# History Boletes Itself

Morel Dilemma Episode 6 Script. Written and copyright Elizabeth S Gall 2016.

[Music begins]

*Izzie:* Welcome to Morel Dilemma, an exploration of why some mushrooms are so highly sought, some are so heavily cultivated, and some are so very dangerous. Today I'll be addressing a question I've gotten from a few people, and often wondered myself: why are some mushrooms brightly colored while others are drab?

[Music ends]

*Izzie:* If you go to a grocery store, the portabella, cremini, and button mushrooms are all in the tan-brown color range. At a specialty store like Whole Foods, you might find white enoki, grey oyster mushrooms, and yellow chanterelles. A farmer's market stall might offer more vibrantly colored selections, like the neon orange sulfur shelf, flame-colored Lobster Mushroom and blood-red Ox Tongue. Perusing images of fungi online can reveal even more colors that rarely reach the table: bottle-green Parrot Waxcap, bubblegum-pink *Cortinarius magellanicus*, and baby blue Pixie's Parasol.

I was hoping to talk about the chemistry of these fungi - exactly what pigments lead to the brighter colors, and why only some fungi have them. Unfortunately, it turns out that talking about that on a podcast would be so. Boring. All those molecular names are tongue-tying and even when boiled down decently well, the chemistry talk makes for terrible radio. At best, it sounds like a rap of the most boring Pokemon of all time.

[The Pigments Rap fades in and out]

*Izzie:* It's boring to listen to! And most of the actual color things happen at the molecular level, so you'd need to look at diagrams and UGH nobody wants that.

So instead we're going to take a very quick trip to science class, and then delve into some truly weird and wonderful history about fungus dyes. I'll post links to some good physics resources on the blog, in case you do want to know more of the nitty-gritty.

First of all, let's talk about light. You may have heard that light is both a particle and a wave. Right now, just pretend it's a wave of energy. That means the energy travels up and down a certain height at a regular rate. Because the speed of light is a constant, the difference between the high point and low point of the wave is the same for all bits of light, which are called photons. However, the distance between the peaks of the wave isn't the same for all photons. That distance is called the photon's wavelength. Photons with shorter wavelengths hold more energy than those with long wavelengths, because a shorter wavelength means the photon is bouncing more quickly to travel the same horizontal distance.

The electromagnetic spectrum is the name for all the possible wavelengths photons can have. The longest, least energetic wavelengths belong to photons that make radio waves and microwaves. Though all photons are so small they practically don't have any mass, the wavelengths for these photons are as big as people, or even buildings. On the other end of the spectrum are the highly energetic photons with very short wavelengths. These photons are responsible for X-rays and gamma rays, and their wavelengths are only about as long as an atom.

Somewhere in the middle of the electromagnetic spectrum are the wavelengths we humans can perceive. These wavelengths make up the visible spectrum, which runs from the highly-energetic violet to less-energetic red. Any source of white light, such as our sun, emits all the visible wavelengths of light. Thanks, sun! That's pretty cool of you.

So as the sun is sending out all these photons with all these wavelengths, a few of them are going to hit objects. Physical objects absorb some wavelengths, but not others. The wavelengths that are absorbed aren't visible, but the other wavelengths bounce off the object. If a visible photon reflected from that object comes into your eye, you can see the object!

For example, if a white light source sends all its photons at a red object, all the non-red photons will be absorbed. Only red photons bounce away from the object, and some of the reflected photons hit our eyes and tell our brains the object is red. The part of a molecule that allows it to absorb or reflect certain wavelengths is called the chromophore, which literally means "the thing with the color." Naming things is easy!

Dyes and pigments are molecules that can be applied to objects to change the wavelengths of light that are absorbed or reflected, therefore changing the object's color. A white wall reflects all incoming photons. But if we paint the wall red, all the violet, blue, green, yellow, and orange photons will be absorbed, leaving only the red ones to bounce back to our eyes.

Ta-da! That's the least exciting part of the episode, done. Now let's talk a bit about why plants and animals might use pigments.

