What are common contaminants of the mushroom culture?

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Most specialty mushrooms are grown on sterilized substrates, and once a contaminant gets a foothold, it flourishes in the absence of competition from other contaminants. In nature, complex interactions among hundreds of other fungi, bacteria, nematodes, etc. maintain an ecological equilibrium. In a sterilized medium, the grower provides ideal conditions for the contaminant to prosper. In sawdust bags, contamination usually involves another fungus living off the waste products or on the remains of the cultivated fungus, or sometimes on the living mycelium or fruiting body of the cultivated fungus. The only competition for these contaminants is the cultivated fungus itself.

Wet Spot, Sour Rot - *Bacillus sp*

In grain spawn jars, one commonly encounters *Bacillus*, which sometimes survives the sterilization process as heat resistant endospores. A dull gray to mucus-like brownish slime characterized by a strong but foul odor variously described as smelling like rotting apples, dirty socks or burnt bacon. *Bacillus* makes uncolonized grain appear excessively wet, hence the name "Wet Spot". Pallid to whitish ridges along the margins of individual grain kernels characterize this contaminant. *Bacillus* primarily reproduces through simple cell division. In times of adverse environmental conditions, especially heat, a single hardened spore forms within each parent cell body - bacterial endospores, which can survive high temperatures for prolonged time. The most practical method for eliminating bacterial endospores involves soaking the grain at room temperature 12 - 24 hours prior to sterilization. Endospores, if viable, will germinate within that time frame and then be susceptible to standard sterilization procedures. And, new endospores won't form in the moist environment of the resting jar of grain.
Bacterial Blotch - *Pseudomonas tolaasii (P. fluorescens)*

Yellow to brown lesions form on mushrooms. Typically, spotting occurs at or near the edge of mushroom caps. Blotch occurs when mushrooms remain wet for a period of 4 to 6 hours or longer after water has been applied. The bacterium is spread in air-borne soil particles. Controls include lowering humidity and watering with a 150 ppm chlorine solution (calcium hypochlorite products are used since sodium hypochlorite products may burn caps). If the mushroom stays wet, however, chlorine has little effect since the bacterial population reproduces at a rate that neutralizes the effect of the oxidizing agent. Shiitake caps are affected by a bacterial disease caused by *Pseudomonas gladioli (Burkholderia gladioli)*. Sanitation is a critical component of control measures.
Cobweb mold or Dactylium Mildew - *Hypomyces sp.*

A cottony mycelium grows over casing. When it contacts a mushroom, the mycelium soon envelopes the mushroom with a soft mildewy mycelium and causes a soft rot. It is also a parasite of wild mushrooms. Cobweb mold is darker than mycelium... almost grey as compared to white. The difference in color is sometimes hard to tell for somebody that hasn't seen them side by side before. Cobweb has several other indicators... the one that sticks out is the speed of growth. A small patch the size of a dime will spread to cover an entire jar/casing in just a day or two. Cobweb is also very very fine strands, while mycelium tends to be thicker ropes.

Cobweb mold is favored by high humidity. Control strategies include lowering humidity and/or increasing air circulation.
Green Mold - *Trichoderma harzianum, T. viride, T. koningii*

Green mold caused by *Trichoderma harzianum* is characterized by an aggressive, white mycelium that grows over the casing and onto mushrooms, causing a soft decay. Masses of spores that eventually form are emerald green. Heavily infested patches of compost are barren. This is currently the most important disease in the U.S. Agaricus industry. Many farms spread salt on the compost in affected areas when green mold is first recognized. Strict sanitation is essential. Shelving, trays, walls, floors, etc. may be surface disinfected as a matter of routine, but it is done with a sense of urgency following an outbreak of a disease. Many commercial products are available for cleaning surfaces. The base ingredients in these materials include chlorine, iodine, phenol, or quaternary ammonium, among others. Surface disinfectants are used farm-wide, from equipment sanitation to room washdowns to foot-dip solutions to picking basket pre-wash. Other Green Molds may be better defined as indicators since they don’t seem to be as aggressive as *T. harzianum*. These species of *Trichoderma* also sporulate on the casing surface and may sporulate on infected mushrooms. These fungi indicate that carbohydrates are available, possibly due to inadequate nitrogen supplementation during Phase I or undercomposting. *T. viride* reportedly produce toxins that dissolve mushroom cells walls. A wet compost low in ammonia prior to pasteurization, flies, poor sanitation, anaerobiosis, and other factors influence green mold. These fungi are common in sawdust and commonly occur in the production of specialty mushrooms. *Trichoderma* is often mistaken for *Penicillium* or *Aspergillus* molds (and vice versa), being that all three look very similar and are not easy to tell apart without the use of a microscope. Some pictures underneath possibly show any of the three genuses out of the aforementioned reason.
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More:

