family
*Acer sp.*- red maple tree branch. Aceraceae family
*Mahonia aquifolium* - Oregon grape ramet. Berberidaceae family
*Alnus rubra*- red alder tree branch, Betulaceae family
*Corylus sp.* - horticultural hazelnut tree branch. Betulaceae family
*Symphoricarpus albus*- snowberry ramets. Caprifoliaceae family
*Gaultheria shallon* –salal ramet. Ericaceae family
*Ribes sanguineum* – flowering- current ramet. Grossulariaceae family
*Prunus sp.*- Bing cherry, horticultural species, tree branch . Rosaceae family
*Rosa nutkana*- Nootka Rose ramet. Roseaceae family
*Rubus spectabilis*- salmon berry ramets. Rosaceae family
*Tilia americana*- linden tree branch, bass wood. Tiliaceae family
*Vitus sp.*- grape horticultural ramet. Vitaceae family
*Perovskia atriplicifolia*- Russian sage, herbaceous perennial, annual stem. Lamiaceae family

**Gymnosperm samples: in order of family**

*Cupressus nootkatensis* (*Chamaecyparis nootkatensis*), yellow cedar. Cupressaceae family.
*Thuja plicata* – western red cedar. Cupressaceae family
*Abies amabilis*- pacific silver fir, Pinaceae family
*Picea sitchensis*- Sitka spruce. Pinaceae family.
*Pseudotsuga menziessi*- Douglas fir. Pinaceae family.
*Tsuga heterophylla*-hemlock. Pinaceae family.
*Taxus brevifolia* –yew. Taxaceae family.
7.2 Pith anatomy of dicot trees and woody shrub branches and ramets

(Because of the large number of samples the image titles include descriptive information.)

7.2.1 Pith anatomy in a woody tree branch of *Acer* sp., a red maple-horticultural species, *Aceraceae* (Sapindaceae) family Figs.7.2a-d

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**Figs. 7.2a-d  Pith anatomy in a woody tree branch of *Acer* sp a red maple -horticultural species. mlphoto**

Fig.7.2a red maple sample shows 6 growth rings, branch diameter 1.1cm. It is small which is characteristic for dicot trees.
Fig. 7.2b red maple pith 1.3 mm diameter and the pith cells variable in size and are tightly packed. The large primary tissue vascular bundles, give the pith a six sided hexarch appearance.

Fig. 7.2c red maple the pith cells are round, closely packed and have variable sizes, larger cells in center.

Fig. 7.2d red maple, pith cells diameter 0.2-0.5 mm, mainly larger sizes. This sample was stained lightly with water soluble saffranin, to determine the presence of lignin. The top pink tissue is 2nd xylem tissue stained positive for lignin. The middle yellowish area is primary tissue of vascular bundle. It is these vascular bundles that give it its hexarch shape. It probably has lignin but partially masked by brown polyphenols. The pith cells are without lignin. The pith cells that have a dark outline still have air in the sealed cells.

7.2.2 Pith anatomy of pith of woody tree branch of *Acer circinatum*, vine maple. Aceraceae (Sapindaceae) family Fig.7.3a-e

Fig. 7.3a

Fig. 7.3b

Fig. 7.3c

Fig. 7.3d

Fig. 7.3e

Figs 7.3a-ei Anatomy of pith in a woody tree branch of *Acer circinatum*, vine maple. mlfphoto

Fig. 7.3a *Acer circinatum* branch size - largest 7mm, smaller 3mm. Larger piece may have slightly smaller pith due to compression of multitude of xylem growth rings.
Fig. 7.3b *Acer circinatum*, smaller branch (1 year old) showing polyarch shape of pith. The pith diameter is 1 mm. The light colored ring around outside of the secondary xylem are phloem fiber groups. These are used ethnographically for imbrication in baskets.

Fig. 7.3c *Acer circinatum*, shows larger piece, with hexarch pith shape. The pith diameter is 2 mm and branch 2-3 years old.

Fig. 7.3d *Acer circinatum*, smaller piece showing pith cells 0.05-0.03 mm. This maple has similar family characteristics to the *Acer macrophyllum*, broad leafed maple.

Fig. 7.3e *Acer circinatum*, showing dead twig – 4 years old – showing circular pith with slight polyarch appearance. The brown color is the result of polyphenolics produced by the stem to waterproof and to act as a biocide. Some cells in pith show content.
7.2.3 Pith anatomy of a woody shrub ramet of *Mahonia aquifolium*  Oregon grape, Berberidaceae family

Figs. 7.4a-c

Fig. 7.4a

Fig. 7.4b

Fig. 7.4c

Figs. 7.4 a-c Pith anatomy of *Mahonia aquifolium*, Oregon grape, woody shrub ramet.

milphoto
Fig. 7.4a. *Mahonia aquifolium* shows near circular pith with evenly placed vascular bundles that barely interrupt the circle. The uniform groups of 2nd xylem are separated by distinct ray parenchyma bands. The pith is as wide as the 2nd xylem.

