POWDERY MILDEW & FUNGICIDES
WHITE PAPER

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Powdery mildew is a common fungal disease of angiosperms (basically, any plant but conifers). The growing fungus looks grayish white and powdery.

Powdery mildew disease is caused by an infection from one of the many fungal species of the family Erysiphaceae (ee-rhy-suh-facie).

Powdery mildews live, for the most part, external to their host not within it. In other words, they are ectoparasites, not endoparasites. Furthermore, powdery mildews' parasitic process requires the host cells remaining alive...making them what scientists call obligate biotrophic parasites. Biotrophic pathogens usually cause disease on only a relatively small group of host plants. This is because of the different genetics and molecular processes/structures required for wider ranging host-pathogen interactions.

Powdery mildew is not systemic. In other words, powdery mildew doesn't grow into a part of the plant, propagate internally throughout the plant, and then pop-out somewhere else on the plant.

There's a common misconception about the word "systemic". Use of Eagle 20 would be an example of a systemic fungicide attacking a non-systemic fungus. Eagle 20 is a systemic fungicide—after you spray a plant with Eagle 20, the fungicide moves throughout the plant. The fungus doesn't move throughout the plant, only the fungicide. Just because a systemic fungicide attacks a fungus, doesn't mean that the fungus was systemic.

First symptoms of a powdery mildew infection are dusty gray or white spots on either side of the leaves. If untreated, the growing fungus will produce spores and rapidly spread through leaves and into stems and flowers. Powdery mildew fungi doesn't usually kill the host plant, but it can cause early senescence and it does stunt the plant's growth and development by stealing nutrients and increasing plant stress. Some plants will show local necrosis when infected badly.

The fungus can be transmitted by pests such as aphids or by touch, tools, clothing, shoes, and even by airflow through previously contaminated spaces. Those are all sometimes called "transmission vectors", or simply vectors, i.e. - "Aphids on that clone were the vector that brought PM into my garden."

Relative humidity plays an essential role in the control or spread of mold. Molds and fungus particularly like dry leaf surfaces and humid environments. For the best inherent protection during growth phase, relative humidity (RH) should be kept between 40% and 55%. Relative humidity over 50% poses danger during flowering.

Most critical are the night time RH levels. The night time RH spike is often underestimated by growers. Consistent climate control is very important during growth phase, but it's critically essential during flowering. Flowering requires drier conditions, humidity should be held between 25-45% RH.

Crowding your plants can produce pockets of stagnant, high humidity air—so give your girls some room. Wide RH swings are also conducive to powdery mildew infection. It's good to keep the lower fan leaves trimmed because these are the most vulnerable to infection. Washing leaf surfaces can help flush fungal spores off the leaves. But be sure to wash early in the day so the leaves will be thoroughly dry before the dark period.

SANITIZATION = STANDARD OPERATING PROCEDURE

Dedicated shoes, or a boot bath, and washing hands (alcohol based hand sanitizers are good) before entering the grow area are your first line of defense. Also, it's a good idea to not wear your outdoor clothes into your grow.

Clean and sanitize tools and equipment that come into contact with multiple plants. Immersing tools for a couple minutes in a sanitizing solution helps prevent contaminating healthy plants. 1-pint of household bleach made up to 1-gallon with tap water will work well.

Use your sanitizer solution to spray pots, plant trays, water tanks & pipes, and all other hard surfaces of equipment. Wetting porous surfaces, even with bleach, doesn't do the good things you'd hope it does—don't spray water solutions onto porous surfaces. Minimize porous surfaces in your grow rooms.

Monitor and inspect for plant infection on a regular basis (at least daily). Upon noticing the start of a new infection, the infected plant parts should be clipped-off when possible. Put them directly into a plastic bag, without waving them around. This is your alarm bell to get moving or to adjust your treatment program. More on this in the Treatment section.

Between grows, thoroughly sanitize rooms and all surfaces with a commercial-duty hard surface disinfectant. Always pre-clean before using any disinfectant. Let the cleaners clean and the disinfectants disinfect.

To clean between grows, there are several effective products. Bleach is one of them. Bleach is easily available and inexpensive, it does have downsides though: irritating odor, it can produce noxious chlorine gas, and is inactivated by relatively small amounts organic matter.

