The Art and Science of Woodturning: A Year in Exploration

by
Claudia Andersen

A THESIS

submitted to

Oregon State University

Honors College

in partial fulfillment of
the requirements for the
degree of

Honors Baccalaureate of Science in Renewable Materials
(Honors Scholar)

Presented May 22, 2018
Commencement June 16, 2018

AN ABSTRACT OF THE THESIS OF

Claudia Andersen for the degree of Honors Baccalaureate of Science in Renewable Materials presented on May 22, 2018.

Title: The Art and Science of Woodturning: A Year in Exploration

Abstract approved:

____

Seri Robinson

Abstract: Woodturner, artist, and scientist, Claudia Andersen, describes various anatomical features of wood, from the differences between softwoods and hardwoods to the various types of spalting. Over the past year, they have learned and developed their skills in woodturning. In this project, they accompany one woodturned piece with a description of the relevant anatomical feature or phenomenon present in the wood and address how they must adapt their technique to create the piece.

Key Words: woodturning, wood science, art, figure, spalting

Corresponding e-mail address: andercla@oregonstate.edu

The Art and Science of Woodturning: A Year in Exploration

by
Claudia Andersen

A THESIS

submitted to

Oregon State University

Honors College

in partial fulfillment of
the requirements for the
degree of

Honors Baccalaureate of Science in Renewable Materials
(Honors Scholar)

Presented May 22, 2018
Commencement June 16, 2018

Honors Baccalaureate of Science in Renewable Materials project of Claudia Andersen presented on May 22, 2018.

APPROVED:

Seri Robinson, Mentor, representing Wood Science and Engineering

Ruth Fore, Committee Member, representing Wood Science and Engineering

Ray Van Court, Committee Member, representing Wood Science and Engineering

Toni Doolen, Dean, Oregon State University Honors College

I understand that my thesis will become part of the permanent collection of Oregon State University, University Honors College. My signature below authorizes release of my thesis to any reader upon request.

Claudia Andersen, Author

Contents

Artist Statement

My work is an expression of time, process, and change with the ultimate intention of seeking to understand how physical spaces and physical objects are reflections of our emotional spaces. All my pieces are a result of making, seeing, feeling, and moving, with a vision translated through physical movements into a tangible reality. My work is art as much as it is science, and I inhabit the space between these falsely separated categories because I believe in having a fundamental understanding of materials and physical properties. My work is art because it provides me with the space to reflect on change. In this case, I am as much a constantly changing person as wood is a constantly changing material. Respecting that change means learning to not force my work or my life and to accept and adapt to change when it comes.

Website: claudiacandersen.wixsite.com/welcome

Softwoods and Hardwoods

Softwoods

Figure 1: Norfolk island pine bowl with blue stain, 4.25" w x 2.5" h, 2018

Woodturners must understand the anatomy of each piece of wood they approach. In softwoods, longitudinal tracheids are the dominant feature and are represented by the thin and thick square shapes in illustration below of the transverse section of Norfolk island pine (*Araucaria heterophylla* (Salisb.) Franco). Tracheids account for 90 to 95% of the wood volume, are approximately 3-5 mm in length, and conduct water throughout the wood (Bowyer, Shmulsky, & Haygreen, 2007; Hoadley, 2000). Longitudinal parenchyma, or storage cells, can also be found in softwoods, but they only account for up to 1-2% of the total volume and are only about 0.1-0.22 mm in length (Bowyer, Shmulsky, & Haygreen, 2007). Radial cells are another type of cell in softwoods. As opposed to running parallel to the bark, they run from the center of the tree out to the bark. In softwoods, rays are generally only one cell wide, or uniseriate (Bowyer, Shmulsky, & Haygreen, 2007). The rays are composed of either radial tracheids or radial parenchyma. Some species of softwoods naturally produce specialized parenchyma that surround resin canals and produce resin (Bowyer, Shmulsky, & Haygreen, 2007).

The ordering of earlywood and latewood tracheids create what we know as growth rings. Earlywood tracheids have a much larger diameter and thin cell walls while latewood tracheids are smaller in diameter and have thicker cell walls, also seen in the illustration below. This creates a visual change in appearance, whether very gradual or abrupt, between the earlywood and softwood cells.

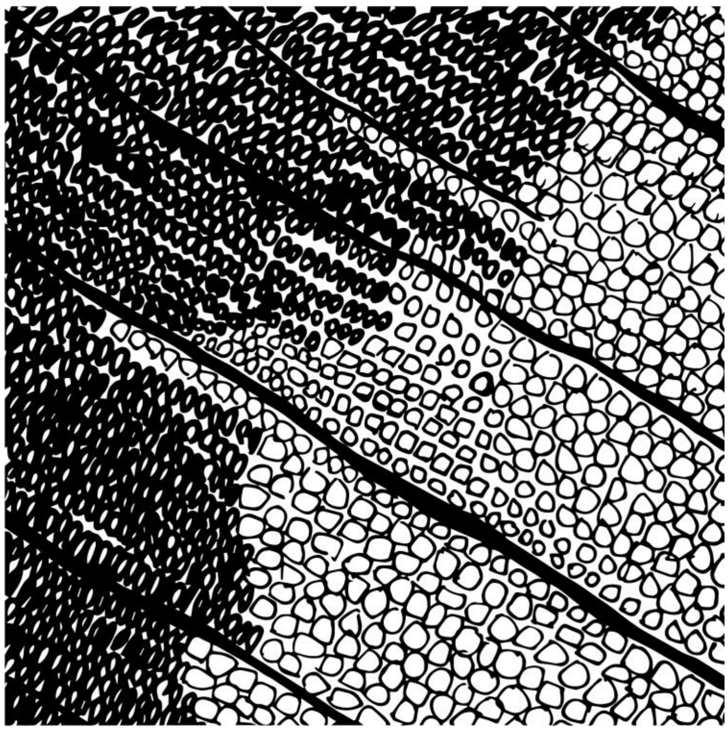

Figure 2: Transverse plane of Norfolk island pine

The anatomy of each wood piece influences turning significantly. Density differences can be very apparent when turning a softwood species with abrupt latewood rings. Pines are generally a fairly soft species, so while the tool easily catches, the tear out is not as startling as with a denser wood; however, in pines the tear out is often deeper. This tear out is greater because the tracheid cells are smaller and there are fewer and mostly uniseriate rays, reinforcing the wood against tear out. This softwood species is also good for practicing tool skills. It is very obvious when you are riding the bevel of a chisel or gouge because the grain is very fuzzy and soft when incorrectly tooled and a smooth surface when correct. This teaches the individual the difference between cutting and scraping. Cutting is the goal, and in pine it can produce nice curls of wood off the piece.

