Yippie Yi Yo, Mycota Ki Yay!

A Mycologist's Fervently Biased Account of How the American Western Frontier Was Molded by Spores and Mycelium

Frank M. Dugan
USDA-ARS Western Regional Plant Introduction Station,
59 Johnson Hall, Washington State University,
Pullman, Washington 99164-6402 USA
fdugan@wsu.edu

Summary: Forget Kit Carson, General Custer, Billy the Kid and Geronimo. The real actors (good and bad) in the Wild West were made of spores and mycelium! And they didn't need fictitious sidekicks like Silver, Tonto, Rin Tin Tin or Old Yeller—they rode on the wind, or had very real "pardners" with six legs and numbering in the millions! Collectively, they sustained or destroyed vast landscapes, brought salvation or ruin to entire communities, deluded prophets and financiers, or provided sustenance and joy. Fungi made the Wild West, and are still shaping the West's ecological, economic and cultural destiny.

Key Words: blister rust, cereal rusts, dung fungi, *Entomophaga*, mushroom, mushroom poisoning, mushroom wars, pébrine, *Puccinia*, rots, *Saccharomyces*, smuts, sourdough, *Sporormiella*, *Tilletia*, Valley Fever, yeast

What are spores and mycelium?

Fungi make spores, each of which makes *mycelium*, which makes more spores—right? Okay, but what *are* fungi? A formal and lengthy definition would precisely define the word "Mycota" and might quickly alienate most of my readership. So, for those not already well familiar with fungi, suffice it to say that examples of fungi ("Mycota" and stuff that looks similar) are mushrooms (edible or otherwise) molds, and yeast; that fungi can cause rusts, smuts, leaf spots or cankers on plants, and that many fungi can rot fruit, vegetables or even stored grain. Sometimes (rarely, thank goodness) fungi can cause disease in humans. Mycelium (plural, *mycelia*) is a bunch of thread-like stuff that comprises the "body" of a fungus (whether mushroom or mold) and fungi make a variety of spores (about a hundred different kinds) which grow up to become more fungi.

What is (or was) "The Frontier?"

What is (or was) "The West?"
Although fungi are difficult to define precisely for the lay person, defining "The Frontier" and "The West" is just as challenging, probably because they're always changing! For Americans of colonial times, the Frontier could be anything west of the eastern foothills of the Appalachians. Even after independence, "western frontier" might mean today's Midwest (e.g., Indiana, Ohio, even western Pennsylvania). "American West" today generally implies geography considerably west of the Mississippi (probably because "westerns" vastly outnumber movies about Hiawatha), but during and just after the Civil War, areas in the central USA were still "frontier" (certainly the Dakotas, Nebraska, Kansas, Oklahoma, even parts of Texas and Minnesota). My boyhood was in "wild" Montana, with Dairy Queen and Safeway within comfortable walking distance, but with wild-roaming elk nearby and buffalo within an hour's drive. Perhaps "frontier" is best defined as close proximity to aboriginal inhabitants resisting, by force of arms, encroachments of farmers, miners and ranchers. (Today, most parties use lawyers, seldom bullets or arrows, to resolve issues of land, water, or cultural sovereignty.) Alternatively, "frontier" might mean far (in distance or time) not just from amenities, but from passable roads, medical care and law enforcement, in which case the frontier persisted well into the twentieth century in many places. I've only been on horseback twice in my life, and I've never seen an arrow fired in anger, but I've worn out several pairs of cowboy boots, served on a fire lookout tower miles from the nearest road, listened to the sweet howl of the coyotes, and

consider myself from "the West"—so, I hope to be forgiven if I leave such terms as "the Frontier" and "the West" intentionally vague.

So why were fungi (however you define them), important to the West, or the Frontier (however you define it)? There are several, overlapping areas of impact. Fungi directly altered landscapes by attacks on vegetation, or maintained landscapes via nutrient recycling; they deteriorated produce and commercial products, or were used to make them; they caused disease in crops or (more rarely) humans; and they were a source of sustenance, and have become "crops" in their own right. In fact, harvesting rights for morels are one of the few remaining issues which might be resolved "informally" with fists, or even revolvers, more frequently than with lawyers. If you're in the wrong place with a little bad timing, parts of the West can still get uncomfortably wild, and all because of some pricey mushrooms. The following are some of the more important examples of the myriad ways that fungi molded (pun intended) the western frontier.

Impacts on western grasslands

Paddies of the past: Who cleaned up after the buffalo?

In spite of all the "western" movies with scenes of deserts, sagebrush or chaparral, to many of us, "The West" conjures images of vast grasslands and herds of buffalo. The most conspicuous components of these grasslands were grass (duh!), buffalo, and buffalo poop. We know, more or less, where all the grass went (it succumbed to the plow, and was replaced by grain—what was left went under livestock or asphalt), and where the buffalo went (well, they mostly got shot and skinned, or just shot, and were replaced by cattle, sheep and horses). But buffalo were around for a long time. And for every mouthful of grass going into the front end of the buffalo, there eventually was poop coming out the back end, and the same was true for domesticated grazers (Figs. 1 and 2). So, long before they got shot, why weren't buffalo wading at least ankle deep in buffalo paddies? What happened to all the poop? It was mostly "eaten" by fungi!

Who were some of the primary doo-doo fighters of yore? *Sporormiella*!

Figure 1. When buffalo graze, buffalo chips can accumulate quickly! (Photograph courtesy of Ray Wegner, www.raydw.com).

This fungus (and several relatives) live off the remnants of plant material in herbivore dung. High numbers of spores of this dung-decomposing fungus in sediments are used to infer the past presence of large numbers of grazing animals, be they cattle, buffalo or mammoths (Davis and Shafer, 2006; Kinney, 1996). Actually, *Sporormiella* was probably most abundant in the age of North American grazing megafauna (of which the mammoth is the most symbolic—imagine how much poop came out of just one of those!), and was conspicuously resurgent with the introduction of cattle, whose occasional concentrations created veritable poopscapes (Davis and Schafer, 2006). The presence of abundant *Sporormiella* spores has also been correlated with overgrazing by livestock in the 1890s (Davis and Kolva, 1977). In addition to *Sporormiella* species, those in *Podospora* are especially important on cattle dung (Angel and Wicklow, 1975, with many other species discussed). The poop-degrading capabilities of *Sporormiella* species were early recognized (Fig. 3).

Figure 2. Even with the buffalo in decline, buffalo chips remained so abundant they could be used for fuel (Photograph courtesy of *Chronicle of the Old West*).

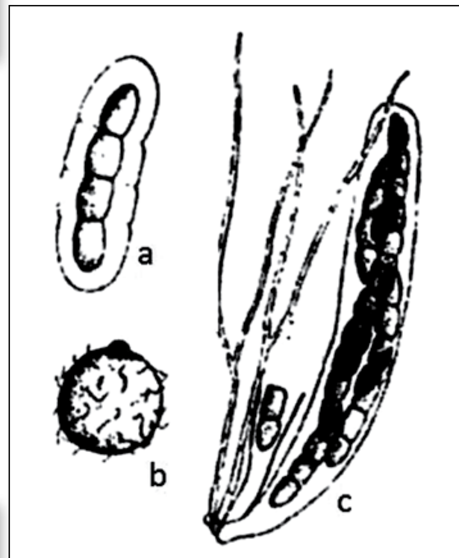

Figure 3. An unsung hero: *Sporormiella intermedia*, poop destroyer (from an early mycological treatise, Griffiths 1901).

