PRESIDENTIAL ADDRESS

THE INFLUENCE OF FUNGI IN HUMAN AFFAIRS

LELAND SHANOR
University of Illinois, Urbana

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Some months ago when I casually mentioned to a colleague of mine that I was having to give some thought to an appropriate subject for a presidential address to the Academy, he made the comment that presidential addresses are always a problem. As he pointed out, however, on such an occasion it seems one is privileged to talk on almost any subject he wishes—even a moldy one. I decided, therefore, on a topic in the area of my own scientific work, one of a sufficiently general nature that it might include something possibly of interest to most members of the Academy.

Twenty years ago this coming June, I published my first paper dealing with that group of plants which I shall discuss; I have been working and contributing in this

area, both as an investigator and as a teacher, since that time. Therefore, it seemed that a brief review of some of the ways in which this particular group of organisms touches upon our lives, and has influenced the affairs of man, would be an appropriate topic.

This year the Illinois State Academy of Science will be concluding its 50th year as an organization. During these 50 years, all branches of science have made remarkable, and what might have been considered at the beginning of this period undreamed of, advances. This is certainly true of my own field of investigation, mycology. This field represents the special branch of plant science concerned with the study of molds, mildews, rusts, smuts, and other simple non-green plants which we include among the fungi. During this past half-century, we have learned much about controlling those fungi that cause plant and animal diseases, about those that spoil our foods and contaminate the products of our industry, and about those that we have been able to domesticate and control to produce useful products. It might be of interest at this time also, to recall some of the events in history that have been influenced by the activity of fungi. To many of you it may come somewhat as a surprise to know that the effects of fungal activity have caused spectacular emigrations of people, have affected the course of military campaigns, and in other ways have played a significant role in history. Fungi are becoming responsible for an increasingly longer list of products that contribute to a better way of life and are known to affect man in many more ways, and to a degree, not suspected 50 years ago. Before we consider any of these specific areas, however, perhaps it might be well to delay a moment to say a few words about how fungi live. For with this in mind, you may appreciate better some of the things that fungi do.

Since the fungi do not contain the green pigment, chlorophyll, that enables most of the other kinds of plants to manufacture their own food, fungi must obtain their food from existing food sources. Some of these fungi are parasites and derive their food from living plants or animals. Others are saprophytes, or saprobes, and obtain their food from dead plant or animal bodies or from products of plant or animal origin. Those that must utilize such complex substances as cellulose, lignin, proteins, and related materials must possess the ability to break these down to simpler substances which can be taken into the fungus body to supply the carbon, nitrogen, and additional elements needed for growth, reproduction, and other processes. Because their ability to do this is so remarkably diverse, especially for those that are saprophytes, fungi have been compared to a very efficient chemical factory. They produce a remarkable variety of enzymes which make them capable of breaking down a very diverse array of complex materials and which enable them to build up other complex substances from these. These activities are strictly chemical, carried out within or associated with the fungus itself. A prominent mycologist in this country, Dr. William H. Weston of Harvard University, has pointed out very pertinently that the fungi were

living very well in luxuriant carboniferous swamps on the DuPont slogan "Better things for Better Living through Chemistry" long before man himself had made his appearance on this earth.

At least some of the topics I have selected for comment here are well known to biologists generally, but others may be familiar to only a very few whose area of science is very closely related to my own. Science has become so diverse and complex that often we understand well the significance of only a small number of the areas most closely related to our own.

I should like now to consider some of the ways that fungi affect man adversely and then some ways in which they contribute to a better way of life for all of us.

Fungi are Harmful and Destructive

One very significant way in which fungi influence man adversely is as a cause of many different kinds of plant diseases. Plant diseases annually take a toll reaching into the billions of dollars in the U.S. alone. For man the problem of plant diseases is an old one, and one that is likely to remain in spite of advances which are being made in plant-disease control. In the course of history, there have been very significant epidemics of fungal plant diseases, some of which have occurred during our own lifetimes. Among these might be mentioned the chestnut blight disease which has, for all practical purposes, eliminated the American chestnut, recurring epidemics of stem rust of wheat, blight of oats, and others. Spreading now conspicuously in this area we have the Dutch elm disease, and appearing even more recently, the Wisconsin oak wilt.