This piece, shown in Figure 1, was challenging due to this soft grain. There was heavy tear out at the bottom of the bowl due to this factor as well as it being end-grain turned.

While some of this was corrected with small, slow passes with a sharp bowl gouge, heavy sanding was required to create the current smooth surface.

Hardwoods

Figure 3: big leaf maple hollow form, 3” w x 3” h, 2017

Vessels are the major distinguishing difference between hardwoods and softwoods. Instead of the primary longitudinal tracheids of softwoods, hardwoods have vessel elements that are much wider in diameter than softwood tracheids (Bowyer, Shmulsky, & Haygreen, 2007), as seen in the illustration below of the transverse plane of big leaf maple (*Acer macrophyllum* Pursh.), a native Oregon hardwood. The primary purpose of vessels is conduction while the hardwood fibers serve as the structure and mechanical support for the wood (Bowyer, Shmulsky, & Haygreen, 2007; Hoadley, 2000). The density of the wood is often determined by the proportion of fibers present. Longitudinal parenchyma are much more prominent in hardwood species than in softwood species, composing up to 24% by volume in domestic species and nearly 50% in tropical hardwoods (Bowyer, Shmulsky, & Haygreen, 2007). Radial parenchyma are also often much more prominent in hardwoods. The rays are likely to be more than one cell wide (multiseriate) while some species have ray cells up to 30 cells in width (Hoadley, 2000).

In turning, wider rays can present a challenge. With wide rays, the ray ends act like spots of end grain within the side grain. Turning side grain is like pulling away straws from one another, but turning end grain is like hacking off the tops of a lot of straws at once, and can produce more catches Turning across side grain and end grain at the same time results in a greater likelihood of tear out, so focusing on only sidegrain is best for beginning turners. Most turners complete spindle work with the endgrain running parallel to the spindle piece, so the turner only has to work with side grain (radial and tangential planes).

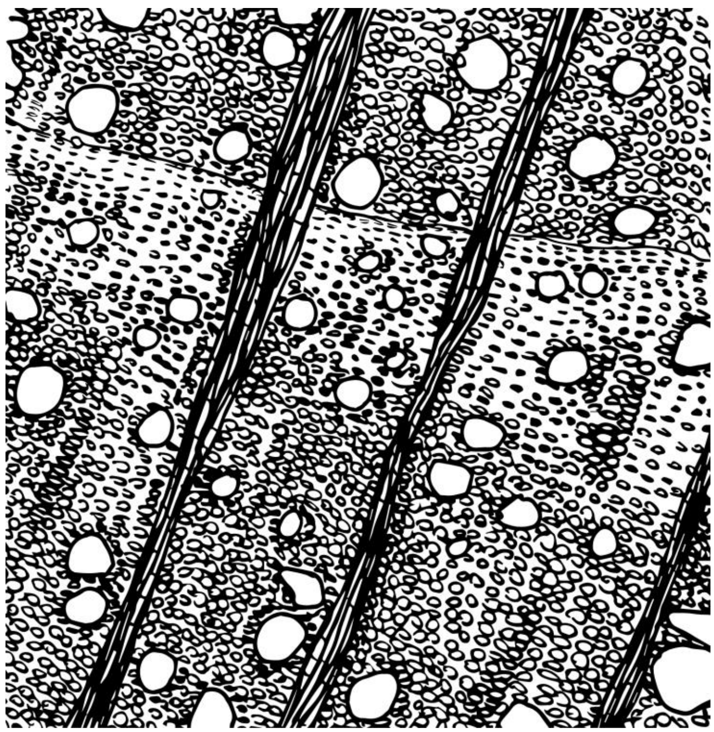

Figure 4: Transverse plane of big leaf maple

Turners often use hardwoods in turning because they tend to be medium or high-density woods, and the fibers do not tear or fuzz in a similar manner to some softwoods because there are more and wider ray cells which prevent tearout. The hollow form in Figure 3 and the illustration show big leaf maple, which is one of the most popular species in turning for its even color and medium density. It was easier to approach a more challenging hollow form using this less challenging species. There were no major density changes throughout the wood, making it easier to turn an even wall thickness throughout the piece using a skew chisel on the inside of the piece.

Diffuse Porous, Semi-Ring Porous, and Ring Porous

Diffuse Porous

Figure 5: big leaf maple bowl, 5.25" w x 2" h, 2017

The growth rings are fairly indistinct in diffuse porous hardwoods. There is often little difference between the diameter of earlywood and latewood pores, and they are usually spread evenly throughout the earlywood and latewood sections (Hoadley, 2000). In ring and semi-ring porous species, latewood will produce more fibers in proportion to vessels by volume (Hoadley, 1990).The homogeneity of diffuse porous hardwoods makes big leaf maple a popular hardwood to turn, especially for beginners. Turning a piece of wood that has more consistent results in fewer catches. This bowl, shown in Figure 5, was again challenging due to its form rather than the wood species. The walls were turned to approximately 2 mm thick, requiring many very small, slow passes with a bowl gouge to prevent tear out or breaking of the piece.

