The Fine Art of Decay

A woodworker becomes a scientist in seeking out the perfect fungal pigments.

Sara C. Robinson

The sheer magnitude of decay in the woods of the Pacific Northwest, where I live, is thrilling and sometimes overwhelming. Life in these forests involves soggy leaves, soggy children, and that ever-present smell of decomposing vegetative matter. Children love to crawl around on the forest floor for treasures. And who hasn't enjoyed kicking apart a soundly rotten log, watching the dry bits scatter, and hearing the mushy bits make that delightful *squelching* sound?

I'm certainly not one to deny such visceral pleasures of the forest. But that log is so much more than decay. It is an ecosystem, a potential nurse log for new trees, or cover for small animals. Insects, bacteria, and fungi work together to provide a steady stream of nutrients that are cycled again and again through the forest. It is also something much more personal: It is art. And it is my life.

I wasn't always obsessed with fungus. As a teenager, I knew only that I wanted to be a woodworker, and I spent countless hours in my high school woodshop learning furniture design and turning. I couldn't have cared less about other subjects; by the time my senior year rolled around I was too busy turning red-stained boxelder bowls brought in by my woodshop teacher to bother with math, physics, or chemistry. Academics weren't for me. I wanted to turn, and I wanted to do it with brightly colored wood.

My parents were hoping I would choose a four-year degree, *any* four-year degree, over a carpenter apprenticeship. Through a great deal of research on their part (I had nothing to do with it—I had no interest in college), they found a university that offered a four-year degree in woodworking. After one trip to visit, upon seeing the room filled with lathes, I was hooked. I agreed to pursue an art degree if it meant having access to multiple lathes. I'm easily persuaded by shiny pieces of metal.

Pigments and zone lines caused by spalting in sugar maple wood (*Acer saccharum*) showcase a stunning variety of colors.

Four years later I was blocked, left with a solid grounding in art but no real additional wood skills. There was no one to supply me with brightly colored wood, either, and most of my turnings from this time relied on playing with the interface between the dark inner heartwood and the lighter outer sapwood to keep my aesthetic attention. I was bored; I was upset. I wanted more information about wood so that I could be a better woodworker, not more history lessons.

Michigan Tech's forestry program ended up offering me the opportunity to learn more, but in a rather convoluted fashion. I applied to a master's degree program there through the Peace Corps, hoping that two years abroad might help quell my growing wanderlust. But when two successive placements fell through due to bad timing and local rebellions, I was left with no option other than a standard master of science degree.

In desperation, I contacted the only professor of wood science left at MTU, Peter Laks, and asked him if he knew of any type of project that I could work on to finish my degree. We chatted. I'm sure he thought I was nuts. Eventually he asked me to bring in examples of some work that I had really enjoyed. I pulled a bright red bowl from my days in high school and brought it to him, gushing about wood colors. Boxelder wood is typically a pale cream color, but occasionally streaked with bright red/pink stain, usually around areas of knots or other wounding. This bowl showcased

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A love for lathes for wood-turning and working with brightly colored wood led to a career in science studying fungal pigments. Work in the lab resulted in colorful spalted bowls, such as this one. (All photographs courtesy of the author, unless otherwise noted.)

the reason the popular term for stained boxelder wood is *flame stain*. The conversation went something like this:

Dr. Laks: "Interesting bowl. What makes the colors?"

Me: "I don't know. Beetles? I think? Maybe fungus?"

Dr. Laks: "Are there other colors like this?"

Me: "Uh, maybe?"

Thus my entire future was launched. I pulled papers and did research. I began to delve into a history of ancient craft and modern science. Once it became apparent that fungi could in fact cause colors on wood (although fungi did not cause the flame stain in boxelder that launched my research), I started experimenting with fungi. Which ones made the appealing colors? Which ones made those neat lines? I was mesmerized by the idea of living art, using pigments produced through natural growth processes to color wood. And, to be honest, I was mostly excited about making neon-colored bowls.

Through my research I found that although a lot of the pigment residues left by fungi on wood, called *spalting*, were known to science, no one in the scientific community was particularly interested in inducing them. They were associated with decay, and wood scientists had spent decades trying to keep fungi *off* wood to prevent structural damage. Wood crafters and artists weren't too interested in fungi either, seeing them as either pests that discolored wet wood or deadly human pathogens that should never be brought into the house. Amusingly, spalted wood has actually been used in craft since at least the 1500s, if not before, and entrepreneurs have been attempting to stimulate wood pigmentation for economic gain since the very early 1900s. But no one had really been able to reproduce spalted wood reliably, and especially not in any type of quick time frame.