If you look outside, you will probably see grass, a bush, a tree, herbs, or flowers. Even in cities you can generally find some plant life. If it's not winter when you're listening to this, most of the plants are probably green. From the mighty oak tree to the irritating dandelion, plants are green because of chlorophyll, a pigment that absorbs all the visible wavelengths except green, and stores all that photon energy in sugar via photosynthesis. The pigment called chlorophyll supports almost all the life on Earth, because that sugar is where all of our energy comes from. All food chains come down to the green stuff. So that's purpose number 1: pigments can help organisms get the energy they need to live.

Pigments can also protect organisms from *too much* energy. Ultraviolet radiation can be dangerous, because the photons are so energetic they can mess up your cell's molecules. This is why people can get skin cancer from too much sun exposure. But when you get a tan, or if you naturally have lots of melanin in your skin, you are less susceptible to UV radiation. That's because the melanin is a protective pigment that absorbs most of the harmful photons, letting your cells get on with their lives. Fungi use melanin too, for the same reason. Studies have shown that fungal spores with more melanin are much less susceptible to UV damage than their lighter-colored counterparts, even in the same species. So that's purpose number 2: protection from dangerously high energy.

Fungi can also use melanin to fight off other fungi in what can only be described as bloodthirsty turf wars. A fungus can use melanin to steal resources away from an enemy, or shore up its own cell walls for defense. Some melanins may actually help fungi mount frontal offenses, against enemy fungi or into a plant ripe for the taking. The lines of pigments where these battles are waged can sometimes be seen in wood, if the fungi involved are competing parasites of a tree. That is pigment purpose number 3: attack and defense on a cellular scale.

So now we've reached the point where I'd like to be able to tell you why some fungal pigments are brown, while some fungi are purple or blue or orange. I'd like to let you know which colors are most employed for what purpose - maybe pink and red are mostly used for fighting, and orange for defense. I'm afraid I don’t have an answer for you. There is a common belief that the brightly colored mushrooms are more toxic, which isn't true - the Destroying Angel, the most deadly mushroom in the world, is completely white. There's a theory that bright colors are meant to deter potential mushroom eaters, but there's also a theory that the bright colors are meant to *attract* animals to eat the fruit so the spores get spread around. Basically, there's a good amount of science around what these molecules look like, but not as much about the purpose each one serves in each fungus.

There's also the issue that fungi are a motley crew. I don't mean that they're a mishmash of different personality types that somehow work together to come out on top. I mean their color choices are reminiscent of a court jester's motley outfit. The mycelia of a white mushroom may be black, while its spores are purple, as in the case of the Poisonpie mushroom, *Hebeloma crustuliniforme*. The Redspored Dapperling, *Melanophyllum haematospermum*, has a tan cap and stem with deep red gills and spores that *can* be red… or blue-green. One of the most colorful species descriptions ever has to be for *Amaurodon mustialaensis,* which the fungus identification encyclopedia MycoKey describes as "More or less bluish… when fresh, drying yellowish-greenish, with…violet spores." And yet I haven't found any scientific exploration of why the different parts of a fungus should be so varied in color. If you know of any information or research out there, please send it to me, because I'd love to read it!

Perhaps the most surprising lack of information I came across when researching this episode actually has less to do with how the fungi use their own pigments, and more to do with how *humans* use them. Fungal dyes have been around about as long as plant or insect dyes, more than three thousand years. And yet nobody seems to know, chemically, how fungal dyes work. I would have thought that anytime people use something, they want to know how it works… I guess all the big money in science is being tied up in unimportant things like cancer research. Lame. So we'll have to leave it at that for now.

After the break, I'll shed some light on a very famous color with a little-known background, and a lot of little-known colors finally starting to get some attention.

[Intermission music]

*Aden Brown:* Hello, my name is Aden Brown and I am a student at Tufts University.

So there I was - it was the summer of 2015. I was traipsing through the back woods of Harvard University in a place called Harvard Forest. I was up there as part of a research team, studying recruitment and mortality rates of young trees in forests. Now, as I was going through the woods, I saw a flash of color out of the corner of my eye. I bent down to take a closer look, and found a brilliant gem: a mushroom that was purple in color! *Cortinarius iodes* was the name of this little, purple mushroom I had found.