Of course, fungi are not the only organisms documented as decomposing dung. Arthropods and bacteria are very important, too. But of the arthropods, those belonging to a minimum of eight families are actually feeding on dung fungi that previously colonized the paddies (Floate, 2011, on cattle dung in Canada). Both arthropods and microorganisms are essential to efficient poop removal (if either is lacking, poop persists—as was the case with cow paddies in Australia before the right beetles were introduced). Ecological relationships between dung beetles, fungi and bacteria are complex, but fragmentation of the paddies by insects apparently boosts rates of decomposition (Lussenhop et al., 1980; Wu et al., 2011). The species of fungi colonizing dung

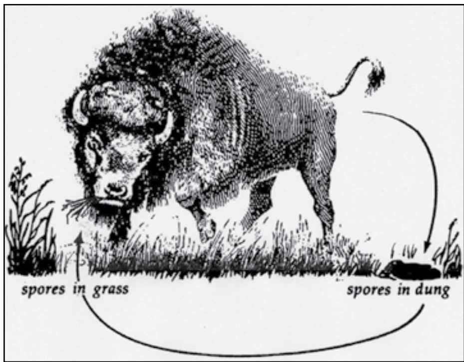

Figure 4. The old in and out: dung fungi life cycle.

are highly diverse, and apparently differ by the type of dung which they prefer, e.g. pronghorn antelope versus bison, etc. (Herrera et al., 2011). A detailed synopsis of the importance, ecology, and taxonomy of coprophilous fungi (many of which must pass through the digestive systems of herbivores in order for spores to germinate, see Fig. 4) is available (Krug et al., 2004). The next time you have a picnic on a nice grassy meadow, remember that it's thanks to the fungi that you aren't picnicking on top of poop.

Fungal disasters of forest and farm

White Pine Blister Rust

European settlers were not the only invaders to alter entire Western ecosystems. White pine blister rust is, as the name implies, a disease of white pine and other closely related pines (Fig. 5). It was introduced into North America from Europe in (or about) 1906, and had a devastating effect on the growth of white pines, drastically reducing the utility of these trees which were highly prized for timber production. In nature, the rust cycles back and forth between the pine and an alternate host, gooseberry and currant bushes (*Ribes* spp.). Ultimately, control efforts involved attempts at destroying the alternate host plant on "more than 20 million acres of private, state and federal lands in over 30 states" (Maloy, 1997). *Ribes* eradication efforts, beginning in earnest before World War I, persisted for some fifty years. Although enormous in scale, the effort was not particularly successful, and such control as exists today is largely on the basis of producing pine trees that are genetically rust-resistant. But for decades *Ribes* plants were hand-pulled or poisoned with chemicals by workers, including high school boys, men in the Civilian Conservation Corps, war internees, college students and others.

The eradication program began in the western states in 1919. In the inland Pacific Northwest (the "Inland Empire") the number of men pulling *Ribes* plants in 1934 was 11,000 (Maloy, 1997); over 8,700 laborers were employed in the work in 1936 (Benedict, 1981). "Large numbers of teachers and college students worked on the project, since the *Ribes* season coincided with their summer vacation" (Benedict, 1981, see Figs. 6 and 7). Having grown up in western Montana, and having worked in the

FUNGI (ISSN 1941-4943) is published five times per year (four seasonal issues plus a special issue) by FUNGI, P.O. Box 8, 1925 Hwy. 175, Richfield, Wisconsin 53076-0008, USA. Subscriptions are $38 per year for USA residents; $40 for residents of Canada and Mexico; $50 for all others. Checks should be made out to FUNGI. For credit card orders please see our Web site: www.fungimag.com

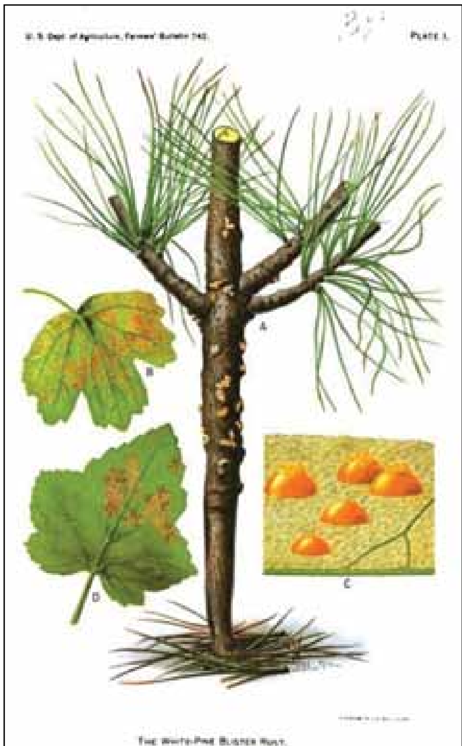

Figure 5. Blister rust, *Cronartium ribicola*, on white pine and on *Ribes* (USDA, reproduced in Severin, 1919). A. On white pine, B-D. On *Ribes*.

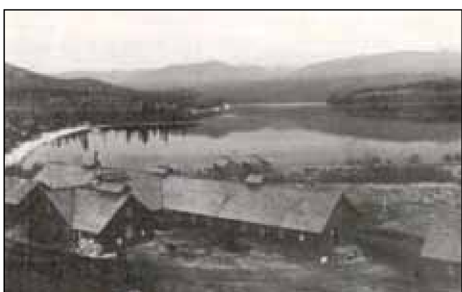

Figure 6. Blister rust camp, Priest Lake, Idaho, mid-1920s (Benedict, 1981).

Figure 7. Blister rust camp in northern Idaho, one of many in the 1930s (Benedict, 1981).

forests there for over twenty years, I met several old timers who paid their way through college by pulling gooseberry bushes! I paid for a bit of college myself by planting rust-resistant white pine. Despite this positive fallout in the form of wages translated into college education, "white pine blister rust has been an ecological disaster for the West" (Ciesla, 2002).

Bark beetles and their fungi

Most readers in the West will be aware that bark beetles spell bad news for forests, and sometimes for urban conifers. Fewer are aware that the beetles have a partnership with certain fungi, and even have special structures ("mycangia") for transporting their fungal buddies (Harrington, 2005; Six and Paine, 1999). The beetles construct tunnels ("galleries") in the inner bark (sapwood) of their conifer hosts. If numerous, the tunnels girdle the sapwood, and cause death of the trees. Adults and young feed on the fungi that colonize the galleries. Similar beetles (ambrosia beetles) live in the xylem (water conducting cells) of the tree, and feed on fungi that are transported by the beetles and colonize the xylem, and these trees likewise die. These partnerships (symbioses) between beetles and fungi are ancient, and involve multiple species of both beetles and fungi (Fig. 8). The negative impacts of these fungus/

Figure 8. *Ophiostoma* fungus in a gallery of *Ips* bark beetles attacking pinyon pine/juniper woodland (US Forest Service, www.fs.fed.us/rm/grassland-shrubland-desert/research/projects/drought-damage/). The long "necks" protrude from globe-shaped fruiting bodies that make spores.

beetle symbioses on western forests are astounding. Most statistics and all press reports refer to the beetles (you don't need a microscope to see them), but it's important to remember that the beetles can't do what they do without their fungal partners.

Of course, neither Native Americans nor the pioneers had the resources to make extensive surveys, but modern statistics are revealing. In the US Forest Service Northern Region (northeastern Washington, northern Idaho, Montana, and parts of North Dakota and South Dakota), more than 1.4 million acres of conifers were infested by bark beetles in 2005, with 2.7 million trees killed in 2006 (Gibson, 2008). "Eastern Oregon ... had about 370,000 acres ... where bark beetles had killed more than 25 percent of the conifers over a decade" (Dunham, 2008). In Alaska, spruce beetle (Fig. 9) impacted

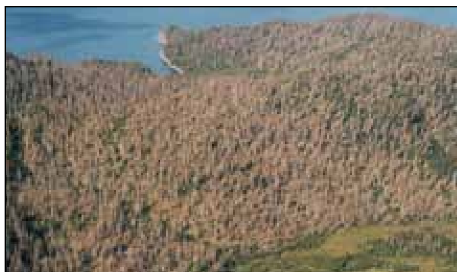

Figure 9. Spruce beetle outbreak in Alaska—reddish brown trees have been killed (Negrón et al., 2008).

