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MYCOLOGICAL RELEVANCE IN THE NINETEEN SEVENTIES*

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(With 12 Text-figures)

President Ingold, fellow mycologists, ladies and gentlemen, I wish to begin by reading to you three short excerpts from pronouncements made recently by prominent educators in the U.S.A.

First (Pusey, 1970, p. 7), from the President of Harvard University in his annual Report for 1968–9: '. . . everywhere one turns within the University . . . one senses a widening impatience with narrow scholasticism . . . a deeply held conviction that it is not sufficient to pursue knowledge for itself, but that somehow knowledge must be put to work for moral, social and political ends'.

Second (Potter, *et al.* 1970,† p. 1591), from the Chairman of the Interdisciplinary Studies Committee on the Future of Man, University of Wisconsin: '. . . we feel that there is a great danger that universities will be so inundated with problems of the immediate present that they could become merely "public utilities", yet', he continues, 'ways should be found to allow students and faculty to engage in . . . interdisciplinary efforts. . . . Such an orientation might help to close the "*relevance gap*" that now exists between faculty and students' (italics added).

Third (Glass, 1970,† p. 1041), from an editorial on 'Educational Obsolescence' by the Vice-President for Academic Affairs in the State University of New York: 'The cry of the student throughout the land is for "*relevance*" in the curriculum' (italics added). But, 'The content of the curriculum should . . . embrace *both* the timely *and* the timeless, for topical and social *relevance* and timeless natural law alike deepen our perspective and assist us to adapt ourselves to altered circumstances' (italics added).

These three statements provide a good setting for the ideas I wish to develop here with you this afternoon. For in this, the first of all International Mycological Congresses, it seems particularly appropriate to consider and analyse the relevance of our speciality to the age and society of which we are now a part. My own involvement with this analysis began many years ago (Emerson, 1952) and has grown with each passing decade. Most recently, my thoughts about mycological relevance were sharply

* Adapted from a General Lecture, 'Mycological Relevance – 1971', presented at the First International Mycological Congress in Exeter, England, 13 September 1971.

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106th Year No. 223 HOME EDITION *

Nixon's Plan to Save Environment

(a)

Urgent Call To Congress For Action

Times-Post Service

Washington

America faces "ecological disaster" unless it

Nerve Gas Trains Start Rolling

Reuters & A.P.

Richmond, Ky

A train carrying more than 3300 obsolete rockets with deadly nerve gas warheads left yesterday on schedule on its controversial trip through the south toward eventual disposal in the Atlantic Ocean.

(b)

The Southern Corn Leaf Blight Epidemic

A new race of the fungus *Helminthosporium maydis* threatens domestic prices and corn reserves for export.

L. A. Tatum

16 San Francisco Chronicle ☆☆☆ Sat., Dec. 12, 1970

Mushroom Mistake Kills Retired Chef

(d)

Ermete Lavino, a retired chef who had picked and eaten wild mushrooms since he was a 12-year-old boy in Italy, died late Thursday at Kaiser Hospital in Terra Linda

University of California in Berkeley said Mr. Lavino, who lived at 12 Savanah road in San Anselmo, had eaten a deadly mushroom variety called amanita phalleides.

4 San Francisco Chronicle ☆☆ Sat., June 19, 1971

Biochemists

Cyclic-AMP --Why It's So Important

(e)

By David Perlman
Science Correspondent

BUY WORD

from Home Economist, HELEN BLACK

(c)

MOLDY BREAD IS STILL A NO-NO

Advertisers are now burbling "there's no preservatives in our product!!!" and I suppose the money is just pouring in. After all, people are panicked about chemicals in foods, these days. Advertisers have responded quickly. But they don't necessarily tell the whole story. Take bread, for example. Is it better to have moldy bread than calcium proprionate?

... Rio Is Talking About ...

Fungus in the Coffee

By Leonard Greenwood
Times-Post Service

Rio De Janeiro

BRAZIL'S coffee industry—the largest in the world — is threatened by a fungus which wiped out the coffee industry of the Indian empire a century ago.

The fungus has already infected hundreds of millions of trees in about 70,000 square miles of Espirito Santo, Bahia and Minas Geraes states.

Frederick Wellman, one of the world's top plant pathologists, who was invited to Brazil from the United States to advise local

says Jose Maria Sebastiao, one of the country's experts. Sebastiao says there are more than 2.2 billion coffee trees in Brazil. In the affected area, there are 500 million though not all have been hit.

(f)

Other countries in South and Central America are watching Brazil's campaign anxiously. Coffee is a vital part of the economy of many Latin American states and there seems to be little to prevent the rust spreading.

The infestation has stunned Brazil. It is the first time rust has ever been found here. Tests indicate some trees have had it

Truffle-Hunting Pig Now Pork

By JOHN VINCOUR

CHACOLY, France (AP) — Marcel Pomeurel recalls fitting the knife blade in the soft folds of Minette's neck last winter and then doing the job he had been putting off.

Minette, a truffle pig, lived longer than she should have. She was an anachronism in a time when pigs are almost phased out of the truffle-hunting business which has come upon hard years.

On good days a decade ago, scratching and sniffing at the roots of stunted truffle oaks, Minette could unearth 45 pounds of the gnarled, pungent black tubers that the French think of as the most

"The government has recently gotten around to helping with a $150,000 grant for research. And the truffle world has an unusual patron in Sylvain Floirat, a self-made multimillionaire whose holdings in France include the private radio station Europe No. 1.

Floirat is 72 and came from the Perigord region. He has plowed big sums into an experimental plantation with varieties of oaks planted in various types of soil.

"Some people say truffles are aphrodisiacs — Napoleon thought so — but the real excitement is in seeing if we can bring some rationality to their cultivation," Floirat says.

"It's very important too, in

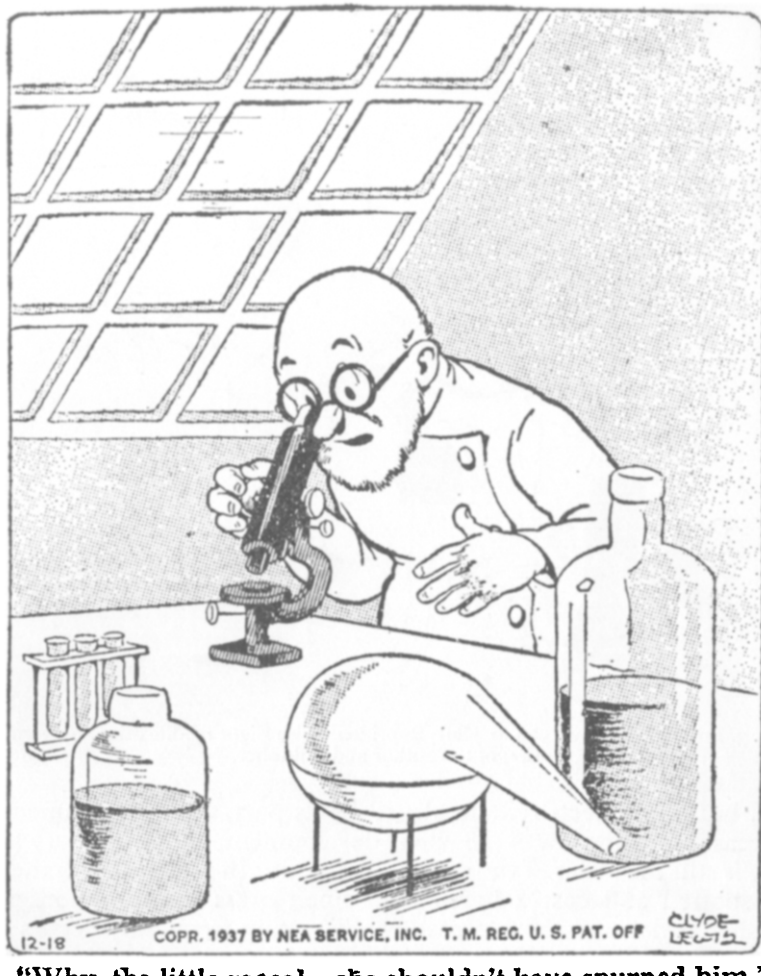
Most of the adv farmers so far is more oaks. If they' rules for planti should in theory be 10 years.