In the very early literature, mention of crop diseases is found frequently. Of course, in ancient times any true conception of what caused these diseases was not suspected. The cause was looked upon as a deep, dark mystery, often being regarded as the visitation of some angry god. Grain rust, for example, was recognized as a devastating disease many hundreds of years ago. This same disease remains today one of the major problems of wheat growers. New resistant varieties of wheat are constantly being developed by plant breeders. Just about as rapidly the rust fungus produces new strains that are capable of attacking these new varieties. It sometimes seems to be a rather discouraging race, one in which the plant breeder never appears to be much in the lead. Loss of wheat from black stem rust in North America in 1916 exceeded 300,000,000 bushels. Almost 20 years later, in 1935, after it seemed that great progress had been made in eradicating this disease, a severe epidemic broke out on this continent and almost a quarter of the wheat crop was lost. In 1950 there was a near repetition of this disaster. You may be sure that the wheat rust fungus is a clever adversary. There are over 200 races of it known, and none of our varieties of wheat, even the most recently developed, are immune to all of them.

Probably one of the most devastating and spectacular plant disease epidemics in history was the late blight disease of potato during 1845 and 1846, caused by the fungus,

Phytophthora infestans. Although serious on the continent of Europe at that time, and to a lesser extent in America, it was in Ireland that the effects of the epidemic were most tragic. The potato represented almost the sole source of food for the impoverished Irish of the period. People on the continent and in America felt its effect much less because the diets of those living in these areas were much more diversified. When the blight of potato struck Ireland, the result was so devastating that almost a million people died of famine. Another million and a half emigrated to America. Ireland lost one-third of its population in the years between 1845 and 1860 because of this potato disease. This famine in Ireland affected history in another way, because its impact set the stage for the repeal of the corn laws in England and thus initiated a policy of free trade. The impact of this epidemic on English-Irish relations is still felt.

In the 20th century the potato blight fungus has also played an important, but perhaps relatively little recognized, part in history. In 1917, when Germany was dependent upon the potato as its principal war-time food crop, *Phytophothora infestans* again produced an epidemic that wiped out a third of the annual production in that country. Although reasonably effective control measures had been developed in the form of chemical fungus-killing materials that could be sprayed or dusted on the potato plant to protect it from the cause of the disease, the necessities of war required that materials, such as copper, which might be employed in fungicides, be used for immediately critical military demands. The late blight fungus was on hand for just such an opportunity and the result is now a matter of history. The resulting reduction in the already short food supply of Germany contributed very significantly to the breakdown in morale and physical endurance that led to the ultimate defeat of the German army.

The list of plant diseases caused by fungi is a long one, but the effects of the two just mentioned have been among those most significant. Many other plant diseases are of lesser importance in the affairs of man than these two, but each year the total destruction of food plants, fiber plants, timber, and other crops is staggering. New fungi parasitic on plants are being reported every year, and many plants have not been searched as yet for their fungal parasites. Each year it seems that new and more virulent strains of some of the previously less significant pathogens make their appearance. Although we have been combating plant - disease - producing organisms for a long time and have made progress, much remains to be done before we can assume we have succeeded satisfactorily in this continuing conflict between man and the fungi that seriously damage his crops.

Although the fungi causing diseases in man have not had the same impact upon history as some other kinds of pathogens which cause diseases, for example bubonic plague and cholera, their effect on the individual is, nevertheless, significant and a large percentage of the population, at one time or another, may suffer from a fungal infection. Athlete's foot and ring worm represent two of the most widespread of the human diseases caused by fungi.

