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Mycoremediation in Maryland

Jared Urchek
MAW Second Vice President

This summer, I had the opportunity to partner with Fox Haven Farm, a non-profit land steward and organic farm in Jefferson, MD to help mycoremediate a small stream that runs through their property. It could perhaps be looked at as a quixotic effort in being so small. Yet, we were able to demonstrate that the basic mycoremediation techniques we modeled off of were replicable, and that our mycelia were at least healthy and functional enough to thrive and fruit in situ. Continued site observation and testing will tell us more, but for now, I am happy with how this progressed to date. Continued work will allow us to develop a larger and more functional system.

For those of you who are not familiar with the idea of mycoremediation, it is the practice of using living mushroom cultures to digest, degrade, or otherwise mitigate various types of pollutants and waste streams. There are many industrial and agricultural applications of mycoremediation, as well as many smaller scale applications.

The stream in question originates from an area of small suburban style runoff, as well as drainage from a retention pond on an adjacent farm. The adjacent farm uses chemical fertilizers and pesticides, and the runoff from the neighbors' yards is assumed to be a typical outflow of household fertilizers, pesticides, and chemicals. This project was undertaken as an attempt to "give back" to the land. As a caveat, the techniques I used were not intended or expected to ameliorate all of the toxins and problems present, but simply to try and help as much as possible. Furthermore, they were intended as a demonstration to inspire greater and more effective implementations in the future.

There were three major goals of this pilot mycoremediation project: 1. Attempt to remove toxins in the water; 2. Work to prevent erosion of stream banks from storm surges; and 3. Add living native cultures to the drainage to encourage native biodiversity. Let's break these down a little further.

1. Attempt to remove toxins in the water. Firstly, "toxins" is just a broad term…

Continued on Page 2

Reindeer Lichen (*Cladonia rangiferina*)

William Needham
MAW President

Editor's Note: This article is the final installment in a series of articles about lichens that appeared in Sporophore this year. Parts 1-3 can be found in this year's previous issues.

This is the fourth and final article on lichens. It covers one of the most common lichens found mostly at elevations over 1,000 feet and notably in Shenandoah National Park. It is equally the most important lichen from the perspective of boreal ecosystems as the most important food for the herds of caribou and reindeer that range across the northern hemisphere. The reindeer lichen is also known as reindeer moss, caribou moss, and the combination reindeer moss lichen. This name accounts for its importance to reindeer (*Rangifer tarandus*) and their North American counterparts called caribou. The lichen's highly branched growth pattern, known as fruticose, is similar in appearance to moss, explaining the misnomer — it is a lichen and not a moss. The scientific name *Cladonia rangiferina* is from the Greek *kladon* which means "sprout" to signify the shrub-like appearance of the branching segments of the lichen, combined with the reindeer/caribou genus, Rangifer. The reindeer lichens are sometimes taxonomically assigned to their own genus Cladina.

To summarize the basics covered more fully in previous articles, a lichen is a mutualistic combination of a fungus and an alga; mutualism is a type of symbiosis in which both entities share in the benefits of the association. Lichens thrive in relatively extreme environmental habitats due to the successful combination of attributes, the mycobiont fungus provides moisture and minerals and the photobiont alga provides photosynthetic nutrition. One fifth of all fungi or about 20,000 species exist only as lichens; they do not occur…

Continued on Page 4

Mushrooms

Continued from Page 1

… for "things we don't want to be there." These include excess nitrates from fertilizers, petroleum-based chemicals from road runoff, various pesticides from the farm as well as the nearby houses, bacteria, and also excess topsoil runoff which chokes off native stream life. Just as mushroom mycelium has the innate capacity to break down waste products of the forest and to absorb and utilize nutrients, it also is well known for its ability to break down and absorb energy from lots of chemical waste (especially petrochemicals, which are comprised of long-chain hydrocarbons similar in molecular structure to the long-chain hydrocarbons of wood fibers).

2. Prevent erosion of stream banks from storm surges. As you may know, an increase in hardscape (roof tops, pavement, concrete, and any surface that does not allow rainfall to naturally filter into the land) leads to an increase in stormwater surges. The less that rain is able to penetrate the soil, the more it is channeled into nearby streams. As this water builds from small drainages to larger streams, the surge becomes very damaging, eroding the banks of stream beds, disrupting ecosystems, and carrying more and more topsoil downstream.