Pomeurel, sit kitchen with a gla settie in hand, is Pointing to a field laces were bursting,

(g)

"My father plan out there 30 years there's never been Everybody around the ground is worn flex mostly, I'm stil some truffle chips in the pig's food, hoping the taste. But the y are no better then trees. I worry mo about planting tree

Fig. 1. News headlines referred to in the text. (*a*) upper left, *San Francisco Chronicle* 11 Aug. 1970, p. 1; (*b*) centre left, Tatum (1971, p. 1113); (*c*) lower left; Black (1971); (*d*) upper right; (*e*) centre right; (*f*) lower right, Greenwood (1970); (*g*) bottom, Vincour (1971). (*a*), (*d*), (*e*) and (*f*) by permission of the *San Francisco Chronicle*; (*b*) copyright 1971 by the American Association for the Advancement of Science, by permission of the author and publisher, (*c*) by permission of the editor of *Co-op News*; and (*g*) by permission of the Associated Press.



"Why, the little rascal—she shouldn't have spurned him."

Fig. 2. Student's-eye view of the author doing 'irrelevant' mycological research on the sexual behaviour of a water mould. This has also been referred to as 'Underwater Kinsey'. Reprinted by permission of Newspaper Enterprise Association, Cleveland, Ohio.

focused as a result of those very student outpourings which began in 1964 with the 'Free Speech Movement' at Berkeley and brought world-wide attention to our university in California. Indeed many believe that Berkeley was to blame for starting the entire episode. Certain it is that we were not alone, for, in the years that followed, the general unrest of young people spread to the four corners of the earth, and quite aside from each man's opinion about the rights and wrongs, the effects were deeply felt and are likely to be long lasting. I shall not dwell upon the loss of university presidents, chancellors, and assorted lesser administrative lights. At some institutions such positions rotated so rapidly, the personalities became a mere blurr. The details of how the ferment waxed and waned are already

Fig. 3. From Parsegian (1969, p. 380). Reprinted, with slight modification, by permission of the author and publisher.

fading, but two aspects remain clear; for its part, the establishment took an increasingly dim view of the whole development, and retaliatory budget cutting is still the order of the day in California; the students, on the other hand, spotted and cast a harsh light upon gross contradictions in the established order and the confused thinking that frequently occurs in the highest places (Fig. 1*a*). Nor were they prone to spare the lash when it came to their mentors. There was much for educators to ponder deeply. Students shouted raucously for participation in the planning of their education and called increasingly for relevancy in their studies. Man's world, they said, was on the point of collapse from over-population, crass greed, and total disregard of the fundamentals of ecology. What, they demanded, were their professors doing about it!

Under these circumstances, even the most single minded of mycologists must glance up from his test tube or microscope and gaze about. I recall with some pain a particular afternoon during the last of the Berkeley upheavals in the spring of 1970, for it was on one of these days that the patience of my own students appeared to run out. They accused me in ringing terms of wasting my time with basic research and narrowly conceived teaching. Who was I (Fig. 2) to pursue the sex life of water moulds while the world was about to collapse? Much disturbed, I mumbled some platitudes about the social benefits of pure science. No one listened. The atmosphere was charged with cross currents – Viet Nam,

the SST, the elections, what to do about Earth Day. But back at my desk I found it impossible to accept the charge that had been levelled at me. My eyes wandered from posted charts of Teaching Assistant assignments, course loads, and the first budgetary cuts, to some of the mycological books I most enjoyed. Ranged along the shelves at my elbow were such old favourites as the Rolfe's (1926) *Romance of the fungus world*, Christensen's (1965) *The molds and man*, Large's (1940) beautifully written *Advance of the fungi*, and Ramsbottom's (1953) intriguing and superbly illustrated *Mushrooms and toadstools*. Other titles even had the ring of great practicality. George Smith's (1969) *Industrial mycology* was there along side of Gray's (1959) imposing technical volume on *The relation of fungi to human affairs*; T. A. Britton's (1875) old treatise on *Dry rot in timber* was next to Ramsbottom's (1937) fascinating account of *Dry rot in ships*. Could the students really believe that *Mycology is irrelevant* (Fig. 3)?

It occurred to me then that what we needed was an undergraduate course which dealt with the ideas in these books and others like them. Not a technical account of the fungi with their human implications squeezed in, but a running story of fungi and mankind with whatever minimum mycological technicalities had to be provided. The more I thought about it the more certain I became that the immediate relevancy of basic mycology can be demonstrated in this fashion to all comers whether they be sceptical freshmen, legislators, hippies, establishmentarian alumni, Science Foundation Directors, or John Q. Public. Here this afternoon, then, I shall consider with you a few selected examples of *relevant* problems, often with both old and new facets, that involve fungi and man in the way I am talking about. According to my own predilections and interests, I shall mention some special people, places and episodes of mycological history along the way. I have not attempted to make this account (or my bibliography) truly international – which of course it should be – because the field is very large and our time here as well as my own linguistic abilities are equally limited. I leave it to others to contribute gems from other lands.

FUNGI, FOOD AND WASTE

I shall begin with the most obvious and spectacular aspects of moulds and man. We are fortunate that Carefoot & Sprott (1967), in their exciting volume, *Famine on the wind*, have told such a vivid story of major events in *Man's battle against plant disease*. Placed in a setting of world population growth and food shortages, this book is a particularly fine addition to Large's (1940) account written some thirty years ago. With such material available no student can miss the urgency and immediate relevancy of plant pathology to mankind. From his earliest agricultural efforts right into the nineteen-seventies man has battled against fungal pathogens. Moreover, every thinking person in the world today must be concerned about the interaction between modern man and the environment of our planet, and one major component of this interaction is compounded out of the annual $25 billion world crop loss from plant disease (Cramer, 1967, p. 483) and the farmer's efforts to counteract this staggering blow by every means at his disposal. Hardly a week goes by without news reports

"Hello! What's this? 'Caution: Ingestion of This Mushroom May Be Hazardous to Your Health.'"

Fig. 4. Drawing by Geo. Price; copyright 1968, the New Yorker Magazine, Inc.; from the *New Yorker*, 17 September 1968 (vol. 44, no. 29, p. 25) by permission of the publisher.

highlighting these interwoven problems. Paddock (1970), and others, have asked: 'How Green is the Green Revolution'? Will the new races of wheat and rice that are now feeding millions in Latin America and the Orient suddenly succumb to new races of fungi? Articles (Gruchow, 1970; Tatum, 1971) in *Science* (see Fig. 1*b*) stress an immediate object lesson to be seen in the current corn (maize) blight in the U.S.A., while the News Report of the National Academy of Sciences in Washington focuses upon the identical problem with an analysis headed 'Research panel examines genetic vulnerability of crops – how narrow is the base?' (Tufty, 1971). According to these reports, some 10% of all U.S. maize was lost to the new race of *Helminthosporium* in 1970, and the destruction ran as high as 50% in some southern states. In the U.S.A. nearly all corn is hybrid and 90% of the hybrids now grown carry the male-sterile gene that obviates expensive hand-detasselling when crosses are made. Susceptibility to the new *Helminthosporium* is linked to male sterility!