Quaternary ammonium compounds (Quats) have been used for many decades as high performance sanitizers. They work by disrupting the cell walls of bacteria. Quats are known to also apply a heavy selection pressure on fungi. A couple of representatives are: Naccosan, it sanitizes hard surfaces and inhibits the growth of mold and mildew. Physan-20 is similar to Naccosan but also has a bit of ethanol (should you feel ethanol ever helps).

Be sure to change all your air filters between grows. Bag the filters as you pull them out and remove them from the premises into a closed trash container. Don't go walking around with a used filter full of who-knows-what.

POWDERY MILDEW TREATMENT

Fungicides are most often grouped by "mode of action" (MOA), they've been split into approximately 42 groups (some groups aren't numbered...and some don't apply to powdery mildew). Group numbers are assigned by the Fungicide Resistance Action Committee (FRAC) according to different modes of action. The mode of action simply means the way in which they attack the fungus. The two mode-of-action groups most commonly mentioned are Group 3, the demethylation inhibitors (DMI), and Group 11, the quinone outside inhibitors (QoI).

Fungicides kill by damaging fungal cell membranes, inactivating critical enzymes or proteins, and/or interfering with key metabolic processes like fungal respiration. The best method to prevent fungal infection is a multi-pronged approach where you rotate through a few various systemic and contact (surface) fungicides. The idea is to use methods having different modes of action. Your combinations should aim to provide contact kill, spore suppression, and to limit fungal spread.

Fungi tend to develop resistance from overuse of some treatment methods, those products are labeled on their application notes to not be used more than (usually) twice on the same crop. Rotate through different fungicides having different modes of action. The goal here is to reduce the opportunity for those few individuals with strongly-resistant genomes to take over your fungal population. You do not want to develop your own superfungus. Rotation gives you much more effective control.

Remember to always test for phytotoxicity (toxic to plant growth) on a small area of the plant before use. Some amount of slight damage is usually tolerable when weighed against the alternative of powdery mildew.

Demethylation inhibitors (AKA-, sterol biosynthesis inhibitors) must be inside plant tissue to be absorbed by the fungus. This group inhibits sterol biosynthesis in the fungal cell membrane, DMIs do not prevent spore germination or germ tube growth. Triazoles are in this group, other examples are Banner MAXX, Eagle, Hoist, Rubigan, and Terraguard.

Quinone outside inhibitors act on a broad spectrum of fungi. They inhibit respiration and impede spore germination. They are excellent preventative treatments. They should be applied prior to infection or in the very early stages of disease development. One type of QoI is kresoxim-methyl products (such as Compass O, Cygnus, and Heritage). Another is the strobilurins such as Quadris (azoxystrobin). Due to the narrow targeting action of strobilurins, fungal resistance is a major concern.

Fungicides designed to attack one single protein or enzyme molecule are said to be "single site acting". Some examples of this are the triazoles (Group 3), which focus on the demethylase enzyme; the strobilurins (Group 11), which target the succinate dehydrogenase enzyme; and the carboxamides (Group 7) that go after the ubiquinol oxidase enzyme.

Fungicides that attack via a wide spectrum of pathways are termed "multi-site acting". Multisite fungicides are often used with single site products to reduce the risk of developing treatment resistant fungal strains. Examples are copper (sulfates, oxides, hydroxides, and copper linked to organic molecules) and chlorothalonil (Bravo, Echo, and Daconil). Chlorothalonil targets

one fungal molecule, but that molecule is widely used. Copper ions do general damage to the enzymes critical for fungal cell function.

Another way to describe a fungicide's mode of action is to say it is used as a protectant, as a curative, or as an eradicant.

Protectants are applied to healthy plants, they employ contact action to prevent fungal spores from germinating or penetrating host tissue. It follows from that they must be applied before fungal spores infect the plant. Protectants generally are not effective once the fungus grows into plant tissues, so plant tissue that develops after application may not be protected.

Curatives are systemic fungicides that generally act within the plant and are effective against fungi shortly after fungal germination. These products must be applied within a certain time after infection starts.

Eradicants kill fungi on contact. Recent formulations such as triadimefon and myclobutanil not only kill growing mold but also prevent spore production.

RESISTANCE MANAGEMENT

Resistance management is a critical practice and must be considered during decisions setting the treatment course. There are two types of resistance: qualitative and quantitative resistance. Qualitative describes an either/or situation: Either the fungus is resistant, or it is not. Either it has, or does not have, the quality known as resistance to the treatment. Quantitative, on the other hand, brings percentage into the picture: Some percentage of the fungi may be resistant to treatment. Some quantity of the fungi is resistant.