Part of the assessment of this particular stream we worked on was noticing how the bank was being notably eroded by these storm surges, and how the stream bed was being affected by soil runoff (evidenced by the higher-than-average presence of silt in the stream bed; low-silt streams will have their rock and gravel bed clearly delineated, while high silt streams will have their rock and gravel bed covered with a thick layer of silt).

Oyster mushroom mycelium colonizing bags of straw. The colonized straw cylinders will then be moved from plastic bags to burlap bags and placed into the environment for mycoremediation. Photo: Jared Urchek.

3. Give back to the ecosystem by adding living native cultures to the watershed and encouraging native biodiversity. By adding in native cultures of oyster mushrooms (*Pleurotus ostreatus*) and wine cap mushrooms (*Stropharia rugoso-annulata*), we are adding mushrooms into the landscape that will encourage the presence of other natives that rely on them (various insects, the animals that eat those insects, etc), as well as allow for a larger spore dump into the landscape when these mushrooms fruit and mature. As mushroom hunters, we often take mushrooms from the landscape, preventing or limiting their spore dispersal. Mycoremediation allows us to give back, adding more 'seed' to the land.

While this is nice in theory, it is also a delight we can look forward to when the spores of these projects lead to more instances of our wild edibles fruiting in our landscape. I have seen many times that installing an outdoor grow operation leads to a noticeable increase in subsequent years' wild flushes due to their spore babies traveling to nearby logs and trees.

* * *

So, all this theory aside, how does this actually look in practice? The techniques I used in this demonstration were two-fold: The use of "Oyster/straw logs" installed into the stream, and the installation of a "wine cap bed" on the upper stream bank.

Oyster/straw logs: These "logs", comprised of oyster-inoculated straw packed into reclaimed burlap tubes, are useful for a number of reasons. First of all, they are a physical macro-filter in three ways: the burlap, the straw itself, and the matrix of three-dimensional mycelium all act (separately and together) as a filter for large particles of pollution and runoff. The mycelial matrix that holds the straw together also acts as a micro-filter to trap and

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Upcoming Events

The events listed below may change, so read MAW emails and check our website at **http://mawdc.org** for up-to-date information on events.

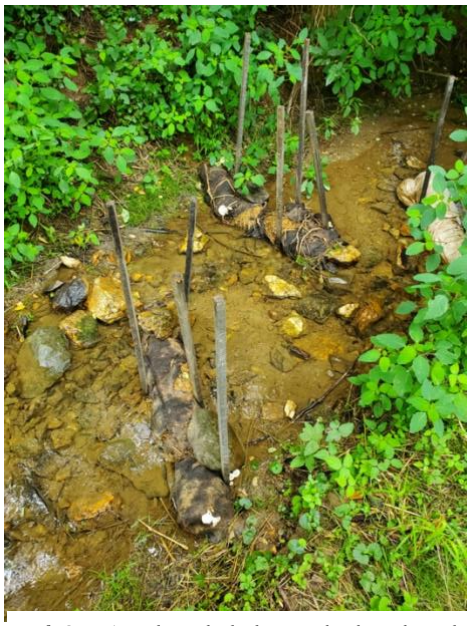
Upcoming Scheduled Programs

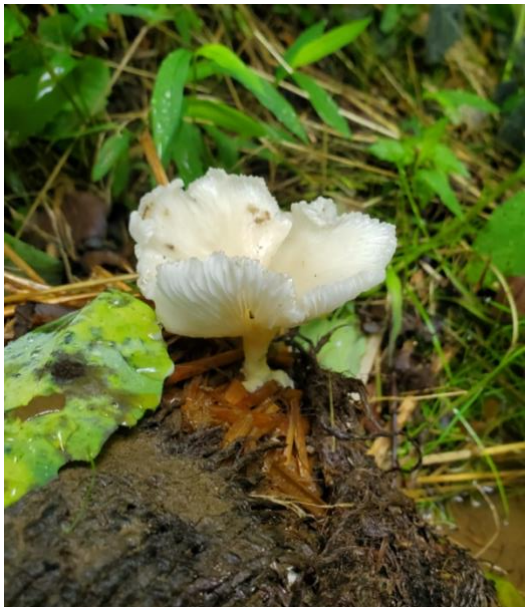
Jan 5 **Monthly Meeting** featuring John Plishke III and Judy Mackenroth of the Western PA Mushroom Club. Topics to include crust fungi, polypores, and more!