In July of 1970 a local San Francisco paper (Fig. 1*f*) carried an account of the spread of coffee rust (*Hemileia vastatrix*) in Brazil, the largest coffee producer in the world today. Will this fungus destroy the coffee economy of Brazil as it did that of Ceylon 100 years ago? Woodham-Smith (1962) has devoted an entire volume, *The great hunger, Ireland 1845–1849*, to the devastating and infamous Irish potato famine caused by *Phytophthora infestans* in the last century, an event which altered the course of British history and made a lasting impact upon American politics. These and other landmarks in the history of plant pathology have recently been reviewed by Klinkowski (1970) in a summary of *Catastrophic plant diseases*. Surely no one, student or non-student, can fail to recognize the relevance of plant pathogens in the world of the nineteen-seventies.

Making an abrupt about-face, we may turn for a few moments now to the whole joyous topic of man's delight in eating fungi through all the ages. For, whatever else their inclinations, over the centuries students have always relished their food and wine. Mushrooms, truffles and morels are particularly *in* today with a variety of young people whether they are gourmets, food faddists or, as we shall see later, seekers after Nirvana. With their orientation toward nature and their concern about the environment, they will gather enthusiastically at the mere suggestion of a mushroom collecting trip. Interest in mushroom identification then becomes a matter not only of great relevance but of life and death – or at least an upset stomach (Fig. 4) – as the fascination of mushroom toxins and poisons unfolds. 'In America', so an old joke runs in *Punch Magazine*, 'a man acquired a fortune from mushrooms. At least his wealthy relative thought they were mushrooms.' In December of 1970, on the eve of the annual Mushroom Fair at the California Academy of Sciences, the local papers headlined (Fig. 1*d*) the death of a French chef, long a collector and devotee of the San Francisco Mycological Club. Under such circumstances, by no means unusual, mycology takes on a very poignant and personal significance, and it is only a step to tales of murder, poison mysteries, and the Borgias (Wasson & Wasson, 1957). Then there is the outlandish expense and wonder associated with those little potato-like fungi under the ground. Lavishly reproduced colour photographs in the latest *Life Magazine Cook Book* (Claiborne & Franey, 1970, pp. 52–55) show M. Robert Leygonie in Perigord setting forth for a day's truffling with his prize sow. At $20 a pound (wholesale) these fungi will bring the collector a golden harvest. But in May of 1971 an article in *Time Magazine* (Fig. 5*c*)* is headed 'No Truffling Matter': it reports that M. Leygonie is not so well off after all; there is a mysterious decline in the truffle crop, only 40 tons per annum, whereas it was closer to 2000 tons a century ago. And a month later, alas, the *Oakland (California) Tribune* (Vincour, 1971) cries 'Truffle-Hunting Pig Now Pork' (Fig. 1*g*). Shades of truffles shipped from North Africa for the tables of Roman Emperors; dreams of would-be modern mycologists discovering how to culture the golden harvest; scientific study of that wonderful symbiosis revealed in the mycorrhiza. And so it goes, each facet of the tale more relevant than the last.

Happily, Professor William Gray's concern with fungi and mankind has

* Figs. 5 and 12 are half-tone plates, see end of article.

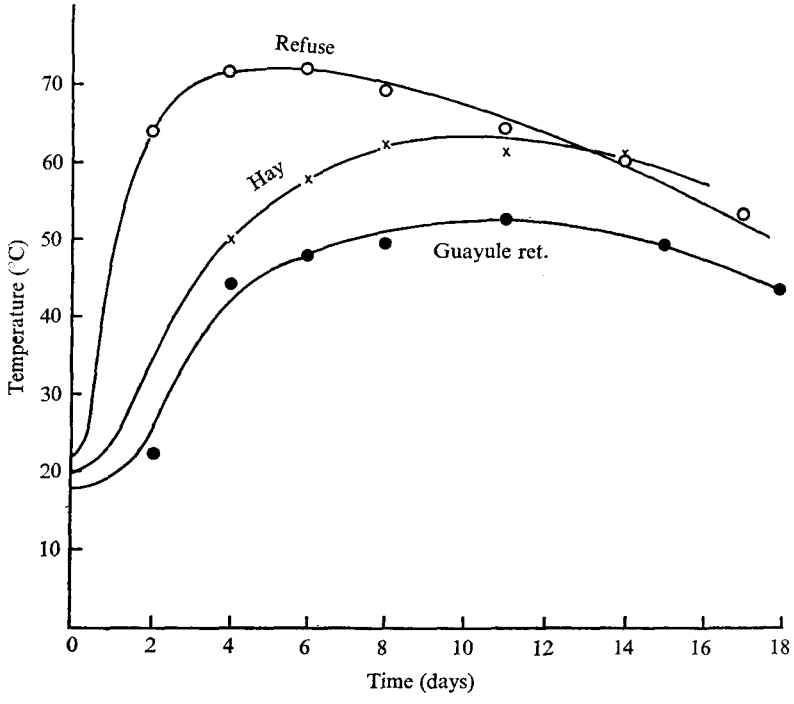


Fig. 6. Representative curves showing the time course of microbial thermogenesis in large masses of self-heating organic materials. Refuse, redrawn from Golueke and Gotaas (1954, Fig. 2); Hay, redrawn from Hüni (1954, Abb. 1); Guayule ret, data for defoliated, baled, whole shrub (from Ralph Emerson and P. J. Allen, unpublished).

not flagged and we have at hand his latest review (1970) of *The use of fungi as food and in food processing*. Despite its anomalous publisher (the Chemical Rubber Co.), its missing index, and its high price ($13), its 110 pages are packed with information from modern commercial mushroom growing to the curing of mould-ripened cheese and the mass production of single-cell fungi for protein in order to solve, perhaps, the dietary deficiencies already troubling half the world. Hesseltine's (1965) *Millenium of fungi, food and fermentation* provides detailed information on tempeh, sufu, miso, and a variety of other fermented foods that have been processed by fungi in the Orient since time immemorial. There are already strongly developed interests among many young people in the western world to concoct their own preparations of these tried and ancient foods, and various ones (e.g. ragi, funyu, etc.) are already for sale in local markets. Many more details on fungi as food appear in Singer's (1961) *Mushrooms and truffles*, and people young and old become ecstatic over the wealth of glorious illustrations of fleshy fungi to be found in such current books as those by Boedijn (1969), Kleijn (1965) and Lange & Hora (1964).

Another aspect of fungi that cannot fail to challenge today's students is the matter of *waste*, both the prevention of food and fibre waste from moulding and the purposeful disposal of solid waste by moulding and

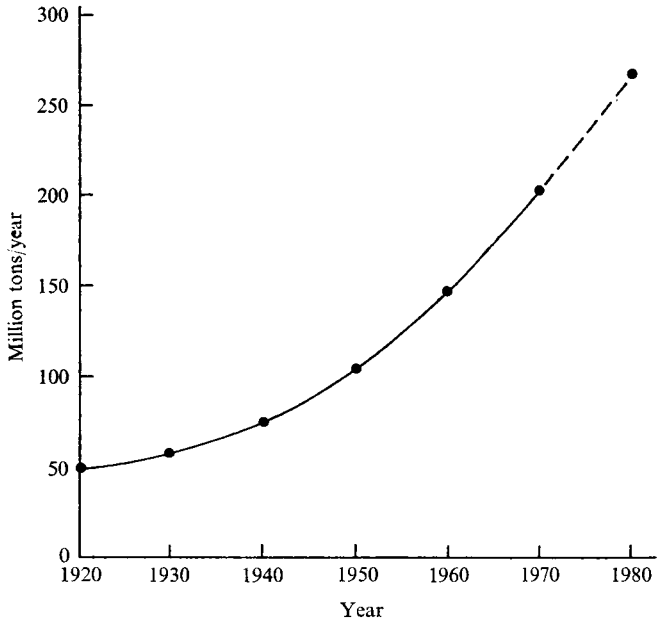


Fig. 7. Refuse production in the U.S.A. Redrawn from Meller (1969, Fig. 1).