Fig. 7.4b *Mahonia aquifolium* has characteristic groups of primary tissue. Each one is of a similar size, with a fluorescent v shaped cap and a dark region. Each one represents a primary vascular bundle. Extending from each one is double banded 2nd xylem. Each one of the group is separated by broad radial ray. This pattern is unique for this species.

Fig. 7.4c pith cells 0.02-0.04mm, densely packed.

**7.2.4 Pith anatomy of woody tree branch of *Alnus rubra*- red alder, Betulaceae family**

Fig. 7.5a-e

Fig. 7.5aFig. 7.5b

Fig. 7.5c Fig. 7.5d Fig. 7.5e

**Figs. 7.5 a-e. Cross sections of *Alnus rubra* - red alder- woody tree branch. mlfphoto**
Fig. 7.5a *Alnus rubra*, shows the pith remains approx same size in branches of different ages. Different shapes are due to age differences and leaf/branch traces.

Fig. 7.5b *Alnus rubra*, smallest piece, pith triangular in shape, dark brown regions of primary tissue. Pith size 2x2x1.7mm. Red-brown deposits are present in meristematic tissue seen as a line on the center right.

Fig. 7.5c *Alnus rubra*, brown dense line of cambium in leaf/branch trace cells and adjacent primary tissues. This image also shows the presence of red tissue.

Fig. 7.5d *Alnus rubra*, details of above. Dark band in embryonic primary tissue has red color. Pith cells have irregular sizes with thick cell walls.

Fig. 7.5e *Alnus rubra* pith cells variable, 0.05-0.07 mm mostly 0.05mm larger cells towards center.

### 7.2.5 Pith anatomy in a woody tree branch of *Corylus sp.*, horticultural hazelnut.
*Betulaceae family*

Figs. 7.6a-d

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Fig. 7.6a

Fig. 7.6b

Fig. 7.6c

Fig. 7.6d

Figs. 7.6a-d. Anatomy of pith in a woody tree branch *Corylus sp.*, horticultural hazelnut.

milphoto
Fig. 7.6a *Corylus* sp, three samples, right to left: 10mm-1 growth ring; 13mm- 2 growth rings growth rings; and 15mm–3 growth rings. The pith sizes are similar (2-2.5mm), and appear circular. The green color is due to the presence of chlorophyll. This is a species specific characteristic. The pith is outlined by a dark color.

Fig. 7.6b *Corylus* sp, pith has 5-6 primary tissue bundles making it look polyarch. The pith cells are brown in color and appear circular.

Fig. 7.6c *Corylus* sp , the smaller sample shows the brown colored pith cells and chlorophyll restricted to the primary vascular bundle ring.

Fig. 7.6d *Corylus* sp the pith cell walls are brown, the cells appear circular and are attached to each other but not angularly. The size varies from 0.02-0.05mm.
7.2.6 Pith anatomy of woody shrub ramet of *Symphoricarpus albus* - snow berry, Caprifoliaceae family Figs.7-7a-d

**Fig. 7.7a**

**Fig. 7.7b**

**Fig. 7.7c**

**Fig. 7.7d**

**Figs. 7.7a-d** pith anatomy of *Symphoricarpus albus* - snow berry. Woody dicot shrub ramet.

**mlfphoto**

Fig.7.7a larger branch 11mm, 4 growth rings, smaller 3mm diameter. Both show the central hole of the pith (lacuna). The lacuna is a result of autolysis (self digestion).

Fig.7.7b larger piece, shows empty pith region, 6 +/-, sided pith with a green primary tissue region lined with a few rows of brown pith cells. Pith diameter 2mm.

Fig.7.7c almost continuous green primary tissue bundles, 2nd xylem with many narrow wood rays and a few layers of rich brown pith cells on its margin and large lacuna.