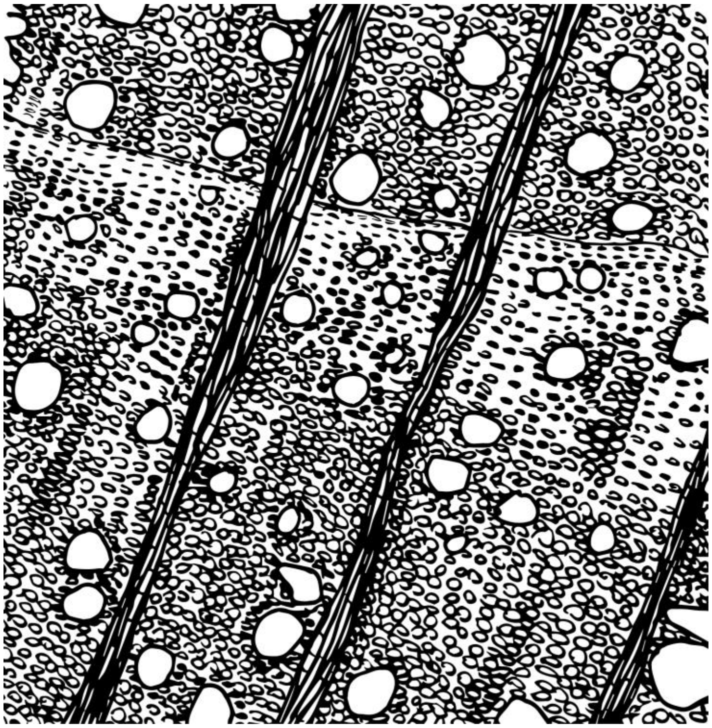

Figure 6: Transverse plane of big leaf maple

Other diffuse-porous hardwood species include sycamore (*Platanus occidentalis* L.), red alder (*Alnus rubra* Bong.), black cherry (*Pruus serotina* Ehrh.), American beech (*Fagus grandifolia* Ehrh.), yellow-poplar (*Liriodendron tulipifero* L.), birch (*Betula* spp.), and cottonwood (*Populus* spp.) (Hoadley, 1990).

Semi-Ring Porous

Figure 7: black walnut bowl with curly figure, 5” w x 2.5” h, 2017

Semi-ring porous hardwoods, sometimes known as semi-diffuse porous, are somewhere between ring and diffuse porous. There is often a visual difference in the diameter of the pore size, but there is not a clear line where the division occurs instead there is a gradual change between the earlywood and latewood pores. Semi-ring porous hardwoods, such as black walnut (*Juglans nigra* L.), illustrated below, can be slightly more challenging to turn than typical diffuse-porous hardwoods, but since the change between early and latewood is not abrupt, there is not usually as much difficulty using these species.

The bowl in Figure 7 was turned primarily to highlight the bark still included on the original block of wood. The bark was retained using a glue along the boundary line between bark and wood to prevent it from loosening during turning. Overall, the piece was still semi-ring porous, so there were no major density changes that challenged the turning of this piece.

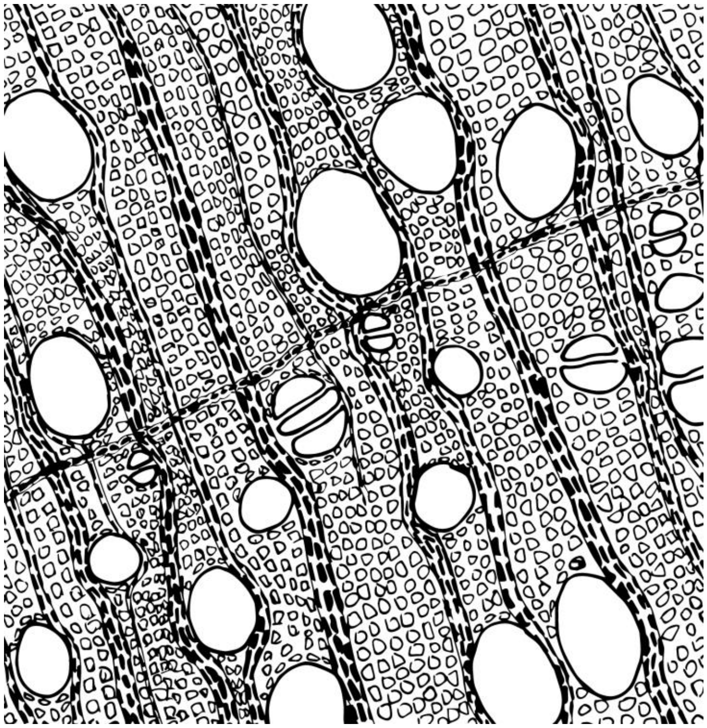

Figure 8: Transverse plane of black walnut

Some other semi-ring porous hardwoods include tanoak (*Lithocarpus densiflorus* (Hook. & Arn.)) and butternut (*Juglans cinerea* L.) (Hoadley, 1990).

Ring Porous

Figure 9: American elm plate, 6.25" w x 1.25" h, 2018

In ring-porous hardwoods, earlywood is identifiable by the large pores, or vessels, with distinct transitions into smaller pores that signify the latewood. Often the change is extremely abrupt. This causes a noticeable difference in density of the wood since, in the latewood, the proportion of fibers to vessels is much higher along with the cell walls being thicker (Hoadley, 2000). This density change requires greater skill in keeping the tool steady and riding the bevel. With correct use, the exposure of the transverse section can show very beautiful lines between the early and latewood.

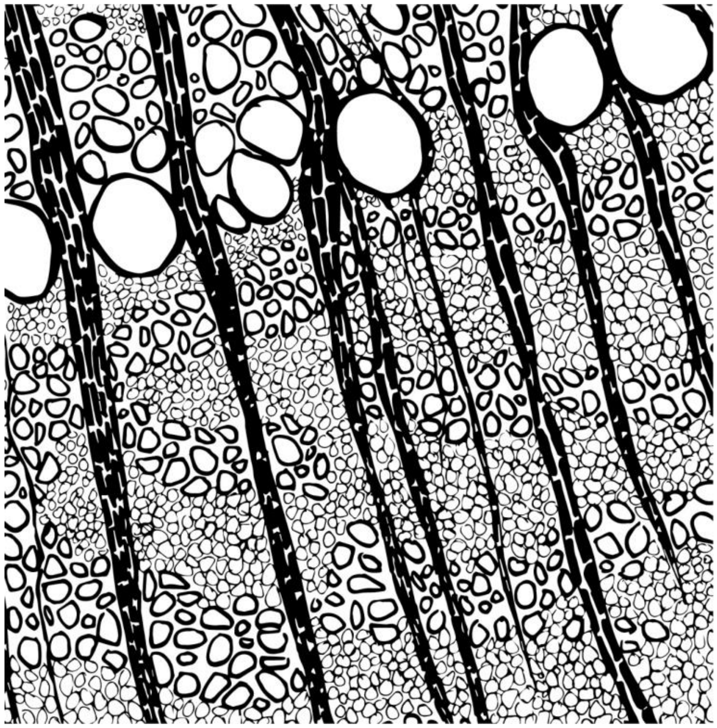
Figure 10: Transverse plane of American elm

American Elm (*Ulmus americana* Willd.), as seen in the illustration above, has a very abrupt change between earlywood and latewood cells. The earlywood can be seen with one distinct row of pores while the latewood is characterized by smaller rows of pores arranged in wavy lines. The plate form of the piece in Figure 9 highlights the abrupt change between these earlywood and latewood pores in its large flat surface.