composting. I like to recall that this large and complex topic is all held together by the discoveries of Hugo Miehe (1907, 1930) (Fig. 5*a*), the German botanist who set out to explain and control the heating and spontaneous combustion of damp hay around the turn of the present century. He, more than any other investigator, is responsible for revealing the role of thermophilic fungi (Cooney & Emerson, 1964) as well as other micro-organisms in the microbial thermogenesis of large masses of organic matter (Fig. 6). The principles he enunciated can be applied today to the continuing problem of barn fires, to the heating of improperly dried and stored grain, to the outdoor storage of mountainous piles of wood chips awaiting pulping (Fig. 5*d*), and to all sorts of large-scale composts whether for mushroom growing (Fergus, 1964) or solid waste disposal (Golueke & Gotaas, 1954). These and other similar industrial operations depend upon fungi for their success or failure. Prevention of moulding and heating of stored grain is a problem of such great practical importance it is surprising that the first book on the subject appeared only recently (Christensen & Kaufmann, 1969). The heating and spontaneous combustion of wood chips (Tansey, 1971) has, on the other hand, become critically important only in the last decade so that reading in this area must be done in the journals. One of the world's mammoth lumber and pulp companies (Weyerhauser Co., U.S.A., personal communication) was plagued by a continually smouldering fire in its stored chips at Eugene, Oregon, for 14 months. The tonnage of wood destroyed or deteriorated by this sort of action is well worth careful consideration by those who ache for the loss of virgin timber throughout the world. Whereas the great

wooden navies of old (Ramsbottom, 1937) were undoubtedly responsible for deforestation of large areas of Europe, newspapers, paper bags, cardboard cartons and countless other woodpulp products account for square miles of timber today. It has been aptly remarked (Dean, 1970, p. 21) that 'the person ... who found a way to prolong the life of a railroad tie probably saved more forests than anyone doing the more exciting and satisfying job of saving a redwood forest'. The same may be said some day about the mycologist who learns to control large-scale microbial thermogenesis.

Having used the newspaper, the box, or the bag, modern man wants to dispose of it. As his numbers increase, so is he burying himself further in his garbage (Fig. 7). The wise elimination or recycling of organic solid waste is another looming headache for the conservationist and the environmental seer. Despite its almost total lack of organization, its complete lack of an index, and its tiresome repetitiveness, *Garbage as you like it* (Goldstein, 1969) is a genuine plea for composting as a solution to the problem. Many of today's students, along with their interest in organic gardening and natural living, are devotees of natural fertilizers and the garden compost pile (Rodale, 1969). They are often in great need of some simple instruction in plant nutrition (Galston, 1972), but there is no holding them when they discover the pervasive role of fungi in the entire process of waste elimination and recycling. A visit to a local refuse disposal site, especially if it is a large municipal one (San Francisco handles 2000 tons a day) with imaginative leadership, is instructive in many ways. The relevance of mycology will never be forgotten. Recycling is another *in* word and it cannot be divorced from *fungus*.

MOULDS AND MOLECULES

As an interlude of quite a different sort, we might consider the fungi in an era of biological molecules. What can we do for the student inclined toward biochemistry? There is a vast array of possibilities. The fungal antibiotics alone have had such an impact upon health practices and mortality figures throughout the world that their relevance hardly needs emphasis. Every thinking person should appreciate the direct relationship between these 'wonder drugs' and the population explosion. Surely, as the *National Reporter of Zero Population Growth* captioned its February, 1972 issue (vol. 4, no. 2): 'The population mushroom is everybody's toadstool'. Less easily apparent is the fact that the present comparative lack of broad spectrum antibiotics against the fungi themselves is one of the stumbling blocks in the path of certain of the present trends in modern medicine. It is impressive, for example, to learn that the much publicized medical treatment by human organ transplant may be stalled by pathogenic moulds that attack patients whose resistance to foreign invaders – as well as foreign organs – has been broken down by immunosuppressant drugs. The picture has been summarized thus in a current review article (Spencer, 1971, p. 477): 'Unless the problem of imposed fungus infections is resolved, it will jeopardize the use of many of the newer life-saving treatments (organ transplants, deep irradiation, steroids, etc.) in many cases.'

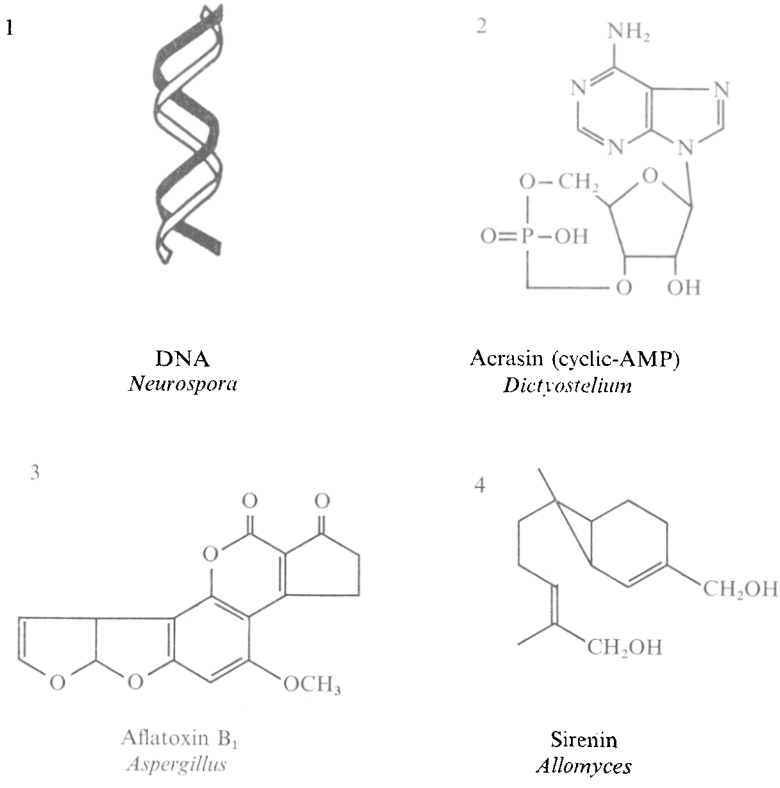


Fig. 8. Four famous molecules and their associated moulds.

However, it is my purpose here to speak briefly of a kind of mycological relevance that is often overlooked, the purely mycological study whose relevance was ignored because it came about long after the basic work of the mycologist was done. Such, for example, is the tale of DNA (Fig. 8) and the red bread mould *Neurospora*. Nearly every school child today can tell you about the DNA helix and its central role in the marvellous molecular mechanism that is life. It is already easy to forget that a cardinal step toward DNA was the Nobel-Prize-winning idea of 'one gene, one enzyme', whose proof was worked out by the geneticist Beadle and the biochemist Tatum (Beadle & Tatum, 1941; Beadle, 1946) with the fungus *Neurospora*. Never, however – well, *hardly* ever (see Rogers, 1949) – is it recalled that the availability and remarkable suitability of *Neurospora* as a genetic tool depended in the first instance upon the pioneering research done by one of America's great mycologists, Bernard O. Dodge (Dodge, 1927; Shear & Dodge, 1927; and papers cited in Rogers, 1949).

