FUNGI AND MAN*

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A few years ago the speaker was deeply concerned over a number of ecological problems such as why more fungi occur during autumn than in the springtime, when an observer ventured the chance remark,—"Why spend so much time on these peculiar forms of life? Are they of any value to man?" Two answers to these questions may be proposed. The first is supported by all true scientists and includes the idea that all pure science is, across the centuries, of far greater value than the form which for personal reasons goes forth to find evidence in support of a proposition or conclusion arrived at from inadequate data. The second is based on our knowledge of the harm done by this great group of plants in causing decay of economic products. We know much more about their destruction than their control; we see the collapse of a structure weakened by the inroads of wood-inhabiting fungi; we are made aware of the constant expense incurred by replacement of decayed ties and timbers along our railroads; we note the dead and dying trees in our forests, and sometimes try to salvage some of the lumber before decay has completely destroyed its value. We look at fungi as food and hope that here we may find sufficient defense for their existence, and are dismayed to discover food value but little in excess of that found in cabbage. All these are superficial, and yield but little toward our understanding of this great group of plants and wherein they fit in the economy of life.

The greatest contribution of fungi to the balance of life is related to the decay of organic material. We need but imagine the effect of removal of all decay activities from our forests. Trees broken by wind or lightning crash to the earth year after year and lie until the forces of decay or fire change their nature from debris to soil. Unaffected by these forces the forest eventually would accomplish its own suffocation, mounting fallen timbers would heap higher and ever higher to mingle, first, with the lower branches, kill them by suffocation, and finally, bring death to the entire forest. Fungi increase in number with food supply, the debris of the forest furnishing food for countless numbers of them; with more debris more fungi appear; with decrease in this food supply occurs a corresponding decrease in fungi. In a complicated relationship these agencies continue to exist interdependent in their life needs. A dead branch lies on the ground but a short time before the scavengers of the plant world begin their work upon it. Sometimes the reduction process is accomplished by a single visible species, sometimes by many causing several forms of decay.

Each autumn, leaves carpet the earth, but in a few weeks all have disappeared except for a few kinds. Maple leaves color and make beautiful the autumn forest but on the ground they soon decay. Poplar leaves are more persistent as part of the forest carpet; not until spring has decay completely decomposed them. The dominant in any such carpet in this region is a mixture of leaves from some of the nine species of oak. The thick, leathery leaves and the presence of tannic acid make possible their persistence for more than a year. As rainfall slowly leaches preservatives from them, decay gradually softens the tough protective covering to produce a leafy substratum for the growth of many species of Marasmius, Collybia, and other small pileate fungi.

What are some of the environmental results of the carpet of leaves? The first important one accrues from the blanket-like covering of the soil tending to retain heat within the soil when the outside air is cold, and the prevention of warming processes from the outside during the time when the air is much warmer than the soil. Consequently the soil retains sufficient heat during the autumn months for the growth of terrestrial fungi long after the normal expectancy. During November it is not

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unusual to find such species as Hygrophorus Russula and Tricholoma personatum among others pushing the leafy covering upward, tent-like, to gain position for spore dissemination. During this time humus is abundant and moisture has been retained sufficient for the wide spread development of mycelium. These conditions are ideally favorable for fructifications, providing the precipitation is at least average, and if no unusually long periods with freezing temperatures have occurred to penetrate the leafy-blanket and halt the development of the vegetative structure from which carpophores arise. With average autumnal conditions prevailing, the beneath-the-leaves habitat is populated by a flora unusually rich in species of fungi.

It is natural to question the application of the above facts especially when we account for the abundance of mycelial growth and fructifications for autumn only. Do not the same conditions have a vernal application? Do the results exactly correspond? The answer to the first question is yes, to the second, no. The leafy carpet retards the change of soil temperature both during autumn and in spring, but the retardation in one case while soil temperature is becoming warmer is disadvantageous and in the other when the change is from warm to cold is advantageous. In other words, the autumnal retardation of temperature change makes possible a continued production of fungi, while the vernal retardation delays the production. Consequently we find the first terrestrial fungi appearing at least a month after the vernal equinox, likewise abundant production continues for a month beyond the autumnal equinox.

Many people are disappointed by the absence of fungi during the months April until August, inclusive. The weather is warm and rainfall, especially during spring and early summer, is often sufficient for the growth of these elusive plants. Why are they not everywhere conspicuous, especially in the forests? A few reasons may be proposed, each explaining a different phenomenon.