http://www.ppath.cas.psu.edu/MushGrowInfo/Trichoderma%20Green%20Mold.html

**Cinnamon Brown Mold - Chromelosporium fulva (Peziza ostrachoderma)**

The color of this mold ranges from yellow gold to golden brown to cinnamon brown. It grows rapidly in circular patches. It is very common in soil, and flourishes on damp wood. Areas in compost overheated during spawn run may be colonized. Improperly conditioned compost will also support growth, but it is most commonly known as a re-colonizer of overly pasteurized casing, possibly living on dead microorganisms. It often occurs on sterilized soil. Sexual fruiting bodies may appear several weeks after the first appearance of the mold. Spores are airborne.

**Lipstick Mold - Sporendonema purpurescens (Geotrichum candidium)**

This fungus colonizes compost or casing. As spores mature, the color of the mold changes from white to pink, to cherry red, and finally to dull orange. It is slow growing. Spores spread in air, during watering, and on pickers. The lipstick mold utilizes certain fats in the compost. It is an uncommon problem. Control is centered around sanitation.
Pink Mold, Red Bread Mold - *Neurospora*

Commonly to occasionally seen on agar and grain. *Neurospora* is fast growing, sometimes taking only 24 four hours to totally colonize a media filled Petri dish. It is ubiquitous in nature, occurring on dung, in soils and on decaying plant matter. Since this fungus grows through cotton stoppers or filter discs, a single contaminated jar, though sealed, can spread spores to adjacent spawn jars within the laboratory. This condition is more likely if the filter discs or cotton plugs are the least bit damp; or if the external humidity is high. Furthermore, *Neurospora* spores germinate more readily at elevated temperatures. The pink mold seen in mushroom culture is most frequently *Neurospora sitophila*, a pernicious contaminant that is difficult to eliminate. All infected cultures should be removed as soon as possible from the laboratory and destroyed. A thorough cleaning of the laboratory is absolutely necessary. If contamination persists, remove all spawn and start anew.

Sepedonium Yellow Mold - *Sepedonium spp.*

This white, sparse mold grows in the compost during spawn run. With age, it turns dull yellow to tan. Spores are airborne. Thick-walled spores may survive peak heat. The mold colonizes compost considered ideal for spawn growth.
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Black Whisker Mold - *Doratomyces* spp.

This fungus produces black powdery spores that appear as smoke when disturbed. This mold indicates the presence of certain carbohydrates in the compost at spawning time. It also indicates that the straw has been incompletely caramelized or underheated in Phase I (therefore, carbohydrates are in a form easily utilized). The proportion of carbohydrates, particularly cellulose, may be too high. The black whisker mold is also present in compost that overheated during spawn run. Simple carbohydrates are utilized by this fungus but it can also utilize lignin. *Doratomyces*, *Aspergillus*, and *Penicillium* produce copious numbers of spores and may cause respiratory problems (nasal and throat irritation, chest congestion, breathing difficulty, etc.).

Blue-green Molds - *Penicillium* spp.

Abundant blue-green spores are produced on the surface of the substrate. Similar to *Aspergillus*. Favorable conditions parallel those for the black whisker mold. *Penicillium* spp. utilize simple carbohydrates, as well as cellulose, starch, fat, and lignin. These fungi are very common on specialty mushrooms and are one of the chief concerns in agar and grain culture. Spores are airborne and ubiquitous.
Black Mold (also Yellow Mold and others) - *Aspergillus sp.*

Very common in agar and grain culture, and in compost making. Found on most any organic substrate, *Aspergillus* prefers a near neutral to slightly basic pH. Well used wooden trays and shelves for holding compost are frequent habitats for this contaminant in the growing house. Species range in color from yellow to green to black. Most frequently, *Aspergillus* species are greenish and similar to *Penicillium*. *Aspergillus niger*, as its name implies, is black; *Aspergillus flavus* is yellow; *Aspergillus clavatus* is blue-green; *Aspergillus fumigatus* is grayish green; and *Aspergillus veriscolor* exhibits a variety of colors (greenish to pinkish to yellowish). These molds, like many others, change in color and appearance according to the medium on which they occur. Several species are thermophilic.