The trick to controlling wood spalting, it seemed, was a thorough understanding of the biological process. Wood decay fungi in the phylum Basidiomycota, which includes all mushrooms, come in two primary groups: the brown rots, which predominate on conifers, and the white rots, which prefer hardwoods. White and brown rots generally only grow in dead or severely stressed trees. Unlike the rest of mycology, in which technical jargon dominates, the terms *white rot* and *brown rot* are actually very descriptive of the end result of the log. Brown rot fungi leave behind a crumbly, brown, lignin-rich shell. White rot fungi, capable of breaking down lignin, leave behind mushy, lightened wood instead. Other fungi, habituated to wood but unable to cause substantial decay, grow slowly inside the log, some before the rots, some concurrently, some after, digesting the easy sugars of the wood rays and occasionally producing melanin and other pigments in an attempt to protect their resources from desiccation, light, or other fungi.

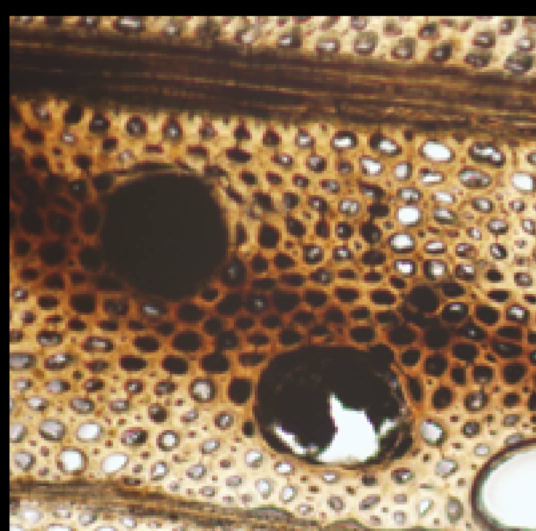
Fungi do not always play nicely with each other. There are limited resources in any given log, and many fungi want a piece of the action. Those that can colonize quickly have an initial advantage, but, as in any war, you have to be able to hold the land you've captured (not just plant your flag and go) if you want lasting success. 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: This winding, sometimes thick, sometimes thin line of black, brown, yellow, orange, green, or red, is composed of pigments, primarily melanin. Zone lines are thought to serve a variety of functions depending on the fungus. Some may help prevent desiccation of the log; others may protect against damage from ultraviolet light. 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. And although most zone lines occur at the boundary between two different white rot fungi, they have also been documented surrounding soft rot fungi and various pigmenting fungi from the phylum Ascomycota, which produce sac-shaped fruiting bodies rather than the stereotypical mushroom shape.

But pigmentation doesn't happen just in zone lines. Some fungi, most no-

Dr. Jeremy Burgess/Science Source

White rot (*left*), and zone lines resulting from white rot antagonism, among other mechanisms (*below*). At bottom, a microscopic view of a zone line show melanin formation in the lumens of sugar maple wood. Photograph at bottom courtesy of Daniela Tudor.



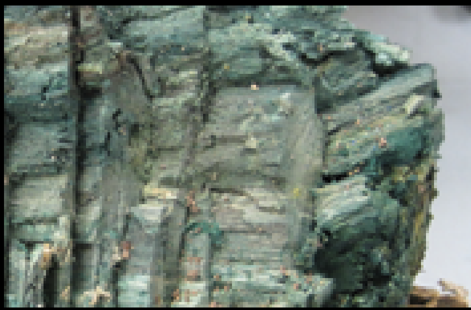
tably the *Chlorociboria* genus, produce extracellular pigment that changes the color of the wood where they grow. It is thought that pigment secretion is a way to quickly capture a log so that other fungi cannot colonize it, giving the slow-growing *Chlorociboria* species time to establish. Other pigment fungi—such as the Ophiostomatoids, which produce a dark melanin that appears blue due to light refraction off the wood, and the multicolored genus of *Scytalidium*—may have a variety of other reasons for producing pigments, such as a reaction to components within the wood or environment or a response to environmental stress. But the effect is the same: Out there, in the forest, is a crayon box filled with pigmenting fungi that are drawing all over downed and decaying wood in an attempt to carve out an existence in a competitive world.