"Aha," I said to myself, "*iodes*. It makes so much sense, because it's like iodine, which is a purpley color! Sort of. But it's also sometimes yellowish on your skin." And I was just awestruck by the range of colors that the natural world can produce.

Thanks, Izzie, and I really love your podcast. Looking forward to this episode.

[Music]

*Izzie:* I want you to think about a color. Think about its name, and what it means. Think about the social weight behind naming a color like this. Ready? The color is Royal Purple.

Right off the bat you know this color is probably special. Most colors are named after tangible objects, like tomato red or dandelion yellow, sky blue and grass green. Some colors are named by how similar they are to other colors - like yellow-orange or blue-green. But this color is named for a status. Royal Purple. It doesn't tell you much about what the color looks like, but it sure tells you about who can use it.

In 1500 BCE, the Phoenician civilization began. Within about one thousand years, the Phoenicians built up an enormous maritime trading empire, stretching from modern-day Lebanon to the straits of Gibraltar, which collapsed 200 years before the founding of Rome. One of their greatest contributions to the ancient world was Royal Purple, then called Tyrian purple, after the Phoenician city of Tyre where it was presumably first discovered. Many historians believe that "Phoenicia" actually means "land of the purple". Naming yourselves after the first thing you invented: What a way to label your civilization!

Tyrian purple was created by predatory snails before it was borrowed by the Phoenicians. The snails use the purple secretion to stun prey or to confuse predators, much as squids use their ink. The snails were abundant in the Mediterranean, and also in Mesoamerica, where their dyeing potential was also recognized. In Mesoamerica, the purple secretion was farmed by "milking" the snails - basically, poking them so they felt threatened and released their purple ink. The snails could then be released, making the dye a renewable resource.

The Phoenicians were, shall we say, less gentle. They went with the direct approach, crushing the snails and grinding them up to get at the dye faster. Even so, collection was a hard and time-consuming process. Ten thousand crushed snails might yield a single gram of Tyrian purple dye - maybe a gram and a half. And from the second this color hit the ancient shelves, demand was high. Throughout human history, those with the most have loved flaunting their wealth, and I suppose the incredible destruction of snails and the many hours of labor that went into a Tyrian purple garment were just too exciting for ancient Mediterranean nobles to pass up. As the snail population declined - and really, who can say why *that* happened? - the price of the dye went up. In the year 300 CE, the Roman price for one pound of Tyrian purple dye was *three pounds* of gold. So, yeah, literally worth thrice its weight in gold.

In order to keep up with production and reduce the strain on the snail population, some brilliant or lucky ancient person came up with an alternative. They discovered a dye that could be added to Tyrian purple to stretch the precious snail secretion and still provide a lasting, rich color. This new supplement came from an unassuming brown rock lichen name of *Roccella tinctoria*, commonly known as Orchella weed. Nobody knows exactly when this lichen's coloring properties were discovered, but Theophrastus, Aristotle's pupil, wrote about the lichen dye around 350 BCE. Several lichen-inclined writers of the 19th century and beyond believe that a bible verse actually refers to the lichen. The verse is Ezekiel 27:7, "Your awning was blue and purple from the coastlands of Elishah." Now, both the lichen and the snails come from coastal areas, so there's no definite evidence that Ezekiel was talking about the lichen specifically.

Even if he wasn't, though, there's still good historical evidence that the marine lichen was used for its purple dye up to three thousand years ago. The method has been preserved, and it's amazing. Here's how it goes: Scrape a lot of Orchella off rocks. I couldn't find a direct conversion for how much lichen you need per gram, unfortunately. Let's just say "a bunch." Take your bunch of lichen and crush it into a jar. Fill it with ammonia - in the ancient world that means pee. Then let your lichen-pee tea sit in the jar, uncovered, for sixteen weeks. At the end, the jar is full of strong purple dye.