Feb 2 **Monthly Meeting** featuring Dr. Natalie Howe on lichens, and Fluff Berger on Summer mushrooms.

Mar 2 **Monthly Meeting** featuring Chris Wozniak, John Kough, and Jeannine Kausch from the EPA who will discuss how fungi can be used as bio-control agents in agriculture. We'll also learn about a bizarre fungus that infects cicadas.

For the time being, monthly meetings will be held on the first Tuesday of the month at 7:00 PM online via Zoom (www.zoom.us). Links will be emailed to members before each meeting, posted on the club's Facebook page, and can also be found on the MAWDC website. Members of the public are welcome to attend. To participate in the virtual mushroom ID session, email pictures of mushrooms ahead of time to forays@mawdc.org.





Left: Oyster/straw logs in burlap bags are placed into the creek and stabilized with wooden stakes. Right: an oyster mushroom emerges from the straw log. Photos: Jared Urchck

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digest any damaging microbial runoff (*E. coli*, fecal coliform bacteria, and other common waterway contaminants have been shown to be degraded by mycelium).

For anyone who has been around construction sites, you know that these plain straw logs (just a straw tube/cylinder, wrapped in a fishnet plastic net) are commonly used in construction sites to keep topsoil from washing off site, as well as to slow down the flow of water. Of course, the faster the water is moving, the more soil it can erode. This is all to say, even if our oyster mycelium is not actively mycoremediating anything, is actively mycoremediating the environment but not in a worthwhile amount, or happens to die quickly after installation, the physical nature of the straw log by itself is useful for preventing erosion around the creek.

We know from observing the site that the oyster/straw logs we installed were very happy, and even fruited from the submerged substrate at least once this season. That is to say, in addition to the physical benefit of having a set of straw logs in the creek, we were able to contribute oyster spores to the ecosystem.

Wine Cap Beds: We also installed a bed of wine cap mushrooms on wood chips and straw. This bed was installed on the upper side of the stream bank. Previous observation noted that there was a small oil slick that was coming out of the hillside and draining into the creek. The hillside seems to have been 'built up' with concrete rubble, and knowing how humans often work, it seems reasonable that whoever dumped all the concrete rubble there also tossed in some kind of oil-leaking waste (old oil cans, car parts… you know how we do…).

The Wine Cap bed was strategically placed on the slope between the oil leak and the creek, so as the wine cap bed began to grow and thrive, the mycelial network would act again as a physical and biological filter to trap and digest residue from the landscape, and prevent it from moving into the creek system.

* * *

To recap: What did we do and why did we do it? In trying to be better stewards of the land, we realize that we have to give back instead of just taking. This was an attempt at giving back. Giving back, even in small ways, can be powerful rituals to re-connect us to our land. I think many of us know this by the other side of that coin - taking from the landscape, even a small meal of chanterelles or some wild oysters, can be a potent way to tap us into the gifts of the land. By doing these things, we remember who/what truly feeds us, where our fresh breaths and water come from.

Even though this demonstration was small, and any amount of chemicals and runoff that it did remediate from the system would have also been small, it was a successful exercise in implementing a few well known mycoremediation techniques. We established a small set of living straw logs in the creek, and a small bed of wine cap mushrooms above the creek, to filter out and digest possible contaminants. In observing how they fruited in situ we know that the mushrooms were able to live and thrive in the creek environment for at least a month.

I hope that this project as it is was informative and educational, and that these projects can continue to build into something more substantial in the future.