The Art History of Spalting

As I discovered several years later, however, pigmented wood was not unknown to the art world. There are a plethora of examples of the green-stained *Chlorociboria*-infected wood in European intarsia (wood inlay that uses tiny pieces of wood to make a larger picture). The blue-green wood of *Chlorociboria* was commonly utilized as color for grass or water, and was a prized find by many crafters. An easily accessible example is the pulpit intarsia in St. Mary's Church in Greifswald, Germany, by Joachim Mekelenborg. In addition to blue-stained wood (common in sky areas), wood marked with zone lines was also used in intarsia. There wasn't a technical name for such wood ("Pilz-Pigmente," as it was called in German, literally just means fungus pigment), but artisans saw its value as a way to avoid harsh dyes and sought it out for use in their works.

Unfortunately, the Industrial Revolution, when handmade craft gave way to machine-manufactured products, played a large role in the decreasing interest in intarsia and naturally pigmented wood, and by the early 1900s, the use of spalted wood in wood crafts was down to a trickle. Even the arts and crafts movement, designed to raise awareness of handmade craft, keep old techniques alive, and value the craft over machine-based products, didn't keep this colored wood in use.

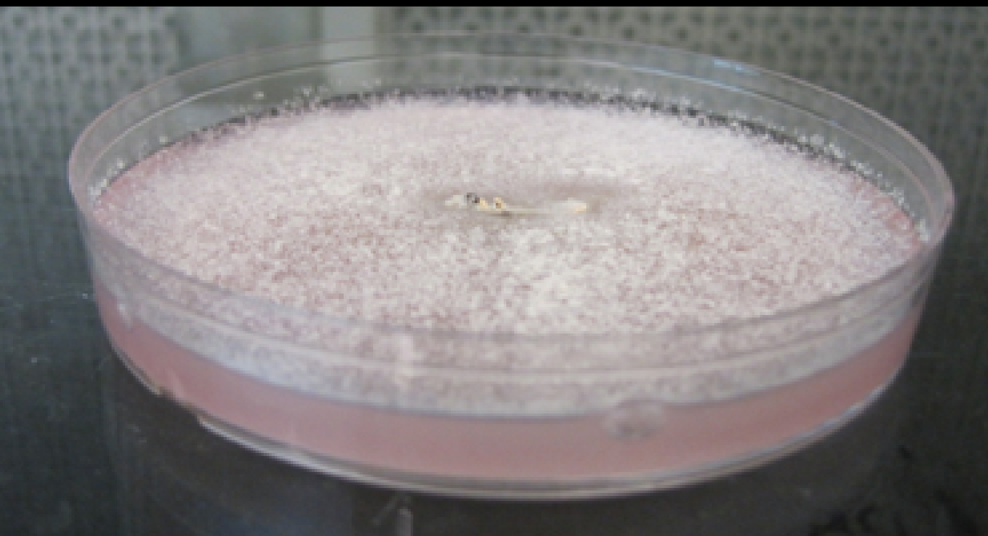
But like any beautiful thing, colored wood couldn't stay hidden for long. In the 1970s Mel and Mark Lindquist, a father–son duo, were making waves in the craft and art scene with their use of found zone-lined wood for wood turnings. They gained a great deal of



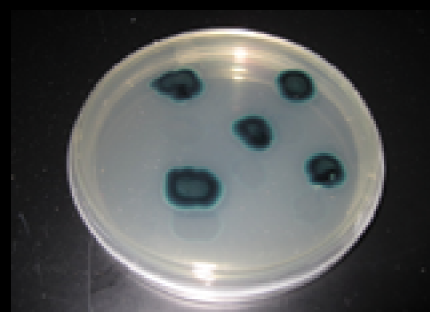
The fungi in the genus *Chlorociboria* have bright blue-green fruiting bodies (*right*) and cause blue-green pigmentation throughout the wood in which they grow (*far right*). Wood with a green stain caused by this fungus was used as inlay depicting a bird and leaves in the pulpit intarsia in St. Mary's Church in Greifswald, Germany (*above*). (Photograph above courtesy of Hans Michaelsen.)