Fig.7.7d pith cells, tightly angularly packed, variable in size, 0.04-0.06mm and shapes, brown cell walls colored.
7.2.7 Pith anatomy of woody shrub ramet of *Gaultheria shallon*-salal. Ericaceae family, Figs. 7.7a-d. mlphoto

![Fig.7.7a](image1)

![Fig.7.7b](image2)

![Fig.7.7c](image3)

![Fig.7.7d](image4)

Figs. 7.7 a-d Pith anatomy of woody shrub ramet of *Gaultheria shallon*-salal. mlphoto

Fig. 7.7a *Gaultheria shallon* ramet 7mm diameter, one growth ring of xylem

Fig. 7.7b *Gaultheria shallon*, pith size 2x2x2 mm, triangular, one growth ring of xylem.
Fig. 7.7c Gaultheria shallon, pith with two groups, many large lacuna (empty space) surrounded by small parenchyma pith cells, irregular to circular in shape, containing starch, making then appear dark. The lacunae vary throughout in size.

Fig. 7.7d Gaultheria shallon large lacunae circa 0.07mm and small parenchyma cells circa 0.05mm that contain many small starch bodies.

7.2.7 Pith anatomy of woody shrub ramet of Ribes sanguineum – flowering current, Grossulariaceae family, Figs. 7.9a-d

Fig. 7.9a

Fig. 7.9b

Fig. 7.9c

Fig. 7.9d

Figs. 7.9a-d pith anatomy of Ribes sanguineum (flowering current), a woody shrub ramet.

mlfphoto
Fig. 7.9a *Ribes sanguineum* samples diameters: two largest 15mm, central sample 12mm. The wood of the oldest 2nd xylem growth ring has characteristic white color. The pith is extremely small with only fragments present, appears almost hollow, and has a natural pink color.

Fig. 7.9b *Ribes sanguineum* pith is 1mm in diameter, circular with primary vascular bundles making it polyarch-like. It shows deterioration by autolysis- self digestion, leaving a lacunae, and dissociation of the pith cells.

Fig. 7.9c *Ribes sanguineum*, shows details of some near circular pith cells, sizes range 0.03-0.05mm with natural pink color.

Fig. 7.9d *Ribes sanguineum*, there appears to be spaces between the groups of pith cells that are not delineated by a cell wall and thus must be due to autolysis.

7.2.9 Pith anatomy of tree branch *Prunus sp.*, Bing cherry, horticultural species, Rosaceae family Figs. 7.10a-d
Fig. 7.10c, Fig. 7.10d

**Figs. 7.10a-d Pith anatomy of *Prunus* sp.- Bing cherry, horticultural species, tree branch.**

*mlphoto*

Fig. 7.10a, the pith is very small in diameter and remains close to one size as the branches increase in age and size. Branch sizes: 15mm with 5 growth rings; 13mm-4growth rings; 10mm- 3growth rings. Pith remains close to 1.5mm in diameter.

Fig. 7.10b shows pith polyarch shaped with 5-7 points, primary xylem region obvious. Some of the points may be leaf traces. Pith diameter 1.5mm. Large primary tissue vascular bundles a brown color. Radial rays in 2nd xylem many and obvious.

Fig. 7.10c, shows details of brown primary tissue bundles between 2nd xylem and pith, metaxylem xylem cells shown at tip of arches and towards center whitish region of protoxylem. The many radial ray parenchyma bands in 2nd xylem are variable in size and obvious due to brown color.

Fig. 7.10d, the pith cells are variable sizes 0.02-0.05 mm, appear loosely packed and surrounded by brown material that may be a gum. Gummosis is a general non specific condition of *Prunus* trees.
7.2.10 Pith anatomy of woody shrub ramet of *Rosa nutkana*- Nootka Rose. Roseaceae family Figs. 7.11 a-d

Fig.7.11a-Fig7.11b

Fig.7.11c-Fig.7.11d

Figs. 7. 11a-d pith anatomy of *Rosa nutkana* - Nootka Rose, dicot woody shrub ramet, Roseaceae family. mlfphoto

Fig.7.11a branch – 3 growth rings-diameter fresh/ dried 15/ 11mm, large circular white pith, ramet characteristic.

Fig.7.11b large pith, 3 growth rings of secondary xylem. Pith cells variable in size and shape, crackle appearance, unique appearance.

Fig.7.11c pith cells uniquely elongate and irregular shape and variable in size 0.4 - 0.2mm, mostly 0.4mm. Primary vascular bundles adjacent to the region pith cells are organized around it, pointing towards center. Dark circles are air bubbles from slide preparation.

Fig.7.11d shows more groups of cells around a central dark colored region in the middle of the pith with elongated irregular cells, that are species specific shapes.
7.2.11 Pith anatomy of woody shrub ramet of *Rubus spectabilis*- salmon berry. Rosaceae family. Figs 7.12a-d.