Some *Aspergillus* species are toxic. *Aspergillus flavus*, a yellow to yellowish green species, produces the deadly aflatoxins. *A. flavus* attacks cottonseed meals, peanuts and other seeds high in oil that have been stored in hot, damp environments. Of all the biologically produced toxins, the aflatoxins are the most potent hepatocarcinogens yet found. The toxicity of this species was largely unknown until, in 1960, 100,000 turkeys mysteriously died from an outbreak of this disease in Great Britain. Since *A. flavus* grows on practically all types of grain, this species is of serious concern to mushroom spawn producers. Careful handling of any molds, particularly those of the genus *Aspergillus*, should be a primary responsibility of all managers and workers in mushroom farms. *Aspergillus fumigatus* and *Aspergillus niger*, two thermotolerant mesophiles, are also pathogenic to humans in concentrated quantities. The affliction is called aspergilliosis or "Mushroom Worker's Lung Disease". Spent compost is the most frequent source of *Aspergillus fumigatus*. 
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Plate 21 Aspergillus, the Green Mold, growing on malt agar media.
Inky Cap - *Coprinus spp.*

These are evidence of free ammonia in the compost. Ammonia seems to be a nitrogen source. Their delicate gray caps autodigest quickly. Inky caps are indicators of nitrogen over-supplementation or a poorly managed Phase II compost. If there is too much residual ammonia, Phase II thermophilic microflora may be unable to convert all the ammonia into microbial protein. In addition, areas in the compost that did not remain within the range of 115 to 135 F from 72 to 96 hours after pasteurization may contain residual ammonia. This fungus is strongly cellulolytic.
**Oedocephalum (Brown) Mold - *Oedocephalum spp.***

This mold makes light gray growth on compost surface, later becoming brown as the spores mature. It forms erect spore-bearing structures with spherical clusters of large spores at its top end. This mold indicates that ammonia and amines were not completely eliminated during Phase II (which might be the case when carbon sources are limiting and nitrogen can’t all be converted into microbial protein). Its ecology is similar to *Coprinus*, and often occurs with it.

**Olive Green Mold - *Chaetomium spp.***

Fruiting structures of this mold look like olive-green cockleburs - 1/16 inch in diameter - that develop on compost. Although its heat tolerant spores survive 140 F for 6 hours, the mold appears only in compost improperly managed during Phase II, especially where Phase II ventilation is inadequate. Lack of oxygen when compost temperatures are greater than 142 F permits formation of compounds produced in anaerobic conditions. These compounds are toxic to spawn growth but are utilized by the olive green mold. It is highly cellulolytic.

**Pin Molds - *Rhizopus spp.***

A very fast growing fungus. Once it sporulates, it forms many tall aerial hyphae adorned with black-headed pins. It grows on readily available carbohydrates. Along with *Aspergillus* and *Penicillium*, species of this genus are the primary contaminants of grain spawn. It is also very common on straw.
Plaster Molds and Flour Molds - *Papulaspora byssina*, *Thielavia thermophila*, *Botryotrichum piluilliferum*, *Trichotheceum spp.*, and others

These molds develop when nitrogen sources (ammonical compounds and amines) from Phase I are not completely utilized by the microbes during Phase II and when the nitrogen is not converted into microbial protein. They are often seen in raw compost. Aerial hyphae aggregate on compost surface, resembling plaster of paris. White plaster mold (*Botryotrichum piluilliferum*) forms dense white colonies. *T. thermophila* is thermophilic (unique among the indicator molds), and may grow rapidly during the last days of Phase II. It indicates hot spots during spawn run, inhibiting spawn growth (resulting in black areas). Brown plaster mold (*Papulaspora byssina*) forms dense brown colonies on compost.

**La France Disease - an isometric virus**

Symptoms of this disease include a degeneration of the mycelium, suppression of fruiting, and rapid dying of mushrooms. In time, the mushroom mycelium disappears. Infected mushrooms are off-white and drum-stick shaped. Other fruitbody symptoms include dwarfing, premature opening of veil, development of an elongated spindly stem with a small cap, formation of a thickened stem with a thin flat cap, and malformed or absent gills. Mushrooms should be picked before the veil opens since spores may carry virus particles (75% infection rate of spores from infected mushrooms). Pasteurization of wood after the compost has been removed is essential. Initial sources include infected spores or mycelium in or on wood, compost, casing, people, and equipment. Wood should be cleaned, disinfected, and steamed. The virus may enter a mushroom farm from neighboring farms and from wild mushrooms. Controls include pasteurization (145 F for 6 or more hours) of compost, spawn, equipment and empty rooms), cleaning HEPA filters, and general sanitation. In 1962, Hollings first identified viruses in mushrooms, also the first report that fungi had viruses. Another virus with a lipid membrane is found in all hybrid spawn; its effect is unknown. PCR is now used by makers of spawn for early detection of viruses. An outbreak of viruses on a farm can be devastating.