3.2 million acres in the 1990s (Cain and Hayes, 2009). "Mountain pine beetle, Douglas-fir beetle, and spruce beetle were the direct cause of much of the mortality in the West in 2006, affecting over 4 million acres" (US Forest Service, 2007) (Fig. 10).

However, two other factors are added, which are truly transformative for landscapes: drought and fire. When these two are added to the unholy alliance of fungus and beetle, the results are devastating for landscapes and humans alike (Fig. 11). "Researchers have increasingly placed more emphasis on the apparent reciprocal and sometimes synergistic association between fire and bark beetles" (Cain and Hayes, 2009). Essentially, beetles are attracted to fire-damaged trees, and beetle-killed trees provide fuel for fires. Historical beetle-fire interactions have been documented

Figure 10. Bark beetle outbreaks in the West, 2006 (US Forest Service, 2007).

as early as 1914 (Pyne, 1982). These interactions make for dramatic press headlines, especially for populated areas of the urban-forest interface : "New study shows beetle-killed trees ignite faster" (*Missoulian*, May 5, 2011, complete with dramatic photo of trees ablaze). Or: "Fire officials in a tri-county area said they're seeing extreme fire behavior in areas with trees killed by the mountain pine beetle" (*Helena Independent Record*, May 5, 2011). The masthead of the online Kenai Peninsula Borough Spruce Bark Beetle Mitigation Program (www.borough.kenai.ak.us/sbb/) consists of

Figure 11. Fire in beetle-killed timber, Crater Lake National Park, June 20, 2009 (photo by National Park Service).

a photograph of a massive fire front smoking its way through beetle-killed timber. There are indications that fire suppression and other recent factors have worsened beetle outbreaks, but there can be little doubt that the deadly duo of beetle + fungus was present in western forest ecosystems from the earliest of times, and their impacts continue to be highly visible.

Smuts and Rusts

Smuts of wheat and barley have been the farmer's enemies for millennia, and were especially so in the inland Pacific Northwest. There are several smut fungi parasitic on grain – each grain (wheat, barley, oats, etc.) generally is attacked by one or two main species of smut. Smut makes grain look dirty, and it stinks!

Figure 12. Clouds of smut *(Tilletia)* spores during threshing (Price and McCormick, 1916).

Figure 13. Smut-exploded early combine (Price and McCormick, 1916).

Moreover, some smuts (the bunts) replace grain kernels with balls of smut spores. One might think that the greatest hazard of smut would be economic damage to the crop. Not so. The greatest

Figure 14. Dense clouds of smut spores during wheat harvest. (APS, www.apsnet.org/edcenter/intropp/lessons/fungi/Basidiomycetes/Pages/StinkingSmut.aspx).

hazard was getting blown up. The ignition of explosive concentrations of smut spores by static electricity was a threat in grain elevators and combines during the early days of agriculture in the region (Price and McCormick, 1916). It was not unusual to have 6-10 explosions a day in combines across the region, and some days there were dozens (Price and McCormick, 1916) (Figs. 12 and 13).

But, of course, even if farmers didn't get blown up, smut was a threat to their livelihood through destruction of the crop. "The farmer in whose field the picture [Fig. 14] was taken [in 1956] estimated that he had lost 15,000 bushels of wheat" (Fischer and Holton, 1957). In the latter nineteenth century, bunt "sometimes destroyed one-fourth to one-half of the wheat crop in the state of Kansas" and analogously high losses are recorded for parts of Montana, the Dakotas, and Nebraska (Fischer and Holton, 1957). Losses in early twentieth century Arizona were heavy, and in Utah were as high as "25 to 50 percent to individual farms in 1925" (sources in Fischer and Holton, 1957). The average annual loss in the Pacific Northwest during the early twentieth century was five percent (4,000,000 bushels), but losses for individual farmers could be nearly ninety percent, essentially disaster for a farming family (Fischer and Holton, 1957). Moreover, some early investigators gave greater estimates for average annual losses, e.g., "at least one-fifth of the cereal crops ... destroyed by smut" in North America (an estimate from 1908, in Olmstead and Rhode, 2002). "In the early settlement of western Canada ... it frequently destroyed 30 to 40 percent of the crop (sources in Fischer and Holton, 1957). Similar stories attend smut of oats, rye and other cereal crops. For the

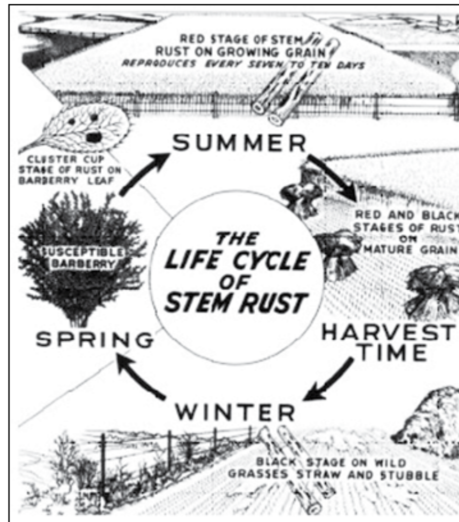

Figure 15. Stem rust (*Puccinia graminis*) life cycle poster, used in the campaign against barberry; note the harvest is shown bound in sheaves, the common practice prior to mechanization (poster from United States Department of Agriculture).

frontier farmer, smut was truly a feared enemy whose visits could spell ruin.

Likewise, cereal rusts extracted a horrible toll on crops. Stem rust, one

Figure 16. Stem rust as a demon, image used in the campaign against barberry (poster from United States Department of Agriculture).

of several rusts attacking cereals, is an excellent example. "Normal stem-rust losses are estimated at 5-10 percent of the wheat crop in the late-nineteenth and early twentieth centuries. Regional epidemics in 1878, 1904, 1914, 1916, 1923, 1925, 1935, and 1937 pushed losses much higher. The 1916 stem-rust epidemic is estimated to have destroyed ... in the United States ... over 30 percent of the harvested crop" (Olmstead and Rhode, 2002). When you add in leaf rust and rusts on other cereals, "there is good reason to think that formal estimates seriously understate the losses" (Olmstead and Rhode, 2002). However, "All plant scientists agree that without changing varieties and taking other defensive measures, losses would have been much higher than actually observed"—"Aided by the rediscovery of Mendel's laws around 1900 ... this research accelerated the development of rust-resistant hybrids" (Olmstead and Rhode, 2002). An eradication program against barberry (Figs. 15 and 16), alternate host for stem rust, was more successful than the attempt at eradicating *Ribes*, the alternate host for white pine blister rust.

Conditions of economic development

Spoilage and the curse of distance & time—To market, to market (before it rots!)

Distance from markets has always been a problem for the frontier farmer. High rates of spoilage characterized Ohioan and other "western" farm produce, shipped to markets via New Orleans prior to the building of canals more directly connecting Ohio to eastern markets (Gieck, 1988). "Considerable corn was ruined owing to spoilage" during shipment downriver on the Mississippi during 1834 (Dick, 1971). The system of canals alleviated but didn't eliminate spoilage. "Spoilage on the Erie Canal was 'so large, that there are dealers at Albany and also at Buffalo, whose business it is to buy damaged grain' " (in O'Brien, 1988).

