Urban Mushroom Propagation and Mycoremediation

Fruiting Oysters, *Pleurotus Ostreatus*
What about mushrooms?

• Edible- high in protein food
• Medicinal-help fight cancer, boost immune system, lower cholesterol.
• Nature’s recycling plant- help to clean environment from pollutants, including deadly petrochemicals and heavy metals.
• Easy to grow on urban trash like cardboard and all paper products.
• The fruit body is the product of mycelium.
• Fruiting Temperature: 45–65° F
• Ideal Wood Types: alder, maple, oak, beech, birch, ash, sweetgum
• The Blue Oyster mushroom is ideal for mushroom growers who live in cooler climates. It tends to fruit well in the early spring and fall, producing beautiful steel-blue to blue-gray mushrooms. Like its sister species the Pearl Oyster, the Blue Oyster is extremely aggressive and grows on a wide range of deciduous hardwoods.
• Plugs From Fungi.com pic from addisonslab.com
Mushroom Morphology

- Fungi are composed of filaments called **hyphae**; their cells are thread-like and connected end-to-end.
- The body of the organism is called **mycelium**, a term which is applied to the whole body of any fungus, which can be miles in diameter.
- Colony in Oregon: 2,400-acre (1,665 football fields) in size and 2,200 years old
- When reproductive hyphae are produced, they form a large organized into primordia and then a structure called **sporocarp**, or mushroom. This is produced solely for the release of spores.
- Mycelium is the informational “internet” or “brain” of Nature, sensing chemical changes and imbalances from miles away. The structure resembles the neurons of the brain.
- On the picture: Oyster mushroom mycelium, the living body of the fungus

History

• Fungi exist on this planet since 1 billion years ago; some believe the spores traveled to Earth from outer space. (there is water on Mars!)
• Closer to animals then plants; need O2, digest foods with external secretion of acids and enzymes and then absorb it.
• We share the same ancestry from 600 million years ago. Animals evolved from some Fungi by developing enclosed stomach.
• When meteorite struck the Earth 250 million years ago, killing 90% of living things, fungi did the clean-up, making room for dinosaurs.
• Recent discovery: Researchers report they've discovered dormant algae and a thriving community of carbon-chomping fungus deep beneath the ocean floor in 2.7-million-year-old mud. These fungal communities are ancient and isolated.
• Source: huff post science 01/10/14
Mushroom life cycle

- Each spore contains only 50% of the genetic material necessary for propagation of specie.
- Spores germinate and reproduce mitotically.
- Hypha of two compatible spores fuse and combine genetic material into strong dicaryotic mycelium.
- When mycelium is mature, it begin to form dense clusters - primordia, which grow into mushrooms. It takes 4-15 days and require moisture of 98-100 rH or condensing fog and high oxygen.
- Some light is needed for correct formation of mushrooms.
- Monocaryotic mycelium from single spore will produce infertile mushrooms or no mushrooms.

Picture from http://foragedandfoundorganics.com
Spore production

The method of spore ejection is still a mystery. Erlenmeyer flasks An oily gas bubbles forms and inflates, swells and explodes. Spores are ejected with a force 10,000 times higher than space shuttle To escape gravity and to achieve orbit.

Pic. From wikipedia.org
Types of Mushrooms

- **Saprophytic** fungi - the premier recyclers on the planet. The enzymes and acids they secrete degrade large molecular complexes into a simple compounds. The end result is the return of carbon, hydrogen, nitrogen and minerals back into ecosystem in form usable by plants, microorganisms and other organisms.

- Primary saprophites - fast-growing oysters, shiitake, *Lentinula edodes*, King stropharia.

- Secondary decomposers - button mushrooms *Agaricus*

- **Mycorrhizal** – beneficial to plants. The mycelium helps absorption of nutrients and water. Truffles, chanterelle, boletes. Their growth depends on tree root by-products. They are the health and information matrix of the forest.

- **Parasitic** – live off the host plant. Edible Honey mushroom (*Armillaria*). Washington state has a colony that is 2.200 acres, 2.400 y.o
Pleurotus Ostreatus

- *Pleurotus* is a genus of gilled mushrooms which includes one of the most widely eaten mushrooms.
- Oyster mushrooms are native to both deciduous hardwood and conifer tree species, fruiting both in the spring and fall.
- Species of *Pleurotus* may be called **oyster**, **abalone**, or **tree mushrooms**, and are some of the most commonly cultivated edible mushrooms in the world.
- *Pleurotus* mycelium have been used in mycoremediation of pollutants such as petroleum, as a bio filter for bacteria-laden city and agricultural run-offs, to control root-crop damaging worms. The mushrooms are used as food and medicine.

