Spalting, Science, and Fungal Extracts – Retooling an Ancient Art for a Green Planet

Sara C. Robinson

Fungi come in a vast array of colors, from pale pinks to bright blue-greens to dark blacks. And yet, when most people think of fungal colors they think of the fruiting body. Some, especially those in the field of blue stain control, may think of fungal mycelium and the melanin bound within the hyphae that creates that blue-grey color in wood. And an even smaller group may think of the extracellular pigments made by mold fungi such as *Penicillium* and *Trichoderma*, whose pigments can penetrate several centimeters into various substrates.

But there is an even finer class of fungal colorants – a strange, eclectic collection of ascomycetes that release extracellular pigments deeply into wood, resulting in a completely penetrating stain of their substrate. In temperate forests these fungi are sporadic at best, having a low presence on both conifers and hardwoods. In the tropics they occur with a higher frequency, yet are still uncommon enough to have attracted little to no attention.

Fungus hunters are likely familiar with at least one of these pigment-producing fungi, *Chlorociboria aeruginosa* or its very similar cousin *Chlorociboria aeruginascens* (both known as "elf's cup"). The blue-green cup fungus grows on very decayed wood and leaves behind the stunningly beautiful pigment called xylindein. Wood colored by *Chlorociboria* has been used for centuries in Europe to add natural color to wood marquetry and intarsia. Brown oak, oak colored a rich brown through the colonization and pigmentation of *Fistulina hepatica* ("beefsteak fungus") has also been popular for several hundred years for furniture making, especially in England.

Both the blue-green wood of *Chlorociboria* species and the brown wood from *Fistulina hepatica* are still in use today, primarily in Europe and North America where wood artists and crafters are using them as part of a greater "spalting revival." The word spalting is relatively new, having only been in the general English language since the mid 1970s, and generally refers to color *in* wood that came from a fungus (note the emphasis on *in*, as color found *on* wood from mold fungi is not considered spalting). Three types of spalting are recognized: the white rot of hardwoods that leaves the wood with a visibly lighter appearance, the zone lines (often black or brown, but other colors exist) that delineate fungal boundaries or are made as a response to changes in climatic and substrate conditions, and extracellular pigments, such as those discussed above.

"Fungi do not always play nicely with each other… The beautiful colors and boundary shapes produced by some of these wood-colonizing fungi are a by-product of the means by which to protect their property. One major artifact left behind by white rot fungi is a zone line… composed of pigments, primarily melanin… What is well proven is that many white rot fungi will erect zone lines if they detect the presence of another fungus of comparable strength."-Sara C. Robinson, 2014, in "The Fine Art of Decay," ***American Scientist*** **102[3]: 206-213. What to learn more about spalting of wood? Check out this article, you can find it at the link: http://www.americanscientist.org/issues/feature/the-fine-art-of-decay/1**

Brown and black zone lines in the Amazon.

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Top Left: pink stain and black zone lines in the Amazon.

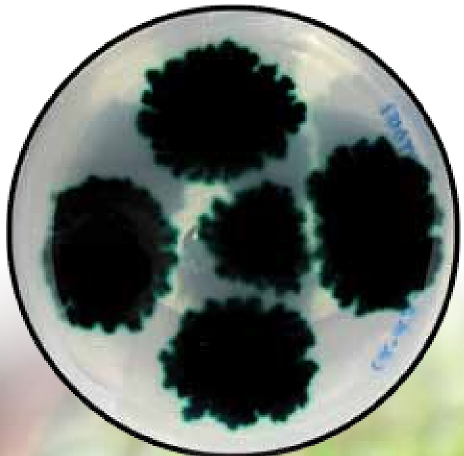
Middle Left: brown and black zone lines in the Amazon.

Bottom Left: wood blocks being tested with extracted fungal pigments.

Top Right: purple and green stain on wood in the Amazon.

Bottom Right: green stain and green zone lines in the Amazon.

Five-point inoculation of *Scytalidium cuboideum* on 2% malt agar.



Five-point inoculation of *Chlorociboria* sp. on 2% malt agar.

Five-point inoculation of *Scytalidium ganodermophthorum* on 2% malt agar.

In the United States, zone lines have been the dominant form of spalting found on woodworking objects, especially turnings. The prevalence is due to the pioneering work of the Lindquists, father and son Mel and Mark, who popularized the zone line in their wood turnings in the 1970s through 1990s. In Europe, brown oak remains popular, and the green stained wood of *Chlorociboria* species can be found still on English Tunbridgeware and in jewelry from European artisans.