Fig. 7.12a the diameter of the ramet is 1cm and the pith 7mm. The wood is very hard. It has 1 years growth ring of 2nd xylem. The large pith is a ramet characteristic.

Fig. 7.12b shows characteristic wide bands of ray parenchyma in 2nd xylem The pith cells are densely packed together. The pith diameter is 7mm.

Fig. 7.12c shows the large number of primary xylem vascular bundles from which develop the wide, green ray parenchyma bands. These rays are sites of photosynthesis. The many vascular bundles give the pith an irregular polyarch margin. Many of the irregularly shaped pith cells are still filled with inherent air. Small primary tissue cells can be seen adjacent to the pith. There is only one growth ring despite the fact it is several years old.

Fig. 7.12d, shows the variable sizes and shapes of the pith cells. The pith cells are irregular size circles and have a material between the cells, adhering them together. Pith size varies 0.03-0.07mm.
7.2.12 Pith anatomy of tree branch of *Tilia americana*, linden tree, bass wood, Tiliacea family. Figs. 7.13a-e

Fig. 7.13a

Fig. 7.13b

Fig. 7.13c

Fig. 7.13d

Fig. 7.13e

Figs. 7.13 a-f pith anatomy of *Tilia americana*, linden tree, bass wood, dicot tree branch.

Fig. 7.13a branch sizes 13mm-4 growth rings (gr); 11mm-3 gr; 10mm-3gr.

Fig. 7.13b smallest piece shows a few large empty cells. The coloration may be the result of air oxygenation.

Fig. 7.13c largest piece, pith circa 1mm in diameter. Both b and c show unusually large empty cells that are probably protoxylem cells that surround the pith.

Fig. 7.13d and Fig. 7.13e, shows details of empty cells that are adjacent to the pith. They are 0.3-0.1mm. They may be skewed because of a slightly angular cutting. The large empty structures do not show epidermal secretary cells at their margins thus are unlikely to be mucilaginous ducts thus probably protoxylem cells. There presence in a ring is a salient feature for *Tilia* branch identification.
Fig.7.13f, variable size of pith cell sizes 0.05-0.03, tightly packed.

7.2 13. Pith anatomy of woody vine ramet of *Vitus*, grape horticultural sp. Vitaceae family. Figs.7.14a-d.

Fig. 7.14a  Fig. 7.14b

Fig. 7.14c  Fig. 7.14d

**Figs.7.14a-d pith anatomy of *Vitus*, grape horticultural sp. Dicot woody vine ramet.**

*mlfphoto*

Fig.7.14a the branch diameters vary from 6mm-1.5 cm and the piths vary from 2-3mm.

Fig.7.14b the pith is circular and surrounded by primary xylem vascular bundles that give the pith an irregular edge. The green ray parenchyma bands between 2nd xylem bands are sites for photosynthesis.

Fig.7.14c at top is 2nd xylem band with circular vessels separated by green radial rays. Below is a layer of clear cells of protoxylem groups of the vascular bundles. Below are pith cells. The black pith cells contain air. The pith cells sizes vary between 0.01-0.035 mm.

Fig.7.14d the parenchyma cells sizes vary between 0.01-0.035 mm. larger at outer edge smaller towards middle. Pith cells mainly large irregular shapes fitting into each.
### 7.2.14 Table of salient features of pith in dicots branches and ramets