From the paucity of terrestrial vernal fungi a few facts may be gleaned by direct observation. Fungi which are to be found are in pastures, open woods, and other habitats where sunshine may exert its warming influence. The genera Morchella, Peziza (see fig. 1), Coprinus, Panaeolus, Naucoria, and various field puffballs, although widely separated, make up the collections found during April and May. The warm sunshine has a drying effect in addition to its heat, consequently the arid months arrive almost simultaneously with the proper soil temperature within the forest. Add to these factors the time element required for vegetative growth of a fungus and the presence or absence of fungi during the various seasons becomes reasonable. Yes, but what is this time element? We have always supposed "mushroom growth" to be very rapid, requiring but a few hours, and that any time during the year when a high moisture content and warm temperature prevail, even for a very short time, mushrooms should be everywhere ready for collecting. The answer is: "mushroom growth" refers only to the production of carpophores and takes no account of the two weeks required, under most favorable conditions, for the mycelial growth necessary before our smaller fungi will appear in fruit, or the several weeks required for larger fungi. As evidence of the time element requirement, new data accumulates each year during August and September when, after several weeks of dry weather, rainfall again becomes normal or above normal, yet at least two weeks intervene before some of the smaller terrestrial forms appear, to be followed by medium sized and finally after several weeks by the very large ones. What interpretation may we consider applicable to such evidence? Certainly the accumulation of nutrition within the mycelial network and a widespread growth of the structure in order to contact and contain the supply of nutrition must occur before the dicaryophase condition and its stimulus brings forth rapid production of fructifications. The widespread growth and the large accumulation of nutrition required for larger species is relatively comparable to the extended time required for these plants to come to fruition. It is also true in general that large mycelial structures accompany and produce large fructifications, and comparatively small vegetative structures produce small carpophores. Hence, with the recurrence of rainfall regularly and abundantly following the deadening affect of several arid weeks, events follow in normal sequence; one or two weeks of rainfall in which no fructifications appear, a week in which small fungi, such as species of Mycena, Collybia, Marasmius, and Coprinus are dominant, followed by succeeding days with new and larger forms gradually coming into and adding to the total number composing the fungal flora.

The continued growth of the vegetative structures of these saprophytes greatly reduces the leafy covering of the soil. Here again a balance is maintained between the amount of moist decaying leaves and the numerosity of fungi. The annual budget of fallen leaves is rapidly becoming an integral part of soil when the time arrives for the new autumnal carpet.

The normal human questions during spring invariably deal with why fungi are so few and far between. Recollections of the autumnal forest densely beset with hundreds of terrestrial fungi has led the usual observer to expect similar growth during the vernal season. The somewhat detailed discussion of ecological factors bearing on these questions serves to make reasonable the contrasting paucity and abundance.

Mosses, lichens and liverworts constitute a living substratum, nestled among and beneath the leaves to invite other entirely different types of fungal communities. Usually somewhat removed from the leafy floor and from the living mosses, liverworts and lichens, grasses grow, their roots and dead leaves giving sustenance for fairy rings of Marasmius oreades (see fig. 2) and Agaricus campestris on pastures and fairways.

An analysis of the interrelationship of the various parts of the substrata brings forth the tremendous importance of fungi. On a single stump, somewhat decayed, one may find six or seven species of fungi, each with its own peculiarities of action, but all functioning to eventually return the wood to the soil. In the growth of fungi chemicals are ecologically more important than for seed plants where physical factors are largely responsible for associational differences.

Diversity of saprophytism and parasitism is illustrated by the presence of Polyporus Schweinitzii always on pine, Mycena vulgaris on pine needles, Marasmius oreades attached to grass roots, Polyporus conchifer (see fig. 3) on elm twigs, Tricholoma transmutans on black oak roots, Polyporus tsugae on living hemlock and Nyctalis asterophora on another fungus, Russula nigricans.

