FUNGI IN RELATION TO MAN*

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FUNGI AS FOOD

MOST people in Great Britain would classify the numerous fungi of our woods and fields into two groups, the first including one species, the mushroom (*Psalliota campestris*) which is edible, the other including the rest which are called toadstools and are labelled poisonous. Those who have eaten abroad with a true spirit of gastronomic adventure know that certain toadstools make an attractive dish and even in London continue to sample cèpes (various species of *Boletus*), morel, chanterelle and truffle. This list, however, can be much extended, and forty or fifty species are far more delicate in flavour than the field mushroom of which, moreover, certain of the wild forms are much superior to those usually cultivated. Formerly, several species were sold in Covent Garden market, and blewits, blue-leg or blue stalks (*Tricholoma personatum*) is still sold in the north-east, midlands and west, though round about Berwick-on-Tweed it is now bought by dyers for the extracting of a blue dye, the price offered being two shillings a stone; it would be wiser to eat them than to sell them at this price.

In these days of war, no one could accuse our diet of lacking experiment. Even so, if one suggested that toadstools might be added, there would probably be an outcry about the great danger of poisoning. The fact, however, is that very few of those that anyone would think of cooking are even suspect. But one wholesome-looking species, *Amanita phalloides*, is not only deadly poisonous, but also causes intensive and extensive agonies. One or two allied species such as *Amanita mappa* are usually considered dangerous, but it may be that there has been confusion in identity. The best-known poisonous toadstool is the fly agaric (*Amanita muscaria*) with its scarlet, white-spotted cap, which makes it the most pictured and modelled of all fungi. Here the effects are not deadly though they are severe. The remaining poisonous fungi which grow in Great Britain can be counted on one's fingers and their characters could be learned by any ordinary person with little trouble.

The food value of fungi is not very high if we judge merely by calories, but they serve as an attractive addition to meals or as flavouring and have, moreover, a vitamin content, B and D, and

sometimes A, which is appreciable. To purchase cultivated mushrooms at their present exorbitant price is uneconomical for anyone having to consider either food values or his purse, but there is no reason why in rural districts there should not be some organized scheme by which information could be given about edible fungi and various methods of cooking them; they might even be sold in local markets. A little confidence but not rash experiment is all that is needed.

It is strange that in Europe and North America only the field mushroom is cultivated and this by a method which apparently originated in France in the seventeenth century. Attempts have been made to cultivate truffles and other fungi on a large scale but without success. The Chinese and Japanese have cultivated shiitake, an edible fungus, on logs, for more than two thousand years, and in all tropical countries a species of *Volvaria* may be said to be cultivated, for special beds are prepared for its growth though there is no inoculation.

PARASITIC AND SAPROPHYTIC FUNGI

Before it was recognized towards the end of the seventies of last century that bacteria are the main cause of certain diseases, it was known with some certainty that fungi occurred in association with diseases such as ring-worm and were usually regarded as causing them. A century ago, about the time when many of these fungi were first recognized, it was more customary than not to regard what we know now as a parasitic organism not as the cause of a disease but as the result of it. The penetration of one organism by another, with the resulting disease, and the spread of the contagion was first clearly recognized by Bassi, who after long years of research on the muscardine of silk worms showed that it was due to a mould now usually known as *Botrytis Bassiana*. It is difficult to realize that this work was published only a year before Queen Victoria came to the throne. During the following forty years there was as much advance in our knowledge of the nature of disease as there has been in the last forty years in methods of locomotion. There were many false starts and one of these was a tendency to regard all contagious human diseases as due to fungi. However, the true path was shown by a host of investigators whose names are prominent in the history of bacteriology, and the fungi were

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gradually relegated to a minor position, though in Great Britain the pendulum has swung too far.