Some other wood species known for being ring porous are oaks (*Quercus spp.* L.), white ash (*Fraxinus americana* L.), American chestnut (*Castanea dentata* (Marsh.) Borkh.), hickory (*Carya spp.*), and black locust (*Robinia pseudoacacia* L.) (Hoadley, 1990).

Green Wood and Shrinkage

Figure 11: cherry bowl with natural edge, 4.25” w x 2.75” h, 2017

All wood starts off naturally wet, or green, and this wood is often easier for woodturners to obtain than kiln-dry wood. However, kiln-dry wood is typically 12% moisture content by weight while the percentage of water in freshly cut wood can be above 100% depending on species, as seen in the figure below (Bowyer, Shmulsky, & Haygreen, 2007). Many woodturners also prefer working with wet wood because it cuts easier and dulls tools much more slowly. Unfortunately, there are a few downsides to turning wet wood. First, with extremely wet wood and at high speeds, water often sprays in turners’ faces as they cut. Secondly, the wood will inevitably dry and warp into a different shape from shrinkage due to loss of water volume. This shrinkage is not proportional in all directions. There is actually negligible shrinkage in the longitudinal direction in comparison to the shrinkage in tangential and radial directions (Bowyer, Shmulsky, &

Haygreen, 2007). As a result, woodturners cannot expect their wet turned pieces to remain in perfect circular shapes. For example, the cherry (*Prunus* spp.) bowl shown below is an oval shape because of the water loss affecting its width. Cracks appear due to the wood shrinking more in this direction. Cherry is also highly prone to cracking and splitting, so this may be easier to prevent in other species with proper, slow drying.

	Moisture content (%)	
Species	Heartwood	Sapwood
Hardwoods		
White ash	46	44
Aspen	95	113
Yellow birch	74	72
American elm	95	92
Sugar maple	65	72
Northern red oak	80	69
White oak	64	78
Sweet gum	79	137
Black walnut	90	73
Softwoods		
Western red cedar	58	249
Douglas fir	37	115
White fir	98	160
Ponderosa pine	40	148
Loblolly pine	33	110
Redwood	86	210
Eastern spruce	34	128
Sitka spruce	41	142

Source: United States Forest Products Laboratory (USFPL) (1999).

Figure 12: MC of green wood (Bowyer, Shmulsky, & Haygreen, 2007)

Warping is often inevitable when turning wet wood, but this is an appealing factor for many. People appreciate the appeal of variety and unique qualities in the handcrafted pieces they buy, especially if the intended use of the piece is for art and not function.

Finally, users of any should not submerge final wood pieces in water because the piece will swell and then shrink, causing warps and cracks in the wood. If pieces come in contact with food, the users should only rinse and leave the piece where air can evenly dry the wood from all sides.

Tropical Woods

Tropical woods have special characteristics that help to differentiate them from other woods. Due to the greater diversity and number of insects and fungi, as well as a very warm and wet environment, tropical woods develop special defense mechanisms to protect themselves (Arango, Green III, Hintz, Lebow, & Miller, 2006). These combative techniques are recognizable as smells, conductive fluids or extractives, silica or non-organic content, and color. An additional difference seen in tropical wood species is that do not have definite growth rings (Rowell, 2012).

Extractives often increase wood density, and many are toxic to humans, so be mindful of the end purpose of the object, as many extractives are water soluble and will move from the wood into food and liquid from wood items like cooking spoons, cutting boards, and bowls.

Purpleheart

Figure 13: purpleheart platter with curly figure, 12.25" w x 1.75" h, 2018

Purpleheart (*Peltogyne* spp.) is a diffuse porous hardwood species native to Central and South America. The wood starts off a dull purple and becomes more and more brown over time with exposure to ultraviolet light as well as general oxidation. Growth rings can be distinct or indistinct depending on the growing conditions, so there may not be significant differences in earlywood and latewood densities compared to those seen in temperate softwoods and hardwoods. (Hoadley, 2000)

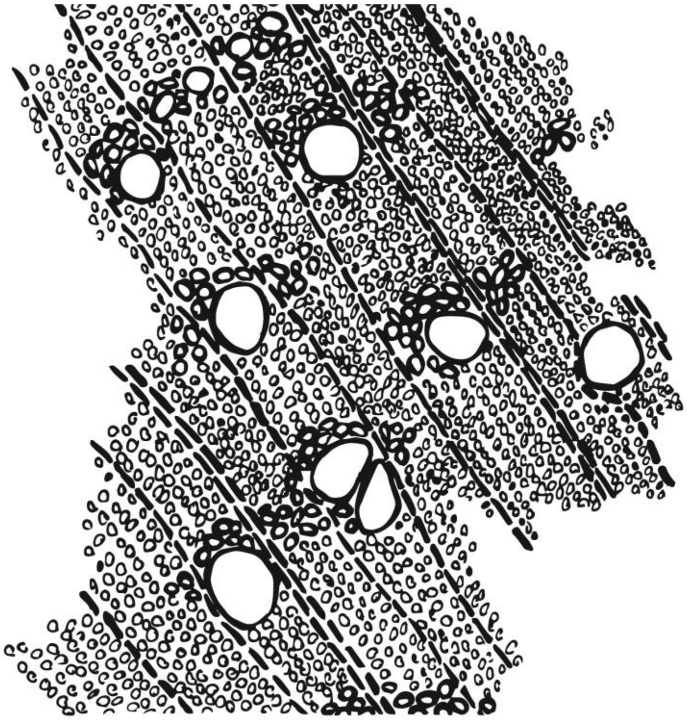

Figure 14: Transverse plane of purpleheart

Purpleheart has a high density of 0.79 g/cm3 (Fearnside, 1997) where big leaf maple is 0.49 g/cm3 (Bilby, Heffner, Fransen, Ward, & Bisson, 1999). The high density of purpleheart means that tools will dull very quickly, which was consistently experience during the turning of the platter in Figure 13. In addition to the high density, purpleheart exhibits conduction in the form of a gummy resin extractive that secretes from the endgrain. This piece required immediate finishing after sanding to prevent these extractives from moving out of the vessels on the end grain to create a rough, sticky surface. A clear acrylic or lacquer is recommended for this species. Danish oil was initially used on this piece, but due to the high density and extractive content, the oil did not properly penetrate the wood and created a rough surface while also dulling the color of the wood.