<table>
<thead>
<tr>
<th>Tree/shrub branch, /ramet/</th>
<th>Age of sample</th>
<th>Pith diameter mm/color</th>
<th>Pith shape</th>
<th>Pith cell shape and characteristics</th>
<th>2nd xylem</th>
<th>Salient features</th>
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<tbody>
<tr>
<td><strong>7.2.1 Acer</strong>&lt;br&gt;tree/branch&lt;br&gt;-red maple</td>
<td>-6 yrs</td>
<td>-1.3</td>
<td>-round to polyarch from primary vascular bundles (pvb)</td>
<td>-variable 0.04center 0.02edge</td>
<td>-circular packed</td>
<td>-small ray parenchyma bands between 2nd xylem ray</td>
</tr>
<tr>
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<td>-1- and 2-3yr</td>
<td>-1 and 2</td>
<td>-round to polyarch</td>
<td>-variable 0.03edge-0.05center</td>
<td>-circular</td>
<td>-small ray parenchyma bands between 2nd xylem</td>
</tr>
<tr>
<td><strong>7.2.4 Alnus rubra</strong>&lt;br&gt;-red alder&lt;br&gt;-tree branch</td>
<td>-2 and 4yr</td>
<td>-2x2x1.7&lt;br&gt;-chlorophyll 1 in pith</td>
<td>-tetrarch points with pvb -brown concentration at pvb points</td>
<td>-0.05-0.07 mostly 0.05-thick walled</td>
<td>-circular</td>
<td>-narrow ray parenchyma arise in an arch from pvb</td>
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<tr>
<td><strong>7.2.5 Corylus sp.</strong>&lt;br&gt;-hazelnut&lt;br&gt;-tree branch</td>
<td>-1 and 3 yr</td>
<td>-2 x2.5&lt;br&gt;-with chlorophyll 1</td>
<td>-irregular circular polyarch because of extended pvb</td>
<td>-variable 0.02-0.05</td>
<td>-circular &amp; angular-fit in tightly</td>
<td>-narrow ray parenchyma bands</td>
</tr>
<tr>
<td>Tree/shrub branch, /ramet/</td>
<td>Age of sample</td>
<td>Pith diameter mm/color</td>
<td>Pith shape</td>
<td>Pith cell size mm</td>
<td>Pith cell shape and characteristics</td>
<td>2\textsuperscript{nd} xylem</td>
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<td><strong>7.2.7</strong>Gaultheria <em>shallon</em> -salal -shrub.,ramet</td>
<td>-one growth ring-others will occur annually</td>
<td>-2x2x2</td>
<td>-tetrarch</td>
<td>-0.02-.05- and 0.07 -two types</td>
<td>-irregular sort of circular</td>
<td>-obvious few large ray parenchyma</td>
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<tr>
<td><strong>7.2.3</strong>Mahonia <em>aquifolia</em> -oregon grape -shrub branch</td>
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<td>-two samples- 3 and 2</td>
<td>-nearly circular with many small pvb that ring the circle - ring of v shaped caps of primary xylem -side by side</td>
<td>-0.02-0.04</td>
<td>- mainly circular -densely packed</td>
<td>-broad ray parenchyma -2\textsuperscript{nd} xylem in narrow , regular, pie slice pieces</td>
</tr>
<tr>
<td><strong>7.2.9</strong> Prunus <em>sp.</em> - horticultural cherry -tree branch</td>
<td>-5,4 and 3 growth rings in three samples.</td>
<td>-pith 1.5</td>
<td>-Star shaped polyarch with large pvb -obvius ray parenchyma bands</td>
<td>-0.02-0.05</td>
<td>-circular -- obviously not attached to each other</td>
<td>-brown gum in pvb and pith</td>
</tr>
<tr>
<td><strong>7.2.8</strong> Ribes <em>sanguineum</em> -flowering current -shrub branch</td>
<td>-oldest two ,other 1 growth ring -youngest growth ring white</td>
<td>-1 in three samples</td>
<td>-circular with pvb under going autolysis and disorganized</td>
<td>-0.03-0.05 with natural pink color</td>
<td>- near circular pink colored</td>
<td>-few narrow ray parenchyma</td>
</tr>
<tr>
<td>Tree/shrub branch, /ramet/</td>
<td>Age of sample</td>
<td>Pith diameter mm/color</td>
<td>Pith shape</td>
<td>Pith cell size mm</td>
<td>Pith cell shape and characteristics</td>
<td>2nd xylem</td>
</tr>
<tr>
<td>--------------------------</td>
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</tr>
</tbody>
</table>
| **7.2.10 Rosa nutkana --nootka rose**  
-shrub ramet | -one growth ring  
-on aging can form annual growth rings | -3 | -circular white | -0.2-0.4 | -uniquely elongate and irregular arising from pvb | -few ray parenchyma bands – narrow xylem ring | -uniquely elongate pith cells  
-extremely large pith cell  
-white pith |
| **7.2.11 Rubrus spectabilis**  
-salmon berry  
-shrub ramets | -one growth ring  
-only one 2nd xylem growth ring throughout life of ramet  
-7 | -circular white  
-ringed with small pvb | -0.02-0.04 | -mixed shapes and sizes  
-some with air storage  
-cells connected | -broad ray parenchyma bands arising from pvb | -broad ray parenchyma and 2nd xylem bands make up characteristic design  
-mixed pith cell sizes and shapes  
-large pith |
| **Sambucus (no sample)**  
 | Only one growth ring throughout life of ramet | -5 | Circular | | Some pith cells with contents |
| **7.2.6 Symphoricarpos albus**  
-snow berry  
-shrub branch | -4 growth rings in older sample one in youngest  
-2, same in both samples  
-brown colored cells | -circular hole rimed with pith cells | -0.04-0.06 | -circular to angular  
-tightly attached  
-angularly | chlorophyll in xylem  
-many, very narrow ray parenchyma bands | Hole due to autolysis  
-lining of brown pith cells on margin- |
<table>
<thead>
<tr>
<th>Tree/shrub branch, /ramet/</th>
<th>Age of sample</th>
<th>Pith diameter mm/color</th>
<th>Pith shape</th>
<th>Pith cell size mm</th>
<th>Pith cell shape and characteristics</th>
<th>2\textsuperscript{nd} xylem</th>
<th>Salient features</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.2.12 \textit{Tilia americana} -linden tree, bass wood -tree branch</td>
<td>-4 and 3 growth rings</td>
<td>-1-1.5</td>
<td>-circular polyarch</td>
<td>parenchyma cells -0.05-0.03 -mucilage ducts 0.3-0.5 -in a ring close to pvb ring</td>
<td>- parenchyma near circular -closely packed in center of pith -cells not attached</td>
<td>-many very narrow ray parenchyma bands , not easily seen</td>
<td>-ring of large mucilage ducts -polyarch shaped pith</td>
</tr>
<tr>
<td>7.2.13 \textit{Vitis} horticultural sp.,</td>
<td>-produces annual growth rings</td>
<td>1.2-3 Varies with age</td>
<td>-circular to polyarch -scalloped edge by many pvb -golden brown</td>
<td>0.01-0.03 -mainly large -smallest outside -dark brown</td>
<td>-circular to angular and closely packed and attached</td>
<td>-obvious , many ray parenchyma bands</td>
<td>-large pith -scalloped pith margin -bands of ray parenchyma and 2\textsuperscript{nd} xylem characteristic design -brown color of pith cells</td>
</tr>
</tbody>
</table>

