Staining wood with fungal pigments has a long history in fine art, especially wood naturally stained blue-green by fungi from the genus Chlorociboria. Recent innovations have allowed for controlled application of extracted pigment for reinterpreting this old art form. This technology is showcased in objects created for a production of The Blue Forest by Louis Aubert, representing the power of nature and natural magic within the play.

PRODUCTION OF THE BLUE FOREST

The Blue Forest (La Forêt Bleue) was produced by Oregon State University’s College of Liberal Arts in the spring of 2016 and represented a collaboration from a number of OSU departments and fields, including chemistry, art, music and wood science. The relatively unknown opera was first produced in 1913 in Boston and combines the traditional fairy tales of Red Riding Hood, Hop-o’-my Thumb and Sleeping Beauty to create a poetic and joyful story [1]. As a short summary, Red Riding Hood and Hop-o’-my Thumb are lost in the wood with human-eating ogres and are saved by fairies who proceed to show a prince the location of Sleeping Beauty. The latter two kiss and live, of course, happily ever after.

Materials used in the stage design of the opera included crafted objects intentionally representational of wider themes. This was important, as theatrical and operatic sets create context for the viewer. An opera without a set has been described as “an incomplete art form,” as the staging of the opera brings it to life [2]. As a short summary, Red Riding Hood and Hop-o’-my Thumb are lost in the wood with human-eating ogres and are saved by fairies who proceed to show a prince the location of Sleeping Beauty. The latter two kiss and live, of course, happily ever after.

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A prominent theme of the opera was an exploration of the classic dichotomy between culture and nature, exhibited by contrasting use of two dyeing technologies. The first, an artificial blue dye (YInMn) recently formulated at OSU [4], was used to color the garments of royalty in the play. In contrast, a naturally derived blue-green fungal pigment was used on the weapons and costuming of the fairies and Sleeping Beauty’s casket—objects of natural power within the play. This second coloration technology is a result of developments that have reinterpreted use of a historical artistic material mostly fallen into disuse—wood pigmented by fungi (spalting). Herein we discuss this technology, its roots in history and its applications within the play.

HISTORY OF WOOD PIGMENTED BY SPALTING FUNGI IN ART

The use of wood colored by fungi has a long history in fine woodworking. This wood, referred to as “spalted,” undergoes changes in appearance due to fungal colonization. This can include bleaching of wood, production of thin, twisting dark lines known as zone lines, and pigmentation. This final form is associated with soft-rotting decay fungi, of which the Chlorociboria genus is the most famous in historic art. These fungi produce the pigment xylindein as they grow, coloring wood a bright blue-green [5].

The blue-green wood produced by Chlorociboria spp. was a highly valuable component of woodcraft in continental Europe from the thirteenth to the eighteenth centuries and was the only known long-lasting blue-green material for coloring wood available until the 1600s [6]. The wood most often appeared as a component of intarsia, a form of inlay wherein thin pieces of wood are cut and placed into larger wood panels. The Gubbio Studiolo, a perspective marquetry masterpiece from the fifteenth-century Italian renaissance, now displayed by the Metropolitan Museum of Art in New York, shows intricate use of blue-green wood in intarsia details such as leaves and book covers [7]. The wood was also used in production of religious works of art, such as the intarsia panels produced by Fra Giovanni da Varona for Italian
monasteries and churches [8,9]. *Chlorociboria*-stained wood has also been identified as decoration on instruments such as violins [10] and in intarsia work on fine cabinetry and chests [11].

Use of blue-green wood reached its heyday in sixteenth-century Germany, with fine intarsia work being a highly valued commodity [12]. Work produced by German masters moved around Europe; for example, bureaus commissioned from Augsburg, Germany, by nobility were brought to Spain [13]. An example of such works is shown in Color Plate B (top).

The invention of various synthetic dyes eventually usurped the use of natural staining, as *Chlorociboria*-stained wood was hard to find and even harder to work with [14]. Only a few guild families held the secrets to its use, and they tightly controlled the methodology. Eventually, synthetics completely replaced spalted wood use in Europe, and the decorative wood became very nearly lost to history until a resurgence event in the 1950s and 1960s in the United States (the Studio Woodturning Movement) brought it back into artistic consciousness. From its new use in woodturning, it has also once again found popularity in the sciences.