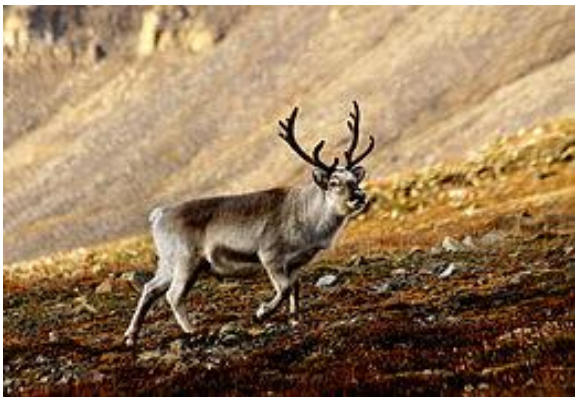
Mushrooms

Continued from Page 1

without algae. The fungal constituent of the lichen physically predominates over its algal partner, comprising about 90 percent of the overall biomass; it forms the primary structure or thallus of the lichen that anchors it to a substrate and absorbs water and minerals from the environment for sustainment. Because of this primacy, the lichen is named for the fungus. The photobiont alga of the reindeer lichen is *Trebouxia erici*, one of the green algae. Unlike their myriad mycobiont associates, 90 percent of all photobionts come from only three genera, *Trebouxia*, a unicellular green alga genus, *Trentepohlia*, a filamentous green alga, and *Nostoc*, a cyanobacterium (formerly called blue green alga). Though the photobionts have the ability to exist in the natural environment without their fungal symbionts, they are rarely found; free-living populations of *Trebouxia* have never been found. Syllogistic logic would conclude that the algae and fungi of the lichen are totally dependent on their mutualism for survival.

The regeneration of reindeer lichen in particular and lichen in general afford some seemingly insurmountable obstacles in consideration of the paucity of resources available in their habitat and the lack of any naturally occurring constituent fungi and algae. These constraints impose a potential reproductive impasse that is resolved by vegetative regeneration, a form of asexual reproduction in which portions of the existing growth (vegetation) provide the genetics for replication. However, rather than a piece of the lichen thallus (containing both algal and fungal cells) breaking off and starting a new growth, it is more common for the lichen to form specialized structures that contain undifferentiated cells of each constituent. There are a number of different vegetative reproductive structures that are employed to this end; for lichens in the *Cladonia* genus, small balls of fungal hyphae called soredia enclose several algal cells. The soredia are dispersed by wind, water or animals just like the spores of the fungus would be. Once a reindeer lichen is established in a new location, slow growth is balanced by longevity; a growth rate of about 8 millimeters per year over an average century-long lifetime. The dominance of reindeer lichen in the boreal forest regions is evidence of their success in regeneration; lichen cover typically ranges between 50 and 90 percent. The lichen mats contribute to their own dominance by intercepting the rainfall, thereby inhibiting the germination of the seeds of any alternative species. Seedlings that do manage to survive in the soil frequently wither when the soil becomes desiccated or are pulled out by the repetitive expansions and contractions of the lichens.

Reindeer lichen is used as a general term to refer to any of several species that are consumed by the reindeer of Eurasia and the caribou of North America. The circumpolar habitat of the reindeer/caribou is congruent with that of the eponymous lichens which constitute about 90 percent of their diet in winter and about 50 percent of their diet in summer. The names of *R. tarandus* reflect two etymologies: Reindeer is from the Norse *hreinn* which is thought to derive from the word *ker* meaning "top of the head" - emphasizing the characteristic horns and *dyr* meaning animal (ergo, horn-animal); Caribou is from the Algonquian Indian word *khalibu* which means "that which scratches or paws." Reindeer are essentially lichen-dependent. In the seminal tome *Lichens of North America,* it is recounted that caribou were introduced to Saint Matthew Island in the Bering Sea in 1943. They thrived on the indigenous lichens to the extent that the herd had expanded to about 6,000 in 1963. When the lichens ran out; only 50 survived that winter. Although other boreal ungulates (including mule deer, white-tailed deer, elk, moose, and mountain goat) eat lichens, only eat the reindeer lichens. The difference is that reindeer have developed a technique for uncovering the terrestrial lichen; they kick holes in the ice and snow to create a "crater" large enough to expose their meal. "Cratering" affords them an advantage over the competing herbivores, who must rely on arboreal lichens for sustenance. From the dietary perspective, lichens are high in carbohydrates and low in protein. Ruminants like the reindeer can break down the complex carbohydrates in the bacteria in their rumen, but they still must eat protein-rich foods to survive. In addition to grasses and shrubs, reindeer have been known to eat lemmings, bird eggs, and mushrooms.