The commonest fungi which affect man are the members of the ring-worm group, some attacking the heads of children, others causing eczema-like eruptions on the skin; a frequent focus for the last type is between the fingers or toes, the usual pathogen then being *Epidermophyton interdigitale*. Infection of the feet by this or allied forms has become more common during the last few years, apparently being picked up on the recently popular sea cruises or in public or school baths, where bare feet encounter contaminated wood-work. The throat trouble 'thrush' is still occasionally troublesome in babies owing to the use of dirty feeding-bottles, but even women of the poorest classes have learned sufficient about hygiene to reduce materially the prevalence of this disease.

An important point about the majority of these mycological diseases is that they are due to fungi which can live either normally or secondarily as saprophytes. Thus *Oidium albicans*, the fungus of 'thrush', occurs in sour milk, and ring-worm fungi affecting cattle have been found growing also on the dung in the byre. The phenomenon is not surprising, having regard to its known frequency with disease-producing bacteria, but it is often overlooked. Not only man but also his ox and his ass are subject to occasional fungal infections, and birds and fish have also a few mycological diseases. Insects are very frequently attacked, one large family (Laboulbeniales) being confined to them as hosts and numerous genera are peculiar to certain insects. Attempts have been made to control insect pests by infecting them with their special fungus parasite.

The most important and numerous diseases caused by fungi are, however, those of plants. Though there are bacterial diseases of plants and also virus diseases, they are few compared with those due to fungi.

Although diseases of crops have been recognized since the earliest times—indeed it would be well-nigh impossible for them to have been overlooked—the urban population of to-day has little idea of the loss that occurs even when every civilized country has its phytopathological service. Estimates of the losses due to fungal disease have been published from time to time. Many of the older estimates refer to years when the losses were exceptional, but modern figures show what enormous losses occur every year. Thus it has been calculated that in the United States more than £10,000,000 is lost in an average year by stem-rust of wheat, whereas it may be five or six times that amount in a bad year; bunt takes an average toll of £2,500,000 and loose smut nearly

£1,000,000—and these are not the only diseases which affect wheat, nor is the United States exceptional in the severity of these diseases. The losses in the main crops of the United States are estimated as ranging from two to fifty per cent; 200,000,000 bushels of maize, for example, are lost annually. The figures for world losses are astounding. The downy mildew of the vine has been estimated as causing an annual loss of £500,000,000. The classical example of what a fungus disease can do at its worst was shown a century ago by the potato disease. This disease spread all over Europe causing devastation and dismay. It afflicted Ireland, causing a famine which wrecked a British Cabinet and produced other political and economic effects the results of which are still apparent.

Disease also takes its toll of forest trees. Of the disease-producing organisms fungi are usually the more prominent. The large bracket fungi growing on the boles or roots of trees are for the most part wound parasites requiring some break or crack before they can gain entrance. The result of such an attack is generally a rotting of the heart wood. As the defect occurs in unworked wood it is known as 'wet rot', as opposed to 'dry rot' of worked wood. It should be obvious that the tree trunks which have been so attacked are in a state in which further decay can occur in certain conditions, but sometimes it is the practice merely to remove the parts which are visibly affected. But the filaments of a rot-producing fungus do not stop dead in their progress at the point where their destructive action is apparent, but have usually extended beyond this. Different fungi behave somewhat differently, and it is only a broad general outline that can be mentioned here, and that mainly to stress that care must be taken to ensure that timber affected by wet rot is entirely rid of mycelium before use for structural purposes, or alternatively that it is stored and afterwards used in conditions which do not permit the fungus to renew its growth.

A certain amount of decay takes place in timber yards and there are well-proved practices to reduce this to a minimum. What I have said about the possible continued presence of the mycelium of wet-rot fungi is important, for it is wood stored for use that is affected. Proper sanitation and aeration are the best preventives.

But, from the aspect we are considering, rot in worked wood, that is dry rot, is much more important. There are several kinds of dry rot, but by far the most destructive, the most widespread and the most abundant is that due to *Merulius lacrymans*. Strange to say, this fungus is confined to buildings. An outdoor form has been described, but it is very rare and of no consequence except

taxonomically. It would be difficult to overstate the amount of damage caused in buildings and the ease with which this could be prevented. Wherever there is imperfectly seasoned or damp wood with insufficient ventilation the fungus is almost certain to appear, sooner or later. Having got a start it is able to spread, passing by strands over or through substances from which it cannot obtain nutriment and devouring other woodwork with which it meets. Attacked wood is reduced to powder. Water is formed from the breaking down of the substance of the wood, and this enables the fungus to continue its growth. Excess water is exuded from the fungus as drops, which explains the scientific name of the fungus but puzzles many whose sole knowledge is that their house is said to be suffering from dry rot.