Kingdom: Fungi  
Phylum: Basidiomycota  
Class: Agaricomycetes  
Family: Pleurotaceae  
Genus: Pleurotus  
Type species: *Pleurotus Ostreatus*
Growing mushrooms in the City

- NYC recycles only 50% of 2100 tons of paper a day. That is, 1050 tons of paper a day becomes a waste.

- Initiative: Grow expensive food on free trash like coffee grounds or paper waste. Also on Straw, cereal hulls, coconut fiber, corncobs, tea leaves, nut hulls, plant waste.

- Grow under your bed or in the basement, together with fish in Aquaponic systems (they both need warmth, water and darkness)

- Mushroom spawn can be bought on-line, transferred from existing patch or spores can be harvested. Mushroom butts will grow into mycelial mat as well.

Urban Mushroom Propagation by Anya Pozdeeva FoodUnderYourFeet.com SAVEfarms.org
Low- tech growing mushrooms.

- You will need:
  - Cardboard. Do not use cardboard made in China, some of it may contain harmful chemicals.
  - 3-5 gallon plastic bag or a bin (indoor); wood or cardboard box (outdoor)
  - 2% Peroxide solution to disinfect the cardboard
    - Mushroom spawn, stem butts, mushroom spores
    - Water, oxygen, indirect light.
  - Lack of light causes Oysters to mal-form into coral-like structures.

Soak cardboard in 2% Peroxide solution for 30 min; rinse with fresh water.
Place the cardboard in your container of choice and mix with the spawn. To ensure successful, use at least 20% of spawn. Close the container loosely with a lead to ensure oxygen delivery. If using a plastic bag, punch small holes.

Incubate a patch for 2-3 months at a room temperature, see white mycelium take over the cardboard, make sure it stay moist. When the cardboard is fully colonized, use

**Initiation strategy for temperate species:**
Cold shock at 60-65F for 2 days, then
soak the mycelium in
container in cold water, fully submerged, for 24 hrs.
Take out, bring to 70-80F spray few times a day with non-chlorinated water and watch mushrooms pop.
A better way to compost

- Mushrooms are essential element of soil growing and urban food production.
- Add the mushroom patches to your vertical garden, vegetation will provide the shade.
- This left-alone mushroom patch yielded 2-3 lbs of mushrooms from 2 medium-sized cardboard boxes, while turning them in rich soil.
- Mushrooms will self-reseed.
- To build healthy rich soil on unusable land: make layers of compost and cardboard inoculated with mushrooms and let Nature take over.
- Trick: don’t miss the fruiting!
- Skunks like mushrooms too.
Permaculture with Mushrooms

• Pleurotus species and King Stropharia thrive in complex compost piles, helping to build soil. Most effective at soil temperatures of 55-65F
• CO2 production by mushrooms boosts growth of plants
• Mycelia reduces load of harmful bacterial like e-coli, reduces amounts of harmful nematodes and purifies soil of hydro-carbon based toxins.
• No till method preserve mycelium
• Use mushrooms to create Hugelcultur – the ultimate raised gardens.

Urban Mushroom Propagation by Anya Pozdeeva
FoodUnderYourFeet.com
SAVFarms.org
Growing mushrooms on stumps and fallen trees

• Taking advantage of hurricanes, using unwanted trees, chip stump removal.
• Helping Nature and Park Department to clear debris, while growing food for yourself, community and wild life.
• Faster return of nutrients into the ecosystem invigorates it.
• Preventing ecosystem from parasitic species like honey mushrooms, which are responsible for destroying thousands of acres of conifers.
• Katrina Hurricane-resulted in disasters and mushroom farms on public land.
Growing on stumps

• Stumps roots still pump the water, providing moisture. Stump must be 2-3 months fresh, shaded better than in full sun, unless you are growing puffballs.
• You can multiculture varieties of mushrooms on the same large stomp.
• Small stomps fruit faster than large, but for shorter time.
Log Culture Instructions
You will need: **power drill, and a 5/16" drill bit, fresh hardwood log, cheese wax, lighter, inoculating plugs, rubber mallet.**