Bloodwood

Figure 15: bloodwood bowl, 5.25" w x 1.5" h, 2018

Bloodwood (*Brosimum rubescens* Taub.) is a diffuse porous hardwood species native specifically to the tropical regions of South America. The heartwood has an orange-red color that tends toward a reddish brown over time with exposure to UV light and general oxidation. Parenchyma are winged and confluent. (Bloodwood, n.d.)

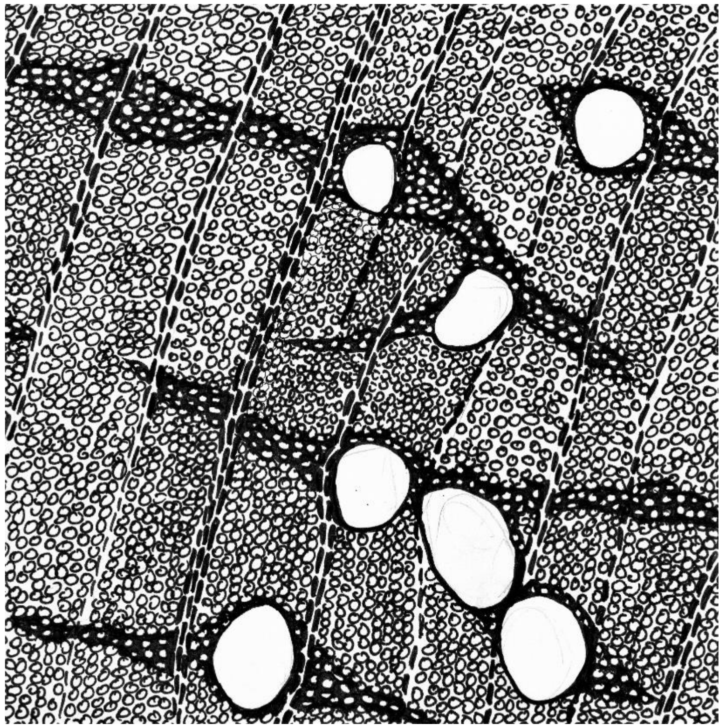

Figure 16: Transverse plane of bloodwood

Bloodwood has a density of 0.87 g/cm3 (Fearnside, 1997), where big leaf maple has a density of 0.49 g/cm3. The hardness and high density of bloodwood means that tools will dull very quickly. This was again experienced in the turning of the bowl pictured in Figure 15. This wood was very brittle and cut in a damp powder as it was slightly wet. In general, turning at very high speeds and sharpening tools frequently will help when working with this wood. Bloodwood does not actively secrete extractives, so final pieces do not require any finishing products to lock in extractives to preserve surface finish. Oil finishes are still not recommended as they will not penetrate the highly dense wood.

Figure

Curly Maple

Figure 17: curly figure on maple bowl, 6” w x 2” h, 2018

Figure refers to a distinctive visual characteristic on a piece of wood’s longitudinal surfaces (not on the end-grain) (Hoadley, 2000). Any variation in the appearance of wood is almost always caused by the interaction of environmental factors and the tree’s genetics. Often environmental factors, such as reactions to cold, rain, or pressure on parts of the tree, trigger the change in fiber angles. There must be a release of the constant pressure on the fibers, and this can be in the form of the fibers popping out from their typical orientation and continuing to grow in a new direction, creating this figure (Bragg & Stokke, 1994; Bragg, Mroz, Reed, Shetron, & Stokke, 1997; Mroz, Reed, & Frayer, 1990).

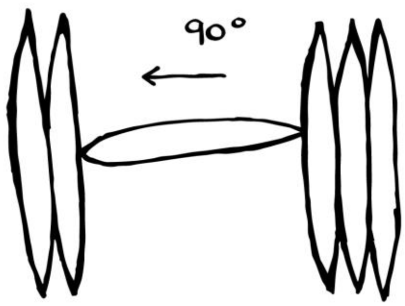

Figure 18: Fiber angle change in curly figure

In the case of curly figuring in woods, not including fiddleback, tigerstripe, or flame, the grain angle flips 90 degrees. Curly figure is often most noticeable when the wood is quarter-sawn, or showing the radial plane on the face of a bowl blank. It creates a wavy or "washboard" appearance, or like stripes running perpendicular to the longitudinal grain direction, shown in this bowl in Figure 17. Due to the extremely heavy figuring of this piece of wood, the bowl was turned with a wide, flat bottom to show this washboard appearance. Curly figure itself is not exclusive to just maples. It can also be found in walnut, ash, cherry, koa (*Acacia koa* A. Gray), etc.

Quilted Maple

Figure 19: quilted figure on big leaf maple bowl, 5.75" w x 2.5" h, 2018

As with curly figure, quilted figure is not exclusive to maples. However, quilted big leaf maple is extremely abundant in the northwest region of Oregon (Niemiec, Ahrens, Willits, & Hibbs, 1995; Pfieffer & Wolllin, 1955) and thus will be the focus of discussion here. The figure is most distinguishable when the wood is flat-sawn, meaning that the tangential plane will have greater definition of figure (Beals & Davis, 1977).

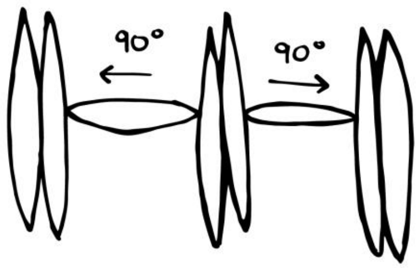

Figure 20: Fiber angle change in quilted figure

In the case of quilted figured woods, the grain must first flip 90 degrees in one direction and then 90 degrees (or 180 degrees if next to each other) in the other direction. This creates little clouds within the wood on the tangential plane. With the grain constantly changing in opposite directions, the tool easily catches. The figure is often best seen on the tangential plane, and is best displayed on the bottom surface of a bowl. It can still be difficult to show this figure properly when turning a relatively small piece, such as the bowl in Figure 19. A larger surface and shorter height are likely more beneficial in showing the full extent of quilted figure.