Another, most extraordinary mould-molecule association came to light only very recently. The mycological part of the duet began in a delightfully obscure way by publication in the 'Collecting Net' (a journal of the Woods Hole Marine Biological Laboratory) of a half-page report by a

young Associate Professor from Agnes Scott College, Ernest H. Runyon (1942), summarizing his summer project on 'Aggregation of separate cells of *Dictyostelium* to form a multicellular body'. It ended 25 years later with a contribution to the *Proceedings of the National Academy of Sciences, Washington*, by Theo Konijn, John Bonner, and their associates (1967, also 1968) showing that acrasin – the substance hypothesized by Runyon and named by Bonner – is none other than CAMP, cyclic adenosine monophosphate (Fig. 8). What is extraordinary is the quite separate history of CAMP in biochemistry and animal-human physiology, started 10 or 15 years later and involving investigators who knew little about mycology and probably never heard of the cellular slime mould *Dictyostelium*. The amazing current relevance of this small molecule (Fig. 1*e*) to medicine and man's well being is amply documented by the two imposing volumes devoted to it just recently (Greengard & Costa, 1970; Robinson, Butcher & Sutherland, 1971). From bacteria to man CAMP is involved in cell growth and behaviour, the activation of hormones, the synthesis of enzymes, and the expression of genes, and its possible role in cancer is being explored. This very morning (13 September 1971) we have learned that E. W. Sutherland has received the Nobel Prize for his biochemical investigations of cyclic AMP. It is particularly noteworthy for us here that Runyon was observing the effects of this molecule on a cellular slime mould 30 years ago. Moreover, the mycology of *Dictyostelium* and the concepts of acrasin activity were brilliantly developed immediately thereafter by Kenneth B. Raper, John T. Bonner, and their students and associates (see Bonner, 1967). Indeed this extraordinary union between mould and molecule is discussed by Bonner (1969, p. 78) in his article on 'Hormones in social amoebae and mammals' in these words. 'One of the pleasures of science is to see two distant and apparently unrelated pieces of information come together. In a flash what one knows doubles or triples in size.' This is not only a beautiful expression of the joy of the scientific method, it is a bit of mycological relevance to be well remembered.

Aflatoxin–Aspergillus is my third combination. The molecule (Fig. 8) is a relative newcomer that arrived with a bang in the past decade, so that Goldblatt's (1969) book, *Aflatoxin, scientific background, control and implications*, could include reference to hundreds of articles on this highly toxic chemical and its widespread effects upon man and animals. In his preface the author says: 'The presence of mould toxins is potentially the most serious quality problem which faces producers, manufacturers, and handlers of food and food products.' Most mycologists will recall the circumstances which led directly to identification of aflatoxin: turkey-X disease and 100000 dead poultry in England in 1960, similar fowl 'epidemics' in Africa, mass death of trout in America; all showed hepatomas but no evidence of any disease-causing micro-organism; all turkey feed used at stricken farms in Britain traced to one producer and all shown to contain mouldy peanut meal from Brazil; toxin found in the meal and traced to *Aspergillus flavus*; four different aflatoxins chemically characterized by 1963! This is a most remarkable tale of mycological relevance and the co-ordinated efforts of scientists from various disciplines. We must never forget that, like the discovery and elucidation of penicillin, the

association of aflatoxin and *A. flavus* depended upon the superb monographic studies of the genus *Aspergillus* by Charles Thom, Kenneth B. Raper and Dorothy I. Fennell (Raper & Fennell, 1965). For the young, who sometimes seem to subsist entirely upon peanut butter, the causal relation between aflatoxin and certain types of cancer is impressive. Moreover, in an editorial headed 'Federal support of cancer research', Abelson (1971) pointed out that 'primary cancer of the liver may be as much as 500 times more frequent in the African population of Mozambique than among black people in the United States. The probable cause is aflatoxin. . . .' Meanwhile, dozens of other fungal toxins are being run down and their overall significance in human food and health is being assessed all over the world today (Ciegler, Kadis & Ajl, 1971; Hesseltine, 1969). Furthermore, any consideration of mouldy food inevitably opens up the whole problem of food preservatives and additives in general, a topic that often engenders more heat than light among natural food devotees, who need to appreciate the immediate relevance of mould control in the storage and processing of their own foods (see Fig. 1*c*).

Now for obvious reasons (Emerson, 1955), I shall close this chapter with a few words about a molecule that has not yet reached the limelight. You may remember that Hans Kniep's (Fig. 5*b*) last two research papers (1929, 1930), just before his brilliant career was closed by an untimely death, described his discovery of a unique kind of sexuality and alternation of generations in a water mould. Like much of Kniep's research, these observations might be considered today irrelevant in the extreme. He even foresaw the possibility of hybridization between the epigynous *Allomyces macrogynus* and the hypogynous *A. arbuscula*, a development we were able to report some years later (Emerson & Wilson, 1954). We showed that the mechanism controlling sexual differentiation in these hybrids was so disturbed that some were nearly pure female whereas others were virtually pure male. One might say – as my students had so roundly – that these observations were still irrelevant were it not for the fact that they become almost immediately of the greatest importance to my colleague, the plant physiologist Leonard Machlis. In 1956 he started looking for the hormone which he predicted was being formed by the female gametes and attracting the male. It was essential that he have 'female plants' to produce the hormone, and 'male plants' to produce the male gametes, for the ingenious assay he developed. Some 12 years and several hundreds of thousands of dollars later Machlis and his colleagues (1968) were able to report the structural chemical formula of sirenin (Fig. 8), the first plant sex hormone to be so characterized.* Some will hold that the matter is *still* irrelevant. Possibly so, but why then have several prestigious laboratories around the world – London, Tokyo, Berkeley – been busily synthesizing sirenin and its analogues? Who is to say (Fig. 9) what pill or wonder drug or mind twister may not come of a molecule that has such profound effects on a water mould?

* Another fascinating tale of interaction between mycology and chemistry can be told regarding antheridiol, the sex hormone from *Achlya*, demonstrated years ago by John R. Raper (1939) and just recently chemically defined by Barksdale (1969) and her associates in New York.

"We figure they may hit on something."

Fig. 9. Copyright 1970, The Consumers Union, Mount Vernon, New York: from *The Medicine Show*, revised ed. 272 pp. (Consumer Reports, 1970, p. 146), by permission of the publisher.

MUSHROOMS, MYTHS AND MIND

And that brings me to the third part of my story, for who can deny the fascination and delight associated with the folklore of the fungi? Whether it be leprechauns, Beatrix Potter's *Tales of Peter Rabbit*, or *Alice in Wonderland* (Fig. 10), toadstools and mushrooms have played a central role in man's myths through the ages. Poets, writers, painters, and mystics have, it is well known, been particularly taken by what mushrooms can do to the mind, and the present generation of young people sometimes seem as if they were each and every one a poet, a painter, or a mystic! What, I ask you, could be more relevant to students today than the effect of mushrooms on mind? There have been some fascinating books written on this subject in the past 15 years. First, of course is the Wassons' (1957) *Mushrooms, Russia and history*. I only regret that this beautiful two-volume work, which was $125 in the original limited edition, is now worth $300 or $400 and never was really available to most of us let alone the perennially impecunious student. Some enterprising publisher should certainly re-issue these books in an inexpensive edition, preferably paperback. There followed Puharich's (1959) *Sacred mushroom, key to the door of eternity* and a second gorgeous limited edition by Wasson (1968), *Soma, divine mushroom of immortality*. The latter sold for $200 and would have been largely unknown had not a $15 hardback (Wasson, 1971) been provided soon after. These volumes deal with a large complex of interrelated subjects involving linguistics, theology, mythology, anthropology, psychology and chemistry as well as mycology. The argument goes somewhat as follows. From the most ancient times right to the present day (Wasson, 1957; Hoffer & Osmond, 1967; Schultes, 1969) in many different parts of the world, man has sought visions with the hallucinogens of mushrooms, probably first

Fig. 10. Drawing by Fisher; copyright 1963, The New Yorker Magazine, Inc.; from the *New Yorker* 19 October 1963 (vol. 39, no. 35, p. 132) by permission of the publisher.

with *Amanita muscaria* and perhaps later *Psilocybe* and others. For millenia he has believed that these mushrooms allowed him to know God's will. So a series of widespread and varying rituals have been developed in which the mushroom became essentially a holy sacrament. Thus Wasson (1968), as have others before him, proposes that hallucinogenic mushrooms were at the very heart of the great religions, including Christianity, witness, for example the thirteenth-century French fresco at Plaincourault in which

Amanita muscaria appears to figure (Ramsbottom, 1953, pl. 1) as the tree of good and evil in the Garden of Eden.