- Drill holes the size of the wood plugs, 4-6 inches apart in a diamond shape. Drive cultured plugs into holes using rubber mallet. Cover with cheese wax.
- If incubating indoor, place in a perforated container/plastic bag to prevent moisture loss, keep at 75F for 2-3 months or until fully colonized.
- To initiate fruiting, soak in water for 6 hrs. and place in a cooler area or outdoors in spring. Fruiting temperature for Blue Oysters is 45-65F
- Cultivate Maitake, Reishi, Shiitake and Oysters.
- Careful! A deadly poisonous mushroom which often grows on stumps, Galerina autumnalis, looks similar to Flammulina velutipes (Enokitake, openok zimnii, or Winter mushroom)- avoid cultivation. Pic from [www.mushroomexpert.com](http://www.mushroomexpert.com) and [botit.botany.wisc.edu](http://botit.botany.wisc.edu)
More on Log culture

- Use sawzall to cut logs 3-5 inches wide or chainsaw for larger logs. [Link](http://www.huffingtonpost.com/2014/01/08/jennifer-mccarthy-vagina-gun-_n_4563551.html?utm_hp_ref=mostpopular)
- Logs should be cut in winter/early spring when sap is rich in sugars and kept off the ground.
- Or the wedges on the logs can be cut and put back with spawn sandwiched in and nailed in place.
- Logs are stocked up or vertically buried into sand.
- Mycelium grows slower compared to sterilized saw dust/ship mix, but this method is low-tech.
- Good non-aromatic hardwoods such as **oak, poplar (cottonwood), sweetgum, elm, alder, maple, birches, walnut, and similar hardwoods** are suitable for log cultivation.
- Mushroom candidates: Oysters, Shi
- Conifer logs: grow Enokitake, Reishi, Turkey Tail, Clustered woodlovers, Oyster, Califlower mushrooms

Pic. From Fungi.com
Trees

Sweet gum tree, wikipedia
Alder tree, wikipedia
Yellow poplar, by Bruce Marlin

Wych elm, wikipedia
Seeds 45% crude protein, and less than 7% fibre by dry mass.
Musilageous inner bark of the Slippery Elm (Ulmus Rubra) has long been used as a demulcent
Home Vertical garden: Mushroom Pole

- Use a fresh medium-size log (many available in public parks such as Van Cortlandt or Riverdale Park)
- Inoculate the log with shiitake or oyster mushrooms
- Bury one end of it into a pot with sand (bottom) and soil in top
- Grow herbs or climbing vines on the bottom
- Place a pot with soil on top securely and plant cascading edibles like strawberries and/or ornamentals
- Damp soil will keep the log moist, plants give shade
- Watch mushrooms pop from your flower/herbs garden
Spore-Mass Inoculation

Collects spores by making spore prints or make a spore-mass slurry.
Choose mature mushrooms (buy at store or use once you have grown before) and submerge them in 5 gallon bucket of water.
Adding a couple grams of salt will inhibit growth of bacteria yet will not harm spores.
Adding 50 milliliters of molasses will stimulate spores into germination.
After 4 hours of soaking remove mushrooms from the bucket- after mushroomed released tens of thousands of spores.
Allow the broth to sit for 24-48 hrs at 50-80F (10-26C). The slurry can be expended by a factor of 10 in 48 hrs.
Prepare cardboard patch outdoor as described above.
Pour the slurry in between the cardboard sheets. Cover with debris and try not to miss the fruitarian.

• Source: Mycelium Running, Paul Stamets
Spore mass masters

- Remove indoor grown mushroom at maturity 4-5 inches in diameter and place in 1 gallon sterilized sugar-enriched water.
- Shake for a minute and pour in another sterile container (spore master1). The spores germinate within minutes, respiration cycle begins. Aerate the master with air bubbler.
- The SM1 can inoculate 100 times its mass, 1:25-1:200
- After 2-4 days of fermentation at 75F, another 100-fold expansion is possible, after which it can be sprayed into sterilized straw or sawdust.
- Take 0.1 ml onto perti dish to detect contaminants cultures or use microscope.

- Hundreds of strains are formed and competing with each other; the strongest will invade the weaker ones.