It is noteworthy that interest in spalted wood is growing – not just in countries where it was once popular, but also in places where it never truly had a foothold. South America is currently a hotbed of spalting development, with Chile and Peru beginning initiatives to find and characterize their own unique spalting fungi and market native woods with the natural coloration.

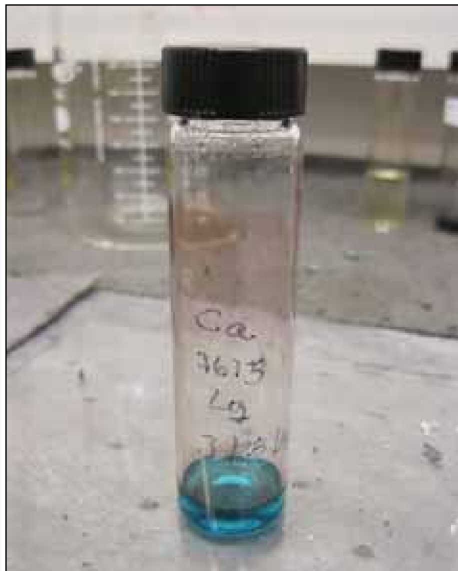
With this growing worldwide interest in spalting, artists and scientists find themselves butting up against the same problems that the old intarsia masters faced – how do you get access to enough spalted wood? Can you make it? How fast can you make it? Is there a way to avoid the softness that comes from wood decay?

A quick Google search will turn up any number of strange recipes for encouraging spalting in wood, and several US companies have even patented methods for inoculating veneer with fungal spores in the hopes of producing zone lines. But all of these methods rely on direct wood inoculation and hope – hope that the fungi will colonize, hope that the substrate is sterile enough to not kill them, and, in the case of zone lines, hope that the fungi will interact enough to make the desired melanin boundary. Add to all of that inoculation takes time to get a decent result. Depending upon fungal and wood species, the incubation time can be a few weeks to a few years – a time scale that makes commercial scale (or even home scale) spalting an unattractive option in comparison to just using an aniline dye.

As an artist who works in the sciences (wood science, to be specific), I have long

***Chlorociboria* fruiting bodies.**

Solubilized pigment from *Scytalidium ganodermophthorum* in DCM.



Solubilized pigment from *Chlorociboria* sp. in DCM.

Solubilized pigment from *Scytalidium cuboideum* in DCM.

Multifiber test strip dyed with pigments from *Scytalidium cuboideum.*

Wallpaper (made from 100% recycled paper), dyed with the fungal pigments

Multifiber test strip dyed with xylindein.

used spalted wood in my wood turnings. Unlike many woodturners, however, I have a research lab at my disposal and a number of undergraduate and graduate students eager to experiment with fungi. Over the past several years my lab has worked on developing the pigment side of spalting so that it can compete on a global market with aniline dyes.

The process hasn't been as easy as we had hoped. Unlike pigments produced from mold fungi or lichens that can be extracted easily with water or a relatively low-toxicity solvent like acetone, the pigments from spalting fungi are meant to be "sticky," in that they have to persist in their environment through all sorts of conditions. These fungi are also specific to woody substrates – meaning that simply growing them on malt agar in the lab isn't going to yield a lot of pigment.

We got around the growth issue by simply including ground up bits of already spalted wood (sterilized, of course) into the malt extract agar. With this new growth medium even

Boxelder bowl with a pigment wash from *Scytalidium cuboideum* to help maintain the native pink color.

Chlorociboria, a very slow growing fungus, would create a large volume of pigment in a short time frame (two weeks – which is pretty fast for a pigment-type spalting fungus). After max growth the plates were dried to get rid of the water, then the pigment was extracted using dichloromethane (DCM). Extractions were also done directly from found spalted wood – a nice time saving step if big enough pieces could be found.

Our early work focused mostly on the two North American *Chlorociboria* species, as well as *Scytalidium cuboideum* (red/pink) and *Scytalidium ganodermophthorum* (yellow/purple). The fungi were grown on the amended wood malt agar plates, then extracted and filtered to yield a brightly colored extract that could be reapplied to wood directly and yielded the same color as if the fungus itself were colonizing the wood.

Having the pigments in a solution separate from the fungus opened new doors to our research. Suddenly spalting wasn't completely about wood anymore. Because of the "sticky" nature of the pigments, applications like textile dyeing (no mordants needed!), paint, glass dyes, wallpaper colorants – a huge range of dye opportunities presented themselves.

With the increase in application came

Maple bowl with white rot and zone lines, and light pink staining through a wash of extracted pigments from *Scytalidium cuboideum.*

Knobcone pine with pigments from *Chlorociboria* sp. (blue-green), *Scytalidium cuboideum* (red), and *Scytalidium ganodermophthorum* (yellow).