The problem persisted and was general. In the early days of wheat farming in the Pacific Northwest, wheat was usually bagged in jute sacks for transport, even if shipped by sea. Grain shipped in bulk through the tropics (either around Cape Horn or via the Panama Canal) would overheat and spoil (Lewis, 1916). "During the earlier years of wheat farming in [the Columbia Plateau], and for world trade in wheat in general, the wheat was shipped in jute (or 'gunny') sacks. Ships did not take wheat in bulk because of possible spoilage of the entire cargo if any got wet" (Shepherd, 2006). However, even after growth of railroads enabled grain to be stored and shipped in bulk, there were serious problems. Pirrong (1995) wrote extensively on friction between the shippers and receivers in Chicago on the one hand, and "the elevators" on the other, over inadequate care of grain resulting in fungal growth. Such spoilage was so consistent that grain standards became a matter of necessity, although agreement on specific standards was slow in coming. Hoffman and Hill (1976) provide details on the history of the US grades and standards for grain. What was at the bottom of all this squabbling? Fungi, of course, rotting the grain.

Figure 17. Without refrigerated, rapid transport, perishable produce arrived playing host to a variety of charming fungi (*Penicillium* species in lemon, photo by W. Janisiewicz, USDA-ARS).

Fruit and vegetables are even more susceptible than grain to fungal spoilage (Fig. 17). The Southern Pacific Railroad (through its subsidiary, the Pacific Fruit Express), enabled shipping of perishable produce to eastern markets, thereby transforming entire agricultural regions of the West (Orsi, 2005). And not only did such refrigerated transport facilitate agriculture, it made life easier for the family. "Although always valuable, kitchen gardens became less crucial to a family's survival as other food sources became available—canned food, first, and later refrigerated and frozen food" (Knobloch, 1996). Railroads revolutionized agriculture by expanding markets for fresh and preserved produce from local to continental (Fig. 18). Primarily because of fungi, western agriculture did not really blossom until this revolution generated refrigerated, long distance transport.

Fungi to the rescue—Slayer of locusts

Most readers raised in the West will be familiar with the "Miracle of the Gulls." The Mormons had successfully trekked to Utah, and their first crops were maturing, when insects ("Mormon crickets") appeared in colossal numbers, and threatened to devour everything. Instead, seagulls devoured the insect host. Personally, I regard this as believable, since seagulls will devour just about anything even vaguely resembling small meat, and it would have made little difference to the gulls whether the crops were threatened by insects or fried baloney sandwiches. Nonetheless, this miracle has, unfortunately, overshadowed the "miracles of the spores" which rescued crops of the Mormon pioneers in 1878 and 1879. In the latter instances, crops were threatened by locusts. Lockwood (2004) quotes an observer:

Figure 18. Rail transportation revolutionized agriculture. Fruit is loaded from wagons onto railway cars for transport to the cannery, 1893, Los Gatos, California. Refrigerated cars would enable transport of fresh fruits and vegetables throughout the country (photo, Los Gatos Public Library, www.town.los-gatos.ca.us/index.aspx?nid=1555).

Figure 20. Silk spinning in the West, or the effects of a fungus far away. When a fungal disease, *pébrine*, knocked out the French silk industry, California and Utah saw opportunity. When Louis Pasteur solved the riddle of pébrine, sericulture in France rebounded, and the industry in the West declined to extinction. Millions of mulberry trees in California and Utah became relics of a dream. Photo from Williams (1902).

"Brother John Dayes, of the 20th ward, called this morning with a number of pests that had clustered together on the sprig of a currant bush, and were holding each other with a death grip. They were mere shells, the whole internal portion of their bodies having been gnawed away by an insect (sic)." Well, Brother John's heart was certainly in the right place, but his gnawing "insect" was really a fungus, *Entomophaga grylli*, the agent of summit disease, which induces exactly the behavior described. The fungus is still around, and sometimes considered for biological control of pests (Fig. 19).

Figure 19. End of the line for hoppers: summit disease, caused by the fungus *Entomophaga grylli*, saved the Mormon crops. Photo courtesy of Sergio Sanchez-Peña.

Beguiling dreams and the pébrine disease of silkworms

At one time, California dreamed of a silk industry, and was enabled to start one by the impact of a pathogenic fungus (*Nosema*, a microsporidian parasite of silkworms) on the silk industry of France. This pathogen "devastated the French silk industry in the mid 19th century by causing the silkworm disease pébrine" (Cavalier-Smith, 2001). By 1869, the principal silk-producing areas of California had over 1,750,000 mulberry trees (Klose, 1961). Enthusiasm continued unabated. "Let the mulberry trees go in by the thousand" (Williams, 1902) (Fig. 20). But sericulture in California ultimately failed, because the French industry recovered (with the help of Louis Pasteur), and because of competition from the Far East, where labor costs were much lower (Klose, 1961; 1964). Similar circumstances surrounded attempts at a silk industry in Utah. Brigham Young himself invested heavily, and supervised the planting of over 100,000 mulberry trees to produce leafy food for the silkworms (Monson, 1996). Utah silk was a notable item at the 1893 World's Fair in Chicago and tens of thousands more mulberry trees were planted. "Today, the only remnants of pioneer sericulture in Utah are the old mulberry trees" (Monson, 1996).

Yeast, the stuff of legend (sourdough!)

There are two conspicuous impacts of yeast on the Wild West: western cooking and the western saloon. More of the latter, later. For western cooking, there is no better example than sourdough (Fertig, 1999). The personification of sourdough, was Sourdough Sam. Paul Bunyan is a prominent part of American folklore (or fakelore, depending on your perspective; he may have been "invented" and was certainly promoted by a lumber company) and Sourdough Sam was one of Paul Bunyan's compatriots and his cook (Haney, 1942; Laughead, 1922). Sourdough batter is made with yeast (several kinds, usually *Saccharomyces cerevisiae*, but all fungal), and Sourdough Sam "made everything but coffee out of sourdough" (Laughead, 1922). Purportedly, "Sourdough Sam came from a reference ['an elaboration'] to a cook whose sourdough barrel blew up and took off an arm and a leg" at Sourdough Lake, Minnesota (Gartenberg, 1950). In spite of his physical handicaps, Sam's exploits were many, including herding giant bees, two of which were kept to make honey for Sam's sourdough pancakes (Fig. 21). In the real world, yeast was a primary foodstuff used for bread, biscuits, cake, pie crust, etc. in the West as everywhere, and was part of the supplies of every logging camp (Conlin, 1979). Use of sourdough by "the Forty-Niners" (from the California gold rush in 1849), still resonates in various cookbooks, e.g., "How did the Forty-Niners make sourdough starter" along with "How did the Forty-Niners make sourdough flapjacks" plus hints on care and "feeding" of your sourdough starter (Ichord, 2003). Sourdough Sam is, of course, also the very sound-of-limb mascot of the San Francisco 49ers football team.

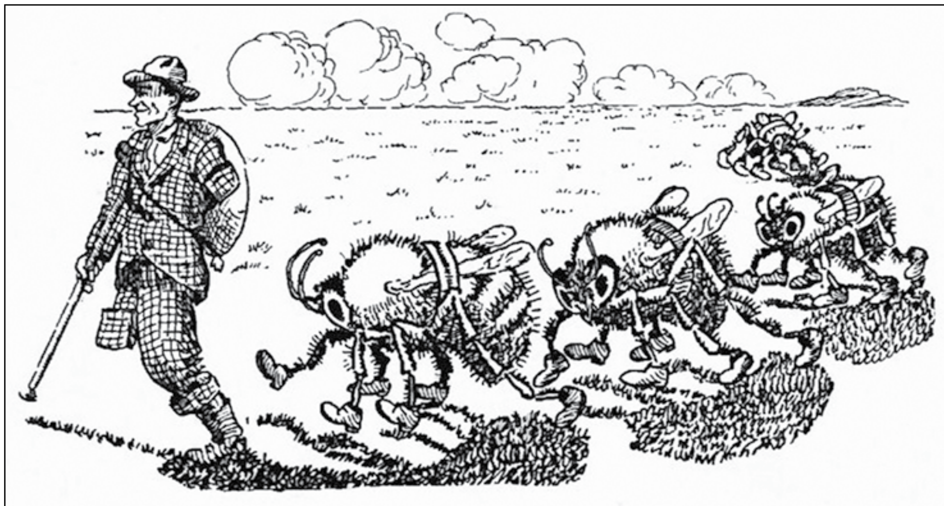

Figure 21. Sourdough Sam leads the giant bees (from Laughead, 1922). His handicapped condition, the result of an exploded barrel of sourdough (over-active yeast!), did not prevent Sourdough's super-human exploits.