Liquid culture

- Liquid culture media:
  - 1000 ml water
  - 40 gr barley malt sugar
  - 3-5 gr hardwood sawdust
  - 2 gr yeast
  - 1 gr calcium sulfate
  - Use Dikaryotic mycelium, not spores. Sterilize media for 1-2 hrs at 15 psi (pounds per sq. inch or 252F) in Erlenmeyer flasks or jars. Collect mycelium from 10 perti dishes, place in sterilized high-speed blender or Eberbach stirrer.
  - Blend and pour into flasks, cover with non-absorbent cotton and aluminum foil.
  - Shake every 2-3 hrs for gas exchange. After 2 days of fermentation, use to inoculate media. 30 ml to ½ gallon (2 liter jars) or grain.
Spore distribution

Make spore prints of gourmet mushrooms on hats or jackets and wear it to your nature walk; The desirable species spore distribution will assure more edible varieties in your park vs. poisonous, inedible or parasitic fungi.
High-tech Pure culture expansion in lab.

- In lab environment, pure culture is grown on sterilized agar media in petri dishes. Each culture of 100x15mm dish can inoculate 10 liters of grain spawn.
- Perti dish gets filled in 5-10 days at 75F
- 2 petri dishes of mycelium can result in 1000 lbs of mushrooms in 12 weeks. Contaminants can grow just as fast.
- The cultures in petri dish can be used to inoculate sterilized grain in bottles, jars or bags.
- Each jar can inoculate 10 times its mass for 3 generations of expansion. Inoculation rate can vary 5-15%, (wet mass of spawn to dry substrate) and can be done in any substrate like sawdust/woodchips, logs or cardboard.
Agar preparations

- Dog Food Agar
- 1 liter water
- 20 gram dry dog food
- 20 gram agar agar
- Mix, sterilize for 45 min at 15 psi (similar to 250F)
- 1 liter can fill 20-40 dishes.
- The pH of agar should be neutral or slightly basic 5.5-6.5; during mycelia growth it becomes more acidic.
- Clone mushrooms by cutting a small piece of inside tissue from just-above-gills area of a young mushroom using sterilized scalpel. Dip in agar dish and cover.
- Inoculate the agar with spores by dropping spores into agar or by dipping agar-covered scalpel in spores and transferring into the petri dish. Transfer germinating spores into other petri dishes.

Urban Mushroom Propagation by Anya Pozdeeva FoodUnderYourFeet.com SAVEfarms.org
Grain spawn

First-generation grain masters or G1

1/2 gallon or 2 liter jars formula. Lids with microporous filter disks.
480 gram rye, 400 ml water, 2 gram gypsum

Standard Spawn bags 7.5x8.25x4.75 inches, equipped with microporous filter
3.300 grams fresh rye
1,400 ml water (38% moisture)
12 grams gypsum
Gypsum keeps kernels separated after sterilization and provides calcium and sulfur necessary for mushroom metabolism.
Mix all ingredients in the bottle and let grain soak for 12-24 hrs, then sterilized for 4 hrs at 15 psi (1 kg/sm2) in autoclave or pressure cooker

Inoculate bags using 200-300 ml of fermented, liquid mushroom mycelium.
The bags are laid horizontally with filters up and gently agitated every 3 days.

When using ½ gallon jars with lids, inoculate grain with cuttings of mycelium from petri dish using sterilized scalpel. Take shower, put on clean clothing, wash hands and wipe them with 80% rubbing alcohol.
Incubate for 2 weeks at 75F or 24C.
Use within a week of full colonization.
Each Grain masters G2 and G3 can inoculate 5-20 time its mass.
Pic from http://ecoculturevillage.org/usefulgardens/lets-grow-oyster-mushrooms/
Fruiting Substrate Formula