When the strands of *Merulius* cannot proceed farther they form fruit bodies with an olive-orange coloured honeycomb-like surface. These fruit bodies produce millions of millions of microscopic orange-coloured spores. A fruit-body a foot across, no unusual size, produces more than enough spores to infect every building in the British Isles. Frequently they form a layer on furniture and other objects in a house and often cause alarm where no other effect of the fungus had been noticed. I once had an egg sent to me which was almost wholly orange-coloured, and was able to assure the sender that there was nothing wrong with it but that the cellar where it had been kept was badly in need of attention.

It is well to stress the subject of dry rot at the present time. After the War of 1914-18, when there was a renewal of building, the prevalence of dry rot in some of the building estates was astounding. With proper ventilation and sound seasoned timber there need be no fear after this War of a repetition of the losses of the last building boom, but if precautions are not taken the damage resulting from dry rot will doubtless be even greater.

Not only food plants but also all food may be subject to fungal attack. Mouldiness is one of the commonest phenomena of everyday life, but it is not universally recognized that moulds are living organisms. Moreover, in common with other organisms, they have certain requisites for growth: they need certain food substances, a certain range of temperature and a certain amount of moisture.

The fact that moulds grow only between certain temperatures is acted on in our methods of preservation; preservation, broadly speaking, is the prevention of the deterioration brought about by fungi or bacteria. If food is kept below a given temperature moulds which can grow only at temperatures above this remain dormant. This is the basis of cold storage. There are many problems

of cold storage, particularly with fruit, but these do not alter the general principles.

Not all fungi are incapable of growth at the low temperature at which chilled meat is transported and occasionally there is trouble from these, as, for example, in black spot (*Cladosporium*), white spot (*Sporotrichum*) and whiskers (*Mucor* and *Thamnidium*). It is noteworthy that *Merulius lacrymans* often occurs in cold storage plant and in refrigerator cars.

Freezing does not ensure the killing of the fungi but only that they are unable to grow, and in growing cause damage. Indeed the spores of many common moulds when dried can be taken down to the temperature of liquid hydrogen without loss of vitality, and are able to withstand the rarefied air, intense cold and blazing sunlight of the stratosphere.

When cold-store meat, fruit and other food is released for use, it is not, therefore, in a sterilized condition; so far as moulds are concerned, it is more or less in the same state as when it went into storage. The only practical method of sterilizing food is by heat, and to keep it sterilized all organisms must be kept out of contact with it or, as we say, no air should be allowed to get to it.

The spread of knowledge about infectious diseases in recent years has opened the eyes of the general public to the widespread occurrence of germs invisible to the naked eye. Invisible fungus spores, of all kinds, are also present in the air in prodigious numbers and have been shown to occur at a height of several miles. Moulds appear with such consistency on foodstuffs and other organic substances that formerly it was commonly thought that putrescence was universal and inevitable and that moulds are the consequence of the decay. It was partly because of this that the similar view about plant diseases was prevalent.

It may be truthfully said that it would be exceptional for any organic material which was not thoroughly dry to escape decay and destruction. Heat is the only safe sterilizer. The temperature needed is higher than is theoretically sufficient because many spores have highly resistant walls which the heat must penetrate to be effective. Sterilization is the basis of the procedure in fruit-bottling, and similar methods of fruit preservation. But obviously so soon as sterilized material is exposed to the air, so soon is it liable to reinfection. Some foods are more readily attacked by mould than are others; moisture has a good deal to do with this, especially if the food is enclosed. Thus biscuits if kept in a dry place, either in a tin or on a plate, will remain wholesome, whereas bread, especially when cut, will soon become mouldy in a bread pan, though not so quickly if left free to

the air, but fortunately the time taken is too long for it to affect ordinary household procedure in normal times.