Flame Birch

Figure 21: flame figure on birch bowl, 2018

Flame figure can be found in maples and other hardwood species, but it is most often found in birch and will be shown as such here. Flame birch is easily mistaken as just being a type of curly figure. The major difference is, again, in the grain angle. Curly figure arises from a grain angle change of 90 degrees, whereas flame birch has only a 45-degree angle change. This figure will be most apparent on the sides of a bowl, as shown in this piece in Figure 21. The change in grain angle is not a severe as in curly or quilted figure, so tear out and catches may occur less. Still, keeping a sharp tool and a fast lathe speed is advisable.

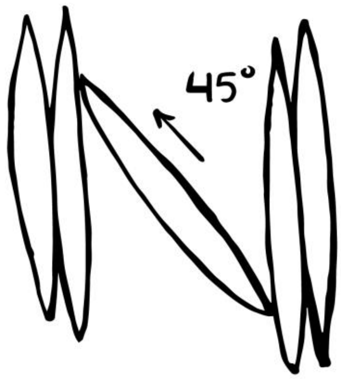

Figure 22: Fiber angle change in flame figure

In some cases, such as in this bowl, the flame figure may not be extremely apparent, but this is usually more dependent on the individual wood and not the type of figure. Often, coating the final piece in a gloss finish will further highlight the figure.

Bird's Eye Maple

Figure 23: bird's eye maple square bowl, 7.75" w x 1.5" h, 2018

Bird's eye figure is most common and best known in sugar maple (*Acer saccharum*) (Hoadley, 2000), but it can also be found in white ash, yellow birch (*Betula alleghaniensis* Britton), red maple (*Acer rubrum* L.), paper birch (*Betula papyrifera* Marsh.), and quaking aspen (*Populus tremuloides* Michx.), along with some conifers (Rioux, Yamada, Simard, Lessard, Rheault, & Blouin, 2003). Bird's eye maple is particularly prevalent in the Upper Peninsula of Michigan. There is belief that the sugar maple there has both a genetic predisposition to producing bird's eye figure along with the help of heavy snowfall compacting and causing pressure on the tree and the fibers for many years (Bragg & Stokke, 1994; Bragg, Mroz, Reed, Shetron, & Stokke, 1997; Mroz, Reed, & Frayer, 1990).

Figure 24: Fiber shape change in bird's eye figure

This is another occasion where the abnormal wood grain creates an appearance distinct from the typical straight-grain appearance in wood. While curly, quilted, or flame figure occurs when the fibers simply change angle, in bird's eye the entire fiber pops and curves inward to create the small pockets, or "eyes" of bird's eye figure. With the curve of the fibers, the pockets have a greater density than the surrounding straight-grained wood, and there are often small void spaces around the eyes (Bragg & Stokke, 1994). With little holding the eye to the rest of the wood, it is easy to catch this dense pocket with a tool and tear it out. As with most other types of figure, fast speeds, a sharp tool, and less aggressive cuts will prevent tear out along with any loose eyes flying towards the turner's face.

The square shape was chosen for this bowl shown in Figure 23 to prevent the loss of as many bird's eyes as possible. The slop of the sides of the bowls shows that the individual eyes, very elongated at these points, can extend far throughout the wood.

Burl

Figure 25: burl figure on bowl with white rot, brown zone lines, and natural edge, 6" w x 3" h. 2018

Burl is commonly understood as the wood that protrudes out from a tree in a great lump, often near ground level (Beals & Davis, 1977). Like other figure, there is belief that it arises from environmental factors triggering a hereditary trait. Burl figure has no distinct grain angle. In fact, while other figure has a distinct grain angle change or curl, fibers in burl wood are angled in any and all directions. In some instances, burl has characteristic eye-like markings that could be seen similar to bird's eye to the untrained eye, but they are distinct in that they are surrounded by swirling and distorted wood all around instead of any straight-grained wood. The haphazard changes in fiber angles create a bud-like figure. (Hoadley, 2000) When turning, this figure is especially challenging because of the constant and unexpected changes in grain angle.

Figure 25 shows a maple bowl taken from a large maple burl. The piece does not have any clear grain direction, making it difficult to turn in addition to the presence of heavy white rot (explained in a later section). The high walls of the bowl were created to highlight the curve of the natural edge as well as the erratic grain direction.

Knots

Figure 26: Norfolk island pine box with knots, 2018

Knots are the remnants of where tree limbs began growing from the main trunk. They act either as extremely dense pockets of wood or as void spaces if they are loose enough to fall out. Curly figure occurs when the grain angle simply flips 90 degrees to one side. With knots, the fibers instead flip to grow outward from the initial fibers and not just to the side. Since limbs grow outward from the tree, the fibers in the knots are acting as endgrain in while the surrounding wood continues to be side-grain.

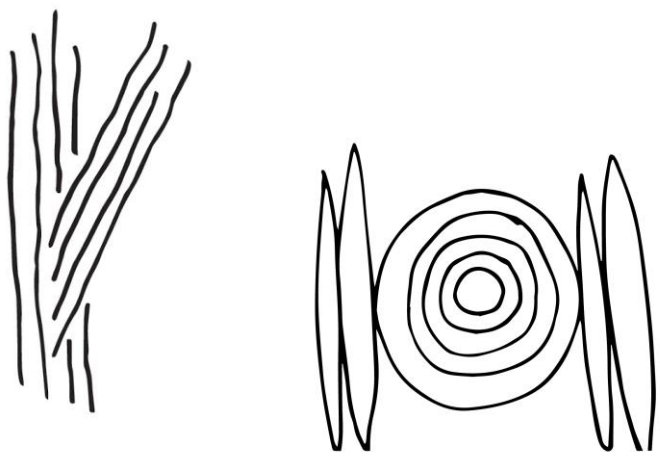

Figure 27: Fiber changes in knots

The extreme changes in density and grain positioning often require less aggressive cuts, especially in Norfolk island pine, where the rest of the wood has a fairly low density. This was particularly apparent in the piece shown in Figure 26. Creating a box form required separating a piece into two parts using a parting tool, then slowly matching the two pieces to fit snugly. The knots happened to sit exactly where the two parts fit together. Keeping the tool very sharp and steady helped to combat the density and grain angle changes between the knots and the rest of the wood. Most of the knots were encased and did not fall out of the box piece.