More:  
http://www.hri.ac.uk/isms/article4.htm

**Mummy Disease - *Pseudomonas aeruginosa***

Symptoms of infected Button mushrooms include curved stems surrounded at the base by an overgrowth of mycelium. Internally, stems have water-soaked, longitudinal streaks. Caps are tilted and dwarf. Tissues become spongy and dry (mummified). Sanitation and reducing free water are control measures.

![Pseudomonas aeruginosa colonies on agar](image)

More:  
http://www.shroomery.org/index.php/par/26841
Wet Bubble - *Mycogone perniciosa*

Symptoms include malformed mushrooms with swollen stipes and reduced or deformed caps. Undifferentiated tissue becomes necrotic and a wet, soft rot with an offensive odor may follow. An amber liquid appears on infected mushrooms. Mushrooms become brown in color. Bubbles may be as large as a grapefruit. The fungus is spread via airborne dust and contaminated casing. It is also a parasite of wild mushrooms. Controls include sanitation and in some countries the use of the compound Sporogone, which is also very effective against Verticillium. Wet bubble is the most important Button mushroom disease in China.

Dry Bubble - *Verticillium*

This disease is caused by Verticillium, a species which produces sticky spores. The symptoms produced vary with the developmental stage of the mushroom at the time of infection. 'Early' infection at pin head formation results in the production of malformed pin heads, which turn a grey/brown colour and remain leathery. Infection at a later stage causes a thickening of the stipe especially at the base, and also a crooked mushroom with a tilted cap and backward peeling stalk. Cap infection can occur at a very late stage in the development of the mushroom, resulting in circular superficial spots, initially pale brown in colour which become grey with age.

Verticillium sp. commonly occur in the soil which may be a primary source of the infection, however, it is more likely that they come with casing or by transfer of infection from house to house by pickers, flies or machinery. Spores can lie dormant until they come into contact with mushroom mycelium which stimulates them to grow. Because the spores are sticky the disease is spread on dust particles from the movement of earth or spent compost. This dust can contaminate fresh casing, or can enter through fans or doorways or be carried in by flies, pickers or even mites. The disease within the production house can be spread by water splash. The spores can also be spread on any other equipment used in an infected growing house. Appearance of the disease at pin head formation signifies infection at an early stage of development, probably at the time of casing. Development of the disease at later stages of the production cycle usually indicates infection has occurred from other cropping houses or from outside sources. Spread by water, flies and pickers can result in 30% of the crop being infected at the third flush and by the last flush virtually all of the crop. The highest standards of hygiene are essential for the control of Verticillium. Other methods of control are as follows:

Control:
1. Avoid soil movement near mushroom houses especially on windy days. Take measures to avoid the accumulation of dust in the vicinity of mushroom houses and also dust movement into the vicinity of mushroom houses.
2. It is essential to control flies and every effort should be made to prevent their entry into cropping houses.
3. As diseased mushrooms appear they should be removed from the beds using a cloth or sponge soaked in disinfectant and then placed in a bucket containing disinfectant.
4. Table salt on top of tissue paper can be used to contain disease.

More:
http://mushgrowinfo.cas.psu.edu/Verticillium Dry Bubble.htm
**Fungus gnats (Sciarids) - (Lycoriella spp.) and phorids (Megaselia spp.)**

Adults are small (1/8 inch long), fragile grayish to black flies with long, slender legs and thread-like antennae. Their wings are clear or smoky-colored with no pattern and few distinct veins. Larvae are clear to creamy-white and can grow to about 1/4 inch long. They have shiny black head capsules. They are attracted to the mushroom crop and their larvae feed directly on mycelium, swarm over the mushroom, and tunnel into the developing or developed mushroom. Tissues that have been physically damaged by flies often become colonized by bacteria which cause soft rot, thereby accentuating the problem. Controls include strict sanitation and general farm hygiene. For example, the grow room must be air tight. Fresh air that is used is filtered. Even a small crack will serve as an entry for the flies. Most farms use sticky tape or some other method that allows monitoring of populations. A biocontrol using nematodes offers effective control when populations of flies are low. In addition to the damage which fly larvae cause by eating mushroom mycelium or killing pins, the adults also carry diseases such as Verticillium, Mycogone and Cobweb.
Mites

Many mites are commonly found in straw and manure, most species are beneficial to mushroom growing as they feed on eelworms and other mites, although some can cause damage.