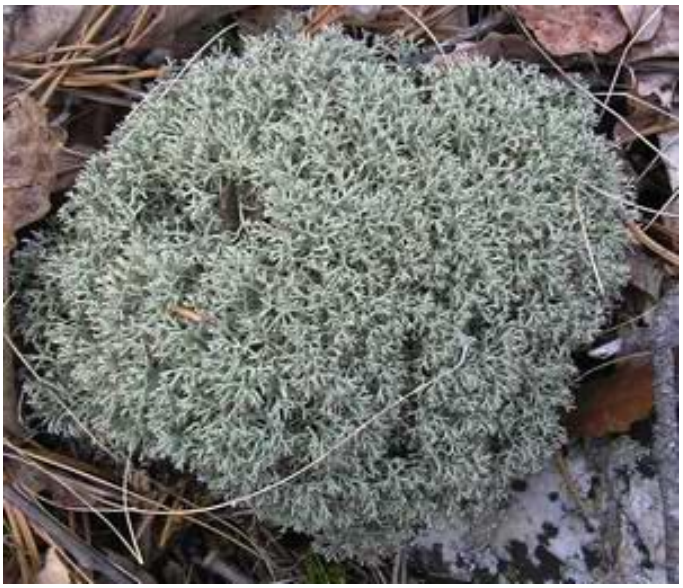


Rangifer tarandus, the type of reindeer that eats reindeer lichen. This Photo is licensed under CC-BY-SA

Cladina rangiferina seen at Strickler's Knob trail in Virginia. Photo: William Needham

There is some disputation concerning the taxonomy of the reindeer lichens; some lichenologists place them in the genus *Cladonia* with many other lichens and some afford reindeer lichens their own genus, *Cladina*. Both genera have hollow stalks called podetia which extend from the granular crustose (like a crust) thallus at the base in branches, an arrangement that is known as fruticose. In lichens, the thallus is the vegetative or growing portion that has both the fungal and the algal components. The difference is that reindeer lichens lack the scale-like squamules at the base of the lichen and the shiny, protective layer on the podetia called the cortex that are characteristic of the species assigned to the *Cladonia* genus (which are accordingly called squamulose-fruticose). However, according to the USDA, several phylogenic studies have demonstrated that DNA sequences, morphological data, and chemical analyses all support the general conclusion that *Cladina* should be included, at least as a sub-genus in *Cladonia*.

There are four species of reindeer lichen that predominate in boreal latitudes and at the higher elevations in the temperate latitudes. The most extensive is the gray or gray-green reindeer lichen, *C. rangiferina*. The others are *C. arbuscula*, shrubby or tree reindeer lichen, *C. mitis*, green or yellow reindeer lichen and *C. stellaris*, star or star-tipped reindeer lichen. They are all eaten by reindeer, but their use by humans to some extent varies according to the species. *C. rangiferina* was used by Northern native people to make medicinal tea for the treatment of colds and fever and as a poultice for arthritic joints. It was used as fodder for cattle in Northern Europe as a means of improving the quality and quantity of the milk. *C. arbuscula* and *C. mitis* are nearly identical in appearance and can only be distinguished by chemical analysis (which is true of many lichen species) or, according to experienced lichenologists, by taste (*C. mitis* is mild and *C. arbuscula* is bitter). The Cree Indians used the green reindeer lichens in a manner similar to the Nordic natives for medicinal teas, specifically for the expulsion of intestinal worms. In general, reindeer lichen don't provide any significant nutritional benefit to humans, as they lack the reindeer's stomach enzymes necessary to break down the complex carbohydrates. However, native peoples did eat the partially digested lichens in the stomachs of freshly killed reindeer, sometimes mixing it with meat scraps and blood to make a nutritious and highly esteemed pudding. Whereas *C. rangiferina* and *C. mitis* are pioneering lichens in that they establish colonies on nearly bare rock (a very thin layer of soil is beneficial), *C. stellaris* is a climax species that gradually predominates in mature lichen habitats. Star reindeer lichen are highly regular with delicate branches that closely resemble miniature trees. They are the primary type of lichen used for miniature trees to add realism to model train panoramas and architectural maquettes. They are also used to make wreaths for graveyards and for other decorations.



Cladina stellaris. Photo: William Needham

Fungi in the News

Annie Greene
Newsletter Editor

Editor's Note: This article contains summaries of notable fungus-related news from September 2020 through November 2020. Visit the URL following each topic below for a closer look.