Bigleaf maple bowl with white rot, zone lines, xylindein (blue-green pigment) from *Chlorociboria* sp. and yellow pigments from *Scytalidium ganodermophthorum.*

Magnolia bowl with a light wash of the yellow pigments from *Scytalidium ganodermophthorum*, done to help soften the silver sheen of the wood.

Come join your fellow mycophiles for a fun, exciting and educational 4 day event, in the beautiful Blue Ridge Mountains.

The climate, topography, and geological history have made the mountains of Western North Carolina the most biologically diverse area in the U.S. We'll have 1,200 acres available to foray along with other nearby sites proven to have great fungal diversity. A NAMA Annual Foray wouldn't be complete without a mycophagy experience along with classes, presentations, entertainment and time to meet and socialize with fellow NAMA members.

Other mycologists, speakers and instructors are:

Dr. Britt Bunyard, Dr. Cornelia Cho, Tradd Cotter, Todd Elliott, Susan Hopkins, Jay Justice, Dr. Julia Kerrigan, Dan Lazar, Dr. Patrick Leacock, David Lewis, Dr. Brandon Matheny, Peter McCoy, Dr. Andy Methven, Alan Muskat, Dr. Ron Petersen, John Plischke III, Elinoar Shavit, Walt Sturgeon, Dr. Rod Tulloss, Debbie Viess, Dr. Rytas Vilgalys and Dr. Tom Volk. This is a working provisional list and there may be some additional speakers.

Watch the NAMA website

www.namyco.org

for registration opening on or around April 1. To be notified when registration opens, email blueridgeforay@gmail.com and put "Notification request" in the subject line.

"NAMA membership required to attend this event."

Participants in the 2014 "fungus of the year" contest, where voting is done through hair coloring.

an increased need for the pigments and once again, a better way to produce them. We needed large amounts of pigments quickly, and so again began to experiment with culture growing conditions. Large volumes of fungus and pigment were finally produced through shake culture – opening up more applications as the shake culture pigments were carried in water (as long as the culture was kept moving – the pigment would begin to bind the moment the movement stopped) and could be applied to applications that would have been melted by the DCM carrier.

This new growth and use model, with or without DCM, made extractable spalting pigments a potentially commercially viable operation. Other countries, especially Peru, began to look into what fungal resources they had that could fit within this model. My lab was invited to field stations in the Amazon to hunt for potential spalting fungi, and we began collaborations with Chile and Peru to help develop this otherwise completely overlooked resource.

Today, at this very moment, spalting fungi are straddling several fields. In my lab, new uses are experimented with and refined every day. In South America new colors are being discovered (orange zone lines!). Information and anticipation continue to build across Europe and North America. Where the first big "break" for these pigments will happen is unknown – whether it will be in the wood, textile, or general colorants market is anybody's guess. Their wide potential applications and eco-friendly appeal should make them very attractive to industry trying to cash in on the green market. But before anything can happen, people have to get excited – a certain buzz has to be generated.

Would you wear a red t-shirt dyed by a fungus? Would you paint with the xylindein of *Chlorociboria*? Would you wallpaper your kid's room with spalted paper stock?

How ready do you think the world is for a new type of green movement, where the "green" is actually green (or maybe more of a *Chlorociboria* blue-green)?

Spalting Education

The menagerie of potential applications for spalting pigments continues to grow and with it, interest from students grows as well. In response, the Department of Wood Science & Engineering at Oregon State University runs several courses where spalting is either the primary focus or a component of the class. A new option in the Renewable Materials minor has even been formed for those interest in the design end of wood science, and gives students the potential for engaging in spalting research and design for their entire undergraduate experience!

Classes with spalting components:

Are You Wearing Mold? (UEngage course – ALS 199; whole class is about spalting)

Are You Wearing Mold?- Love 'em or hate 'em, fungi come in a dazzling array of colors that add splashes of red, green and every color in between to a variety of everyday products. From stunning spalted wood floors to vibrant wools, fungi-based dyes help bridge the gap between nature and design. In this class we'll explore the long history of humans hunting, extracting, and using these pigments for dyes and also learn about recent developments that are producing the stickiest, brightest and most useful dyes yet. We'll also get our DIY fix on by participating in the process. Plan to collect your own native fungi, extract pigments, and dye your choice of materials. Equal parts science, art, design and hands-on activities, you'll never look at mold the same way again.