Despite the fantastic success of Orchella, no other lichens hit the scene as wonders of ancient textile production. In fact, the art of extracting dye from the lichen was lost after the fall of the Roman Empire, around 475 CE. The lichen would be undisturbed in the Mediterranean for a good eight hundred years, until in 1300 an Italian merchant named Federigo Oricellari *quote-unquote* "accidentally rediscovered" how to make the dye. This is how Albert Schneider refers to the resurgence of Orchella's popularity in his 1898 book A Guide to the Study of Lichens: Federigo "accidentally rediscovered" the process. For the sake of Federigo's wife and kids, I hope this means he found a recipe hidden somewhere, and didn't actually forget about an open jar full of lichen powder and pee for four months.

Whatever his methods, Federigo brought Tyrian purple dye back into production in 1300 and made like the Phoenicians, creating his own maritime empire around it. His business was so successful that the common name of the lichen, Orchella, actually comes from his last name, Oricellari. His name is also used for the dye compound in the lichen, which is called orseille.

The rest of Europe began to catch on, and soon orseille dye was known by various names, depending on how it was prepared. The English style was simply to isolate the dye and make a paste, which was called Orchil. Europeans are creative.

The Dutch prepared the dye in firm cakes and called it *litmus*. Around this time, other people besides textile producers were getting into the dye, and chemists discovered that it changes colors depending on the acidity of a liquid. If litmus is applied to an acidic liquid, the solution turns blue; if the liquid is basic, or alkaline, the litmus turns red. The same compound is still used as an indicator of acidity in chemistry today, though it is produced synthetically for the most part.

In 1402, Spain discovered and claimed the Canary Islands, whose rocky shores were the perfect home for Orchella. Those islands became the world's leading supply of orseille. As more European countries worked their way across the Atlantic ocean, more and more islands were claimed and fiercely protected to produce orseille only for their sovereign country. Cape Verde, off the Western coast of modern-day Senegal, was a popular location, as were the Azores Islands, which remain part of Portugal. To this day, some towns on these islands remain named after orseille, such as the parish of Urzelina in Azores.

Around this time, eleven hundred years after *Roccella tintoria* was first used for dyes, people *finally* started experimenting with other lichens. They reportedly had success with the lichen genera *Lecanora, Pertusani, Umbilicaria,* and *Gyrophora*, though I can only find evidence of the last two being used for dyes. *Umbilicaria* lichens give a very similar color to orseille, while *Gyrophora* gives red.

In 1758, the Scottish Dr. Cuthbert Gordon invented a new form of orseille preparation called Cudbear. The new preparation was reportedly so successful and closely protected that the production facility was surrounded by a ten-foot wall and its staff were sworn to secrecy. This preparation has gone down in history because it was the first dye method invented in the modern era and one of very few dyes that can be attributed to a specific person.

In the 1830s, the export of Orchella from Cape Verde brought in an annual revenue of $200,000, or almost 5 million modern US dollars. The cost of Orchella weed was one hundred to one thousand dollars per ton, or up to fifteen dollars per pound in modern US dollars - about the same value as pre-ground Starbucks Pike Place coffee. Do you want your coffee fix, or a purple dress? You can’t have everything.

Unfortunately, the illustrious career of *Roccella tinctoria* was close to its end. In 1856 the first synthetic dye was discovered. From then on, the dye industry was mostly focused on creating new synthetics, which were cheaper than natural dyes and had the bonus ability to adhere better to the new synthetic fabrics coming out of the 20th century. In 1997, the last commercially-sized lichen dyers in the world, Cudbear-producing holdouts in Scotland, ceased production.

[Musical tone]

*Izzie:* But the story isn't over. Because in the 1960s, a whole lot of people suddenly became very interested in getting back to nature, using natural products over synthetics. There was also, I am told, a lot of interest in bright, swirly colors.

Enter Miriam Rice, a multimedia textile artist from California. Ms. Rice was apparently very interested in natural dyes, and would teach workshops for children about plant dyes and the creation of natural inks. In 1968, Ms. Rice went on a clandestine mushroom foray. Something in the vibrant fungi spoke to her, and, so the story goes, she was inspired to toss some bright yellow Sulphur Tuft mushrooms into a pot. Either she was incredibly lucky, or she stuck to it after a number of less exciting attempts that don't make it into the origin story. Either way, the mushrooms dyed a skein of wool lemon yellow, and mushroom dyeing was born.