Table 7.1. Salient anatomical features of branches and ramets of some dicot trees and woody shrubs of some common North American species.(pvb)
7.3 Pith Anatomy of Branches of Common American North West Coast Gymnosperm Species.

7.3.1. Pith anatomy of *Cupressus nootkatensis* (*Chamaecyparis nootkatensis*), yellow cedar 5 year old branch. Cupressaceae family.

Fig. 7.15a and b are pith anatomy of *Cupressus nootkatensis* (*Chamaecyparis nootkatensis*), yellow cedar 5 year old branch Figs. 7.15 a-b. mlphoto

Fig. 7.15a, the wood was unusually hard and fractured with sectioning. The photo shows a very small elongated pith.

Fig. 7.15c, the central region is elongated, 0.1x0.45mm. The larger cells are metaxylem cells 0.05 mm +/- and smaller cells protoxylem 0.01-0.03mm/-.. At the ends of the arms are the large thick walled metaxylem cells-. These are in the region of the primary vascular bundles there does not appear to be any pith cells. The first ring of 2nd xylem has thick walled and irregular shaped compression wood cells. All branches have compression wood and asymmetrically oriented pith.

7.3.2 Pith anatomy of *Thuja plicata*– western red cedar 4 year old branch. Cupressaceae family Figs. 7.16a-c
Figs 7.16a-c pith region anatomy of *Thuja plicata*– western red cedar (WRC) 4 year old branch. mlphoto

Fig.7.16a, the pith region shape is an obvious four armed (tetrarch).

Fig.7.16b, the pith region size including arms is 0.4 x 0.3 mm. Central cells 0.15mm in diameter. It shows on the right side the dark thick walled cells of compression wood. This pith region is similar to yellow cedar (Figs. 7.15a and b). It is unfortunate that the sample is fractured but it shows similar pith. Both WRC and yellow cedar are in the same family – Cupressaceae.
Fig. 7.16c the pith region is made up of central large metaxylem cells with contents in central region and some smaller protoxylem cells (0.01-0.02mm) under edges of arms. The central hole may be a lacuna. There are no pith cells.

7.3.3. Pith anatomy of *Abies amabilis*, pacific silver fir 4 year old branch, Pinaceae family

Figs 7.17a-c

**Fig.7.17a**  
**Fig.7.17b**  
**Fig.7.17c**

Figs.7.17a-c the pith anatomy of *Abies amabilis*, pacific silver fir 4 year old branch. mlphoto

Fig.7.17a, shows a polyarch shaped pith with scalloped margin caused by primary vascular bundle locations. Two needle traces are present and are exactly across from each other reflecting the flat, opposite, position of the leaf needles on the branch. The pith diameter is 1.4mm. The dark region to the right-in the 2nd xylem is the compression wood.