Yeast, the bringer of delights and destruction

Although lacking distilled beverages, Native Americans produced a wide array of fermented drinks using corn, honey, arrowroot, *Opuntia* or sahuara (*Cereus giganteus*) cactus, maguey (*Agave*), and other plants (La Barre, 1938). The fermentative agent is not always documented, but species of yeast were certainly involved. In spite of this widespread, albeit uneven, use of fermentation, the arrival of distilled beverages had a strongly deleterious effect on aboriginal inhabitants. Much has been written about this, so a single quotation regarding the Menominee (residing now mostly in Wisconsin) will suffice here: "Previous to the introduction of alcohol, the Menominee dismissed fermented foods as unhealthy. When the first French adventurers rolled their kegs ashore, the Menominee were loath to drink" (Beck, 2002). But, "many quickly accepted its use" and plying the Indians with brandy "brought large profits for the traders" (Beck, 2002). The correlation of alcohol with diabetes and other diseases among Native Americans is a long and tawdry tale (e.g., Joe and Young, 1993).

On the early American frontier, whiskey functioned as currency (Rorabaugh, 1979). Later, when cowboys had too much currency, they spent it on whiskey and rode their horses into saloons for more whiskey (Carson, 1963, for several versions in folklore). For an extended analysis of alcohol-fomented frontier troubles, including forms of riotous behavior, see Winkler (1968).

Commercially produced alcohol, invariably the product of *Saccharomyces cerevisiae*, was very much in favor with settlers and frontiersmen. Small breweries, distilleries and numerous saloons flourished. The western saloon became an integral part of Western society, legend, and cinema (Fig. 22).

Figure 22. Wyatt Earp's saloon, Tonopah, Nevada, 1902. In spite of being a famous lawman, Earp was arrested at least once for drunkenness (Wikipedia http://en.wikipedia.org/wiki/Wyatt_Earp).

The mixture of alcohol and six-shooters was a perennial hazard, but sustained the plots of the "westerns" film industry for decades. Although beer and distilled spirits, especially whiskey, dominate in the traditional conception of alcohol in the West, there was the other beverage, wine. Carosso (1951) provided a history of California wine covering most of the nineteenth century. Although there were already around 100,000 vines near Los Angeles by 1833, the industry really began in earnest in 1850-1860 with increasing wine consumption during the gold rush, and by the late 1860s, grapes were "one of the most popular crops in California" (Carosso, 1951). Although lack of local glass manufacture and transportation costs initially hindered growth, establishment of a transcontinental railway opened the East to California wines, and by 1874 the rails were the primary carrier for transcontinental wine trade. However, wine was long perceived as the hobo's lullaby (if the wine were cheap), or as an elitist beverage (if the wine were of quality), and wine only recently became part of the Western mystique. Someone, somewhere, may have made a film showing cowboys or outlaws drinking Chablis in the saloon, but I haven't seen it.

Even for those committed to drinking in moderation, there was another down side to progress. Refrigerated transportation "would spell doom for the numerous small-town breweries scattered throughout the West" (Schwantes, 2003). As I write, this trend has been happily reversed, and I'm looking forward to a glass of our local stout or pale ale on my next dining experience. All this misery and joy, commerce and culture, was the byproduct of the yeast, *S. cerevisiae*, a fungus.

Valley Fever and other fungal-caused nasties

Fungi pathogenic on humans are relatively few, but they've been important in the West. The most import fungal disease in the historical West is no doubt coccidiomycosis, caused by the fungus *Coccidiomyces*. "In the 1890s, Portuguese farm labourers who had worked there [San Joaquin Valley, California] were hospitalized in San Francisco" (Homei, 2006). Although the disease was first recognized in 1892, it was not formally described until 1936. The primary area in which the disease was strongly endemic was restricted, but impact in this area was high. "Eventually most of the inhabitants of the region undergo an infection with *Coccidioides*" (Smith, 1940). Fortunately, full blown symptoms and mortality attend only a minority of cases, but an estimated eight to ten thousand persons were infected at the time of Smith's (1940) study, including over two thousand school children. Persons exposed to dust were most at risk.

Although other fungal diseases in the West have not been as publicized as Valley Fever, they bear mention. Histoplasmosis is an exceptionally nasty respiratory disease caused by the fungus *Histoplasma*. There is some evidence for the condition in Alaskan Eskimo mummies (Cockburn et al., 1998). Given the preference of *Histoplasma* for inhabiting bird or bat feces, there is speculation about possible exposure of guano miners working deposits in Missouri, chiefly from the 1880s through the Depression era (Weaver, 2008). Another fungal nasty, *Blastomyces*, causes blastomycosis, of which there were "several possible pre-Columbian cases"; it has typically been documented "mainly in the Ohio and Mississippi valleys ... [including] an endemic focus ... in the boreal forest of northern Minnesota" (Aufderheide and Rodriguez-Martin, 1998). Native Americans and early settlers surely encountered the disease, although the incidence in human populations is low. The disease is sometimes called North American blastomycosis, and is presumed indigenous to North America.

Far more common than either Valley Fever or the respiratory diseases above, was ringworm, a skin disease caused by several species of fungi collectively known as dermatophytes. Ringworm remedies are legion throughout folklore. Those pertinent to frontier situations include: Walnut juice, rubbing with carrot, tobacco dregs or juice, cigar ashes and saliva, milkweed "milk" ("Hoosier" remedies, in Tyler, 1985); milkweed latex (Missouri, in Humphrey, 2000); buttermilk and salt (Pennsylvania German of Ontario, in Doering, 1936); and "ringworm touched nine different ways with a thimble would be cured" ("Old Northwest" in Buley, 1934).

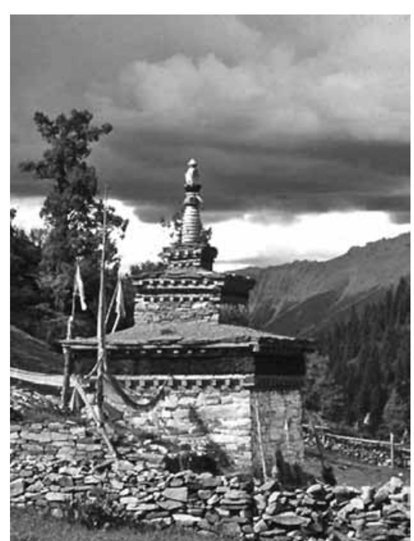

Figure 23. Ringworm was a common fungal disease on the frontier. Home remedies for ringworm varied from harmless and ineffective to disgusting and harmful, such as the one portrayed here. Just in case you were seriously contemplating trying this one, don't! It is inadvisable because it increases danger of serious infection (from Werner, 2010).

Some remedies (Fig. 23) are presently discouraged.

