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Heartwood vs. Discolored Wood: An Observation

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Title: **Heartwood Vs. Discolored Wood: an Observation**

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Abstract:

Trees have many different forms of protection wood including heartwood and discolored wood. Protection wood is described as any wood which exhibits decay resistance. Heartwood and discolored wood have many similarities as well as many differences. I have done research to find many of the qualities of both. Heartwood is the result of a natural process that has been theorized to be age initiated and genetically coded. Discolored wood, on the other hand, is the result of a pathologically induced process. Even though there has been a lot of research done on both heartwood and discolored wood, there is still much that we don't know about them. In this paper, explain the differences and similarities between heartwood and discolored wood. My goal is to provide others with a better understanding of these protection woods and to provide them with a peek at the not well known world of altered wood.

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DEFINE YOUR TERMS

These are a few of the terms that will be used in this text as well as their definitions. Since some of these terms have been used in various ways, this will help to minimize confusion.

Protection wood – Refers to any wood that exhibits a greater resistance to decay than normal wood. (Shigo, 2003; Shigo, 1986)
Heartwood- Age altered central wood that has been chemically changed, resulting in decay resistance. (Shigo, 1986; Shigo, 2003; Shigo, 2002)

Pathological heartwood- Heartwood that has reacted to wounding.

Wound- A physical disruption in the normal functions of tree tissues. Wounds can be caused by animals, machinery, insects, other trees, or even parts of the same tree. (Shigo, 1986)

Compartmentalization- A dynamic process during which a tree forms defensive boundaries to resist the spread of decay causing pathogens (Shigo, 1986).

Discolored wood- Wood that has reacted to a wound, forming a protective barrier around it to prevent the spread of pathogens. (Shigo, 1986; Shigo, 2002; Shigo, 2003)

False heartwood- A central column of discolored wood, which is not heartwood, that is associated with branch dieback. (Shigo, 1986; Shigo, 2002)

Extractives- Chemicals compounds, such as gums, resins, phenols, terpenes, polyphenols, oils, etc, which accumulate in protection wood, resulting in decay resistance. These compounds are called extractives because can be extracted through a series of solvent treatments. (Shigo, 2003; Kramer, et al., 1979; Smith, 2009)

Parenchyma cells- Living cells in wood that have the ability to store carbohydrates, transport sap, and produce extractives. (Hoadley, 1981; Miller, 1999; Shigo, 2003)

Ray parenchyma- Parenchyma cells that have a horizontal orientation. They are responsible for the lateral movement of sap, extractive formation, carbohydrate storage, and support. (Shigo, 2003; Miller, 1999)

Axial parenchyma- Parenchyma cells that have a vertical orientation, and are usually located near the vessels or tracheids. (Shigo, 2003; Miller 1999)

Vessels or Tracheids- Cells that are the main vertical conductors of water and dissolved minerals.

Tyloses- Balloon or bubble like out growths from axial parenchyma cells that block vessel or tracheid cells (Hoadley, 1981; Shigo, 1986; Shigo, 2003).

METHODS

I have collected several samples of wood from various species including, *Acer negundo*, *Acer platanoides*, *Catalpa speciosa*, *Quercus palustris*, and *Ulmus parvifolia* to observe patterns of discolored wood (Figure 2) and heartwood (Figure 1). I also researched heartwood and discolored wood in the scientific literature; and have mainly used information from these articles to gain a better understanding of what is known about discolored wood. I have also been in touch with Kevin T. Smith from the US Forest service in NH, who has done research on tree functions; and with Professor Howard L. Eyre of Delaware Valley College, who teaches the arboriculture course and regularly attends tree function seminars.

Figure 1, Cross section of Chinese elm.

Figure 2, Cross section of Norway maple.

RESULTS AND DISCUSSION: HEARTWOOD

There are many things that we know about heartwood (Figure 1). It contains chemical compounds such as phenols, gums, resins, oils, terpenes, etc (Shigo, 2003; Kramer, et al., 1979). These compounds are known as extractives, and I have always thought of them as byproducts of normal tree functions which cannot be utilized by the tree for any other means than decay resistance. They are thought to be produced in the parenchyma cells and are usually deposited in the cell walls and lumens during heartwood formation (Shigo, 2003; Kramer, et al., 1979). They can vary in concentration and combination from species to species and can be dependent on soil conditions, growing conditions of that season, etc (Miranda, et al., 2006; Kramer, et al., 1979). Heartwood tends to have a uniform distribution of high quality extractives, which gives it an even coloration (Kramer, et al., 1979). Heartwood formation is fairly consistent within species and can have a regular appearance, seeming to follow the growth rings. Although, in many cases heartwood formation doesn't follow the growth rings at all (observe in Figure 1); and in some cases will have an irregular formation which can make it difficult to determine whether or not it is heartwood by looking at it (Eyre, 2009).

Heartwood formation is initiated in the oldest sapwood rings and is believed to begin around the ray parenchyma cells. Ray cells are theorized to be the main transport system of extractives, and every year after formation is initiated, they produce and transport a large amount of extractives to the transition zone. These extractives are deposited in the cell walls and lumens, and the vessles or tracheids become plugged with gums, resins, and tyloses. The transition zone is the area that separates heartwood from sapwood and is the site where sapwood is in the process of being converted to heartwood. The ray cells at this site senesce, and their primary functions shift to support and protection from decay. Sapwood cells undergo a change in structure at this point (Nawrot, et al., 2008); which can probably be explained by the deposit of extractives in the cell walls and lumens. In some cases, lignin is also deposited in parenchyma cell walls (Spicer, et al., 2007).

Heartwood has the capacity to react to wounding through chemical and/or enzymatic interactions with oxygen and possibly with compounds secreted by pathogens as well (Eyre, 2009; Shigo, 2003). This pathological heartwood no longer has the capacity to react to wounding and can sometimes be seen as a discoloration within the heartwood.