Fig.7.17b, shows an inner most dark ring with scalloped edges with metaxylem cell and large internal thin walled parenchyma pith cells. The outer dark circle with scalloped edges is 2nd xylem. The elongated dark region of cells is a needle trace. The pith cells vary in size. They are thin walled and compact with angular joining to each other.
Fig. 7.17c shows the small primary vascular bundles between the thin walled large parenchyma pith cells. The cells at their tips are protoxylem cells. Pith cell size 0.02-0.07 mm.

7.3.4 Pith anatomy of *Picea sitchensis*- Sitka spruce 4 year old branch. Pinaceae family
Figs. 7.17a-c

Fig. 7.17a shows pith shape is a circular polyarch with many primary vascular bundles. The 2\textsuperscript{nd} xylem asymmetry shows the result of presence of compression wood.
Fig. 7.17b shows pith diameter is 0.5mm. Radial ray parenchyma extends outwards from pith into 2nd xylem giving it with arms like a bursting star design. The lower right dense group of protoxylem cells has filled cells suggesting it is a needle (leaf) trace. The radial rays show different thicknesses, the thickest ones will contain a radial resin canal. These would be seen in cross section in tangential view in Fig. 7.5d.

Fig. 7.17c- pith cells size varies (0.02-0.05mm) and shapes. They are thin walled and compact with angular joining to each other. Some of the cells contain contents; the lower large concentration suggests a leaf trace.

7.3.5 Pith anatomy of Pseudotsuga menziessi, Douglas fir 5 year old branch. Pinaceae family Figs. 7.19a-d
Figs. 7.19a-c pith anatomy of *Pseudotsuga menziessi*, Douglas fir 5 year old branch. 

Fig. 7.19a, shows a large pith, diameter approximately 1mm. This pith anatomy is similar with other species in the Pinaceae family. It is a strong polyarch with distinct scalloped edges due to placement of primary vascular bundles. The two angled streaks of ray parenchyma-like bands are needle traces. The asymmetry of 2nd xylem is due to presence of compression wood.

Fig. 7.19b, shows from the middle outwards-the central thin walled pith cells and at their margin, groups of small thick walled metaxylem cells and then a complete ring of first years growth of small 2nd ylem cells still with a scalloped margin. The radial rays are variable in thickness suggesting the presence of resin canals.

Fig. 7.19c, shows variable pith cell sizes- 0.02-0.07mm. Many pith cells are separated by material and others are attached to adjacent cell walls. Some of the largest central empty regions may have been due fractured by sample sectioning or they are lacunae.

Fig. 7.19d, a living Doug fir branch showing scalloped edge and many needle traces that reflect needle position on the branch. There are also variable thicknesses of the radial rays suggesting resin canals. The diameter is 1.2mm-the increase in size is due to its hydrated state as compared to the dehydrated histological preparation. It show first years growth of 2nd xylem also with the scalloped outline. The living cells are filled.
7.3.6 Pith anatomy of *Tsuga heterophylla*-hemlock 5year old branch. Pinaceae family
Figs.7.20a and b

**Figs. 7.20a and b pith anatomy of *Tsuga heterophylla*-hemlock, 5year old branch. mlphoto**

Fig.20a  the pith diameter is small, 0.3mm. The cells in the bands of ray parenchyma are much larger next to the pith region giving it an outstanding bursting star effect. The top right section is compression wood.

Fig. 20b ray parenchyma bands come out like a bursting star. Pith region with noticeably large thick walled metaxylem cells (0.05mm) and smaller primary xylem cell (0.02mm) groups close to the edge of the 2nd xylem cell. There is a central lacuna (0.05mm) hole is surrounded by large thick walled cells. These cells are probably metaxylem cells. They are packed tightly with small spaces between cell to cell corners.

This pith is not similar to the other Pinaceae. The polyarch is not as obvious, there is more emphasis in the ray arms, and there are noticeably fewer and larger pith cells. Taxonomically it is associated with same subfamily as *Abies* but still does not compare with it either.
7.3.7 Pith anatomy of *Taxus brevifolia* – yew 4 year old branch. Taxaceae family Figs. 7.21a-c

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**Fig. 7.21a**

**Fig. 7.21b**

**Fig. 7.21c**

**Figs. 7.21a-c the pith anatomy of *Taxus brevifolia* – yew, 4 year old branch.**

Fig. 7.21a, the pith is small with a ragged circular. The large lower area is compression wood causing a normal off center small pith. The lower half is compression wood.

Fig. 7.21, pith diameter near, 0.21 mm near circular with variable cells sizes. The lobes of 2nd xylem faintly designate the location of primary vascular bundle tissue. The pith is made up of mainly metaxylem cells that range from 0.02-0.04mm and a few thin walled central parenchyma pith cells approx, 0.05mm.