Shrooms in forest and prairie:

American Indians ate a variety of common edible mushrooms (the meadow mushroom, chanterelles, puffballs, etc.) although this was not true of all tribes (Dugan, 2011). Some tribes used specific fungi in ceremonies and for ritual objects, and fungi played a role in Native American folklore (Blanchette, 1997; Dugan, 2011). At least one tribe, the Western Mono (in the Sierra Nevada) conducted burns "to improve quality and promote abundance" of certain morels, cup and coral fungi (Anderson and Moratto, 1996). It is sometimes the case that only a minority of the species can be identified, as with the Miwok (a Northern California tribe), who consumed mushrooms (especially in winter) but only a puffball, *Lycoperdon sculptum* (*Calvatia sculpta*), has been identified to species (Barrett and Gifford, 1933). But the Miwok themselves recognized at least ten species, including the one of which "death was the result of eating it" by bleeding from the nose and vomiting. There was some hope if only a small quantity had been consumed, in which case death might be averted by prompt consumption of boiled deer brain cakes (Barret and Gifford, 1933). Dugan (2011), Kuhnlein and Turner (1991) and Moerman (1998) summarize documentation on mycophagy (essentially, mushroom munching) by Native Americans.

Early explorers had only limited experience with fungi. On 19 June, 1806, Meriwether Lewis ate roasted morels, but was unimpressed ("truly an insippid taistless food") (University of Nebraska Press n.d.; see McFarland, 2010, for a humorous "true" account of the incident). Edible puffballs (*Lycoperdon* sp.) were found, but not consumed by Thomas Say ("quite delicious ... but Say and his men may have been unaware or uncertain of this"), one of the scientific staff on an expedition (1819-1820) led by Major Stephen H. Long to the Rocky Mountains (Evans, 1997). Nonetheless, many European immigrants to the American or Canadian prairies brought with them a fondness of mushrooms. References to immigrants and mushrooms or mushroom hunting encompass persons from Bohemia (Gabaccia, 2000; and Welsch, 1987, the latter referring Willa Cather's writings), Norway (Merriken, 1999), and Switzerland (Sandoz, 1984). Such was the enthusiasm for mushrooms, that Minnesota pioneer Lucy Morris actively "promoted the harvesting of 'The Neglected Crop,' shaggy-mane and horse mushrooms" (Morris, 1976, from introduction to the reprint of 1914).

There are even "manna from heaven" stories about mushrooms, albeit not as spectacular as the Biblical version. Olds (1978) relates a story about a Nevada family in dire need of money and sustenance, reduced to eating bitter sage hen (normally not so bad, but far too "sagey" during August when subsisting on sage brush seeds). Fortunately, one of the children stumbled upon a place where "the entire countryside had popped up with mushrooms." From the description, these were possibly *Agaricus campestris* (meadow mushroom) or a closely related species. At any rate, sale of mushrooms netted ten dollars, which in those days was soon translated into "a wagon load of supplies ... I called that bill of grub my 'Manna from heaven' " (Olds, 1978). Also bountiful, and what was probably another *Agaricus* cousin of the meadow mushroom, were mushrooms which could be "the size of a dinner plate"; a single large specimen "sufficed to make a delicious stew" (Mattes, 1988, on military life in frontier Wyoming).

Mushrooms can be tricky, and mistakes apparently occurred, as on

Figure 24. Good identification guides were unavailable throughout much of frontier times and in most places. This example (Taylor, 1894) illustrated twelve species. There are no valid general criteria distinguishing edible from poisonous fungi, and it is essential to know individual species.

Edgar Dewdney's trek in 1879 from Ft. Benton to Canada, a difficult part of his journey, as "he felt unwell throughout—from eating mushrooms, he surmised" (Titley, 1999). Worse could happen. Medical records of mushroom poisoning in the old West include Dawson (1878), who treated a case of three individuals with ice, opium, blisters, warm hops, hypodermic injections of brandy, and enemas. One of the three expired, either from mushrooms or the treatments. The mushrooms were not identified. In a similar case, Cheney (1871) treated a family of five, three of whom ultimately perished in spite of (or because of) receiving doses of opium and whiskey, and turpentine enemas. Again, the mushrooms were unidentified. Logan (1868) attended to a family of four who had consumed mushrooms and one of whom ultimately died. Dr. Logan's treatments included hot water on the feet, cold water on the head, soapy enemas, a glass of milk, brandy, phosphate of lime, and compounds containing glycerol or camphor. The mushrooms were not identified, but were described as small and resembling "the well known esculent species."

Useful identification guides were slow in coming. One of the earliest specific to the United States was Taylor (1894) (Fig. 24), but the range of species covered was quite small. In the absence of reliable, illustrated guides, people depended on folklore. Some such lore persists, even online. How to poison a cowboy? Tell him some simple "rules" for mushrooms: i) Salt on the gills turns them yellow, poisonous; turns them black, wholesome. ii) Warts on the cap and growing in the woods means poisonous; "true" mushrooms grow in clearings or pastures. iii) "False" mushrooms taste bad, turn blue when cut, and are moist on the surface. iv) Gills of a true mushroom are pink to liver colored and the flesh is white (Dusty, Your Cowboy Sidekick n.d.). Even simpler were the criteria of Louis Tomastik in Sitton (2004), "The good mushrooms were thicker and kind of a different color ... poison ones were thinner, and they had that little comb." (Feel free to eat mushrooms by these sorts of rules, but keep close at hand the phone number of a poison control center, preserve a specimen of the mushroom, and be prepared to sign up for liver or kidney transplants—or maybe keep those deer brain cakes handy, unless you'd rather try the turpentine enemas.)

Mushroom wars – The Wild West returns?

The Wild West is famous for its conflicts over water rights, grazing rights, mining claims, and other fights over resources. Prior to the arrival of settlers, disputes over hunting grounds might be resolved by spears, arrows and war clubs. Now there's a new twist. With the ability to transport refrigerated harvests to high-paying customers, wild gourmet mushrooms have become a coveted, and sometimes hotly disputed, resource. "Some of these confrontations involve verbal threats, others involve display or discharge of firearms" (Parks and Schmitt, 1997) (Fig. 25).

Law enforcement officials were reported as "preparing for a phenomenon that has some of the trappings of the 19th-century gold rush camps: violent confrontations between commercial pickers over the pricey fungus (sic) that are worth close to their weight in gold" (Galagher, 1995). "People get pretty possessive ... somebody comes along ... they get touchy ... A lot of times we wind up with fights, illegal weapons discharge" (quoted in Gallagher, 1995). Sometimes the gunfire is rationalized as warning

Figure 25. Newspaperheadlines about conflicts amongst commercial mushroom harvesters (Parks and Schmitt, 1997).

shots: "Commercial pickers firing shots into the air to establish their territory from time to time were misinterpreted as shots fired at other pickers" (Kimball and Nichols, 2008). Nonetheless, results have sometimes been fatal (Gallagher, 1995). At least one academic has placed the "mushroom wars" into the context of "the Wild West revisited" including analysis of property rights and prediction of "a crackdown on gun play" (Coffman, 1995).

Conclusions

Western grazing lands, forests and farms have histories interwoven with fungal mycelia and drenched in showers of fungal spores. Impacts of fungi on these landscapes have varied from the benign to horrific, and the same may be said of impacts on the settlers, Indians, miners, loggers and other denizens of the West. Fungi made the daily bread and beverages of frontier life, robbed farmers and merchants of livelihoods by destroying their produce, and caused poisoning and disease amongst the unlucky or unwary. The vastness and wildness of the western American landscape rendered many of these interactions unique to The West, whereas others occurred wherever the frontier happened to be as it migrated westwards. If you think the Wild West is over and done, think again if you poke your nose into someone else's morel patch.

Acknowledgements: The author thanks Lori Carris, Dean Glawe and Barry Pryor for constructive review of the manuscript.

Literature Cited

Anderson, M.K., and M.J. Moratto. 1996. Native American land-use practices and ecological impacts, pp. 187-206. In: *Sierra Nevada Ecosystem Project: Final Report to Congress, vol. II, Assessments and scientific basis for management options*. Davis: University of California, Centers for Water and Wildland Resources.

Angel, K., and D.T. Wicklow. 1975. Relationships between coprophilous fungi and fecal substrates in Colorado grasslands. *Mycologia* 67: 63-74.