These are superficial mycoses and can be reasonably controlled with a little attention to proper medication and preventive measures. There are some deep-seated fungal diseases, however, affecting such organs as the lungs, spleen, or other vital organs, which are very difficult to combat and which are often fatal. The mid-west seems to be the focal point for one of these, a disease known as histoplasmosis. The arid south-west is the endemic area for another one of the deep mycoses, one known by a number of names such as "desert rheumatism", "valley fever", "California disease", and the more technical designation, coccidiomycosis.

During World War II, when our armed forces were widely dispersed in the tropical regions of the earth, particularly in the western Pacific, fungal infections among troops became a real problem. The superficial skin infecting organisms, common but usually producing relatively mild symptoms in temperate regions, seemed to be stimulated by the moist, hot climate of the tropics. Infections caused by many of the same group of fungi responsible for athlete's foot and related troubles produced symptoms in the tropics well portrayed by such picturesque names as "jungle rot", "jungle foot", and other similarly enlightening epithets which bear testimony to their severity. Fungal infections of man generally are regarded as occurring more frequently and as being more severe in tropical regions than in temperate.

There are many kinds of fungal diseases of man that are widely distributed over the world, but we will dwell no longer on these ways in which the fungi affect man, except to call attention briefly to one other. This one is quite different but none the less distressing—as a cause of allergy. Those of you who have had scratch tests for hay fever or other forms of allergic reaction may recall such names as *Alternaria, Aspergillus, Hormodendron,* and *Rhizopus,* on the list of things for which you were tested. These represent the names of just a few genera of the fungi now known to include species capable of producing allergies in some people.

The adverse effects of fungi in the affairs of man are not limited to those caused by fungi that damage his crop plants, that affect his domesticated animals, or which invade his own body. The purely saprophytic fungi create many problems, also. The unprotected wood of houses and boats is just as susceptible to fungal attack as was that wood on the floor of the carboniferous jungle or as is that on the floor of our forests today. When the fleets of the world were made up largely of wooden ships, the fungi repeatedly contributed importantly to the outcome of conflicts. In the American Revolution, for example, fungi were on our side at a very critical moment. In the Battle of Yorktown the outcome might have been quite different had not fungi contributed their part in preventing supplies from reaching Cornwallis in time. These supplies were delayed because the ships bringing them were forced to refit at New York before proceeding southward. The fungus-rotted timbers of this British fleet were no match for a crippling storm encountered at sea. School boys and girls know that Cornwallis was forced to surrender, but history books do not record the fact that it

probably was just as much the contribution of the fungi as an ally to our cause that brought about this defeat as the contribution of the strictly military operations.

Even as recently as World War II, modern metal vessels were found to be vulnerable to fungal attack, just as were their wooden predecessors, but in a very different way. Instead of masts, spars, and holds being weakened by fungi, this time it was electrical installations, such as transfer switches, telephone systems, gun directors, and other similar equipment that became affected. The vulnerable spot was found to be generally the normally untreated electrical insulation. This material, without some fungus-inhibiting substance incorporated in it, proved to be a very good substrate for the growth of fungi. The fungi this time affected naval efficiency by disrupting electrical currents and interfering with communications and other operations.

Many items of equipment going into war theaters in World War II were found to be initially very susceptible to fungal attack. Rope, canvas, cotton, and woolen fabrics, and many other items of equipment for the Army, the Navy, the Air Force, and the Marines were discovered to be inadequately protected from fungal attack, both while enroute to the Pacific theater and when put into service. A tent pitched in New Guinea in the early part of the war would withstand deterioration by fungi and weather for only a few weeks. Such a short useful life not only created a major problem from the standpoint of service, but also placed a tremendous burden on our ability to deliver adequate supplies to our fighting forces. To provide protection from fungi, new uses were found for old fungicides and new fungicides which could be incorporated into materials going into the various areas of military operations were developed. Before many months the same kind of tent that had previously lasted but a few weeks in New Guinea, but now treated, had its useful life extended to many months. The danger of possible fungal deterioration of other equipment was reduced also. New synthetic materials not subject to fungal attacks were developed. The war in the Pacific might have been lost in the early days of the conflict had we not been able to recover quickly from the unexpected blow dealt us by the fungi. It is now a standard practice to, as far as possible, either fungus-proof military equipment or use materials that are immune to fungal attack.