The economic importance of fungi as related to the decay of structural timbers has by some been recognized for three-quarters of a century. In a letter of December 9, 1889, P. H. Dudley wrote to Charles H. Peck, state botanist of New York, calling attention to the loss due to decay of bridge timbers, ties, and the lumber used in building freight cars. He mentioned the prevalence of Lentinus lepideus on the ties of yellow pine (Pinus palustris Mill.) He stated that these were so numerous in main line tracks and so conspicuous during September 1889 as to be noticeable from the trains. "Pilei six to eight inches in diameter were frequent, while four in a cluster of small diameter springing from the same mycelium seemed to be a common mode of growth, this unusually wet season. The resinous matter in yellow pine in its natural state does not seem to check the growth of the fungus." This same fungus reaches ten inches across on the timbers used for construction at the parking area near Tower Falls in Yellowstone National Park. Construction here is mainly of Lodgepole Pine. Dudley further writes that Omphalia campanella Batsch (see fig. 4) was found fruiting on white cedar (Chamaecyparis sphaeroidea Spach) from May until October. White oak timbers frequently showed Fomes applanatus Fr. in fruit while Polyporus versicolor Fr. was very abundant. The absence of fungi in fruit upon ties of chestnut (Castanea) was as striking as its frequency on other woods. "It is a well known fact" he writes, "that chestnut ties last longer where the ground is damp, than where it is dry."

Concerning the presence of Omphalia campanella on the white cedar, one explanation seems sufficient. This fungus may have occupied the timbers for months, spreading vegetatively and causing decay without producing a single fruit; then with the stimulus of decay-chemicals in the substratum added to the presence of a moisture supply came to abundant fruition. The same, to a lesser degree, may be said of Fomes applanatus and Polyporus versicolor. They too are prolific in the growth of mycelium, and show but little tendency to fruit until the supply of nutrition undergoes a marked chemical change, then, as though signaled by the code of race preservation, the pilei appear. The procedure varies in degree with different fungi, but the story is much the same. Some produce several successive crops for several years while the decaying wood becomes softer and softer in its reduction to soil.

Another interesting observation by Mr. Dudley concerns the abundance and destructiveness of Lenzites sepiaria Fr. Under the station platforms and the planking of the walks, he found its mycelium abundant, generally without fruiting, and follows with the observation: "This has not set men to thinking of better methods for replanking for they carry on the replanking exactly as of old, that is, in the best manner to promote the growth of a new crop of fungi. Consequently in a few years replacement is again necessary. Unseasoned timbers are especially susceptible and during a damp season will show traces of mycelium in two or three weeks. Well seasoned timbers contain inert mycelium if any at all and this remains inactive until moisture reaches it. This again starts decay. Some have suggested painting the timbers to protect them from the mycelium of decay but this proves of no value if moisture and the mycelium are present within, for in the same short period of time decay has weakened the wood and replacement must follow. Users of wood have long considered the fungi as merely accompanying the decay and not its cause, consequently they have done little to preserve the wood or to eliminate the fungi. So small are the spores and so readily disseminated that every crevice in the timber contains many which await the presence of moisture to begin the growth of mycelium and with it the decay of the wood." During a period of fifteen years the old railroad bridge over the north branch of the Chicago River in Harm's woods, west of Evanston, proved a most interesting illustration of these processes. The most prevalent of all was Lenzites sepiaria (see fig. 5) and ninety percent of the decay was attributable to this species alone. Remembering that these timbers were solid twenty years ago and that the trolley cars were then in use, one could with a minimum of time repeatedly visit these timbers and evaluate the destruction caused by the growth of mycelium within the wood.

The final paragraph of Mr. Dudley's letter is interesting: "As an illustration of simple and effective measures, I will give an example: When I was chief engineer of the Valley Railway of Ohio, I built some extensive trestles. This was in 1873. Before doing so I examined a number of trestles near Cleveland, Ohio, built of 10 by 12 or 12 by 12 timber, the life of which did not exceed seven or eight years. In examining them, I found that while the large timbers were sound upon the outside, internally they were all decayed. The small timbers, 6 by 8 used for braces and of the same kind of wood, were sound. The small size enabled them to season in the structure. This was an important fact, so I made all my timbers small, using more of them to give the proper factor of safety. One of these trestles is in use now, 16 years later. In this case, one of the three essential requisites for the growth of fungi was eliminated, namely, moisture in the interior."