For instance, DMI fungicides are different than some other types such as the strobilurins. DMI fungicide resistance is almost never complete. Because DMI resistance is due to more than one mutation, the various fungal individuals will have different levels of resistance. The kneejerk response to use a higher application rate after an application has failed will usually work in the case of DMI fungicides. Other fungicide groups, like the strobilurins, show qualitative resistance where any application rate is ineffective once resistance has developed.

You may have heard the term "cross resistance". Cross resistance exists when a fungus shows resistance to a fungicide because it has resistance to another fungicide with the same or similar-enough mode of action.

If you've had recent PM outbreaks, it's a good idea to use fungicides protectively (before powdery mildew becomes a problem again). Always apply fungicides at their labeled rates and use as many fungicide modes-of-action (Groups) as possible in your management program.

TREATMENT OPTIONS

- Inorganic: Simple chemicals are often an effective and efficient method to prevent and manage fungal infections. Some chemical treatments are safe to use on edible plants. Rinsing with dilute hydrogen peroxide or applying potassium salts can protect against initial fungal infections and slow the spread of existing infection. Though hydrogen peroxide generally has a very short residual time.
- OxiDate contains 27% hydrogen peroxide and 2%PAA (peracetic acid)
- Potassium bicarbonate works to draw moisture out of the mildew hyphae. It can be a very effective contact fungicide. Mildew cannot easily develop resistance to desiccation. In addition, some of the potassium is absorbed by the plant. This makes it a better product than sodium bicarbonate (baking soda) as too much sodium is very bad for plants.
- Kaligreen (82% micro-encapsulated potassium bicarbonate) is one representative brand. GreenCure is another potassium bicarbonate (85%potassium bicarbonate) based fungicide.
- Vital, by Phoenix Environmental Care is a Potassium Phosphate fungicide some have had success with. MOA Group 33.
- Syngenta's Appear fungicide contains phosphorous acid salt (potassium phosphite) 53.3%.
- JMS Stylet-oil is made-up out of "severely" hydro-treated-paraffinic oil (a petroleum based oil). Many growers report this is an effective protectant.
- SM-90 is coriander oil, modified canola oil, and an emulsifier (solubilizes the oils).
- Some growers claim success using alkaline water. Many mildews cannot grow in highly basic pH. Simply spray foliage frequently with water at 8.0+ pH. Wetting buds isn't recommended. Note that some foliage washes (Mega Wash, Ultimate Wash) were recently found to contain unlisted (non-labeled) pyrethrins.
- Pro-TeKt 0-0-3, according to the manufacturer, "supplies higher levels of potassium and silicon to help plants build stronger cell walls. The stronger cell walls provide a [...] barrier against [...] invading fungi." Its analysis gives potassium (K2O): 3.7% and silicon (SiO2): 7.8%. The company doesn't claim root-feed or foliar spray to be better, but there's evidence that continuous root uptake helps systemically while foliar provides some protectant action.
- Copper compounds show variable performance, and phytotoxicity is likely if foliar feeds or washes tend toward acidic. Copper compounds can have a role as protectants in your product rotation.
- Phyton-35 is copper (II) sulfate pentahydrate
- Organic: Sprays of Neem oil (pressed from the fruits and seeds of the Neem tree), garlic extracts, insecticidal soaps such as M-Pede (based on potassium fatty acids), and dilute (2 to 5%) citric acid (which may reinforce the plant's carbohydrate metabolism against infection).
- Probably the oddest organic treatment is a 1:9 dilution of skim milk (use non-fat because fats can go rancid and smell bad). No one knows the exact mechanism of prevention, but one candidate is ferroglobulin, a protein in whey, which

produces oxygen radicals when exposed to UV light. Contact with oxygen radicals is especially damaging to rapidly growing tissue such as a fungal infection.