**DEVELOPMENT OF NEW SPLATING TECHNOLOGY—THE SCIENCE SIDE**

The fungal pigment that turns wood green-blue, xylindein, was first extracted from wood in 1868 [15], and its structure was elucidated in 1965 by Blackburn and Ekong [16] and Edwards and Kale [17]. While synthesis has been attempted [18–20], it has not been successfully achieved. This makes the pigment a distinctly natural compound—produced by fungi and not replicable by humans.

In addition, xylindein is in demand. There are methods to extract the pigment from fungi [21], and it is being researched for applications including use as a fabric dye [22–24], in paints [25], as a germination inhibitor [26] and as a component in organic (opto)electronics such as photovoltaics [27]. This promise has spurred research into methods to stimulate production of pigment by *Chlorociboria* spp., normally an exceptionally slow process due to the character of the fungi [28,29].

Along with these diverse applications, xylindein can be extracted from found wood in the forest and reapplied to clear, unstained wood—mimicking the color effect without the corresponding decay—after being ground and placed in solvents like dichloromethane [30]. The heavily decayed state of spalted wood limited its use in historic woodworking; however, the ability to extract the pigment and reapply it opens up the entirety of the woodworking world. This also means that spalted woodwork can be functional as well as load-bearing—attributes that are critical components of stage set design.

It is this extracted pigment that we used for *The Blue Forest* to create verdant costumes and weapons for fairies and in the production of a standing casket for Sleeping Beauty. The period in which the use of blue-green stained wood reached its height, the sixteenth century, also marks the very beginning of the festivals and productions that would give rise to opera [31]. The use of this reinvented color to tell a reinvented fairy tale lends a certain appropriateness to its use beyond its natural beauty. The objects made represent a reinvention of an old art form technology, enabled by production of a new material.

**PRODUCTION OF MATERIALS FOR THE BLUE FOREST**

Leaves

We collected *Chlorociboria*-stained wood from the local forest, ground it, extracted the pigment with dichloromethane and then dripped the solution in layers to color the wood used for the “natural” elements of the opera, particularly those from the forest (fairy armor, fairy weapons, wooden casket). We designed an iconic leaf motif—twisting at the tip to represent the flow of natural magic within it—to be replicated across objects. The leaves were made of bigleaf maple veneer with a cold-pressed cotton backing, to prevent cracking and aid longevity. Pyrography detailing of the veins gave the leaves depth, and we applied the xylindein across numerous coats to build the necessary color. Exploitation of natural variations in the wood texture and controlled addition of more or less pigment allowed us to give an appearance similar to that of wood colonized by *Chlorociboria* spp.

Fairy Attire and Weaponry

Costumes are transformative, allowing actors to become their characters. An “effective” costume has been defined as a costume that assists and complements the performance of the actor, anchoring them in the play and communicating information about them to the audience [32]. To this end, the costuming of the fairies was done using materials dyed with extracted xylindein, using iterations of the twisting leaf icon. This not only created a nonhuman appearance but also exhibited the natural power wielded by the fairies. In the opera, it is the fairies that save the children Red Riding Hood and Hop-o’-my Thumb and allow for the rescue of Sleeping Beauty from her trance state. It is therefore important that the fairies are seen as powerful creatures of magic.

Costuming of the fairies consisted of chainmail bandoliers to which were affixed the veneer leaves (Fig. 1a). The several styles of bandolier tied into the weaponry of each fairy: The sword wielder had a smaller yet more secure bandolier (Fig. 1b), the archer a more formed and decorative X-cross bandolier and the staff wielder a sash, to allow for optimal movement. The placement of the naturally dyed leaves where ammunition would be in a traditional bandolier is reflective of the fairies’ ability to wield formidable natural powers. The lack of any protective clothing apart from the decorative chainmail shoulder pad enforces the aggressive power of the fairies, as does their weaponry.