Aufderheide, A.C., and C. Rodriguez-Martin. 1998. *The Cambridge Encyclopedia of Human Paleopathology*. Cambridge University Press, Cambridge, U.K.

Barrett, S.A., and E.W. Gifford. 1933. Miwok Material Culture. *Bulletin of the Public Museum of the City of Milwaukee* 2(4).

Beck, D.R.M. 2002. *Siege and Survival: History of the Menominee Indians*, pp. 1634-1856. University of Nebraska Press, Lincoln, Nebraska.

Benedict, W.V. 1981. History of white pine blister rust control—A personal account. *USDA Forest Service FS-355*. 47 pp.

Blanchette, R.A. 1997. *Haploporus odorus*: a sacred fungus in traditional Native American culture of the northern plains. *Mycologia* 89: 233-240.

Buley, R.C. 1934. Pioneer health and medical practices in the Old Northwest prior to 1840. *Mississippi Valley Historical Review* 20(4): 497-520.

Cain, R.J., and J.L. Hayes. 2009. Bark beetle conditions in western forests and formation of the Western Bark Beetle Research Group, pp.1-23. In: *The Western Bark Beetle Research Group: A Unique Collaboration with Forest Health Protection, Proceedings of a Symposium at the 2007 Society of American Foresters Conference*, October 23–28, 2007, Portland, Oregon.

J.L. Hayes and J.E. Lundquist, compilers.
Carosso, V.P. 1951. *The California Wine Industry, 1830-1895*. University of California Press, Berkeley, California.
Carson, G. 1963. *The Social History of Bourbon*. University of Kentucky Press, Lexington.
Cavalier-Smith, T. 2001. What are fungi? pp 3-37. In: *The Mycota VII Part A, Systematics and Evolution*, D.J. McLaughlin, E.G. McLaughlin, and P.A. Lemke eds. Springer-Verlag, Berlin.
Cheney, W.F. 1871. Cases of mushroom poisoning. *Pacific Medical and Surgical Journal* 5: 119-121.
Ciesla, W.M. 2002. *Invasive Insects, Pathogens and Plants in Western and Pacific Island Forests*, INTECS International, Ft. Collins, Colorado. 120 + xiv pp.
Cockburn, A., E. Cockburn, and T.A. Reyman. 1998. *Mummies, Disease and Ancient Cultures*. Cambridge University Press, Cambridge, U.K.
Coffman, R.B. 1995. The mushroom wars. *The Freeman* 45(6), www.thefreemanonline.org, 8 pp.
Conlin, J.R. 1979. Old boy, did you get enough of pie? A social history of food in logging camps. *Journal of Forest History* 23: 164-185.
Davis, O.K., and D.A. Kolva. 1977. Pollen analysis of Wildcat Lake, Whitman County, Washington: the last 1000 years. *Northwest Science* 51: 13-29.
Davis, O.K, and D.S. Shafer. 2006. *Sporormiella* fungal spores, a palynological means of detecting herbivore density. *Palaeogeography, Palaeoclimatology, Palaeoecology* 237: 40-50.
Dawson, J.A. 1878. Mushroom poisoning. *Transactions of the Medical Society of the State of California* 8: 199-201.
Dick, E. 1971. *Tales of the Frontier: From Lewis and Clark to the Last Roundup*. University of Nebraska Press, Lincoln, Nebraska.
Doering, J.F. 1936. Pennsylvania German folk medicine in Waterloo County, Ontario. *Journal of American Folklore* 49(193): 194-198.
Dugan, F.M. 2011. *Conspectus of World Ethnomycology: Fungi in Ceremonies, Crafts, Diets, Medicines, and Myths*. APS Press, St. Paul, Minnesota.
Dunham, P. 2008. Incidence of insects, diseases, and other damaging agents in Oregon's forests. *USDA Forest Service PNW-RB-257*. 89 pp. www.arlis.org/docs/vol1/A/299614170.pdf.
Dusty, Your Cowboy Sidekick. n.d. Preparing and cooking food in the Old West. Kids-n-Cowboys. www.kids-n-cowboys.com/frontier-foods.html.
Evans, H.E. 1997. *The Natural History of the Long Expedition to the Rocky Mountains (1819-1820)*. Oxford University Press, New York.
Fertig, J.M. 1999. *Prairie Home Cooking: 400 Recipes that Celebrate the Bountiful Harvests, Creative Cooks, and Comforting Foods of the American Heartland*. Harvard Common Press, Boston.
Fischer, G.W., and C.S. Holton. 1957. *Biology and Control of the Smut Fungi*. Ronald Press, New York.
Floate, K.D. 2011. Arthropods in cattle dung on Canada's grasslands, pp. 71-88. In: Arthropods of Canadian Grasslands (Volume 2): Inhabitants of a Changing Landscape, Biological Survey of Canada. K.D. Floate, ed.
Gabaccia, D.R. 2000. *We Are What We Eat: Ethnic Food and the Making of America.* Harvard University Press, Cambridge, Massachusetts.
Gallagher, D. 1995. Expensive fungi thrive on wood ash and soil disturbance. Authorities brace for confrontations between rival pickers. *Los Angeles Times*, 23 April 1995, http://articles.latimes.com/1995-04-23/news/mn-57746_1_wood-ash
Gartenberg, M. 1950. W.B. Laughead's great advertisement. *Journal of American Folklore* 63: 444-449.
Gibson, K. 2008. Bark beetle conditions Northern Region 2007. USDA Forest Service Northern Region Forest Health Protection Field Office, Missoula. 55 pp. www.fs.fed.us/r1-r4/spf/fhp/publications/byregion/barkbeetlecond07.pdf.
Gieck, J. 1988. *A Photo Album of Ohio's Canal Era, 1825-1913*. Kent State University Press, Kent, Ohio.
Griffiths, D. 1901. The North American Sordoriaceae. *Memoirs of the Torrey Botanical Club* 11: 1-134.
Haney, G.J. 1942. Paul Bunyan twenty-five years after. *Journal of American Folklore* 55: 155-168.
Harrington, T.C. 2005. Ecology and evolution of mycophagous bark beetles and their fungal partners, pp 257-291. In: *Ecological and Evolutionary Advances in Insect-Fungal Associations*, F.E. Vega and M. Blackwell, eds. Oxford University Press, New York.
Herrera, J., R. Poudel, and H.H. Khidir. 2011. Molecular characterization of coprophilous fungal communities reveals sequences related to root-associated fungal endophytes. *Microbial Ecology* 61: 239-244.
Hoffman, K.J., and L.D. Hill. 1976. Historical review of the US grades and standards for grain. *Illinois Agricultural Economics*, January 1976: 1-9.
Homei, A. 2006. Medical mycology development and epidemiology in the USA, UK and Japan. *Medical Mycology* 44: S39-S54.
Humphrey, L. 2000. *Quinine and Quarantine: Missouri Medicine Through the Years*. University of Missouri Press, Columbia, Missouri.
Ichord, L.F. 2003. *Skillet Bread, Sourdough, and Vinegar Pie: Cooking in Pioneer Days.* Millbrook Press, Minneapolis, Minnesota.
Joe, J.R., and R.S. Young (eds.) 1993. *Diabetes as a Disease of Civilization: The Impact of Culture Change on Indigenous Peoples.* Walter de Gruyter, Berlin.
Kimball, N., and K. Nichols. 2008. Mushroom pickers clear out after fight. *The Daily Inter Lake*, 15 July 2008, www.dailyinterlake.com.
Kinney, W.C. 1996. Conditions of rangelands before 1905, pp. 31-45. In: *Sierra Nevada Ecosystem Project: Final Report to Congress, vol. II, Assessments and scientific basis for management options*. Davis: University of California, Centers for Water and Wildland Resources.
Klose, N. 1961. California's experimentation in sericulture. *Pacific Historical Review* 30: 213-227.
Klose, N. 1964. Louis Prevost and the silk industry in California at San Jose. *California Historical Society Quarterly* 43: 309-317.
Knobloch, F. 1996. *The Culture of Wilderness: Agriculture as Colonization in the American West.* University of North Carolina Press, Chapel Hill.
Krug, J.C., G.L. Benny, and H.W. Keller. 2004. Coprophilous fungi, pp. 467-499. In: *Biodiversity of Fungi: Inventory and Monitoring Methods*, G.M. Mueller, G.F. Bills, and M.S. Foster, eds. Elsevier Academic, Amerstam.
Kuhnlein, H.V., and N.J. Turner. 1991. *Traditional Plant Foods of Canadian Indigenous Peoples: Nutrition, Botany and Use.* Gordon and Breach, Netherlands.
La Barre, W. 1938. Native American

beers. *American Anthropologist, New Series* 40(2): 224-234.