Over the next several decades, Miriam Rice experimented with other mushrooms and dyeing techniques, combining knowledge of other natural dyes with a healthy dollop of optimism and apparently boundless creativity. She also inspired many other dyers around the country and the world to experiment, such that there are now dozens of books and blogs dedicated to dyeing wools with mushrooms and lichens.

My husband's aunt Mary does a lot with naturally dyed wool, but while she experimented with lichens several years ago, she says she mostly uses plant sources. For lichens and fungi, the dye separation process requires ammonia; which was hard for Mary to come by. Apparently the hormones that women excrete after puberty make their pee less useful for dye extraction. Mary says, quote, "The best stale urine for dyeing comes from pre-pubescent males. Mine was non-cooperative." So yeah, even though it's been a few thousand years, the best way to get pigment out of lichens is still apparently peeing on them. Think about that before you experiment.

I also tried reaching out to some dyers who have blogs online that chart their experiments with lichen dyeing. Sadly, nobody had time for an interview - apparently, autumn is a really busy time for collecting and dyeing. The good news is that one really amazing blogger, Leena Riihivilla, agreed to let me use some photos from her experiments on the blog. Leena has a farm and store in Finland, and she posts all of her dyeing experiments online. Like many dyers, Leena uses different methods of fixing the dye to the wool. These additions to the dyepot, called mordants, can change the color or intensity of the dye that's extracted from a given mushroom variety. I'll be putting up those pictures on moreldilemma.org so you can see how variable the process is. It's really incredible!

And, once again, we reach a point where science has kind of failed me. I feel a burning need, deep inside my soul, to know why mushrooms release dyes that are super different from their own colors. For example, the tan *Hapilopilus nidulans* contains a powerful purple dye, while the orange *Hydnellum aurantiacum* holds a bright seafoam green. In a book called The Romance of the Fungus World, published in 1925, I read a suggestion that the dye color comes from the spores, but the Cinnamon bracket, *Hapalopilus rutilans*, has white spores and dyes wool dark grey-purple.

Conversely, I also want to know why the pigments we see on the mushroom can't be used for dye. Amanita red can't be used to dye wool red. *Cortinarius magellanicus* can't dye wool bubblegum pink. And Parrot Waxcap can't dye things bottle-green. And while we're at it, why do fungal dyes have to be prepared in ammonia, while plant dyes do not? Once again, I guess the important science is stymied by the unfair focus on medical research. Again, if you know where I can find answers to these vitally important questions, please let me know. You can email moreldilemma@gmail.com. I really, really want to know.

I don't like leaving you with so many questions unanswered, but sometimes that's just the way things go. Maybe if Orchella had had an uninterrupted market from 500 BCE until today, we might know some more. But then again, maybe not. Maybe it's enough to know that the brilliant colors of fungi are out there, baffling and beautiful, and while we may harness some, others will ever slip through our fingers.

[Music begins]

*Izzie:* Morel Dilemma is written and produced by me, Izzie Gall. Our theme song is "Fungi Among I," composed and performed by John Bradley. Special thanks to Aden Brown for doing the intermission.

Hey, here’s something new: If you would like to make a donation to support the podcast, you can do that now! Morel Dilemma is on Patreon, where you can receive cool rewards for donating, and donations start at just $1 a month. That would help me a lot! Right now I’m running kind of a giveaway, where the next 10 people to support the podcast will receive the first-ever Morel Dilemma sticker! Check moreldilemma.org for details.

If you can’t donate financially, but you still want to help, that’s cool too! Leaving a review on iTunes would be a really awesome way to do that. Thanks to R.Joseph and Betacarbon for doing just that! You can also help by calling the hotline at 347-41-MOREL and leaving a mushroomy message for an episode intermission. That’s 347-416-6735. You can find other ways to contribute, and other Morel Dilemma content, at moreldilemma.org.

I would like to remind everyone that mushroom hunting is tricky business, and you should never eat a wild mushroom unless an expert has positively identified it in person, and told you it is safe to eat. Remember that everyone is different and allergies to uncommon foods are hard to predict. Species marked as edible in guide books could still make you sick. There are other ways of enjoying fungi. My favorite is photographs. Yours could be dyeing wool.

[Music ends]

## Resources

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