The full assemblage of fairies wielding their weapons can be seen in Fig. 2. The staff, sword, bow and three styles of bandoliers made up the costuming. We used the twisting leaf icon across all costumes not only to represent the fairies’ natural magic but also for uniformity. This is not just helpful for audience recognition; it also created a more formal appearance, as would be expected from a military force under command of a (fairy) queen.
Crafted Forest Stump

A crafted stump was made for the play and was used in the forest scenes. It has a spar-jointed frame with a top featuring entirely hand-burned pyrography. The annual rings tell the entire story of the opera, for those who care to read it, in the “language” of trees—feast and famine, good years and bad. In particular, the discontinuous rings represent unexpected deaths (particularly for Sleeping Beauty), with the number of growth rings between events corresponding to the age of the characters (Fig. 3). Years of magic are shown through large, wide rings heavy with parenchyma (storage) cells. Turbulent teenaged years are shown through thin, fast-growth rings with few parenchyma. Birth is showcased through uninterrupted growth, while death gives a truncated ring.

Sleeping Beauty’s Coffin

Sleeping Beauty’s standing coffin also made use of the twisting leaf iconography. The coffin (Color Plate B, bottom) shows a large tree on both sides, created with pyrography and twisting leaves on top. The tree is near death, with only a few leaves attached and dropped leaves at the base, yet it is not quite dead—just like Sleeping Beauty. The use of the natural xylindein dye here is particularly significant, as the green of the leaves is associated with life and vitality. A standing coffin was critical for the opera element but also provided another allegorical mechanism for the natural world interaction with the synthetic one. The coffin is made from bent plywood—a human-made composite material—and the wood is bent from its original form to suit the needs of humans.

To further this divide, the coffin decorated with xylindein-dyed leaves contains Sleeping Beauty wearing the synthetic blue color created at OSU, which was used on the costuming of all the play’s royalty. The two colors are juxtaposed, with the natural coloration surrounding the synthetic and, in a sense, overpowering it. Sleeping Beauty is in the coffin due to natural magic, showing that the natural power of life and death is stronger than the ingenuity of humanity.

**IMpACT ON PLAY AND FuTuRe APPliCATiONS**

The use of extracted xylindein to create materials for the opera *The Blue Forest* successfully reinvented traditional intarsia work using blue-green wood stained by *Chlorociboria* spp. Through use of the pigment, we were able to create large...
areas of color on sound (unspalted) wood, which would not otherwise be possible with traditional intarsia methods. Coloration of sound wood also made it possible to produce both the weaponry that could be carried by the actors and the thin twisting leaves for the bandoliers.

Themes of the play were highlighted through use of the pigment, helping to bring the fairy-tale story into modern context. The dynamic between the power of nature and the work of humans could be seen, with the strength of nature consistently represented through use of the twisted leaf icon. The use of a natural dye representing natural power and surrounding a synthetic dye is representative of how humanity is still ruled by nature.

The flexibility and increasing availability of extracted xylindein make it a promising artistic material in the future. As a sustainable and highly color-stable product, it is a superior choice over traditional aniline dyes or other materials traditionally used to color wood, and in a society increasingly concerned with “being green,” this technology seems ripe for adoption. The reinterpretation of the style of coloration from archaic fine woodworking practices into a straightforward, sustainable coloration mythology will breathe fresh life into an old art style, as well as old science.

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**ANNOUNCING**

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COLOR PLATE B: FUNGAL PIGMENTS, WOOD COLORING TECHNOLOGY AND THEIR APPLICATIONS IN THE PLAY THE BLUE FOREST

Detail from a bureau dated 1600, made with Chlorociboria-stained wood. Leaves, plants, stone detail and feathers show blue-green stained wood. (© National Museum of Decorative Arts, Spain. Used with permission.) (See the article in this issue by Seri C. Robinson, R.C. Van Court and Claudia Andersen.)

An actor posing in the standing coffin for purposes of the photo. The coffin is decorated with twisting leaf icon and dyed with extracted xylindein. (© Seri Robinson) (See the article in this issue by Seri C. Robinson, R.C. Van Court and Claudia Andersen.)