Spalting

White Rot

Figure 28: white rot in bowl, 6" w x 3.5" h, 2018

White rot comprises the first major category of spalting. It is primarily identifiable by the bleaching of color it causes in wood. White rots target and degrade lignin, a component that adds rigidity and a slight brown color to most wood species, but they can also break down cellulose and hemicellulose, the other two major components of wood (Robinson, Michaelsen, & Robinson, 2016). This leads to those areas with bleaching being soft and even spongey. Over time, white rots can degrade strength so much that it is easy to push your fingernail into the wood and leave an indent, and as a result, many woodturners invest in stabilizers that penetrate and make the wood more solid. Lignin breakdown is not the only factor that lightens the wood. As an example, *Trametes versicolor* (L.) Lloyd (commonly known as turkey tail) and in the illustration below, creates this white color by producing a white fungal mycelium as well as degrading the lignin at an aggressive rate (Robinson, Michaelsen, & Robinson, 2016).

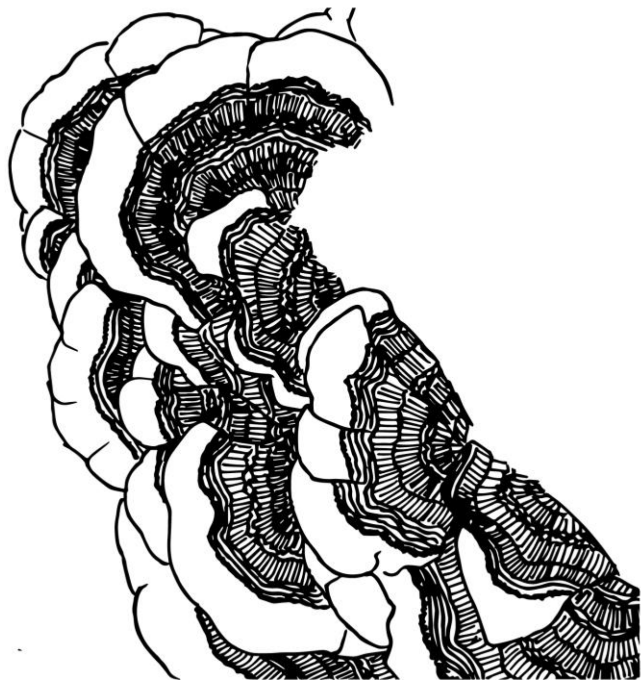

Figure 29: Trametes versicolor fruiting bodies

It is unlikely that all areas of wood in one piece will have the same amount of decay, so visual variations in the bleaching effect often exist. As a result, a turner will be consistently working and cutting across zones of inconsistent densities. While tools will likely not dull as quickly, turners should approach the piece slowly at the beginning and with very shallow cuts as large pieces are more likely to easily fly off. Small finishing passes with the tool are necessary to counteract most of this tear out. Completion of sanding should not be done on the lathe as the areas with low densities will sand out much more quickly, creating dips and pockets. Two or three passes with 80 grit sandpaper may be acceptable to remove major lines before transferring to other sanding methods.

This bowl in Figure 28 was so affected by white rot fungi that it was considerably light. The piece was already cracked from the outside, so turning a very degraded piece with pre-existing cracks meant that this bowl had to be turned very slowly and with very shallow cuts with the bowl gouge. Turning so only a very fine powder was removed with each cut resulted in the best surface quality. Still, most of the surface still exhibited tear out, which had to be primarily removed by sanding off the lathe.

Zone Lines

Figure 30: zone lines in maple bowl, 2018

Generally, zone lines are the result of spalting fungi engaging in a game of resource capture. The physical or mechanical defense system is a creation of deposits of concentrated melanin in the form of lines, like walls that are built to retain these resources. This defense system is in response to antagonizing fungi or to stress conditions. (Robinson, Michaelsen, & Robinson, 2016). Some deposits are fairly thin and others can be very thick. Zone lines have a much higher density than the surrounding wood, especially since this wood is likely affected by white rots. These differences in density require slow turning speeds when constantly interacting with density changes. Sometimes tear out is unavoidable.

Figure 31: Xylaria polymorpha fruiting bodies

Sanding should not be done on the lathe as the soft pockets will sand much faster than the dense zone lines creating a very uneven surface. An example of a spalting fungi that can produce zone lines when in competition with other spalting fungi or in response to stress is *Xylaria polymorpha* (Pers.) Grev., also known as Dead Man's Fingers, shown in the illustration above. These fruiting bodies can be found on logs both in temperate and tropical climates. While this species generally produces black or brown zone lines, other spalting fungi can produce lines in a range of colors from orange to yellow, green, and even purple. (Robinson, Michaelsen, & Robinson, 2016)

This piece in Figure 30 required the most skill and concentration out of all the pieces in this project. The form required half-blind boring to create the depth of the piece and turning void space, or air, for half of each rotation. The dense zone lines presented more challenges during sanding than in turning. In the final piece, many of the locations in the piece with zone lines are raised higher than the rest of the wood because of the density differences. As a whole, the piece evolved from having outside walls nearly perpendicular to any resting surface to having a curved outside shape that reflected the form of the natural edge. Overall, the wide slopes are appealing in presenting the zone lines in this piece.

<u>Pigment</u>

Figure 32: pigment in tamarind hardwood bowl (also with zone lines), 6” w x 2.75” h, 2018

While zone lines are a mechanical defense system, pigment-type spalting is considered a chemical defense system. This type of spalting involves fungi depositing color into wood. The color is often distinguishable from non-spalting fungi pigment by checking how deep the pigment reaches into the wood. Non-spalting fungi only produce color on the surface of wood while spalting fungal pigment can be found throughout the entire depth. The pigment is still a form of resource capture, but it does not employ the mechanical defense of dense melanin walls. Pigment spalting is considered to be very energy intensive as enough of the the chemical defense must be produced to permeate the entire surrounding area whereas zone lines only have specific boundaries.

Trees also produce pigment in response to stress, but they can be identifiable from spalting pigment by examining their light stability. For example, the reddish-pink color in boxelder, a wood commonly in use by turners, is a pigment produced by the tree and not by spalting fungi, so it will fade to a brown over time (Robinson, Michaelsen, & Robinson, 2016; Morse & Blanchette, 2002). It is not a bad choice to use these woods, but it is best to have clear expectations regarding how the piece will change over time. If a turner is looking to maintain a color in their piece, they should look into spalting, such as the blue stain seen in Figure 32. The blue stain seen here is very valuable because of its contrast with the light color of the rest of the wood.