• 100 lbs sawdust, 50 lbs wood chips (1-4 inches), 40 lbs oat, wheat or rice bran, 6 lbs gypsum (calcium sulfate). Mix well and moisten to 60%. Immediately transfer to bags and sterilize in autoclave for 5 hrs at 15 psi.
• If straw is used, pasteurize it for 1 hr in hot water of 180°F.
• Mycelium and Mushrooms accumulate toxins and heavy metals from automobile tires, oil based asphalt. Do not use trees grown too close to highways.
• Sawmills and pulp chip companies provide the cleanest source of wood debris.
• Because Mushroom need O2, substrate should not be too dense and can become anaerobic. Wood shavings too fluffy. Mix media. Mycelium is like fire, runs even in sawdust and explosive on a wood chip.
• Supplements high in protein/nitrogen: grape pumice from wineries and spent barley from breweries, brans, coffee grounds, stale bread from bakeries. Problem: they invite competition from insects, microorganisms and molds in outdoor patches. Extra pasteurization required- up to 4 hrs. at 160°F. Sterilization of agar requires 40 min at 250°F.
• Do not over-sterilize (10 hrs): wood becomes indigestible.
• If thermogenesis happens and temperature of substrate rise, Molds awaken at 100°F.
• Temperature of 75-85°F is ideal for gourmet wood decomposers.
Creating Saw dust spawn

- Used to grow Shiitake, Oyster, King Stropharia, Nameko, Maitake, Reishi.
- Saw dust spawn is produced by inoculating it with grain spawn, 5-15% ratio.
- Saw dust spawn is used to inoculate the “frUITING substrate”: logs or supplemented sawdust and woodchips mix.
- 5lbs bag of saw dust can inoculate 5-20 times its mass.
- Supplemented fruiting formula: 20% rice bran or 20% rye flower or 5% soybean meal, or 5% molasses or 1% sugar. (unrefined sugars are always better)
- Pic: Maitake, Pholiota Nameko (opyata) or butterscotch mushroom from wikipedia.com
Troubleshooting

• One of the most aggressive competitor of Oyster mushroom are Green Molds, shown on the picture. Make sure your substrate, hands, vessels and utensils are clean during the inoculation.

• High carbon dioxide (CO2) concentration inside mushroom houses is one of the major causes of abnormality in fruiting bodies. Proper ventilation is needed.

• Fruiting bodies need indirect sun light to form correctly.

• Too much watering during mushroom formation can cause diseases, too little will dry out the patch.

• Best temperature for fruiting is 60-65F with humidity 80%.
Health benefits of Mushrooms

• The Japanese word "maitake" means "dancing mushroom," a name derived from the reaction of people having found these mushrooms, which were actually worth their weight in silver.
• Cancer prevention
• Immune support, regulate blood pressure and blood sugar control.
• Beta-glucan, a polysaccharide compound that boosts the immune system through the activation of macrophage cells, natural killer cells and T-cells.
• Lower cholesterol. Rats given powdered mushroom preparations saw a drop in both total cholesterol and very low-density lipoprotein-cholesterol.
• Weight Loss: Mushrooms contain no cholesterol, no fats, very low carbohydrates and high lean protein content.
• Pic from formerchef.com
(P. ostreatus) mycelium is carnivorous -- it stuns and eats nematodes and bacteria (Barron, 1998). The mycelium strongly inhibit *Escherichia coli* and staph (*Staphylococcus aureus*). (Stamets, 2005). Viable cell counts were reduced from more than 100,000,000/ml of water to less than 1,000/ml within 24-72 hours when a 1:1 mixture of exudate of extracellular toxins of *P. ostreatus* and bacterially enriched water were combined (Stamets, 2005).

Oyster mushrooms are rich in protein (up to 30 percent by dry weight), plentiful in B vitamins, have no cholesterol, and have significant levels of the cholesterol-lowering molecule lovastatin -- up to 2.8 percent by dry weight (Stamets, 2005; Alarcon, 2003). Because of their native lovastatin content, oyster mushrooms have been studied for their benefits in helping modulate blood cholesterol levels.

Alcohol extracts inhibit growth of colon and breast cancer cells without significant effect on normal cells. (Jedinaki and Silva, 2008)
King Oyster Farm

• In Asia, *Pleurotus nebrodensis* and *P. eryngii* are gaining market share since these thick-fleshed and short-gilled mushrooms have a shelf life that exceeds most species by several weeks.
• Nematodes (tiny worms that feed on living plant and fungal tissue) -- the bane of Portobello industry -- are not an issue with oyster mushrooms.
• *Walls of Pleurotus eryngii, the King Oyster. Photo courtesy of Roel Dreve.*
• Source: http://www.huffingtonpost.com/paul-stamets/oyster-mushroom_b_2522084.html
How mushrooms save the world
Biores Remediation: phyto, myco and micro