- Sulfur: Sulfur vaporization is an economically attractive method for larger grow rooms. Sulfur vaporizes well at around 300 F. Sulfur can also be suspended in water and sprayed which may be more applicable to smaller setups. Sulfur dusting produces a slightly acidic environment and helps prevent spores from germinating on leaf surfaces. Sulfur can irritate eyes and lungs; goggles and respirator should be worn when sulfur is in the air. The spray form of sulfur is probably most easily used for plant protection purposes. Sprays usually incorporate surfactants, which improves mixing with water. Sulfur vaporization is always done during lights-off time and with exhaust fans shut down. Recommendations are usually to run for 12 hours initially (always keep circulation fans running), then 1 to 4 hours per night. For preventative use, run the vaporizer 2 times a week. For active infections, usually vaporize 4 times a week. Don't apply sulfur to plants on which you've used oil-based products within the last 30 days; the combination causes leaf burn on most plants. Also, because of corrosion concerns, sulfur burners may invalidate warranties on electronic equipment such as digital ballasts.
- Fungal and bacterial preparations: There are several preparations of mycoparasitic fungi. These are fungi that parasitize other fungi (sometimes called hyperfungi). There are also a few brands using a strain of specially-cultured bacteria to control powdery mildew infections.
- Bayer Serenade Garden product employs a patented strain (QST 713) of Bacillus subtilis.
  Ready-To-Use Active: 0.074% Bacillus subtilis
  Ready-To-Spray and Concentrate Active: 1.34% Bacillus subtilis
- Cease is 1.3% Bacillus subtillis
  Actinovate contains- Streptomyces lydicus WYEC 108* 0.037%
- Sonata contains- Bacillus pumilusstrain QST2808 1.38%
  Lactobacillus acidophilus is another antagonistic bacterium.
- AQ 10 is based on the hyperfungus Ampelomyces quisqualis. This fungus parasitizes hyphae, conidiophores and cleistothecia of powdery mildew. For AQ-10 to germinate, there must be powdery mildew present for it to feed on. So, application must begin at the first sign of infestation.
- Specialized fungicides: When applying complex chemicals such as most of these engineered fungicides, use a Tyvek suit, chemical resistant gloves, shoe covers or dedicated boots, and some sort of head covering. Most manufacturers recommend wearing a respirator while applying their products—read and follow the instructions. Beyond just extending your life at the very end, shielding yourself from the raw forms of these chemicals can help maintain your health all through the middle part.
- Eagle20 [DMI]: myclobutanil 19.7%
  Spectracide Immunox: "Spray Concentrate for Gardens", myclobutanil 1.55%.
- Syngenta produces a wide array of fungicides:
  Heritage Action™: crystalline silica, quartz and cristobalite, kaolin clay, azoxystrobin, acibenzolar-S-methyl
  Daconil Action™: propylene glycol, chlorothalonil, acibenzolar-S-methyl
  Banner Maxx [DMI]: tetrahydrofurfuryl alcohol, propiconazole
  Banner Maxx II fungicide: propiconazole
  Secure®: fluazinam
  Velista®: kaolin clay, penthiopyrad
- Sovran: kresoxim-methyl (by Cheminova Inc. -FMC Agricultural Solutions-)
- Bayleton FLO [DMI]: triadimefon, glycerine, polyethylene-polypropylene copolymer, naphthalene and alkyl naphthalene sulphonic acids, formaldehyde condensate, sodium salt
- Spectro-90: chlorothalonil, thiophanate-methyl (by Nufarm)

APPROVED CHEMICALS

- A list of Colorado-approved chemicals: https://ag.colorado.gov/plants/pesticides/pesticide-use-in-cannabis-production-information
- Colorado Government Site with good information: https://www.colorado.gov/pacific/agplants/pesticide-use-cannabis-production-information

PLANT BREEDING AS A STRATEGY

Fungal infection resistance in any particular strain of plant can range from immunity (no infection at all) to resistant (some infection) to susceptible (significant infection). Plants that show definite infection resistance during an epidemic can be removed from the immediate danger and used in one way or another as breeding stock.

A planned breeding strategy is resource-consuming beyond the capacity of most growers. But be aware that some people are doing this. Plants do exist that possess fungus resistant genetics. This often involves changes to the composition of the epidermal cell's exterior wall. The cell wall is made more resistant to enzymatic breakdown, thereby making it much harder for the developing spore to get its "hooks" into the plant cell. Other resistant plants have developed enzymes that break down fungal cell walls or fungal hyphal tips.

