Mushroom Workers' Pneumonitis, also known as hypersensitivity pneumonitis, pulmonary hypersensitivity, and extrinsic allergic alveolitis is more common than ordinarily thought. In the past 10 years there have been three outbreaks in the United States. The causes of the disease are multiple and new antigens are continually being discovered. These are listed. Preventive measures are tabulated at the end of the discussion.

MUSHROOM WORKERS' PNEUMONITIS

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Introduction

DURING THE LIFETIME of Louis XIV of France (1638-1715) the underground caves of Paris were widely used for mushroom growing. Stacks of horse manure mixed with earth and chopped up hay were allowed to heat and compost.[1] This material was formed in ridge beds on the cave floor with walkways between the ridges. The compost was then inoculated with known edible strains of cultures of wild fungi. From these primitive beginnings contemporary mushroom farming has evolved.

Mushrooms were first grown commercially in the United States shortly after the American Civil War. They were grown under benches in greenhouses in Chester and Philadelphia Counties. The first special house for growing mushrooms was constructed in 1894 by Seren Rasmussen, head gardener for the John Wyeth family of Westtown, Pennsylvania. The current $140-million mushroom industry in Pennsylvania evolved from this facility. For 45 years the Pennsylvania State University had conducted research in educational programs to assist the commonwealth's mushroom industry.[2-10]

A typical small mushroom farm of today consists of a series of "double" mushroom houses, an open composting yard and storage areas. A typical "double" is of cement block construction and is about 60 feet long by 38 feet wide. Usually some type of head house or packing room is associated with a mushroom farm. Here mushrooms are packaged and equipment and materials are stored. Mushroom beds are about five to six feet wide with an aisle on each side and at the ends for picking, watering and crop protection. Usually there are six or seven tiers of beds; lower beds are raised above the floor. Sideboards on the beds are about eight inches high. A typical house has a catwalk for picking the upper beds, hot water heat and is used for three crops per year, one usually starting in the fall, a second in mid-winter and one later. Most mushroom growers in the United

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States grow mushrooms in trays. Credit for originating this system belongs to Knaust Brothers, Coxsackie, New York, the Yoder Brothers operating a mine at West Winfield, Pennsylvania, and Chef Boy-Ar-Dee Quality Foods, Inc., Milton, Pennsylvania. Dr. James W. Sinden, formerly of the Pennsylvania State University, also made considerable contributions in the tray method of mushroom growing.[2]

With the tray system the compost is placed directly into movable boxes, which are in turn transported by a tractor with a fork-lift or by other means to the various growing houses. The tray system allows greater use of mechanization and of improved composting methods. Tray operations tend to be considerably larger than those with fixed beds. Institution of the tray method of growing mushrooms led to larger houses and to greater capital investments in equipment. Of the many species of edible fungi which have been identified by the botanist, only one, *Agaricus bisporus* (a synonym—*Agaricus hortensis)* is cultivated extensively in the United States.

The fundamental difference between mushrooms and green plants is that plants manufacture their own food whereas mushrooms cannot. Fungi, because of the absence of chlorophyll, cannot carry on photosynthesis and must depend upon organic matter for nutrition. The "seed" of the mushroom are the spores which are of minute size and infinitesimal weight. One mature mushroom will produce 16 billion spores. In nature only one out of a billion spores may grow. Given a favorable environment spores produce a threadlike mass called mycelium which under proper conditions develops edible mushrooms. Mushroom spawn is produced in a laboratory under sterile conditions. The spawn is planted in prepared compost which undergoes a two-phase preparation: Phase I (outdoor composting) and Phase II (indoor pasteurization).

Phase I — Outdoor Composting

In the United States most edible mushrooms are grown on artificially produced compost consisting of various mixtures of hay, straw, ground corn cobs, cocoa shells, peanut shells, bagasse, sawdust, horse, cow and chicken manure, potassium chloride, urea, gypsum, dried brewers' grain, ammonium nitrate, various types of phosphates and other nutrients.