Growing Pigmented Fungi in the Lab

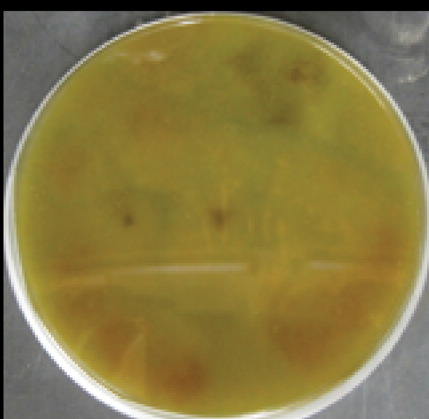
Growing pure culture media in the lab is key to controlling spalting. Understanding growing conditions, type of media, and the general personality of different species can shave months off of incubation time.



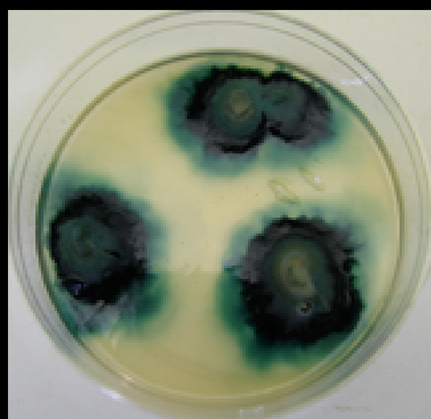
Scytalidium cuboideum **sporulates heavily in culture and releases a pink, red, or orange pigment into the media (*left*). Left for too long, however, this species will start to produce melanin, which will show as a blue pigment. This is a reaction to the pH change in the media and can be a real pain when spalting if you just want the pink color.**



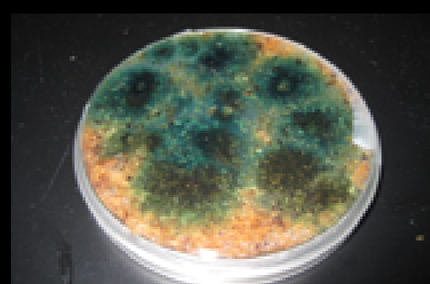
After five colonies of a fungal species in the genus *Chlorociboria* have grown on malt agar plates for one month, one can already see blue-green pigmentation.



Scytalidium ganodermophtorum **grows more slowly than *Scytalidium cuboideum* and is a heavy sporulator. It releases a yellow, brown, or green pigment into the media, beginning at a light canary yellow and deepening to brown, until finally reaching a grass green over time.**



Six months after inoculation, this *Chlorociboria* species is at full-diameter growth. This fungus grows so slowly in media that it is rare to have a single plate completely filled with the blue-green pigment. Adding sterilized chips of prespalted wood, however, stimulates the growth of this fungus, so that full pigmentation is achieved at 10 days.



When sterilized wood chips of white-rotted sugar maple (*Acer saccharum*) are added to the malt agar, five colonies of the same fungus grow much faster: The image above shows the growth after five days.

media attention after they authored several articles about spalted wood in *Fine Woodworking*, the premier wood magazine of that time. These two gentlemen turned the word *spalting* into a name to describe zone-lined wood (its definition was later broadened by my own research). Although this reemergence of spalted wood as a craft and art tool brought naturally colored wood back into the forefront of public consciousness, the pigments were left forgotten, and zone-lined wood was hailed as the new design trend in woodturning.

Due to the emphasis on zone lines by spalted wood users, my own wood research in the mid-2000s began heavily focused within this area. But I also experimented with blue stains, because the fungi that produce such color are numerous. Initial experiments attempting to induce zone lines in clear lumber led to more research and more reading, and it became quickly apparent to me that spalting encompassed a much wider definition than simply black lines—even zone lines could occur in different colors. So when I began publishing my results on how to induce spalting under controlled conditions and began naming fungi that could reliably produce spalting, even though I was primarily working with zone lines at the time, I reset the definition: Spalting was any color on wood caused by a fungus.