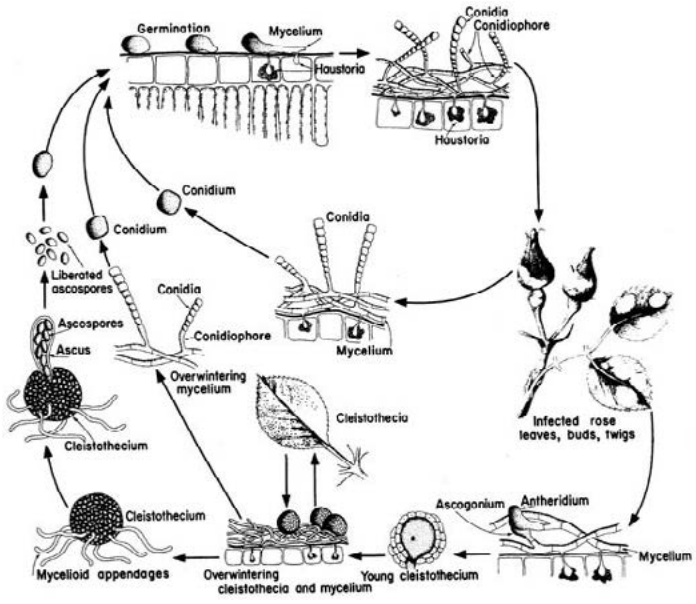
POWDERY MILDEW LIFECYCLE (ADVANCED LEVEL)

The white "powder" isn't powder, it's the mildew's growth and reproductive system. Keep in mind that mildew is mold, and they are all fungi. Powdery mildew is a fungus.

Your mildew infection can start soon after spores brought into your grow room land on leaf surfaces. Powdery mildew spores are well stocked with water and fat content. Therefore, powdery mildew does not require liquid water to germinate. The spores germinate under favorable conditions of 60 to 70 F, dry leaves, and around/over 60%RH. Germination and growth show the small, white, circular patches of fuzz that can be easily wiped off. Don't be fooled, though... those little patches have already produced spores by the hundreds that are quickly spreading to your other plants.

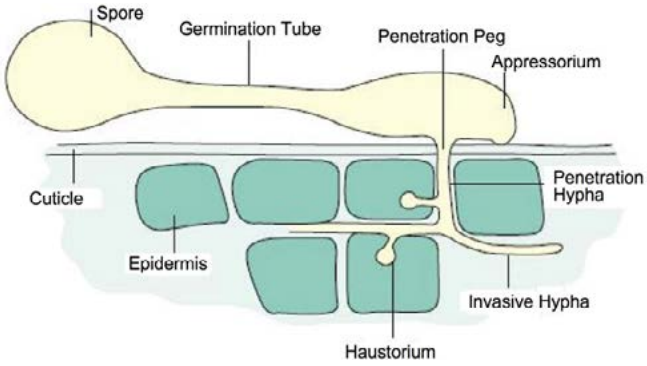
Fungi break into the plant by using enzymes to soften the epidermal cell walls and mechanical pressure to push through. There they find nutrients supplied by the plant's vascular system. As the infection progresses, the fungus spreads toward the tops of the plants and into any available buds.

Spores are the fungal reproductive units, they are much like very fast growing seeds. Spores consist of one or a few cells; spores range in size but are often around 0.001" to 0.003" across. Powdery mildew can produce two types of spores—asexual clone spores (conidia), which it produces quickly after establishing itself within the plant; and sexual reproductive spores (ascospores), which it produces when it advances through its later life cycle. Both of these types, clone spores (conidia) and sexually recombined spores (ascospores), have the same goal at their initial germination: grow a powdery mildew individual. The ascospores grow a new genetic individual while the conidia grow a clone of their source individual. Because the genetic recombination of sexual reproduction produces new genotypes, some of these new individuals may be more resistant to fungicides or other eradication practices than either of the parental genotypes.



Life Cycle of Powdery Mildew[1]

Hypha are the thread-like filaments formed by a germinating spore (multiple hypha are hyphae), the developing hyphal mat is called a mycelium (the whitish looking mycelium is the first visible indication of the infection). The first type of hyphae produced by germinating spores are called germ tubes, these penetrate the plant's epidermal cells. A haustorium is the hyphal structure that grows inside a host epidermal cell in order to more effectively steal nutrients. A conidiophore is a specialized hypha that grows vertically and produces the vegetative spores (conidia). The mass of hyphae, the mycelium, comprises the vegetative body of the fungus.