Formula for Synthetic Compost

Synthetic compost based on one formula is simple both to assemble and to compost. Ground corn cobs and hay are the basic ingredients. The cobs need only be crushed enough to expose the pith and are usually broken in a hammer mill with a large screen. The hay, which can be of any mixture from pure grass to pure clover or alfalfa (though some legumes present give more certain results), is not chopped. Coarse grasses, such as timothy or orchard grass, are better than finer ones such as fescue or blue grass, though the latter can make up part of the mixture. The hay should be cured at the stage best for feeding, rather than when it is hard and mature, as the protein content at the later stage is lost and the stems are not softened during composting.

The proportion of hay to cobs may vary up to 2/3 cobs to 1/3 hay without reducing the yield or changing the costs per square foot very much, since the hay, being the more expensive ingredient, also fills more space per unit of weight.

Preparation of Compost Outdoors

The hay is first wetted when the pile, seven to ten feet wide and five to six feet high, is made. It is compressed thoroughly and the cobs are watered as they are spread over the top. The pile is turned after one to two days and

watered up to the leaching point. The new pile is compressed thoroughly. After one or two days another turning is done and all ingredients added. These ingredients comprise, per dry ton of the cob and hay mixture, 25 lbs. of potassium chloride, 30 lbs. of calcium cyanamide or urea or 25 lbs. of ammonium nitrate, 50 lbs. of gypsum and a maximum of 75 lbs. of dry brewers' grain or 300 lbs. of chicken manure. The amount of brewers' grain or chicken manure is varied with the kind of hay, grass hay requiring the maximum of this protein supplement while for pure clover or alfalfa none at all is needed. The new pile is ordinarily not pressed except in very cold weather or if the hay is extremely hard, making a loose pile.

From this stage, when all ingredients of the synthetic compost are mixed, five to seven days of composting are necessary, with one turn after three to four days. During this time this compost is very hot, often above 175° F. and is high in ammonia. The hay does not soften very much, however, but becomes dark while the cobs turn soft and almost black. The water content at filling must be at a minimum 300% of dry weight. Compost is the result of aerobic fermentation of the ingredients. The total time from start to filling varies from eight to 12 days, depending on the time necessary to wet the bulky material before the other ingredients are added.

Phase II — Indoor Pasteurization

Phase II, pasteurizing, should take only three to four days. In some cases where heating or cooling controls are inadequate, or where the thermogenic capacity of the compost is very high, a prolongation of a few days to a maximum of a week may be necessary. Synthetic compost has a very high thermogenic capacity which makes it sometimes difficult to hold the temperature below 140° F. Much more fresh air is required for the preparation of synthetic compost than for manure compost. At all times the air in the pasteurizing room should be able to maintain a flame.

At spawning the compost is dark but the hay, especially the grass stems, is not as soft as the straw in manure is at this stage. The mushroom mycelium grows very rapidly and vigorously, covering all particles of the compost and penetrating also into large pieces of corn cob. At casing and during production the bed is much more filled with mycelium than is a bed of manure compost, which makes a high moisture content of the material necessary.

Synthetic compost is exposed to natural elements for four to six weeks. During this time it is mechanically ground, turned and mixed. Nutrients necessary for the growth of mushrooms form in the mixture during the process of preparation. The heat generated in the center of the mixture leads to the breakdown of ammonia and the formation of nutrients.

The synthetic compost is now transported by mushroom growers to their growing houses. In the tray system the compost is conveyed in wooden trays, which in turn are placed in the proper position in the closed chambers of the mushroom house. Automated machinery is designed for this purpose. The compost in the placed trays is now pasteurized. Pasteurization is the selective killing of microorganisms and pests known to compete with or injure commercial mushrooms. It is achieved by raising air temperatures to 140° F. with steam, and holding this temperature for a minimum of one to two hours. After several days of further conditioning the compost is cooled. If this process is not properly regulated competitive molds may develop.

The compost in the trays is then inoculated with prepared mushroom

spawn. The spawn is then spread by hand on trays or specially prepared beds of synthetic compost. The spawn is then mixed with the compost either by hand or by mechanical means. Spawn running or spawn growth then occurs for two to three weeks. During spawn run the compost temperature is maintained at 74° F.

