A Few Winter Fungi by Kevin T. Smith

Winter walks around my Portland neighborhood remind me how fungi are exquisitely tuned in to environmental factors including short term weather and seasonal change. Most of this past growing season has been especially rich in fungal abundance and diversity. The same cold snaps that signal autumnal senescence and fall foliage coloration in broadleaved trees also seem to stimulate a last wave of fruiting by a range of macro-fungi. As the northern forest moves into the more muted tones of late fall and the monochrome of winter, I like to imagine that the fungi know that they have a limited time so they hurry along to produce mushrooms. As understory herbaceous plants die back to the ground and the woodland trees and shrubs shed their leaves, fruiting bodies and other fungal survival structures tend to become more prominent.

The challenge of winter

The challenge of winter cold for fungi begins with the simple chemical fact that every 10°C reduction in temperature is accompanied by a halving of the rate of chemical reactions. Fungal mycelia, those thin threads that comprise the thallus or body of a mushroom-producing fungus, are especially vulnerable to low temperatures. As water freezes, ice crystals expand and break cell membranes that both contain and participate in vital transfers of chemicals and energy. As water in the soil or other substratum freezes, living cells are threatened by desiccation as well as freezing.

Under proper conditions, fungi can reduce freeze injury by biosynthesis of specialized carbohydrates and proteins. Biosynthesis of sugar alcohols such as glycerol and ribitol lower the actual freezing point of living cell contents. Sugar alcohols also affect the osmotic relationship of cells to better hold on to water and resist desiccation. Specialized proteins interfere with ice crystal formation, effectively lowering the freezing point of cell contents. Known as thermal hysteresis proteins, these cold protectants were first discovered in arctic fish and have been described for bacteria, fungi, and green plants (Xiao and others 2010).

A few local examples

The brick top (*Hypholoma lateritium*, also known as *Hypholoma sublateritium* or *Naematoloma sublateritium*) is a late summer into fall mushroom that may produce a final flush of mushrooms after a frost or even a hard freeze. The mushrooms are produced on or near wood in ground contact including logs, stumps, and buried woody roots. Some species in this genus form aggregations of hyphae into mycelial cords that seek out new nutritional resources and distribute them throughout the thallus. In my own research, we found that *H. lateritium* grew along a vertical gradient from the dead log, the organic forest floor, and into the mineral soil (Thompson and others, 2012). We suggested that woodland decay fungi such as the brick top support tree nutrition not just by releasing essential fertilizer elements bound into wood, but also by moving elements from the mineral soil (which in our native soils is largely inhospitable for root growth and element uptake) up to the forest floor where fine absorbing roots are available to take up chemical elements.

Fruiting bodies or “conks” of polypores may be present year-round, but seem especially prominent in the winter landscape. This artist conk (to the right, *Ganoderma applanatum)* is fruiting on an ornamental crabapple that has been greatly affected by “people-pressure disease” (PPD). The term PPD is a handy catchall for the particular stresses imposed on trees located in the human landscape including the accumulation of mechanical injuries to the stem and roots, exposure to toxic de-icing salts, and soil compaction year-round. A perennial conk, each year *G. applanatum* produces a new layer of tubes to the outside and beneath the previous layer. The outer ends of the tubes are what we see as pores on the underside of the bracket. This perennial strategy enables the fungus to avoid the metabolic expense of producing an entirely new bracket each year. Although tempting to estimate conk age by the number of layers of pores, that number reflects the number of growing periods which may not be strictly annual. In the first volume of his Researches on the Fungi, Buller (1909) illustrates convincingly that the size and spacing of the pores is optimized for effective spore production and dispersal. For sheer power of observation and common sense interpretation, Buller is still hard to beat.

Another perennial stem decay fungus which seems especially prominent in winter is *Phellinus igniarius* (to the left, formerly *Fomes igniarius*). Common names listed for *P. igniarius* include the willow bracket and fire sponge, although most mycologists and foresters I know simply refer to this fungus as “igniarius”. A serious pathogen of poplar in the Midwest and Rocky Mountains, recent research describes that what has been called *P. igniarius* is likely a complex of at least 16 species (Zhou and others 2016). In Maine, we find *P. igniarius* often on birch and maple as well as poplar. Although associated with extensive decay in living trees, the fungus appears to require an initial attack by some other decay fungus prior to successful colonization and the spread of *P. igniarius* (Shigo and Sharon 1970). Interest in this fungus complex has greatly increased due to observations of medicinal value of the fruiting bodies.