The latest and most extreme treatise in this series of books is by an Englishman who holds the title of lecturer at the University of Manchester and is reported to be among the select group of scholars studying and interpreting the Dead Sea Scrolls. John T. Allegro (1970) goes to great lengths in his *Sacred mushroom and the cross*, happily available in paperback, to convince his readers that Christianity itself is an outgrowth of ancient Sumerian fertility rites based in turn directly upon mushroom cults. He claims that the New Testament is largely double talk designed to hide the early Christian mushroom rites from the establishmentarian Romans! Whatever the final verdict on this subject may be, among young people of the 1970's it is relevance with a capital R. To associate these concepts with serious mycological teaching will take sensitivity and tact. One of my colleagues recently recommended *The sacred mushroom* as interesting collateral reading in a general botany class, only to discover that at least one young lady found the author's interpretations highly offensive. I could not help thinking it is a fortunate circumstance that no hallucinogens have yet been discovered in the stink-horn fungi. Who knows where such a combination might have carried our mystical ancestors!

As a final episode I shall turn now to *Claviceps*, for, with its tragic history of epidemic poisonings of animals and man, its use for centuries in childbirth, and its many modern applications to such disturbances as migraine headaches, the case for relevance of ergot is a favourite one. But when Albert Hofmann somewhat inadvertently discovered in 1943 (Stoll, 1947) what a minute amount of LSD would do to his perceptive faculties, the relevance of ergot was writ large for the student drug scene which was not to appear for another twenty years. Moreover, on a summer day in 1951 in Pont-St-Esprit, a quiet little town in France, the tragic significance of ergot appeared in quite a different setting. Several townspeople died, dozens were hospitalized, and many remain crippled to this day. Fortunately the event, which made headlines in all the major news media of the world (e.g. *Life Magazine*, 10 September 1951), has been chronicled in a superb and gripping documentary novel, *The day of St Anthony's fire* by an American author, John G. Fuller (1968*a*) With a penchant for tracking the incredible in science,* Fuller analysed the tragedy in France person by person and day by day. The poisoning was quickly traced, and no one ever seriously denied it, to bread baked in the town. Although flour was distributed under government supervision, there was endless argument as to the nature of the toxin, and no compensation was ever received by the people of Pont-St-Esprit. In a decision handed down by the Supreme Court of France nearly 14 years later, it was maintained that only those who could demonstrate that they had been poisoned by mercuric fungicide would be compensated. Bové (1970, p. 160) in his recent, indexless, strangely journalese account, *The story of ergot* published in Switzerland, dismisses the entire matter thus: '...toxicologists issued

* His *Incident at Exeter* concerns reports of an unknown foreign object at Exeter. This seemed prophetic to me until I discovered it was Exeter, New Hampshire, not Devonshire!

a report stating that the cause was an organic phosphorus preparation used to spray the grain.' According to Fuller (1968*a*, *b*), however, who lived for many months in Pont-St-Esprit, contacted all the survivors of the poisoning, and talked with many other people who had been involved, medical specialists who were consulted believed the spectacular symptoms were due to ergot poisoning, not mercury or organic phosphorus. Besides the classic ergot symptoms of gangrene and convulsions, resulting directly from known natural alkaloids of *Claviceps purpurea*, many of those who ate the bread suffered persistent and terrible hallucinations or sleeplessness. Some had to be forcibly restrained from jumping from high places, the town bridge, the upper stories of the hospital. These symptoms were more like those brought on by minute amounts of Hofmann's new drug. Indeed, after weighing the massive evidence he had uncovered, Fuller (1968*a*) concluded that the latest French tragedy and possibly many of the devastating earlier ones (Klinkowski, 1970, reports that 40000 people died in the Limoges district in 994 A.D.) were due to traces of lysergic acid diethyl amide or some equally toxic derivative of the ergot-produced lysergic acid nucleus. The last sentence in his book (1968*b*, p. 301) is this: 'But, as one doctor expressed his opinion: "There is one and only one cause of the tragedy: some form of ergot, and that form has logically got to be akin to LSD."'

We are still left with a most intriguing mystery. If LSD was involved at Pont-St-Esprit, where did it come from? You will recall that, so far as we know at present, LSD is not a natural ergot product (Taber, 1967);* it has only been synthesized in the laboratory. Whereas *Claviceps paspali* on *Paspalum* sp. does produce lysergic acid amide (Fig. 11), a much milder hallucinogen, *Claviceps purpurea* produces no known hallucinogenic drugs. Where, then, would LSD or some equally potent inducer of hallucinations have come from in those damp summers in France in 1951 and past centuries? Does *C. purpurea* under exceptional environmental circumstances convert traces of its own lysergic acid to LSD? At Berkeley Richard Mower, a graduate student in Plant Pathology, is making an intensive study of the host–parasite relations and metabolism of *Claviceps*. He points out that in damp weather various secondary moulds can be found growing upon the ergots in the field. He has often seen orange coloured *Fusarium* spp. and other hyphomycetes. It is his suggestion (R. Mower, personal communication) that one or another of these secondary invaders may be converting one of the natural, lysergic-acid-containing alkaloids (e.g. ergotamine, Fig. 11) to an LSD-like substance. If this is so, it will open a whole new basis for appraising the ergot epidemics of the past and avoiding them in the future. If ever a student was to be persuaded of mycological relevance, here is a tale to do so. Here too is a possible way to get young people to ponder the fantastically delicate and beautiful chemistry of their own minds (McGeer, 1971) and the pitfalls to be considered in todays 'Drug Scene' or the joys implicit in these

* This is contrary to the statement made by Christensen (1965, p. 215) that 'D-lysergic acid diethylamide (LSD) is present in the ergot fungus, *Claviceps purpurea*, and produced or elaborated by some other fungi also.'