Much of the discussion in the letter of Mr. Dudley refers to the decay of timbers but this may not apply to the decay internally of trees by parasitic fungi. Some fungi do perform the double function of saprophytism and parasitism exhibiting ability to thrive on a living or on a dead substratum. It is not unusual to find

PLATE I
Explanation of Plate

1a.—Morchella esculenta. The morel, sometimes called honeycomb mushroom occurs during spring.
1b.—Peziza coccinea (Scarlet Peziza) occurs during April. The inside of the cup is a brilliant scarlet color.
2.—Marasmius oreades. Fairy rings of this species and of Agaricus campestris are found on golf courses and pastures.
3.—Polyporus conchifer prefers to grow on dead and fallen elm branches.
4.—Omphalia campanella. Golden trumpets; with golden yellow caps; a multitude of these rapidly decay a log or stump. Caps ½ inch across.
5.—Lenzites sepiaria lower surface is gilled, but in some specimens is somewhat daedaloid; yellow and brown colors make the plant very attractive; on railroad ties.
6.—Fomes applanatus. Species of the genus Fomes are perennial adding a new layer of pores each year. Many of them are obligate parasites.
7.—Hydnum erinaceum. Hydnums are included among our edible fungi.
8.—Amanita phalloides (Deathcup). This is the most deadly of all to those who look for mushrooms for the table.

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1b

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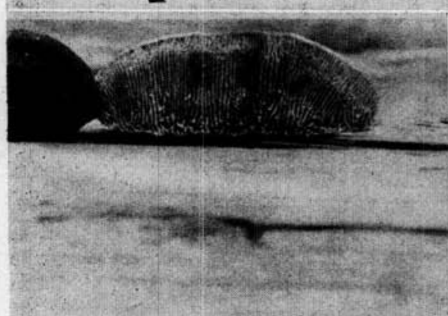

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Polyporus Schweinitzii on the dead trunk of Pinus strobus or on the living trunks or roots of the same species, or to find Polyporus tsugae on either living or dead hemlocks. Because of such latitude of toleration, it is sometimes difficult to formulate laws for determination and prediction as is indicated by the following illustration: On the high point of land bounded by the two streams at the confluence of Turkey Run into Sugar Creek stands a hemlock afflicted for at least twenty years with Polyporus tsugae. The normal expectancy for such a disease includes mycelial growth within the tree until decay has changed greatly the chemical nature of the wood, the storehouse of food for the mycelium, then in the final stage of the life of the tree, the appearance of fructifications. This remarkable tree has all these years been host of a disease, and for at least eighteen years produced on its branches and trunk four or five pilei of Polyporus tsugae, yet the health of the tree has not greatly changed for several years. A few of its branches exhibit internal decay, but always such branches produce pilei of the disease-producing fungus. It is evident in this case that the disease is local in character, that the tree is parasitized in one sector only, the decay-producing mycelial strands follow the grain of the wood upward from its point of entrance, until the tissues of wood divide, some to a branch and some within the tree trunk. Strands then multiply within the branch until decay renders this member an unfit host. When such a condition arises fructifications appear, to scatter the spores on the winds to other hosts.

The destruction of trees in our forest preserves, especially in local areas, furnishes a splendid opportunity for observation and study. A survey of a single forest such as Harm's woods will reveal more than one hundred epixylous species. A few of these are obligate parasites, others fit into a varied classification. Some like Polyporus gilvus show preferment for dead trees and where present on living trees are attached to and deriving nourishment from dead wood. Others exemplified by Fomes connatus derive nourishment from the living wood of the tree trunk. Direct evidence of their presence is withheld from us until a considerable part of the tree is dead when fructifications appear. A third type may be said to live on either dead or living wood. Within this classification may be such as Fomes applanatus, (see fig. 6), usually found on stumps or logs in various stages of decay, but sometimes on the living trunk of Quercus alba. Such obligate parasites as Fomes connatus of maples, Fomes rimosus of Robinia pseudoacacia (black locust), Fomes Everhartii of Quercus, Fomes pinicola of conifers, Fomes pini of pines, Fomes juniperinus of Juniperus Virginiana (red cedar), Fomes fraxineus and Fomes fraxinophilus of Fraxinus (ash), sometimes surprise us by their presence after death has changed the living tissue of the host into decaying wood. These same parasites also sometimes surprise us by their presence on other than the usual host. Fomes pinicola, easily recognized by the presence of red color on younger tissues, is ordinarily expected on pine or other living conifers but sometimes occurs on beech logs. Fomes fraxineus, notoriously a parasite on ash, produces splendid fruits on cottonwood trees along the Des Plaines River near River Forest, west of Chicago. Fomes fulvus does not divide its host genus into species. It grows on any kind of cherry but is not adverse to the other half of the genus made up of wild plums. Fomes fomentarius is found on living deciduous trees but avoids conifers. Fomes ribes prefers bushes to trees, growing on Ribes (gooseberry) or Symphoriocarpus (relatives of the snowberry). On such very large bushes as witch hazel and alder may be found Fomes scutellatus. In Harm's woods where maple is abundant Fomes connatus is prevalent on that tree, and, were you to look no farther, your conclusion would be that this fungus is an obligate parasite. Somewhat rarely in other localities this disease also affects elm and beech. In the forest preserves of Cook County living elms are exceptionally free from parasitism by fungi, but on the dead twigs will almost invariably be found the attractive cup and saucer shaped fructifications of Polyporus conchifer. Had Mr. Dudley who spoke of the absence of fungi on wet chestnut timbers known of later findings, he would have been much surprised to learn that more than 150 different, easily observed fungi could be found on the dead and dying remnant of that tree. That these are not minute species hidden from the average observer is indicated by the facts that—