After the essentially monochromatic polypores above, the orange-russet winter mushroom or velvet foot (to the left, *Flammulina velutipes*) makes a welcome appearance. Successive flushes of mushrooms are produced, usually after the first frost and on mild winter days. The winter mushroom is cultivated to produce the pale, slender enokitake of East Asian cuisine. Because of the economic value of the species, *F. velutipes* is a model system to study the cascade of changes in protein synthesis and energy regulation in response to cold temperatures (Liu 2017).

Another late summer and fall companion, honey mushrooms (species in the genus *Armillaria*) turn to mush with freezing temperatures. However, the rhizomorphs or "shoestrings" of our local species of *Armillaria* (below) are especially eyecatching on debarked stumps and fallen logs in winter. Although species of *Armillaria* occur throughout the northern temperate zone, with some also extending into the tropics, *Armillaria* can be hard to find in true wilderness areas.

Human activity resulting in tree root injury and stumps from tree felling provide excellent habit for *Armillaria* to exploit, making the genus a dominant pathogen of tree nut and fruit plantations, managed forests, and urban trees (Baumgartner and others 2011). Not all *Armillaria* produce rhizomorphs in abundance, but the species complex found in Maine forests certainly do!

Extreme environments

The harshest winter environment for wood-inhabiting fungi is far from the Maine woodlands and is among the historic outposts of polar exploration. Diverse filamentous fungi have colonized wooden structures and other materials from the Antarctic expeditions of Shackleton and Scott of the early 20th Century (Blanchette and others 2010). Here, the wood decay basidiomycetes may have met their match, as only ascomycetes and their anamorphs were encountered. The diversity of wood- and fabric-staining fungi isolated pose a challenge for the proper conservation of those historic sites.

Back in my Portland neighborhood, my walks cause me to question the entire concept of dormancy. Sure, some processes slow or even stop with the seasons. But some fungi always seem busy, whether we notice them or not!

References:

Baumgartner, K. and others. 2011. Secrets of the subterranean pathosystem of *Armillaria*. Molecular Plant Pathology 12(6): 515-534. http://www.ucanr.org/sites/intvit/files/78390.pdf.

Blanchette, R.A., and others. 2010. An Antarctic hot spot for fungi at Shackleton's historic hut on Cape Royds. Microbial Ecology 60: 29-38. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.722.6596&rep=rep1&type=pdf

Buller, A.H.R. 1909. Researches on Fungi. Longmans, Green & Co., 287 pp. https://archive.org/details/researchesonfung01bull/page/n5.

Liu, J.-Y. and others. 2017. iTRAQ-based quantitative proteome revealed metabolic changes of *Flammulina velutipes* mycelia in response to cold stress. Journal of Proteomics 156: 75-84. https://pubag.nal.usda.gov/catalog/5614928.

Shigo, A.L. and Sharon, E.M. 1970. Mapping columns of discolored and decayed tissues in sugar maple, *Acer saccharum*. Phytopathology 60: 232-237. https://www.apsnet.org/publications/phytopathology/backissues/Documents/1970Articles/Phyto60n02_232.pdf.

Thompson, T., Thorn, R.G., and Smith, K.T. 2012. *Hypholoma lateritium* isolated from coarse woody debris, the forest floor, and mineral soil in a deciduous forest in New Hampshire. Botany 90: 457-464. https://www.nrs.fs.fed.us/pubs/40802.

Xiao, N. and others. 2010. Antifreeze activities of various fungi and Stramenopila isolated from Antarctica. North American Fungi 5(5): 215-220. https://www.pnwfungi.org/index.php/pnwfungi/article/view/1091.

Zhou, L.-W. and others. 2016. Global diversity and phylogeny of the *Phellinus igniarius* complex (Hymenochaetales, Basidiomycota) with the description of five new species. Mycologia 108: 192-204.