Powdery Mildew Fungal Infection: Cuticle and Epidermal Cells Penetrated.[2]

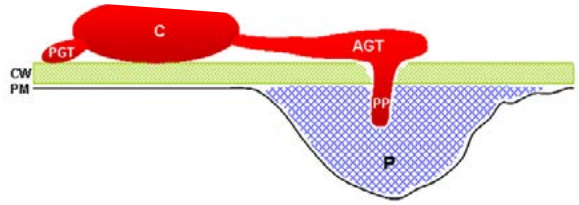
The plant cell wall is not simply a passive barrier, it is a dynamic structure that can be actively reinforced in local regions under certain types of attack.

Plants show 2 types of immune response—pattern triggered immunity (or, basal immunity), which results in local reinforcement of the cell wall (often modifications to pectin); and the aptly-termed hypersensitive response, which kills cells that are under attack. Pattern triggered immunity is triggered when plant cells recognize certain "microbe-associated molecular patterns" (MAMPs) including specific molecules and cell wall components commonly found in microbes. Hypersensitive response can occur as a reaction to infection peg penetration, or haustorial growth; it is a very effective defense in capable plants.

Hyphae are capable of developing a variety of forms under genetic control. Fungi can and do alter the developmental pathway of individual hyphae in response to environmental changes. For instance, the growing fungal germ tube perceives physical cues from the leaf surface. These cues determine when the tip of the germ tube stops growing outward. As outward growth ceases the germ tube hooks toward the leaf and begins to swell. The germ tube tip cells go through a differentiation process forming a structure called an appressorium. An appressorium is a highly specialized infection cell. Substances accumulate within the appressorium which increase its turgor pressure. This pressure increase inside the appressorium works with cell wall dissolving enzymes to help to drive what's sometimes known as an "infection peg" through the plant cuticle and into the plant's epidermal cells.

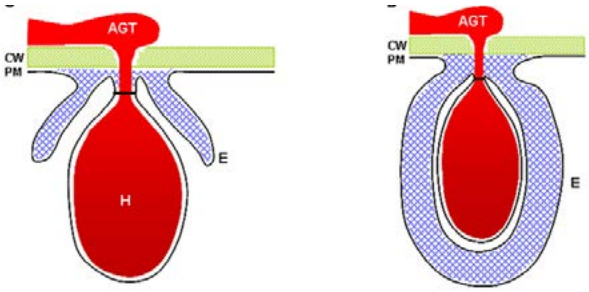
1 Agrios, G.N. (1997). Plant Pathology. 4th Edition.

2 Meng, Shaowu & Torto-Alalibo, Trudy & Chibucos, Marcus & Tyler, Brett & Dean, Ralph. (2009). Common processes in pathogenesis by fungal and oomycete plant pathogens, described with Gene Ontology terms. BMC microbiology. 9 Suppl 1. S7. 10.1186/1471-2180-9-S1-S7. https://www.researchgate.net/publication/24193591_Common_processes_in_pathogenesis_by_fungal_and_oomycete_plant_pathogens_described_with_Gene_Ontology_terms



One example of a plant's basal immunity: Callose deposits.[3]

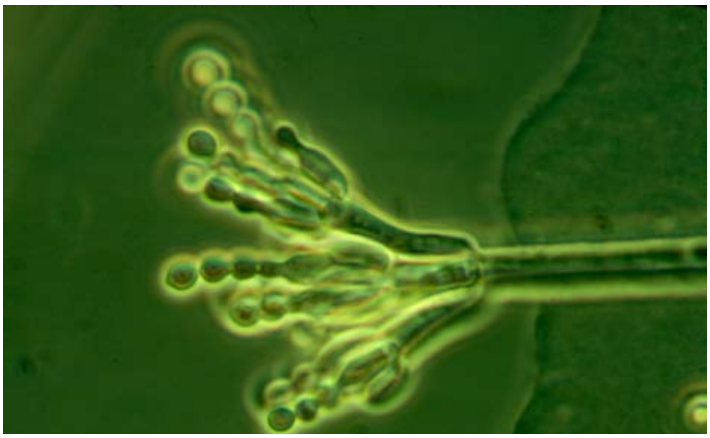
As an example of pattern triggered immunity, plant epidermal cells synthesize and deposit callose which form papillae (much like our own callouses) to fight the attacking mold. If the flat, thick papillae are compromised, the plant can form haustorial collars and haustorial encasements as another defensive response to hyphal penetration. Haustorial collars are nooses around the haustorial feeding tube, while haustorial encasements are the plant's attempt to put a bag around the haustorium. These defensive structures can be chemically suppressed by some fungi. There is constant life and death battle between plant and fungus.