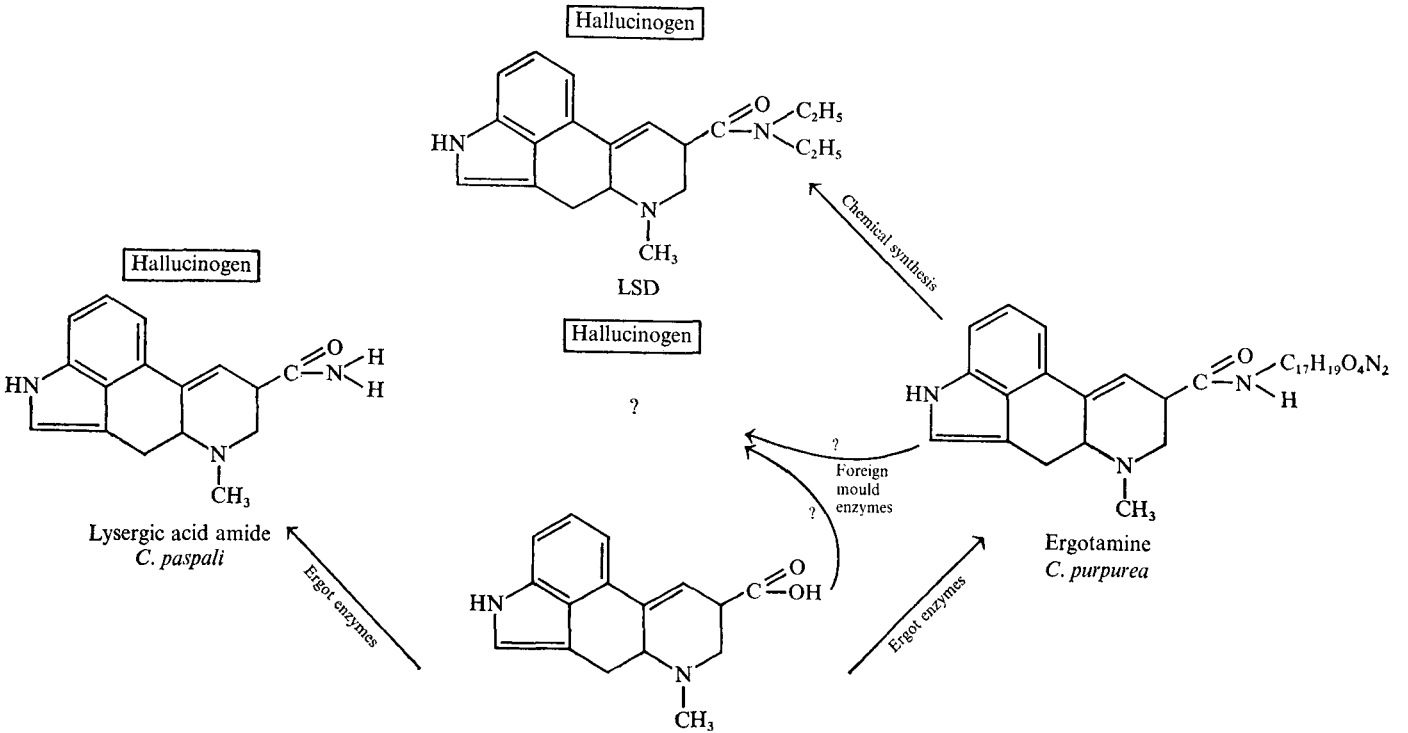


Fig. 11. Whither the ergot? Do the enzymes of foreign moulds convert alkaloids of *Claviceps purpurea* into traces of potent hallucinogens?

charming verses from a poem, *Psychedelics*, by F. W. Hanley (1964 quoted here by special permission of the author and publisher).

Give me a chalice of lysergic
To quaff when my day is done
That I may get a perceptual kick
From my diencephalon.

So ho! let all resistance down
For a transcendental glance,
From the superego's frosty frown
At the cosmic underpants.

Give me a pinch of psilocybin
To sprinkle in my beer
That my psychopathic next-of-kin
May not seem quite so queer.

So hey! it's off for the visions bizarre
Past the ego boundary,
For a snort at the psychedelic bar
Of the new psychiatry!

F. W. Hanley, M.D.

CONCLUSION: RELEVANCY OF RESEARCH AND TEACHING IN MYCOLOGY

It seems quite clear to me, and I hope to all of us here today, that there can be absolutely no question about the fundamental relevancy of mycology. Whether we are talking to students or law-makers, to budgetary officers or presidents, it should be easy to convince them that knowledge of the fungi has brought and will always continue to bring great benefits to mankind.

Not so simple is the matter of basic or pure research. Personally, I still agree wholeheartedly with the Professor at the University of Colorado Medical Centre who wrote (Pearlman, 1971): 'Nothing will stifle the development of new advances more effectively than the deliberate channelling of young scientific minds into the tunnels of activity that strike some people as important in terms of today's immediate urgencies.' I am reminded here of a delightful tale about Roland Thaxter who, so the story goes, was addressing a Boston Ladies Club long years ago on his superb researches into the technicalities of the Laboulbeniales. Weston (1933, p. 83) has characterized Thaxter as 'a man of great dignity and self restraint,' and yet when at the close of the lecture an irate dowager rose to inquire of Professor Thaxter what possible practical application his studies might have, he drew himself up to his full austere height and replied, 'None, thank God, madam'. Today we can certainly sympathize with J. R. Krevans, the Dean of Academic Affairs at Johns Hopkins University Medical School, who told the gathering at a recent colloqiuum on medical education (Krevans & Condliffe, 1970, p. 233): 'I am concerned lest the university become so responsive to society that it loses its ability to make its unique contribution.' 'I am concerned with the term *relevance*. It is the irrelevant part of basic science that is the most exciting and, potentially, the most useful.'

Table 1. *Outline of 'moulds and man', an undergraduate course, without prerequisites, offered at the University of California, Berkeley*, 1972

Week	*Lectures*	*Exercises*
Part I. Mushrooms and Man		
1	Mycological relevance, 1972 Mushrooms, structure and growth Mushrooms as fungi	Laboratory: mushroom parts and their use in identification.
2	Mushrooms in the field Mushrooms as food, industrial production Mushroom poisons	Field trip: mushroom collecting
3	Fungal hallucinogens and toxins Ergot and LSD Fungi and religions	Laboratory: keying mushrooms and fleshy fungi
Part II. Plant Diseases, rots, and rets		
4	Wood decay in homes and forests First examination Naval history vs. soil erosion	Field trip: commercial mushroom producer
5	Irish potato famine Rusts and smuts and more mildews Population *vs.* plant pathology	Laboratory: selected woodrot fungi and crop diseases
6	Storage rots, from field to home Composting, retting, combustion Garbage as you like it	Laboratory: local horticultural mildews, blights, rusts and food rots
Part III. Moulds in industry: makers and destroyers		
7	Holiday Second examination Fungal fermentations: bread, wine, beer and cheese	Field trip: municipal solid waste disposal facility
8	Acids, flavours, hormones and vitamins Human population and antibiotics Product destruction: electrical, optical paint and cloth	Laboratory: microscopic fungi in industry and deterioration
Part IV. Fungal partnerships		
9	Lichens: dyes and pollution Trees, truffles, and toadstools – mycorrhizae Fungi *vs.* worms and insects	Field trips: brewery and cheese factory
Part V. Moulds and man		
10	Skin fungi and deadly fevers Source of protein? Science: basic or applied?	Laboratory: fungi, insects, worms and man

We have, don't we, a sort of everlasting dilemma. Bentley Glass (1970) was right in that editorial from which I quoted at the start: we do need to train our students for both the 'timely' application and the 'timeless' fundamentals. This is our task and it has always been. It was well known to these dapper young gentlemen (Fig. 12) gathered at the Fifth International Botanical Congress 41 years ago in Cambridge, England. We can honour them here: John Ramsbottom for his lifetime interest and genius at promoting mycology in his writings; B. O. Dodge for his pioneering research on *Neurospora* as we have noted earlier; and W. H. Weston, America's greatest teacher of mycology. The message I have endeavoured to give you can be encapsulated in a story from one of

Weston's memorable lectures. He was completing his account of *Penicillium* and speaking of the blue and green citrus rots. It seems he was consulted in the early days by a shipper of oranges whose box cars were arriving in New York a solid mass of *Penicillium*. Weston, well aware that these moulds make their entry only through breaks in the rind of the fruit, was asked to inspect the shipping plant. At the end of the inspection tour he called for a hammer, pounded down a nail that projected into the shute down which every orange passed on its way to the packaging division, and took his departure. Later, when he submitted a bill for one hundred and one dollars, the shipper, now no longer troubled by mould, was only too pleased to pay but was puzzled by the specific amount of the charge. Weston's reply was prompt: the dollar was for pounding down the nail, the one hundred dollars was for knowing which nail to pound! 'Cap' Weston was always *relevant*!! May I urge each and all of you too to ponder further the everlasting question of mycological relevancy.