- **Mycoremediation**
- Crude oil spills
- Hydro-carbon based industrial pollutants can be called “fertilizers” after being broken down by fungi
- Pesticide/herbicide residues
- In existing mycoremediation experiments, more than 95% of many of the PAH (polycyclic aromatic hydrocarbons) had been reduced to non-toxic components in the mycelial-inoculated plots, breaking down contaminants into CO2 and water.
- Wood-decay fungi like Oyster mushrooms (Pleurotus Ostreatus) are particularly effective in breaking down aromatic pollutants (toxic components of petroleum), as well as chlorinated compounds (certain persistent pesticides) (Battelle, 2000).
- The enzymes secreted by many fungi actually stimulate aggressive toxin degradation by other microbes present in the soil as well as plants. Starting with a supporting role, fungi can trigger a chain of commands in the soil ecosystem toward soil health.
- Protection water sheds from Pathogenic bacteria from cattle, city run-offs
• **Heavy metals** (zinc, cadmium, mercury, lead, chromium and arsenic) can become concentrated in mushrooms via bio sorption, and can be extracted and then recycled by companies specializing in metallurgy.

• A less invasive technique is to plant the mushrooms at precise proportions under phytoremediating plants and trees, facilitating a process of break down and absorption of the metals at levels deemed safe.

• Ameliorating impact of **radioactive waste** by sequestering heavy metals.

• Black mushrooms in Chernobyl, which use solely the energy of radiation as food source.

• There is a patent to use mushrooms to destroy nerve gasses like Sarin, as well as chemical and biological warfare components (Venter).
• Mycofiltration: Protection water sheds from Pathogenic bacteria from cattle, city run-offs
• Mycoremediation presents a benign, inexpensive, and sustainable solution that people can implement in their own neighborhoods with minimal work.
• Without having to wait for a government or a corporation to take action, individuals may gain agency with this method.
Easy Method of Constructing mycoremediating barriers @SaveFarms

• Using reject materials, like cardboard boxes, saw dust, woodchips from local wood workshops, coffee grounds from coffee shops. We getting wood shavings from RockingTheBoat, Bronx, who get their wood from NYC public parks.

• Construction: place cardboard boxes in a row to create a barrier. Fill with media, soak with water and inoculate. Loosely cover with newspapers or straw or pieces of cardboard to prevent from drying and excessive exposure to wind and other spores.
Urban Mushroom Propagation by Anya Pozdeeva
FoodUnderYourFeet.com
SAVEfarms.org
Mushroom Harvest

If you are lucky not to miss a flush, which usually takes about a 5-7 days from primordia to maturity, you’ll enjoy delicious mushrooms. All mushrooms, with the exceptions of truffles, must be cooked to destroy heat-sensitive toxins.

**Farmer’s Recipe:** Wash, shop and sauté fresh oyster mushrooms with garlic and onions, wild spinach in olive oil for 15-20 min. Salt, pepper to taste.
Mushroom Facts

• Nearly 50% of carbon base in the wheat straw is liberated as gaseous CO2 in the course of decomposition by mushrooms.
• There is 1 mile of mycelium in 1 sq. inch of substrate.
• A single mushroom can produce 100,000,000 spores
• Mushroom basidia shoot spores with force equal to 10,000 times more than a space shuttle taking off.
• Chinese mushrooms have the greatest aluminum, lead and mercury concentrations, followed by mushrooms from California. Mushrooms from near Chernobil is still radioactive.
• Average conversion is getting 1 lb of fresh mushrooms from 1 lb of dry substrate, 100% biological efficiency.
• Mushrooms can produce vitamin D when exposed to sun light for 2 days. Dry them gills-up. The vitamin D levels in these mushrooms soared from 100 IU/100 grams to nearly 46,000 IU/100 grams Vitamin D levels in mushrooms remain high for at least a year, assuring immune-busting and cancer-fighting supplements during winter.
• in 1950 one of the first antibiotics isolated from mushrooms, pleuromutilin, was found after observing that Pleurotus ostreatus inhibited a wide range of Gram-negative bacteria, including Salmonella.
• ZEN Moment:
• “From dead plant matter to nematodes to bacteria, never underestimate the cleverness of mushrooms to find new food!”- P. Stamets