Woodturners, the group most interested in spalted wood, were rav-

Spalting Wood in the Lab

The pigment fungi are the key to making a two-year process in the field take two hours in the lab. Using either naturally pigmented wood from the forest floor or, in our case, the pigmented wood agar plates, you can submerge the colored wood in any number of organic solvents (*below*). The resulting solution can then be reapplied directly to spalted or unspalted wood and if put on slowly, does not run over the surface (*right*). Many of the useful solvents, like acetone, run quickly through the wood and carry the pigment through as well, giving surface-to-surface color in seconds—instant spalting! As a bonus, the solvent can be evaporated off, and the pigment can be stored dry, making "spalting on the go" possible as well (*below, right*).

enous for information about how to improve and expand their craft. It was broadly understood that fungi were at least partially responsible for spalting, but which fungi and how best to get said fungi in the wood was still a mystery. Conjecture had ruled the gossip chain and Internet for so long that once artisans had actual fungi to experiment with, the topic exploded. With the release of my research, attempts to induce spalting in workshops was no longer a practice in luck, patience, and variable mixtures of leaves, wood chips, and beer (and various other amusing spalting recipes). Lab-derived directions for speeding up growth and getting a reliable result were finally available. Interest grew, along with commercial demand. So my research kept going. Eventually I became bored with zone line research, because wood with black zone lines is exceptionally easy to find in the forest. It is also easy to induce in a lab or garage, because the production of such wood only requires a log and two irritable white rot fungi. I wanted color. I turned my focus back to the pigments, notably the greens and pinks.

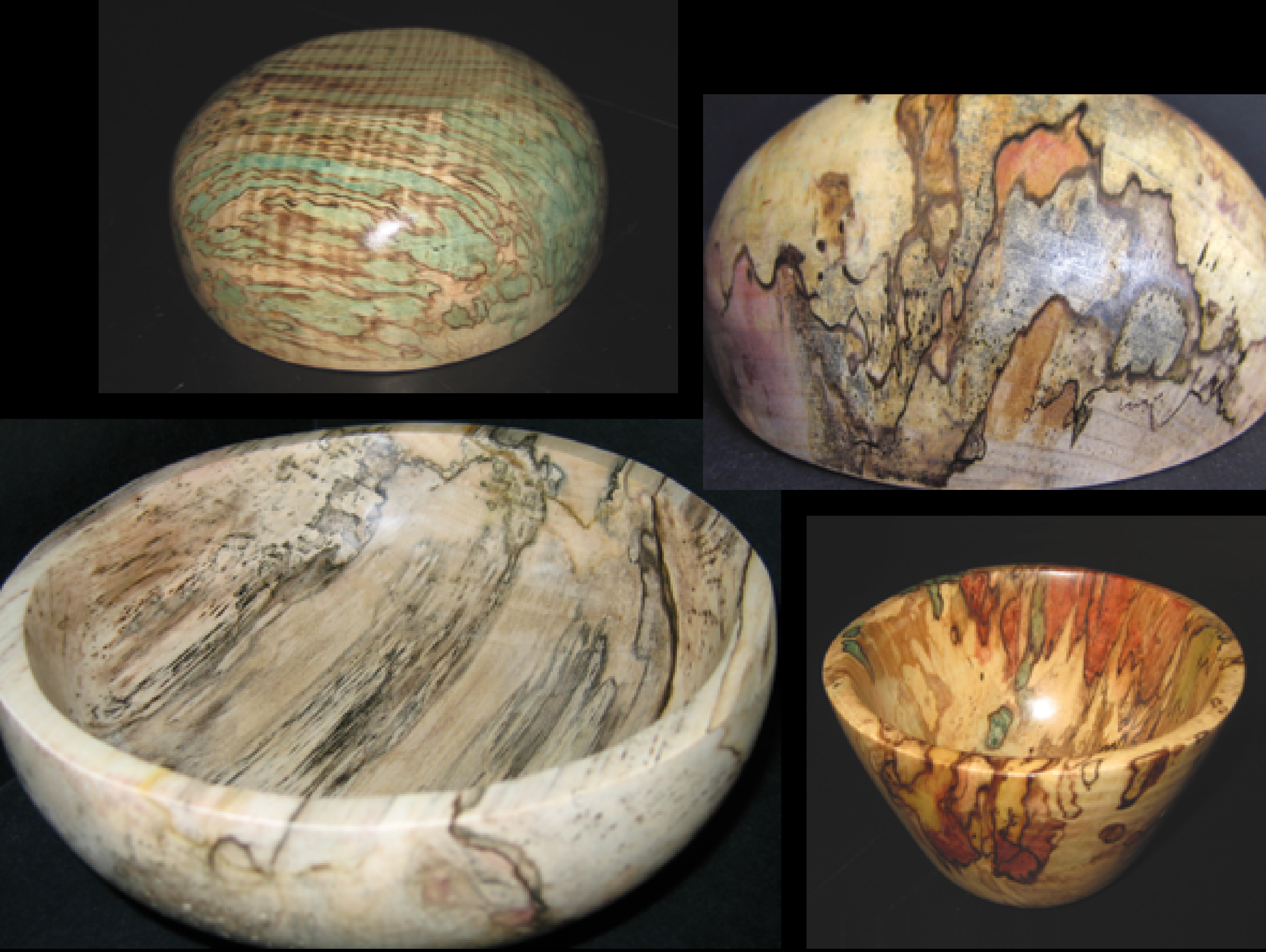
This turned out to be a trickier endeavor. In nature, the brighter pigments, whether in zone-line or full-coverage form, are hard to locate. True wood-inhabiting fungi will be *inside* the log, not growing on the surface (*Penicilliums* and *Trichodermas*, common airborne molds that only discolor the surface of wood, need not apply).