The examples just provided would lead one to believe that most of the activities of fungi in the affairs of man are destructive, and to think of the fungi as only a sinister and treacherous lot. This is not at all the case. Man derives many benefits from various fungal activities, and I should like now to comment briefly upon some of these. I shall limit my discussion to a few of the most important of the contributions which fungi are known to make to improve our enjoyment of living, to provide better health, and to make possible a longer life.

Fungi are Useful

The constant volume of advertising through all media of communication cannot but make one aware of

the magnitude of that part of the fermentation industry devoted to the production of alcoholic beverages. The production of alcoholic beverages and industrial alcohol, along with by-products of this fermentation, represents a large and significant area of industrial enterprise. The brewing of alcoholic beverages is not a development of modern times; its present importance has been brought about by a refinement of techniques, better control of processes, and the necessity for production on a much larger scale than was possible in ancient time. Societies dating at least as far back as 4,000 to 6,000 years were known to make use of some kind of fermented beverage, derived either from fermented fruit, fermented milk, fermented grain, or from some other suitable raw material. What brought about the fermentation was not demonstrated conclusively until within the last 150 years, and the many refinements for the control of the process are largely developments of the last half-century. Under modern fermentation methods, not only are the yeast fungi cultivated for the production of alcohol, but they represent a rich source of vitamins, a rich source of proteins that may be used as a supplement for animal foods and for human consumption, and a source of additional materials.

The production of still other useful products by fermentation in which fungi other than yeasts are used has been a major development of the past 50 years. Certain of the organic acids and the antibiotics represent the two main categories to which such products belong.

Early in the second decade of this century it was discovered that the black mold, *Aspergillus niger*, possessed a high productive capacity for certain organic acids, such as citric, when grown under certain conditions. This has led to the industrial production of citric acid by molds which has largely replaced its extraction from citrus fruits. Prior to this development, citric acid was obtained principally from Italy and we imported many tons of it into the United States. Within the next decade after the potential capacity for citric acid production by the black *Aspergillus* was demonstrated, the United States became self-sufficient for this material and, as a matter of fact, even became an exporter. Citric acid has many uses in foods, in drugs, in confections, in beverages, and in other ways. Other useful organic acids are also obtained from a fermentation in which this same mold and related ones are cultivated under controlled conditions.

Of the many additional discoveries of products obtained from fungi cultivated under industrial conditions, perhaps none have been more spectacular or have contributed as much to human comfort in the conflict of man with his ailments as has the discovery of penicillin. This has been a rather recent development, for the therapeutic value of penicillin was demonstrated as short a time ago as 1940. The discovery and development of all of the other useful antibiotics have occurred since that time. The story of the development of penicillin as an important treatment for many kinds of infections has been so widely publicized I feel certain that all of you have some familiarity with it. Perhaps few of you are aware, however, that it was here in Illinois at the Northern

Regional Laboratory in Peoria that some of the most significant research and useful discoveries connected with the development of penicillin in this country took place. The highest yielding strain of the penicillin-producing mold now used, *Penicillium chrysogenum,* was isolated at the Peoria Laboratory from a moldy cantaloupe obtained from a Peoria market. Mutant strains derived from this original one obtained from a natural source have been produced by x-ray and ultra-violet irradiation which now produce yields of penicillin many times that of the naturally occurring strain obtained from the cantaloupe, or from the species originally used by Dr. Alexander Fleming who discovered and named this antibiotic. The rapid and spectacular development of antibiotics in medicine since the discovery of penicillin by Fleming in 1928, and proof of its therapeutic usefulness by Chain, Florey and co-workers in 1940, probably has left the impression with many that antibiotics had their beginning with Fleming's discovery. It is certainly true that the modern development of this field begins with these discoveries, but antibiosis as a phenomenon in nature had been recognized by mycologists and microbiologists for about as long as they have been culturing microorganisms. The therapeutic value of mold cultures for treatment of certain superficial infections dates back many centuries. Indeed at least as early as 1000 B.C., the Chinese are known to have used molded soy products to combat infections of the skin. It has been reported also that primitive Indians of the western hemisphere employed fungi in the treatment of wounds that had become infected.