Fig. 7.21 c shows mainly the surrounding primary xylem and a few thick walled metaxylem central pith cells. The extremely large thin walled parenchyma pith cells may have been fractured forming lacunae. Some cells contain a substance. The top left cells show typical thick walled, irregular shaped compression wood 2nd xylem cells.
7.3.7 Salient features of pith of branches of gymnosperm coniferales common North American northwest coast species.

<table>
<thead>
<tr>
<th>SPECIES</th>
<th>Pith diameter-in mm</th>
<th>Pith shape-</th>
<th>Pith cell size in mm</th>
<th>Pith cell shape characteristics</th>
<th>Unique features</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Abies amabilis</em>, Pacific silver fir</td>
<td>1.4mm large</td>
<td>-near circular -polyarch -7 pvb -scalloped</td>
<td>range 0.02-0.07</td>
<td>-irregular</td>
<td>-first 2(^{nd}) xylem arrow,dense. -compression wood, scalloped -needle traces opposite</td>
</tr>
<tr>
<td><em>Cupressus nootkatensis</em> (Chamaecyparis nootkatensis), Yellow cedar</td>
<td>-0.10 x 0.45 very small</td>
<td>elongated narrow without pithcells</td>
<td>metaxylem 0.01-0.03 +/-</td>
<td>-irregular</td>
<td>-first ring of 2(^{nd}) xylem compression wood -largest cells may encircle a lacuna</td>
</tr>
<tr>
<td><em>Picea sitchensis</em>, Sitka spruce</td>
<td>-Large true pith - 0.5mm</td>
<td>-pith with obvious primary vascular bundles. -polyarch - not obviously scalloped</td>
<td>-lots of thin walled pith cells 0.02-0.05 mm</td>
<td>-mostly near circular -packed thin walled cells with minute spaces art angles - variable sizes with larger cells in center and smaller cell towards xylem</td>
<td>-first xylem growth ring compression wood. -no lacunae - first growth ring of secondary xylem not obviously scalloped.</td>
</tr>
<tr>
<td>SPECIES</td>
<td>Pith diameter-in mm</td>
<td>Pith shape-</td>
<td>Pith cell size in mm</td>
<td>Pith cell shape characteristics</td>
<td>Unique features</td>
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<tr>
<td><em>Pseudotsuga menziessi</em>, Douglas fir</td>
<td>-true large pith -1mm -two angled needle( leaf) traces are not opposite to each other.</td>
<td>-polyarch -obviously scalloped margin of 2nd xylem -many primary vascular bundles -scalloped shape margin of secondary xylem</td>
<td>- pith cells vary 0.02-0.07</td>
<td>-variable in size throughout -thin walled pith cells ,some separated by material between cells -some larger cells fractured by sectioning -no lacunae -</td>
<td>first ring of 2nd xylem compression wood with obvious scalloped outer margin .</td>
</tr>
<tr>
<td><em>Taxus brevifolia</em>, Yew</td>
<td>-0.21mm</td>
<td>-ragged circle -margin of 2nd xylem initials -</td>
<td>- mainly metaxylem range 0.02-0.04 mm -partially intact 3-4 thin walled large pith cells 0.05mm</td>
<td>-irregular and fractured</td>
<td>-first ring of 2nd xylem compression wood</td>
</tr>
<tr>
<td><em>Thuja plicata</em>, Western red cedar</td>
<td>-0.4x0.3mm from edges of arms -arm length 0.15mm</td>
<td>-tetrarch of close to equal arm lengths. - may be crushed and appear as only elongate - there are no pith cells only primary xylem cells</td>
<td>-metaxylem cells in pith region ,0.05mm -primary xylem ,0.01-0.02 -lacunae –hole -present</td>
<td>-cells in pith region probably metaxylem -circular with contents, thick walled -some small protoxylem along arm edges.</td>
<td>-first ring of 2nd xylem compression wood</td>
</tr>
<tr>
<td><em>Tsuga heterophylla</em>, a hemlock</td>
<td>0.3mm</td>
<td>-near circular -bursting star with large parenchyma bands.</td>
<td>-metaxylem 0.05mm -protoxylem 0.02 +/- -lacunae- 0.05mm</td>
<td>-all cells thick walled -packed with space between angles.</td>
<td>- first 2nd xylem ring compression wood.</td>
</tr>
</tbody>
</table>

Table 7.2 Salient features of pith of branches of gymnosperm coniferales common north American northwest coast species.