Clockwise from above left: Wood specimens found in an Amazon rainforest in Peru showcase orange zone lines, black zone lines with yellow pigment, green and purple stain, and black zone lines with pink pigment.

If you want pigmented wood, you're going to have to dig for it. These fungi also tend to be slower growers without any real decay ability (with one species called *Scytalidium cuboideum* being a glaring exception). They are usually found on logs that are already well colonized by basidiomycete fungi like white or brown rots. This means that the wood is soft, punky, and generally unusable unless you want to do historic intarsia, or to sink about $20 worth of plastic stabilizer into the wood.

It also means that color-producing fungi can be difficult to grow in a lab, where the majority of my work was taking place in plastic tubs and Petri plates. I found that *Chlorociboria* species are especially tricky, because isolates can take months to grow to adequate sizes and do not perform well under wood inoculation conditions. While doing postdoctoral research at the University of Toronto, my research took off in this direction: how to encourage pigment fungi to grow and produce their colors under controlled conditions. They obviously weren't going to be motivated by money or a new car, so we had to get creative. It turned out that a simple addition of white-rotted wood, finely chipped, sterilized, and added to our standard malt agar media, was enough to get our target fungi to rapidly secrete pigment. What once took months for substandard results now took 10 days with amazing results.

We ended up with hundreds of sheets of wood fiber in the lab, pigmented with green, blue, red, pink, orange, and yellow. We were awash in a rainbow of colors we never expected to have in any sufficient amount. Suddenly, the possibilities for these fungi were massively expanded. The pigment was extractable and easy to reapply to wood where we wanted it—no fungus growth needed. The pigment also had an affinity for textiles, and our lab exploded with samples of every fiber



Fungal pigmentation in wood opens up the possibilities for a plethora of designs and colors, which Robinson showcases in her wood-turned bowls. Clockwise from top left: Curly red maple with zone lines and green stain of *Chlorociboria* fungi via extracted dye; sugar maple with zone lines with blue, orange, purple, and pink stains from a menagerie of inoculated fungi; curly red maple with zone lines and pink, orange, yellow, and grain stains applied with extracted dye; aspen with zone lines resulting from inoculation with the white rot fungus *Xylaria polymorpha*.

imaginable, all brightly hued and covering every available surface.

With this breakthrough, modern spalting was born. A mixture of biology, artistry, and luck, the process developed for the lab has reduced incubation time from one to two years in the wild to about two hours in the lab, *still using the same fungi*.

Today, my lab in the Wood Science and Engineering Department at Oregon State University is filled with excited graduate students and undergraduates, all who have different ideas about how these pigments can be used. Nothing is off-limits—we've become a lab of random experiments, of both science and art. Our biggest struggle is deciding on which paths to follow first. Questions that currently interest us include: Do the pigments have any UV stability? Do they have any medical potential? Can they be used as dyes for acrylic paints or dyes for clothing? Does spalting mean wood colored with fungi that are actually grown on the wood, or can it still be spalting if the fungi are grown on a different piece of wood, then the colors transferred in a directed manner?

We are all very excited about the evolution of this ancient art. But in the end, the consumer and artist will dictate how spalted wood and extracted pigments are used, whether for beautiful, time-consuming intarsias, prefab wood veneer floor, or your next pair of running shoes. No matter where our research takes us next, it is guaranteed that it will be brightly colored and beautiful.

For relevant Web links, consult this issue of *American Scientist Online:*

http://www.americanscientist.org/issues/id.108/past.aspx