This piece combines the challenges of tropical hardwoods and spalting. While tamarind (*Tamarindus indica* L.) does not have extractives similar to purpleheart, the density is still noticeably higher than the other species turned in this project. As a result, this piece was turned with relatively thick walls. On the other hand, the density of the zone lines did not create any noticeable difficulties because the rest of the wood was already very dense. The main influence of the spalting pigment was in the form. This bowl was turned with a square bottom to maintain the largest surface of visible pigment in the piece. If the piece had been turned with curved sides, much of the color would have been lost.

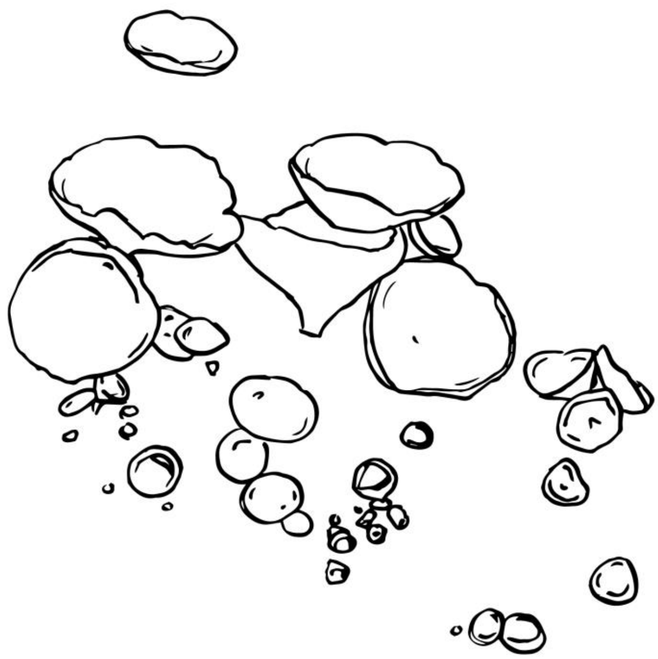

Figure 33: Chlorociboria spp. fruiting bodies

As another example, the most common type of pigmenting fungi in the Pacific Northwest are *Chlorociboria* spp. (pictured above). These fungi create a blue-green pigment that can be readily found in the forests. The corresponding fruiting bodies found on pigmented logs often fruit during or near the end of autumn after a rainfall. In general, these pigmenting spalting fungi are slow growing and do not reduce the integrity of the wood structure to the same extent as white rots (Robinson, Michaelsen, & Robinson, 2016).

References

Arango, R. A., Green III, F., Hintz, K., Lebow, P. K., & Miller, R. B. (2006). Natural durability of tropical and native woods against termite damage by Reticulitermes favipes (Kollar). *International Biodeterioration & Biodegradation, 57*(3), 146-150.

Beals, H. O., & Davis, T. C. (1977). Figure in wood: an illustrated review. *Bull. Agric. Exp. sta., Auburn Univ. Grain, pigmentation, ray structure etc. Review article General article, Grain of wood Spiral grain*, PMBD, 185601663.

Bilby, R. E., Heffner, J. T., Fransen, B. R., Ward, J. W., & Bisson, P. A. (1999). Effects of immersion in water on deterioration of wood from five species of trees used for habitat enhancement projects. *North American Journal of Fisheries Management, 19*(3), 687-695.

Bloodwood. (n.d.). Retrieved May 7, 2018, from The Wood Database: http://www.wood-database.com/bloodwood/

Bowyer, J. L., Shmulsky, R., & Haygreen, J. G. (2007). *Forest products and wood science: an introduction.* Ames, IA: Blackwell Pub.

Bragg, D. C., & Stokke, D. D. (1994). Field identification of birds-eye in sugar maple (Acer saccharum Marsh.). *USDA For. Serv. Res. Pap.*, NC-317.

Bragg, D. C., Mroz, G. D., Reed, D. D., Shetron, S. G., & Stokke, D. D. (1997). Relationship between "birdseye" sugar maple (Acer saccharum) occurence and its environment. *Canadian journal of forest research, 27*(8), 1182-1191.

Fearnside, P. M. (1997). Wood density for estimating forest biomass in Braziian Amazonia. *Forest ecology and management, 90*(1), 59-87.

Grissino-Mayer, H. D. (1993). *An Updated List of Species Used in Tree-Ring Research.* Tuscon, AZ: University of Arizona.

Hoadley, B. R. (1990). *Identifying wood: accurate results with simple tools.* Newtown, CT: Taunton Press.

Hoadley, B. R. (2000). *Understanding wood: a craftsman's guide to wood technology.* Newtown, CT: Taunton press.

Jacoby, G. C. (1989). Overview of tree-ring analysis in tropical regions. *Iawa Journal, 10*(2), 99-108.

Morse, A. C., & Blanchette, R. A. (2002). Etiology of Red Stain in Box elder. *Plant health progess*.

Mroz, G. D., Reed, D. D., & Frayer, W. E. (1990). An evaluation of bole form and microsite conditions for birdseye maple growing in the western upper penisular of Michigan. *Northern Journal of Applied Forestry, 7*(1), 44-45.

Niemiec, S. S., Ahrens, G. R., Willits, S., & Hibbs, D. E. (1995). Niemiec, SHardwoods of the Pacific Northwest. Research Contribution 8. Corvallis, OR: Oregon State University, College of Forestry. *Forest Research Laboratory*.

Pfieffer, J. R., & Wolllin, A. C. (1955). Oregon maple log and lumber grading.

Rioux, D., Yamada, T., Simard, M., Lessard, G., Rheault, F. J., & Blouin, D. (2003). Contribution to the fine anatomy and histochemistry of birdseye sugar maple. *Canadian journal of forest research, 33*(5), 946-958.

Robinson, S. C., Michaelsen, H., & Robinson, J. C. (2016). *Spalted Wood: The History, Science, and Art of a Unique Material.* Atglen, PA: Schiffer Publishing Ltd.

Rowell, R. M. (2012). *Handbook of wood chemistry and wood composites.* Boca Raton, FL: CRC Press.

Zobel, B. J., & Van Buijtenen, J. P. (2012). *Wood variation: its causes and control.* Berlin: Springer Science & Business Media.