DC voters choose to decriminalize psychedelic fungi

With a 76% majority and over 214,000 "Yes" votes, DC voters approved Initiative 81, effectively decriminalizing psychoactive plants and fungi within the District. Congress has been given 30 days to object to the measure, and though 30 calendar days have passed since election day, at the time of publication of this newsletter, there's no readily available information about whether Congress approved or denied the measure. If approved in accordance with voters' wishes, law enforcement officers inside DC will treat possession of psychedelic plants and fungi as a low priority. Small-scale cultivation of psychedelic plants and fungi will likely become a more popular hobby. Read more at: **https://ballotpedia.org/Washington,_D.C.,_Initiative_81,_Entheogenic_Plants_and_Fungus_Measure_(2020)**

Psilocybin-assisted therapy relieves major depression

A study by Johns Hopkins researchers, recently published in *JAMA Psychiatry,* found that two psilocybin therapy sessions successfully decreased major depression symptoms in study participants. Twenty-four people with major depression participated in the trial, many of whom had suffered from depression symptoms for many years and found no lasting relief from pharmaceutical treatments. However, after two therapy sessions assisted by trained facilitators and synthetic psilocybin, participants' average depression scores dropped from 23 to 8 on the GRID-Hamilton Depression Rating Scale. Four weeks after treatment, 54% of participants were considered in remission from their depression. Researchers plan to follow these participants long-term to examine the longevity of these significant improvements in mood and quality of life. Read more at: **https://www.hopkinsmedicine.org/news/newsroom/news-releases/psychedelic-treatment-with-psilocybin-relieves-major-depression-study-shows**

California-based startup looks to fungi for new cancer drugs

Scientists at Hexagon Bio, a California-based startup company, have recently raised $47 million towards their goal of screening fungal species for new anti-cancer drugs. They hope to scan the genomes of thousands of fungal species to find blueprints for yet-unknown molecules that fungi produce. Unlike Alexander Fleming's accidental discovery that mold produces the antibiotic penicillin, Hexagon Bio takes a deliberate approach using powerful computers and DNA-based tools. Perhaps this strategy will yield the next breakthrough drug to treat chemotherapy-resistant cancer. Read more at: **https://cen.acs.org/pharmaceuticals/drug-discovery/Hexagon-Bio-47-million-mine/98/i36**

Matsutake mushroom given "vulnerable species" status

Matsutake is highly prized in Japan as a choice edible mushroom, and has recently been classified as a "vulnerable" species by the International Union for Conservation of Nature. Matsutake grows in red pine forests, a habitat that has been in decline due to the invasive pinewood nematode and changes in pine forest management. This fungus has long-standing cultural significance in Japan; the mushroom is referenced in a seventh-century collection of poetry called *Manyoshu*, one of Japan's most famous poetry anthologies. If mycologists can figure out a way to cultivate matsutake, perhaps this mushroom will remain a Japanese staple despite its declining habitat. Read more at: **https://www.theguardian.com/world/2020/sep/19/japan-matsutake-mushroom-under-threat**

Canadian researchers uncover how mature trees benefit from fungal relationships

Previous research has shown that tree seedlings get an advantage from mingling with fungi underground, and new research out of the University of Alberta shows that older trees benefit from fungal friendships as well. This recent study examined core samples from mature Douglas fir trees and found that annual growth rate was higher in trees with greater number of connections to the mycorrhizal fungus *Rhizopogon vinicolor*. When beneficial fungi such as *R. vinicolor* colonize tree roots, the mycelium forms a pathway for water and nutrients to travel among neighboring trees. This study adds to the body of evidence showing that fungi play crucial roles in forest ecosystems. Read more at: **https://www.ualberta.ca/folio/2020/10/soil-fungi-act-like-a-support-network-for-trees-study-shows.html /**

Best wishes for a happy, healthy holiday season!