The compost in the pre-pasteurized beds or trays containing the mycelium is then covered (cased) with a layer of specially prepared, pasteurized, peat or loam soil. Mushrooms only root in cased trays or beds which are kept in the mushroom sheds where the temperature is maintained at a steady 58° F. with the humidity at 80 to 95%. Cross-ventilation is also carefully maintained. The first growth of mushrooms is usually harvested 14 to 21 days after spawning occurs. Fresh growth of mushrooms appears at 7- to 10-day intervals for up to 6 to 10 weeks. Various bactericides, fungicides, pesticides and insecticides are sprayed or dusted into the mushroom sheds at intervals to prevent infestation of the growing mushrooms.

Mushroom Workers' Pneumonitis

Mushroom Workers' Lung, hypersensitivity pneumonitis, pulmonary hypersensitivity, extrinsic allergic alveolitis — whatever term is used, the disease results from sensitivity to inhalation of an organic dust of particles less than four microns that reach the alveoli. The factors that determine the response to inhalation of an organic dust are immunologic reactivity of the host. The reaction may be atopic type I (reaginic antibody), non-atopic type III (precipitating antibody) or a type IV reaction. The mechanism in the type IV reaction is complex and probably involves more than one cell type.[11-22]

In the past 10 years there were three outbreaks in the United States, all of which were explainable and easily controlled.[23] The causes are multiple (see Table I).

In certain houses in 1960, and again last year (1973), illness occurred in all members of the dumping crew in varying degrees. The symptoms were more severe among men dumping beds near the centers of the houses. None of the other operations, such as mushroom picking or house filling, produced symptoms or complaints. In all cases the men complained of irritation and dryness in the nose and throat which seemed to appear only when the men came out of the house into the fresh air. Returning to the house, however, did not ameliorate this sensation. In a few houses the dumping process caused reactions of increased severity with the typical worker experiencing in sequence:

a. Dryness in nose and throat in four to eight hours.

b. Irritation of skin below the eyes, sides of nose, upper lip and underside of scrotum.

c. Nausea and restlessness during the first night, with burning sensation in nose and throat.

d. On the second day fever of 99-100° F., pulse 80-120 accompanied by dry cough with dermatitis appearing on upper lip, sides of nose, below the eyes and on base of scrotum.

e. Sweating, chills and presumably fever the second, third and often fourth and fifth nights.

f. Third to seventh day: chest pain, cough (non-productive), nose bleeds, inflammation of nasal mucosa.

g. Gradual abatement of symptoms within 10 to 20 days.

There is no indication of any permanent damage to the lungs. Extreme irritation of the oral and nasal sensory receptors with subsequent reflex autonomic nervous system stimulation occurs to such a marked degree that a neurodermatitis is produced on the

TABLE I. SUSPECTED CAUSES

1. Alternaria*
2. Aspergillus
   - clavatus
   - flavus
   - glaucus
   - nidulans
   - terreus niger
   - fumigatus*
3. Mucor pusillus*
   - racemosus*
4. Spicaria sp.*
5. Stachybotrys alternans*
6. Spysanus stemonitis*
7. Sepedonium spysanus
8. Chaetomium
   - globosum*
   - indicum
   - olivaceum
9. Fusarium basinfectum*
10. Meria*
11. Penicillium*
    - atramentosum
    - biforme
    - carmino-violaceum
    - intricatum
    - luteum
    - notatum
12. Trichoderma*
13. Sporobolomyces*
14. Scopulariopsis*
15. Ostracoderma*
16. Phycomycetes
    - Mucor racemosus
    - Rhizopus nigricans
17. Dermatiaceae
    - Alternaria tenuis
    - Helminthosporium interseminatum
    - Hormodendrum cladosporiodes
    - Stemphylium botryosum
    - Pullularia pullulans
18. Monilia sitophila*
19. Candida albicans
20. Micropolyspora faeni
21. Thermoactinomyces vulgaris
22. Agaricus bisporus* (Agaricus hortensis)*

Recently in Germany the spores of Pleurotus Florida have also been implicated.[24 to 26]