Renewable Materials in the Modern Age (WSE 415 / DHE 415 / ART 415; unit on spalting)

An interdisciplinary anatomy class for all backgrounds (art, science, engineering, whatever) that teaches anatomy through hands-on building and experiences. Get up close and personal with fungi, design new wood joints, break some really loud textiles, all while working on your mixed group final project that combines the background of every student involved to address a current issue in renewable materials today.

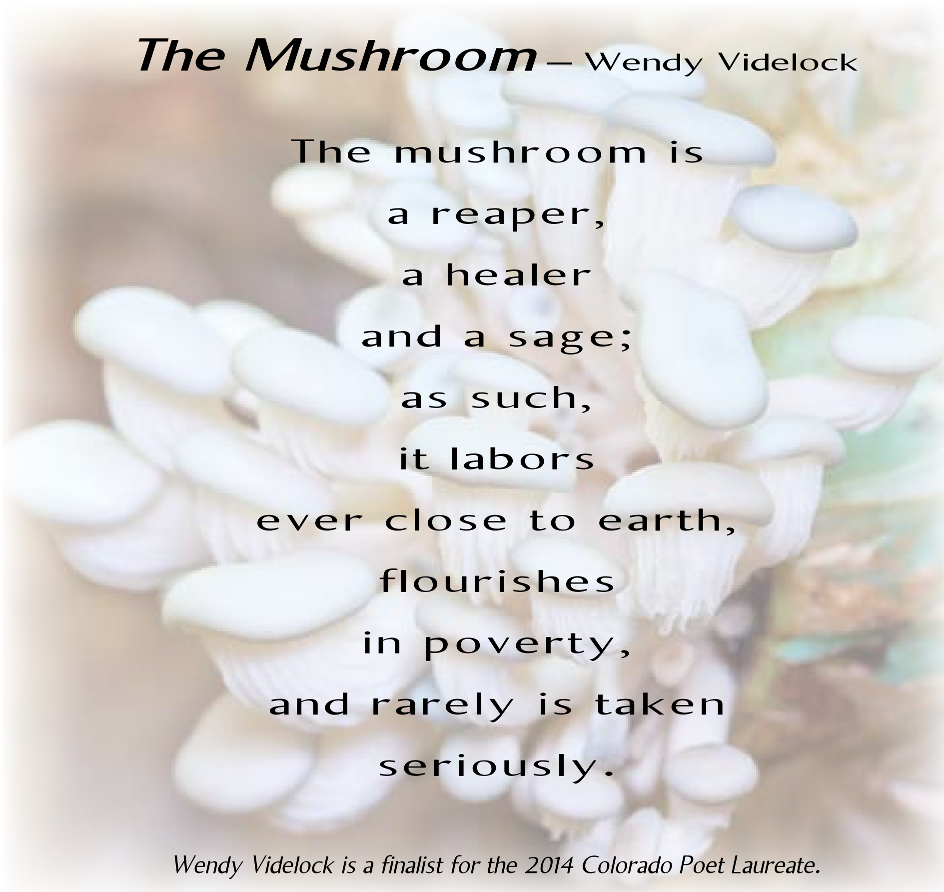
Tropical Woods and the Fungi That Love Them (Study Abroad – spalting in Peru!)

A short, two week, six credit course on wood anatomy and fungal pigmentation specific to Peru. Learn the basics of tropical wood identification in Lima before heading to the Amazon rainforest, where you will be armed with machetes and sent out to look for elusive spalting fungi. Bring back your daily collections for culturing, microscopy, identification, and sequencing. Contribute directly to spalting research by helping us find new fungal species, and help advance Peru's emergence into the spalting world. *A special note – this class runs a simultaneous art component with a science component. Students may select daily assignments from either side. Those* *interested in mycology, wood science, field photography, field illustration, or who just like fungi are welcome.*

Or hey, why not just pick a major where you can spalt ALL THE TIME!

Renewable Materials major with an Art & Design option

This option prepares students to engage with renewable materials (hey, fungi are renewable materials, too!) on an aesthetic level, whether as interior designers, fine artists, or entrepreneurs. In this option of the RM major, students gain not only an in-depth knowledge of renewable materials, but also how these materials can function visually within the human space. In addition to the aesthetic aspect, students will gain an understanding of green building materials and green architecture. Students in the A&D option automatically earn a minor in Fine Arts through the required coursework, and have opportunities to study abroad within their field during the yearly fungi hunting expedition to the Peruvian Amazon.



The Mushroom — Wendy Videlock

The mushroom is
a reaper,
a healer
and a sage;
as such,
it labors
ever close to earth,
flourishes
in poverty,
and rarely is taken
seriously.

Wendy Videlock is a finalist for the 2014 Colorado Poet Laureate.