Annie's Mushroom Gravy

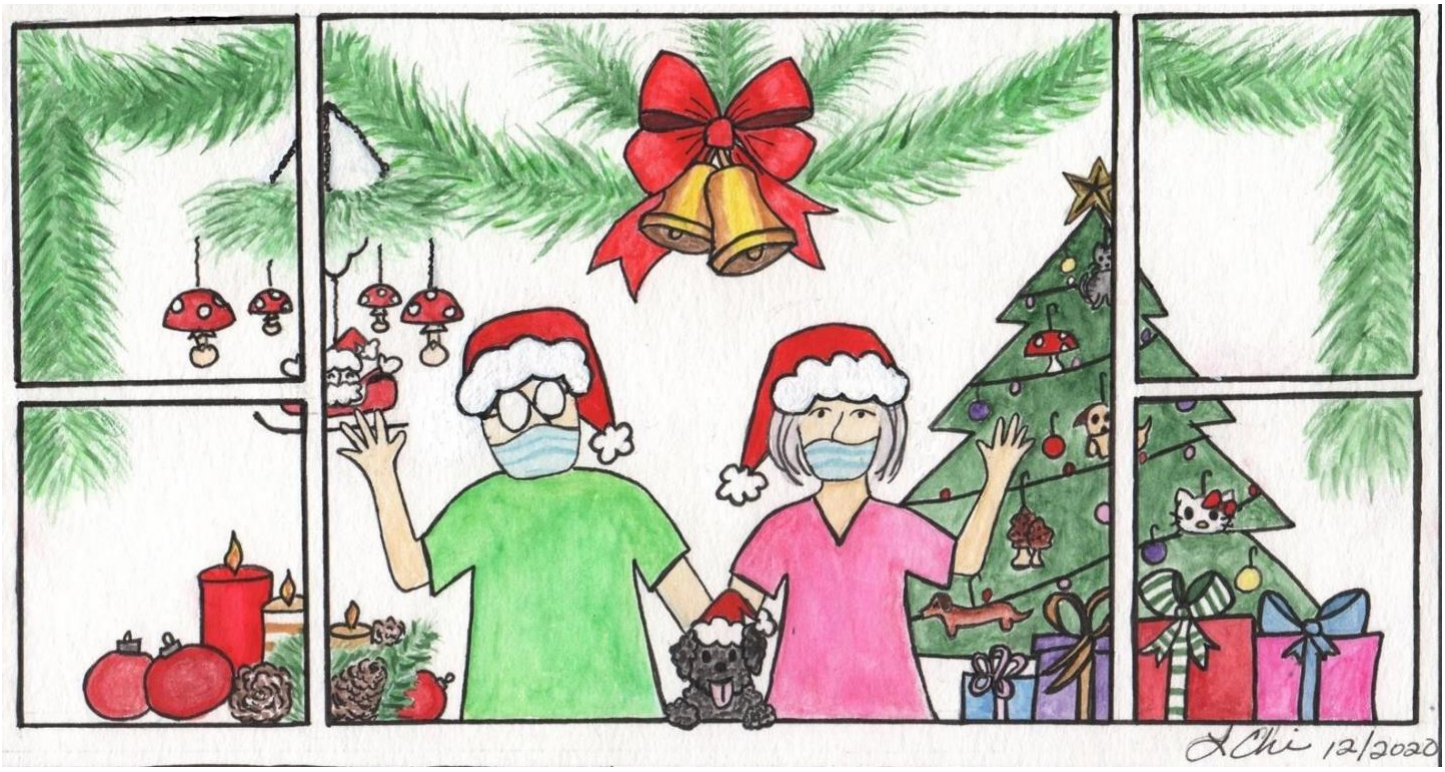
A delicious way to impart savory mushroom flavor to your holiday meals. Vegetarians get to enjoy this gravy, too! This recipe can easily be scaled up or adjusted to your preferred consistency. The recipe calls for baby bella mushrooms and shiitakes, but a mixture of any store-bought or foraged mushrooms will do. More variety means a more complex mushroom flavor!

Ingredients

8 oz	Baby bella mushrooms
8 oz	Shiitake mushrooms
2 Tbsp	Butter or olive oil
1 Quart	Vegetable stock or mushroom stock
1 Tbsp	Tapioca starch or corn starch
3 Tbsp	Water
	Salt, pepper, and dried thyme to taste

Directions

1. Clean mushrooms and slice into uniformly sized pieces.
2. Heat butter or oil over medium heat in a large pot.
3. Add mushrooms to the pot and sauté, stirring often, until all water has evaporated and mushrooms begin to brown.
4. If desired, add a small pinch of dried thyme and sauté for 1 additional minute.
5. Add desired amount of stock; adding the full quart will yield a thin gravy, adding less will yield a thicker gravy. Bring the pot to a simmer, and allow to bubble gently for 5 minutes. For a lower-sodium option, you can use half stock and half water.
6. While the pot simmers, mix the starch with 3 Tbsp water to create a slurry. Set aside.
7. Transfer the contents of the pot to a blender and blend until the consistency is very smooth.
8. Return blender's contents to the pot and add the starch slurry slowly, stirring continuously over low heat, until your desired thickness is reached.
9. Season to taste with salt, pepper, and more dried thyme.
10. Pour over mashed potatoes, roasted vegetables, poultry, or any savory holiday dish. Enjoy!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