Examples of plant defenses against fungal infection.[4]

Conidia (genetically identical to the individual mycelium from which they originate) are usually produced within a few days of successful spore germination. Conidia are colorless, and generally oval in shape. The exposed hyphae grow many conidiophores that produce conidia either singularly or chained, depending on the species of fungus. They are produced as long as (and whenever) environmental conditions are favorable. Conidia excrete an adhesive soon after landing on a leaf surface, this adhesive facilitates recognition of a host plant, which cues subsequent germination. Conidia production is part of the asexual development stage of the powdery mildew fungus.

Outdoors, as the season changes, the fungus moves into its sexual reproductive stage. This stage is rarely, if ever, seen (allowed to occur) indoors.



Asexually produced spores (clones of the individual)[5]

Production of conidia decreases and eventually halts going into fall as the weather turns cooler. Powdery mildew fungi then produce relatively large reproductive (fruiting) bodies called ascocarps. Ascocarps function to hold a type of special container cell called an ascus (plural: asci). Asci contain the sexually produced spores, the ascospores. There are four different configurations of ascocarps. The generally-spherical ascocarp produced by powdery mildew is called a cleistothecium (clice-toe-th-ee-see-um). Cleistothecia are only formed during the sexual reproductive phase of the powdery mildew lifecycle. Ascocarps also allow the fungus to hibernate through poor conditions as they are very resistant to low temperatures and drought.

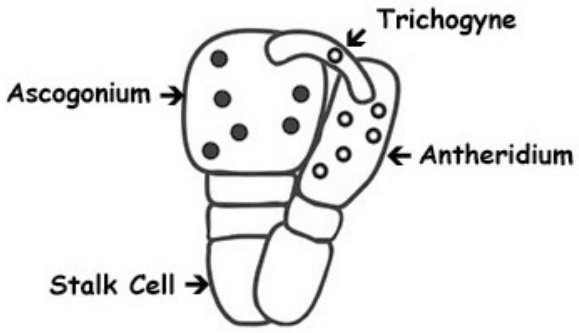
Sexual reproduction begins when a receptor on one haploid hypha detects a pheromone from a complementary mating type. Haploid means it has its usual single set of fungal chromosomes. Specific pathways are activated inside the hyphal cells, and the hypha approaches the source of the pheromone through chemotropic growth. The fungus then exposes it's mating type by developing one of two complementary organs, a "female" (+) ascogonium or a "male" (-) antheridium. These reproductive organs contain only haploid (single set of fungal chromosomes) cell nuclei. A bridge (the trichogyne) forms between them, providing a path for nuclei to move from the antheridium to the ascogonium. A dikaryote (has 2 nuclei) then grows from the ascogonium. Karyogamy (fusion of the 2 haploid nuclei) then occurs, after which the diploid (has 2 sets of chromosomes that are joined) zygote undergoes meiotic divisions to yield the haploid ascospores. The ascospores go through a mitotic (simple clonal growth) division that double their number. All this activity during and after sexual recombination occurs within the newly formed cleistothecium.

3 Underwood, William. (2012). The plant cell wall: a dynamic barrier against pathogen invasion. Front. Plant Sci. https://www.frontiersin.org/articles/10.3389/fpls.2012.00085/full

4 Underwood, William. (2012). The plant cell wall: a dynamic barrier against pathogen invasion. Front. Plant Sci. https://www.frontiersin.org/articles/10.3389/fpls.2012.00085/full

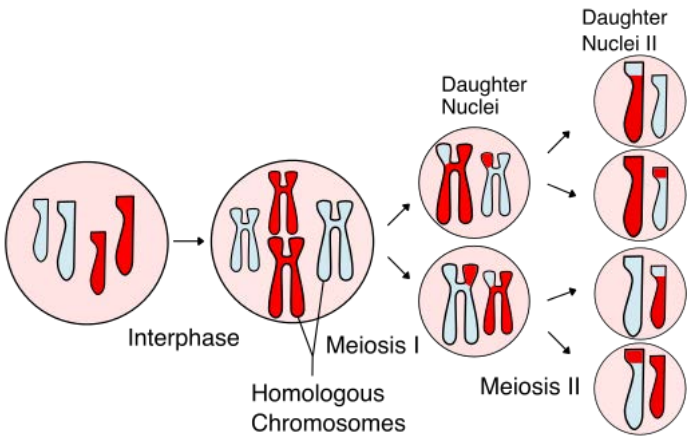
5 Fungi Reproducing Asexually by Means of Conida. http://website.nbm-mnb.ca/mycologywebpages/NaturalHistoryOfFungi/Conidia.html

As an interesting note: Depending upon the species of Erysiphaceae, the fungus can be homothallic or heterothallic. Heterothallic means the fungus require two compatible partners to perform sexual reproduction. A homothallic fungus is capable of sexual reproduction all by itself. Homothallism has less genetic recombination and may be more of a repair process.