Bacteria

1. Bacillus coli
2. Staphylococcus
3. Streptococcus
4. Many other bacteria

Other materials

1. Hay
   - many grasses
2. Straw
3. Ground corn cobs
4. Ground peanut shells
5. Bagasse
6. Brewers' grain
7. Chicken manure
8. Cow manure
9. Fertilizers
   - phosphates
   - nitrates
10. Top soil
11. Gypsum
12. Peat

*Suspected Causes in the United States and Canada

areas of the face affected by the gustatory sweating reflex (as when hot peppers are eaten). The autonomic stimulation reveals the phylogenic relationship of olfactory organ and genitalia (scrotal dermatitis is prevented by the use of a gas mask. Reported in 1960).[23]

Further indications of systemic involvement are episodic periods of blurring of vision and red blood cells in the urine of a few of the affected men. The symptomatology best fits occupational exposure to airborne spores of a fungus or bacteria, containing a toxic alkaloid which is partly volatile. Such spores are thought to be released primarily when the spent mushroom beds are broken up and hurled down upon the moving conveyor belt during the dumping operation.

There is no significant airway obstruction; the condition is largely restrictive, including decrease in vital capacity, pulmonary compliance and diffusing capacity. In the acute state, diffusely, finely granular infiltrates occur, indicating an alveolar or interstitial pneumonia. In the chronic stage confluent areas of involvement can be seen on the radiograph. Pathologically there is alveolar septal thickening with infiltration of plasma cells, lymphocytes and foamy histiocytes. There is involvement of the respiratory bronchiols and interstitial pulmonary tissue. In the chronic stage one sees giant cells and epitheloid cells indicative of a

granulomatous interstitial pneumonitis.

Under controlled conditions aerosol challenge with the appropriate antigen in a patient with extrinsic allergic alveolitis will precipitate all of the symptoms and signs of the disease four to six hours later. A precipitating antibody is seen in practically all mushroom workers including those who work outside in composting. However, precipitating antibody does not necessarily indicate presence of the disease. A high percentage of workers may have precipitating antibodies from a variety of antigens. A careful history with signs or symptoms occurring with exposure and subsequent disappearance of signs and symptoms with avoidance is indicative of the disease. In the southeastern area of Pennsylvania, we feel that mushroom workers' pneumonitis is a bronchopulmonary immunological reaction provoked by various antigens, either (1) from the thermophilic actinomycetes in the pasteurized compost of which there are usually very high concentrations, (2) spores of different species of molds which grow in the compost if it is anaerobic, particulate parasite matter, (3) enzymes present in various molds, (4) endo- and exo-toxins present in bacteria, (5) various chemicals used as fertilizers, pesticides, insecticides, fungicides and (*6) the spores of Agaricus bisporus.

A large variety of antigens has been incriminated in producing hypersensitivity pneumonitis. New antigens, such as described earlier, are constantly being identified. It is probable that this list will continue to grow.

Mushroom workers' pneumonitis seldom occurs if the following preventative measures are employed:

a. Thorough peak heating and pasteurization of spent compost plus the wetting down of all trays and bins before emptying.

b. The subsequent emptying of houses within 48 hours to prevent new mold growth.

c. Making sure that the men who run the mechanical apparatus wear respirators. The parts or discs in the respirators should be changed frequently and cultured. ?

d. Run high speed exhaust fans and depth filters during compost emptying to remove all particulate matter above one micron.

e. Employ selective labor. Do not employ people with a past history of hay fever, asthma or bronchitis and atopics also. Rotate workers. I have found that ethnic association is not valid.

f. Do not employ alcoholics. Chronic sensitization is complicated by alcohol.

g. Generous ventilation should always be employed when mushroom houses are being filled with synthetic compost.

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BOOKS

"Some books are to be tasted, others swallowed and some few to be chewed and digested . . . Some few are to be read wholly and with diligence and attention . . . Reading maketh a full man, conference a ready man and writing an exact man. Therefore, if a man write little, he had need have a great memory. If he confer little, he had need have a present wit. If he read little, he need have much cunning, to seem to know what he doth not. Histories make men wise, poets witty, the mathematics subtile, natural philosophy deep, moral grave, logic and rhetoric able to contend."

Sir Francis Bacon