EPILOGUE

Between the time this lecture was presented and the written manuscript was prepared for publication, a course on 'Moulds and Man', along the lines proposed in my introduction, has indeed been offered at Berkeley in the Winter Quarter, 1972, and some 180 students enrolled. There were three lectures a week for ten weeks and a two-hour demonstration-laboratory or half-day field-trip exercise each week. Because there have been inquiries about the organization and coverage of such an offering, I am including here (Table 1) a class schedule in the hope that it will encourage others to try their hand. The reading for the course was in two parts: first, weekly assignments covering Christensen (1965), Kavaler (1965), and Orr & Orr (1962); secondly, an optional reading project chosen from one of the starred entries in the list of references.

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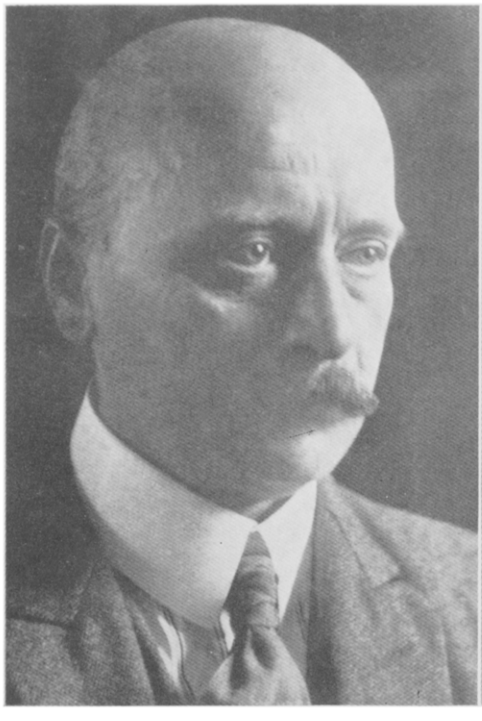
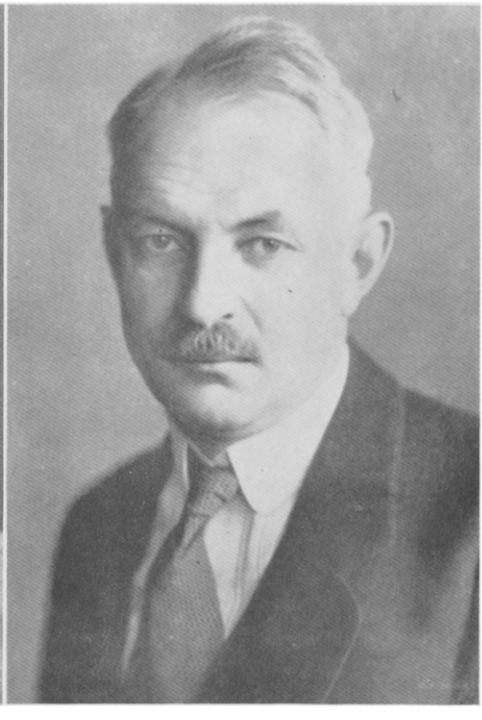


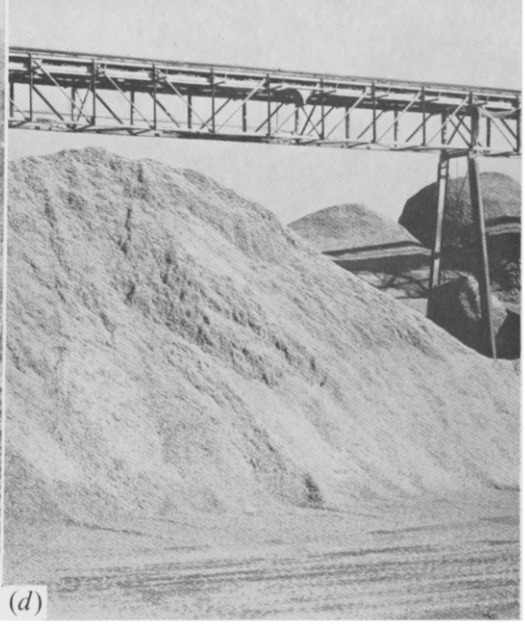
(a)



(b)

FRENCH FARMER WITH TRAINED PIG

(c) *A shortage of witches' spit.*



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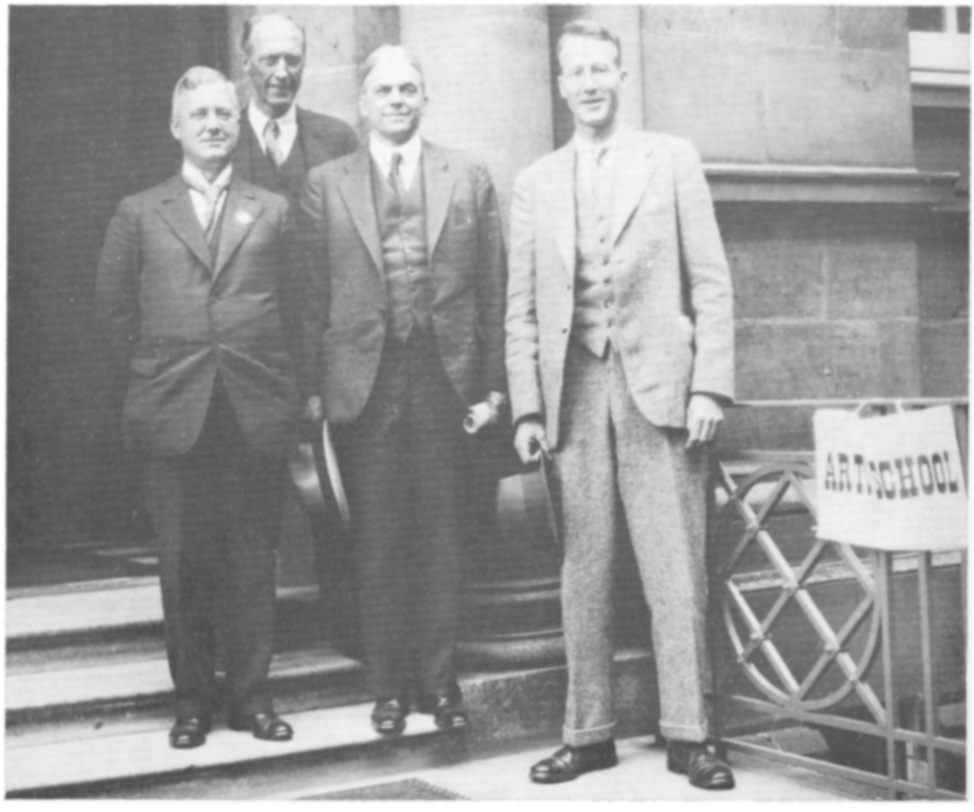
ART SCHOOL

EXPLANATION OF FIGS. 5 AND 12

Fig. 5. (*a*) upper left, Hugo Miehe 1875–1932, from Kolkwitz (1932, opposite p. 163); (*b*) upper right, Hans Kniep 1881–1930, from Harder (1930, opposite p. 164); (*a*) and (*b*) by permission of Gustav Fischer Verlag; (*c*) lower left, photograph by Jean Marquis from *Time*, 31 May 1971 (vol. 97, no. 22, p. 42), by permission of Jean Marquis; (*d*) lower right, Industrial wood chip pile near Antioch, California, containing *c.* 16 million cubic feet of chips, photograph courtesy of Michael R. Tansey.

Fig. 12. Distinguished mycologists at the Fifth International Botanical Congress, Cambridge, England, August 1930. In front, left to right: John Ramsbottom, Bernard O. Dodge, William H. Weston. The member in the background is Edwin F. Hopkins.