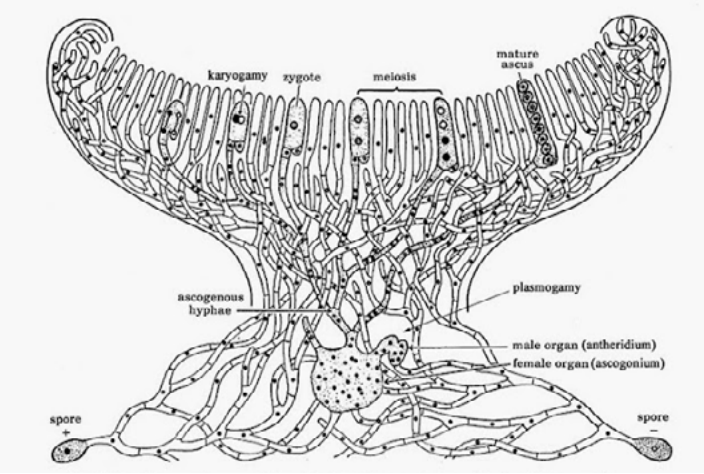
Nuclei From the Antheridium Are Transported into the Ascogonium Through the Trichogyne, Which Originates From the Ascogonium.[6]

Description of the "Chromosome path" diagram, below: The set of chromosomes contributed by the male merges with those contributed by the female in what is termed a nuclear union (because chromosomes are located in the nucleus of the cells). During the interphase stage of meiosis, the chromosomes duplicate and the homologous chromosomes (m/f chromosomes of the same type) exchange genetic information (chromosomal gene crossover) during the first division, called meiosis I. The daughter cells divide again in meiosis II, splitting up the newly formed "sister chromatids" in order to return once again to the usual haploid cells.



Chromosome path for sexual reproduction: From two mating individuals to four new genetic individuals.[7]

These cells go through a cloning (mitotic) reproduction within the ascus structure to double their number from 4 to 8 (this is depicted in the diagram below). They then mature into ascospores, ready for the cleistothecium to break open and their asci to release them into the breeze.



Generic ascocarp showing complete sequence of ascospores production.[8]

Cleistothecia first appear white, turning yellow, orange, brown, and eventually black as they mature in/on the mycelial mats. They develop throughout the fall and are mature over winter. When conditions are favorable, the cleistothecia absorb water and burst open to expel their contents (the asci, or container cells). The asci burst open and discharge the ascospores, which become windborne to eventually germinate on a host plant. When conidia or ascospores contact a suitable host's leaf (top or bottom) they will germinate within 48 hours if temperature and RH are sufficient. Each spore produces a germ tube that eventually generates a short, thin hypha that attempts to pierce the host cell cuticle, and epidermal cell wall, to enter an epidermal cell. On entry into an epidermal cell, the hypha forms the feeding organ, the haustorium. Haustoria rob nutrients from the plant's epidermal cells; nutrients that you and your plant have worked so hard to obtain.

POWDERY MILDEW TAXONOMY

- Kingdom: Fungi
- Phylum: Ascomycota
- Class: Leotiomycetes
- Order: Erysiphales
- Family: Erysiphaceae
- Genus: ~28 genera
- Examples: Brasiliomyces, Podosphaera, Sphaerotheca, Uncinula, Phyllactinia, Oidium
- Species: ~700 species

6 Apothecium Development. http://www1.biologie.uni-hamburg.de/b-online/library/webb/BOT201/Myxomycota/Apothecium_development.htm

7 Rdbickel. (2016). Overview of Meiosis. CC BY-SA 4.0. https://commons.wikimedia.org/w/index.php?curid=49599354

8 Sharp, L. W. (1943) Fundamentals of Cytology. McGraw-Hill Book Co. http://www.asthramedicalacademy.com/2013/11/ascomycetes-fungal-fruiting-body.html