This necessity for moisture was early discovered in man's efforts to preserve his foods, and 'sun-drying' is still practised with numerous fruits. Until 1924, when there was a Government Committee report on the subject, it had become the practice to add such substances as benzoic acid, boric acid and formaldehyde to various foods as preservatives. All these are harmful to some extent and their use was prohibited, except that it is permissible to add small quantities of antiseptics such as sulphurous acid to fruit juices or meat products.

Apart from some chemical solutions which are poisonous to fungi, there are many others in which ordinary moulds will not grow. For this reason fats and oils, vinegar and strong sugar solutions have their use in preserving food.

USE OF FUNGI

We should be more happy without parasites, at least those which affect us, our animals and the plants we use. But what if there were no saprophytes living on dead material? What if there were no decay and no decomposition?

In natural conditions, decay, paradoxical as it may sound, is a method of sanitation. As things are, we are dependent upon plants with chlorophyll for our existence and equally upon organisms without chlorophyll—the ones to build up organic structures, the others to remove them when life is ended. To take a single example. A forest floor as the trees grow is covered with leaves which are later turned into leaf-mould or soil. As the years pass and a tree's span of life is reached it dies and falls or breaks, or it may succumb to the attacks of parasites. Saprophytic fungi grow on the fallen log or broken stump and gradually, over the years, it is reduced to pulp and finally this is also added to the soil. This has gone on through the ages and to such effect that a primeval forest from this aspect looks very little different from a reasonably old plantation, though forestry sanitation demands that there the fallen trees and broken branches should be removed. But this natural removal of fallen trees, leaves, fruits, shrubs, herbs, as well as dead animals, is carried out by fungi and bacteria living saprophytically.

It is perhaps only in places where man congregates—villages, towns and cities—that there is real danger to himself from putrescent material. If he waits until it disappears by what we may call natural means, then there may result those epidemics which hygiene and sanitary science have taught us to expect.

In the centuries man has discovered that not all the effects of fungal activity result in making wholesome food and drink distasteful or poisonous. Every race has its fermented liquors. Most of these fermentations are brought about by yeasts which act on the sugar present in fruits, cereals, plant juices and such like with the production of alcohol. The infection of the yeasts was haphazard, and with experience some degree of certainty about the resulting products was attained. With increasing knowledge of the biological processes involved in the operations it has become possible to control some of the fermentations so that the same species is used under the same conditions with a more or less standard result. The best understood of these is the production of different kinds of beer, but similar scientific methods have been applied, though not so commonly, in the making of wine and cider. Also it is realized that there are diseases of beer and other beverages which are brought about by the growth of alien organisms.

The raising of dough by yeasts in bread-making and the ripening of rennet cheeses by *Penicillium* are now often controlled in the strictest manner. Many moulds have been found to be responsible for products which are desirable for various purposes. Sometimes this may be a new substance or it may be one profitable to produce by fermentation. As an example of the second is the production of citric acid by *Aspergillus niger*, a common and abundant mould. Until a few years ago, lemons were used for this purpose, but the fungus is so efficient that it is used even in Italy, formerly the chief source of the acid—and incidentally one which would not be available to us at present.

There are many other products which the study of fungus activity has made available in industry. When the biochemistry of fungi is more fully understood, we shall have the means of producing with ease many substances difficult to synthesize without their aid, and many as yet unknown substances which will have their uses. The achievements of the past give promise that the attempts to harness some of the activities of the organisms will be profitable.

Just as the fungus known as ergot, which causes a disease of rye and other cereals and which when eaten in bread brings about gangrene or convulsions, has so important a place in modern medicine that it is listed in the Medical Research Council's recent memorandum on drugs the production of which in the United Kingdom should be encouraged, so may we hope that eventually we may benefit by turning what at first sight appears unmitigated evil into something beneficial to mankind.