29 are of the genus Polyporus
24 are Agarics (gilled mushrooms)
19 are Porias
18 are of the genus Stereum
9 are of the genus Fomes

The remainder are largely resupinate forms of the family Thelephoraceae.

Another contrast with the statements of Mr. Dudley are the observations about the reconstructed village, Lincoln's Salem, Illinois. The timbers used in this village are infiltrated under high pressure with zinc chloride. The effect of this salt on the protoplasmic content of the mycelium is immediate and powerful, causing plasmolysis and sudden death. It seems probable that timbers so treated may endure for several centuries.

In more recent time, an ever increasing use of preservatives adds years to the endurance of structural timbers. The conditions prevalent a century past, when lumber and labor were cheap, occur less frequently in modern times for the best economy encourages building for the years.

We cannot but wonder concerning the details of adjustment for the balance of life. What biotic changes occur within the host and how are these adjustments accomplished? The softer plants which furnish food for man have been carefully observed and studied in order that strains resistant to disease may be selected. Nature carries forward a selective process producing on the one hand a host sufficiently resistant for endurance of the numerous parasites, and on the other hand, parasites strong, but not too strong, in order that their life and their food supply may continue. A parasite attaining its ecological factors in one part of the world, suddenly released in another region may destroy its host before resistance adaptations occur. A single parasite nearly eliminated the American chestnut from our forests. Such life processes can in the medical field be many times exemplified by such examples as susceptibility to tuberculosis, of people who come from south of our border. The parasitic germs in this case find a virgin field for development where growth may be rapid and without host resistance. Application of these principles to our forests helps to establish understandings of why trees may in various stages of decay live on for many years, finally to be killed by secondary parasites which find entrance through wounds made by the original fungal growth.

Speaking of fungi and man invariably causes many people to see but one side of the subject and they properly ask, "How can we know without learning to recognize all the fungi which ones are edible?" Without knowing them as individuals your diet must be considerably restricted. Analysis of the fungal flora of Illinois and the region within one hundred and fifty miles of Chicago shows the following rules applicable. Our most poisonous mushrooms are gilled. All fungi are non-poisonous which grow on wood, except the beautiful Clitocybe illudens, which is a large, bright pumpkin-yellow gilled-mushroom. Among other edible fungi are all puffballs if used before the changes for spore production, that is while white throughout the cross section, all coral mushrooms (Clavaria and Tremellodendron), morels and pezizas, and finally the black fungi of the genus Xylaria, as well as the peculiar ones which appear shaggy with white hair-like aculei, belonging to Hydnaceae (see fig. 7). The very poisonous mushrooms grow on the ground and belong to the genus Amanita (see fig. 8). Other mildly poisonous mushrooms of other genera of the Agaricaceae are terrestrial.

In conclusion, I wish to express the hope that some of these scattered ideas may make future visits of yours to forests, fields and mossy bogs more interesting, and that you will try to recognize some of the numerous plants which you formerly passed by with the remark: "Just another toadstool". It is much more than a toadstool and its very presence in a particular place must arouse a whole chain of ideas. Your conclusions may then arouse other new associations out of which may grow *your* ecology. Fungi whether epixylous or terrestrial fit closely into the scheme of human existence and each has an important place to fill in the total organization of relationships between fungi and man.