Although there are other products formed by fungi that might be mentioned in connection with their contribution to medicine, I shall refer only to one more. The chemical activity of certain molds under highly controlled conditions very recently was discovered capable of bringing about the synthesis of a group of medically important materials much more efficiently than was possible by strictly chemical synthesis. These important products that can be produced by mold activity are cortisone and cortisone derivatives, used for the treatment of rheumatism and arthritis, skin disorders, intractable asthma, certain infections of the eye, and other inflammations. Cortisone was originally obtained from animal bile in exceedingly small amounts. The beneficial effect to be derived from the use of cortisone in treatment of arthritis was discovered in 1948. The convenience of production of cortisone and related drugs by using certain fungi to bring about desired stages in the manufacture of them, first revealed in a patent application in 1950, is a significant new development in which fungi are contributing in a previously undreamed of way to a healthier and happier life for many people.

Although many fungi such as the truffles, mushrooms, morels, and some other fleshy forms have long been recognized as prize delicacies, the yeasts seem likely to become the most significant of all as food fungi. Already the nutritive value of yeasts is widely recognized by their inclusion in many foods of man and feed for his domesticated animals. As a

potential source of protein in the diet of large populations of the world, the possible contribution of yeasts is only beginning to be realized. There are many areas on the globe where an adequate supply of protein from the usual source, meat, is not available. This is because either adverse environmental conditions affect the practical production of animals for meat or because of religious bias against the eating of meat. Yeasts may, in the years ahead, contribute materially to the solution of this problem. Certain yeasts are high in protein. They can utilize cheap and widely available carbohydrates to form proteins and fats. They can be cultivated readily and under controlled conditions. Yeasts are not animals and, therefore, would not be subject to religious bias in areas where eating of meat is forbidden. The installations necessary to produce food yeast need not require any of the best agricultural land now under cultivation. To be sure, there are many problems that remain to be solved before large-scale production becomes a reality, but utilization of food yeasts as a protein source represents one way in which the dietary needs of an expanding population, or of an already over-populated area, might be met or improved.

The dairy industry makes good use of some fungi for producing the blue cheeses such as Roquefort, Stilton, Gorgonzola, etc., and the soft cheeses of the Camembert type. For centuries it has been assumed that the production of such cheeses was dependent upon special conditions found in certain famous, cheese-ripening caves in Europe. At the turn of the 20th century, an able young American mycologist employed by the Department of Agriculture, Dr. Charles Thom, demonstrated that for each of these types of cheese one specific mold, from among all of those kinds that might be present, was responsible for imparting the specific flavor and texture to each of these cheeses. The molds were isolated in pure culture and inoculated into properly prepared curd. This, when aged under necessary conditions of temperature and moisture, produced a product as good as, or even better than, the cheese produced in caves. Control was easier. Thus was born our domestic production of these cheeses.

Before leaving this subject, it should be mentioned also that fungi are very important as producers of vitamins and of enzymes.

It can be seen from even this brief survey that fungi have played, and are continuing to play, an important part in the affairs of man. The prospect for their contributing even more to an increasingly healthful, more enjoyable, and longer life in the years ahead is bright. We have just begun to discover the potentialities of the fungi.

It is obvious, too, that the fungi always will be with us. As a mycologist friend of mine, Dr. J. C. Gilman of Iowa State College, pointed out a decade ago, even the Bible promises no escape from them in the hereafter. The 20th verse of the 6th chapter of the Book of Matthew advises, "But lay up for yourselves treasures in heaven, where neither moth nor rust doth corrupt, . . ." This statement would seem to indicate that insects and corrosion are absent in heaven, but no mention is made of the fungi.