Laughead, W.B. 1922. *The Marvelous Exploits of Paul Bunyan, As Told in the Camps of the White Pine Lumbermen for Generations During Which Time the Loggers Have Pioneered the Way Through the North Woods from Maine to California; Collected from Various Sources and Embellished for Publication*, Red River Lumber Company, Minneapolis. Online as a Project Gutenberg Ebook, www.gutenberg.org/files/32994/32994-h/32994-h.htm.

Lewis, H.T. 1916. The elevator movement in the Pacific Northwest. *Journal of Political Economy* 24: 794-804.

Lockwood, J.A. 2004. *Locust: The Devastating Rise and Mysterious Disappearance of the Insect that Shaped the American Frontier*. Basic Books, New York.

Logan, T.M. 1868. Mushrooms, and their poisonings; with cases*. Pacific Medical and Surgical Journal* 11: 481-494.

Lussenhop, J., R. Kumar, D.T. Wicklow, and J.E. Lloyd. 1980. Insect effects on bacteria and fungi in cattle dung. *Oikos* 34: 54-58.

Maloy, O.C. 1997. White pine blister rust control in North America: A case history. *Annual Review of Phytopathology* 35: 87-109.

Mattes, M.J. 1988. *Indians, Infants, and Infantry: Andrew and Elizabeth Burt on the Frontier*. University of Nebraska Press, Lincoln, Nebraska.

McFarland, J. 2010. America's morel history. *Fungi* 3(2): 4-5.

Merriken, E.R. 1999. *Looking for Country: A Norwegian Immigrant's Alberta Memoir.* University of Calgary Press, Calgary, Alberta.

Moerman, D.E. 1998. *Native American Ethnobotany.* Timber Press, Portland, Oregon.

Monson, C.S. 1996. Mulberry Trees: The basis and remnant of the Utah silk industry. Economic Botany 50: 130-138.

Morris, L.L.W. 1976. Old Rail Fence Corners: Frontier Tales by Minnesota Pioneers. Reprint, with introduction, of Old Rail Fence Corners: The A.B.C.'s of Minnesota History, 1914. Minnesota Historical Society Press, St. Paul.

Negrón, J.F., B.J. Bentz, C.J. Fettig, N. Gillette, E.M. Hansen, J.L. Hayes, R.G. Kelsey, J.E. Lundquist, A.M. Lynch, R.A. Progar, and S.J. Seybold. 2008. US Forest Service bark beetle research in the Western United States: Looking toward the future. *Journal of Forestry* Sept. 2008: 326-331.

O'Brien, C.F. 1988. The Champlain Waterway, 1783-1897. *New England Quarterly* 61: 163-182.

Olds, S.E. 1978. *Twenty Miles from a Match: Homesteading in Western Nevada.* University of Nevada Press, Reno, Nevada.

Olmstead, A.L., and P.W. Rhode. 2002. The Red Queen and the hard reds: Productivity growth in American wheat, 1800-1940. *Journal of Economic History* 62: 929-966.

Orsi, R.J. 2005. *Sunset Limited: The Southern Pacific Railroad and the Development of the American West.* University of California Press, Berkeley.

Parks, C.G., and C.L. Schmitt. 1997. Wild edible mushrooms in the Blue Mountains: Resource and Issues. *US Forest Service, PNW-GTR-393*, 22 pp.

Pirrong, S.C. 1995. The efficient scope of private transactions-cost-reducing institutions: The successes and failures of commodity exchanges. *Journal of Legal Studies* 24: 229-255.

Price, D.J., and E.B. McCormick. 1916. Dust explosions and fires in grain separators in the Pacific Northwest. *US Department of Agriculture Bulletin 379*. 22 pp.

Pyne, S.J. 1982. *Fire in America.* University of Washington Press, Seattle.

Rorabough, W.J. 1979. *The Alcoholic Republic: An American Tradition*. Oxford University Press, New York.

Sandoz, M. 1984. *Sandhill Sundays and Other Recollections.* University of Nebraska Press, Lincoln, Nebraska. (Republication of 1970).

Schwantes, C.A. 2003. *Going Places: Transportation Redefines the Twentieth-Century West*. Indiana University Press, Bloomington.

Severin, H.C. 1919. The most important insect enemies and plant diseases attacking the leaves of currants and gooseberries. *Tenth Annual Report of the State Entomologist of South Dakota*: 22-32.

Shepherd, J.F. 2006 (online draft). The settlement and agricultural development of wheat-producing areas in Australia and the Pacific Northwestern United States, XIVth International Economic History Congress, Helskinki, Finland, 21-15 August 2006 (cited with permission of the author). www.helsinki.fi/iehc2006/papers3/Shepherd.pdf.

Sitton, T. (ed.) 2004. *Harder than Hardscrabble: Oral Recollections of the Farming Life from the Edge of the Texas Hill Country.* University of Texas Press, Austin.

Six, D.L., and T.D. Paine. 1999. Phylogenetic comparison of Ascomycete mycangial fungi and *Dendroctonus* bark beetles (Coleoptera: Scolytidae*). Annals of the Entomological Society of America* 92: 159-166.

Smith, C.E. 1940. Epidemiology of acute coccidioidomycosis with erythema nodosum ("San Joaquin" or "Valley Fever"). *American Journal of Public Health* 30: 600-611.

Taylor, T. 1894. *Twelve Edible Mushrooms of the United States.* US Department of Agriculture, Division of Microscopy. Government Printing Office, Washington D.C.

Titley, E.B. 1999. *The Frontier World of Edgar Dewdney.* UBC Press, Vancouver, British Columbia.

Tyler, V.E. 1985. *Hoosier Home Remedies*. Purdue University Press, West Lafayette, Indiana.

University of Nebraska Press/University of Nebraska-Lincoln Libraries-Electronic Text Center. *The Journals of the Lewis and Clark Expedition*. http://lewisandclackjournals.unl.edu.

US Forest Service. 2007. Forest insect and disease conditions in the United States 2006. US Forest Service, 176 pp. www.fs.fed.us/foresthealth/technology/pdfs/ConditionsReport_06_final.pdf

Weaver, H.D. 2008. *Missouri Caves in History and Legend*. University of Missouri Press, Columbia, Missouri.

Welsch, L.K. 1987. *Cather's Kitchens: Foodways in Literature and Life.* University of Nebraska Press, Lincoln, Nebraska.

Werner, D. 2010. *Where There Is No Doctor: A Village Health Care Handbook*, revised ed. Hesperian, Berkeley, California.

Williams, C. 1902. Silk culture in California. *Overland* 40: 365-370.

Winkler, A. M. 1968. Drinking on the American frontier. *Quarterly Journal of Studies on Alcohol* 29: 413- 445.

Wu, X., J.E. Duffy, P.B. Reich, and S. Sun. 2011. A brown-world cascade in the dung decomposer food web of an alpine meadow: effects of predator interactions and warming. *Ecological Monographs* 81: 313–328.