Mites, like fly larvae, may feed on mushroom mycelium and on the mushrooms, where they can cause surface discoloration. They may also live on other fungi (weeds and indicator molds) found in mushroom culture. One example is the red pepper or pygmy mite (*Pygmehorus spp.*). These mites are commonly associated with *Penicillium* and *Trichoderma* molds, upon which they feed. Pygmy mites do not feed on *Agaricus*. These mites have the ability to change into an intermediate stage called a hypopus, wherein they develop flattened bodies and a sucker plate with which they attach to moving objects, like flies. Mites at this stage swarm on top of mushrooms.

1. Tarsonemid mite

   These mites are pale brown and are so minute that they are only visible with the aid of a microscope. They cause damage by feeding entirely on hyphae of mushrooms and the grower will know if he has these mites present, as the base of the stem of the mushroom will show a reddish brown discoloration. Where severe infestations occur the whole base of the mushroom may be detached from the growing surface.

   **Control**
   1. As with eelworms little can be done when mites are present in the growing house, therefore efficient composting and peak heating must take place to ensure that they are killed during the pasteurization process.
   2. Good hygiene should be practised around the farm, especially in the clearance of crop debris.

2. Tyroglyphid mites (*Tyrophagus spp.*)

   These mites can be identified as they are slow moving, translucent, with long hairs on their bodies.

   If these mites are present in abundance they eat small pits in the caps and stalks. These pits then suffer from bacterial decomposition, which breaks down tissues just below the surface. This results in the skin collapsing which leaves an open pit. Tyroglyphids may also feed on mushroom mycelium, where they are present in large numbers, crop reductions can be caused. Mites usually gain entry into the compost by clinging onto Sciarid flies when the mites are the migratory stage. These migratory stages are normally produced when mites become overcrowded.

   The mites should not be a problem where efficient composting and peak heating takes place. Organic debris should not be allowed to accumulate around the farm as it provides a breeding ground for mites.

3. Red Pepper Mites (*Pygmehorous spp.*)

   These mites are not regarded as primary pests, their presence is usually an indicator that *Trichoderma* (green mould) is present in the compost. These mites feed on various weed moulds but not mushrooms, thus their presence indicates that the compost is unsatisfactory. The mites are yellowish-brown in colour, 0.25 mm in length and have a flattened appearance, they also are capable of rapid rates of reproduction.

   As already stated these mites are secondary pets and they often swarm on the casing and mushroom surfaces. Where this happens their presence makes the mushrooms unsaleable. These mites can also spread spores of *Trichoderma* from bag to bag.
Nematodes - *Aphelenchoides composticola* and *Ditylenchus myceliophagus*

These nematodes are common inhabitants of most agricultural soils. Symptoms include a degeneration of mushroom mycelium and failure of mushrooms to form. Normally, an infestation is noticed at the time of third break. Mycelium in affected areas is completely destroyed and as the compost decomposes, it turns black and a medicinal odor is detectable. An effective Phase II is the primary control.

Abnormalities

Several disorders have abiotic origins. Common ones include:

**Browning - tyrosinase (phenolase)** - Is the main enzyme responsible for browning in Agaricus. Calcium chloride in irrigation water decreases bruising by increasing the integrity of vacuole membranes (thus, tyrosinase is not released).

**Flock, hardcap, and open veil** - Physiologically induced malformation of cap and gill tissue. Cap opens prematurely. Causes include some diseases, petroleum based materials, and genetic abnormalities. Hollow core and brown pith - related to water stress, but exact factors unknown. Long stipes and small caps - insufficient light and/or fresh air.

**Rosecomb** - Condition where pink gill tissue, often with a porous appearance, develops on the surface of a mushroom cap. The cause has been attributed to contamination by petroleum based materials.
Scaling - The natural reaction of the mushroom cap to dry air.

Stroma - Dense mycelial growth without fruiting. Stroma occurs if spawn is mishandled or exposed to harmful petroleum-based fumes or chemicals. It also occurs in dry environments.

Weepers - Mushroom exudes water from cap. The cause is not known, but it is seen in low-moisture compost and high-moisture casing.

Literature sources:

- Plant Pathology 40, Edible Mushroom Cultivation Lecture/Lab 8 Pest, Diseases, and Weed Control; Abnormalities, February 26, 1999
- http://www.mold-help.org
- http://www2.truman.edu/~jherrera/colonies/colonies-genera.html
- http://www.hortips.co.uk/mush_2.htm