The formation and function of heartwood is seemingly well understood, although what triggers its formation is not (Kramer, et al., 1979). There were many theories as to how and why heartwood forms and even the most widely accepted theory today has many variances which are topics of debate. It is widely accepted that heartwood forms as a result of natural aging processes which are coded for in DNA sequences. However, there are those who say that heartwood formation is initiated due to the parenchyma cells dying from lack of oxygen as the layers of newer wood become numerous; and then there are some who believe that parenchyma cells die because they become plugged with extractives during heartwood formation.

A recent study was done on the respiration rates of parenchyma cells in sapwood. The respiration rate of ray cells from both the outer sapwood rings and the inner sapwood ring, right next to the heartwood but not including the transition zone, were measured. While the results showed a decline in the respiration rate of the inner sapwood, it was not sufficient to cause cell death. This showed that ray cell death during heartwood formation is not caused by a lack of oxygen, nor is heartwood formation initiated by a lack of oxygen. (Spicer, et al., 2007)

DISCOLORED WOOD

Discolored wood (Figure 2) is associated with wounds, and is usually found in the sapwood from the time of wounding. It is part of the process that the CODIT (Compartmentalization Of Decay In Trees) model is used to explain (Shigo, 2003). The CODIT model was introduced by Dr. Alex L. Shigo in the 1970s as a teaching tool to help educate homeowners on how trees respond to wounding. This model uses the concept of four walls to illustrate how trees compartmentalize around wounds, preventing the spread of decay causing pathogens. The first wall is formed by the vascular tissue above and below the site of wounding. The vessels or tracheids become plugged with tyloses, gums, and resins to prevent the vertical spread of pathogens. This is the weakest wall and is easiest for pathogens to break through. The second wall is composed of the inner growth ring, the growth ring that has not been damaged by the wound, and prevents the inward spread of pathogens. The third wall is formed by the ray cells on either side ofthe wound site. These ray parenchyma cells produce a large amount of extractives, which are toxic to decay causing pathogens and prevents their lateral spread. This is the strongest wall at the time of wounding, although the strongest wall will form the next growing season. This last wall is the new growth layer and tends to be more resistant to decay than normal sapwood. (Shigo, 2002; Shigo, 1986)

Figure 3, Cross section of boxelder maple.

Figure 4, Cross section of catalpa.

There are many different variations and patterns of discolored wood. *Acer negundo* has a very unique discoloration pattern (Figure 3). It is almost like a chrysanthemum flower in cross section and has vertical streaking of red and green. This red discoloration was thought to have been caused by *Fusarium reticulatum*. A study was done to test this theory where several specimens were inoculated with *Fusarium acuminatum*, and *Hypsizygus tessulatus*, which were isolated from samples of red stained *A. negundo* wood prior to testing; by drilling holes and inserting agar with the fungus culture on it. A control was set up using the same media used to culture the fungi, only sterile. These specimens were then harvested between 8 and 52 weeks after inoculation, and discoloration patterns were observed. Researchers tried to recover the fungus that was used to inoculate each specimen and found that they could not recollect the inoculums. Instead they isolated *Fusarium solani* from the majority of the samples, and a closer look at the discolored cells showed a lack of hyphae. They also observed that the control also formed a red discoloration. This indicated that the red coloration was a response to wounding in general, rather than being a result of *Fusarium* colonization. (Morse, et al., 2002)

False heartwood is discolored wood that forms a central column of discoloration and is associated with branch dieback (Shigo, 1986). False heartwood can easily be confused with true heartwood (Giroud, et al., 2008); and at times the only way to be able to tell the difference is to know whether or not the tree in question is a heartwood forming tree. In the case of the *Catalpa speciosa* (Figure 4) I had to ask Kevin T. Smith if it was a heartwood forming tree. The consensus was that catalpa is not a heartwood forming tree and the central discoloration was false heartwood (Smith, 2009). Some heartwood forming trees include: oaks, walnuts, elms, locust, eucalyptus, chamaecyparis, and cherries; and some of the non heartwood forming trees include: maples, catalpa, paulownia, beeches, and birches.

<u>CONCLUSION</u>:

Both heartwood and discolored wood are seen as alterations of the xylem tissue. They can be very similar in look and composition, but also have many differences. I have laid out some of the key similarities and differences between heartwood and discolored wood in Table 1.

Table 1		
Comparison of Heartwood and Discolored wood		
	Heartwood	Discolored wood
Distribution of Extractives	Even	Uneven
Type of Process	Natural	Pathological
Capacity to react to wounding	yes	no
Protection wood	yes	yes
Degree of protection	Higher	Lower
Dependent on environmental and genetic factors	yes	yes
Extractive quality	Higher	Lower

A lot of research has been done over the years on tree functions, and the results have been used to develop better tree care practices. For example, the CODIT model was developed based on studies of wound response and has been used over the years to teach home owners about how trees respond to wounding; the use of wound dressings has been studied and found to facilitate decay; studies of different pruning practices has shown that flush cuts yield more discolored wood than what is now considered proper pruning cuts; etc. Studies of tree functions have not only affected tree care practices, they have also influenced the forestry/timber industries. The study of spacing on the heartwood formation in eucalyptus trees most likely changed the growing practices of eucalyptus as a pulp wood tree.

Despite the amount of research that has been done, there are still a lot of things that we do not know about trees and their functions. More research is needed to determine what the triggering mechanism is for heartwood formation, and all of the factors that affect it. Also, I believe that a more detailed study of the chemical composition of extractives in both heartwood and discolored wood should be done to determine, more specifically, what compounds are present. This may give us an idea as to what the role of each compound is in both heartwood and discolored wood.

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