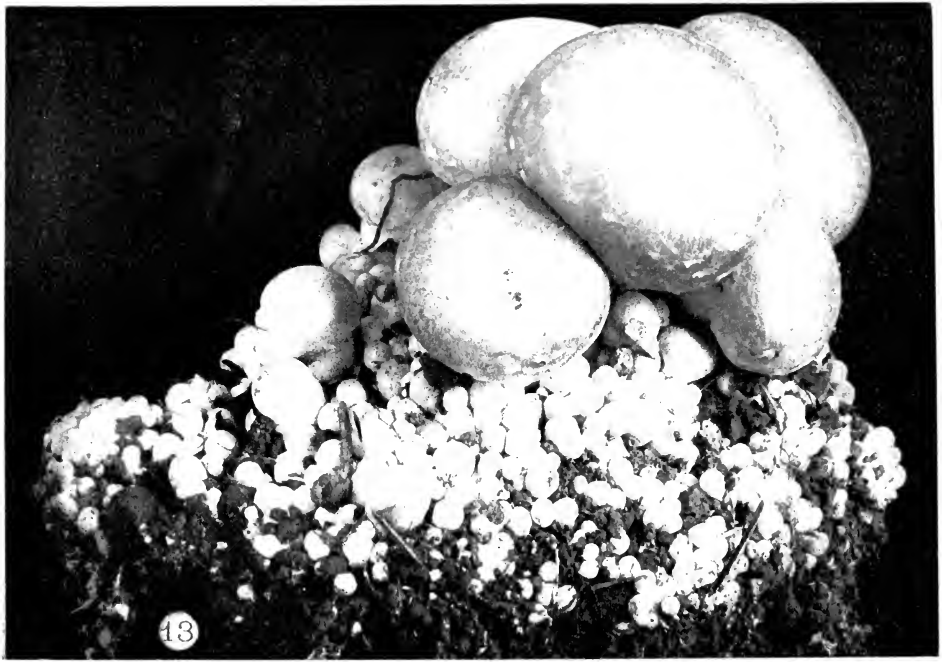
MUSHROOM GROWING

B. M. DUGGAR



Agaricus campestris, "Pin Heads" and "Buttons." From a photograph by Geo. F. Atkinson.

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BY

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FOREWORD

My attention was directed to the culture and use of mushrooms about 15 years ago. Since that time I have followed the problems of mushroom growing and exploitation with increasing interest, especially since undertaking the improvement of spawn-making methods and the establishment of spawn-making on a "pure culture" basis in this country. During this interval I have had the privilege of meeting many persons who have been closely associated with all the different phases of the more important successful and unsuccessful mushroom industries, and likewise with those who have attempted to encourage a more wide-spread appreciation of mushrooms. It is necessary to add that, unfortunately, among the persons whose interests have centered in this work no small number have been found who have used the general ignorance regarding mushrooms and mushroom culture as a means of duping the public. At present, however, education in regard to the requirements of the work is making rapid advances.

While much has been accomplished for the dissemination of information on this subject, through the publication of brief agricultural bulletins, there remains the need of further discussion on mushrooms and mushroom growing. There are already many mushroom books, a few of these on mushroom growing, and many which primarily assist in the identification of mushrooms, but a long experience and a wide correspondence with those interested in mushroom growing have convinced me that a gap remains to be filled. In fact, it seems that there is pressing need for a small volume which shall endeavor briefly to do several things; namely,

(a) First, and chiefly, to describe accurately and faithfully the requirements for success in mushroom culture and spawn-making. In this connection I have endeavored to offer some extended observations upon the best practices of the mushroom growers of the present time, formulating also my personal experience with experimental and commercial production. The widespread interest in the habits of the cultivated mushroom, and educational considerations as well, make it necessary, incidentally, to present an untechnical but fairly complete picture of the life relations of this important fungus.

(b) Secondly, it has seemed an appropriate opportunity to awaken, if possible, the interest of the grower in some of the more important and widely distributed genera and species of mushrooms. If knowledge of a few forms is once attained it will stimulate further interest and confidence in more detailed observation and study. The groups of fungi discussed, include primarily, those which are edible and readily distinguished. They are all economic plants of our woods and fields worthy of being known by every one.

(c) Finally, there have been incorporated brief accounts of certain cultural practices and exploitations in foreign countries, including some observations on European truffles, African and Asiatic terfas, and a general description of the foreign markets for wild mushrooms.

My chief hope is that the information herein offered will be found suggestive and accurate. In this case (1) it will be helpful to those already growing mushrooms for the home or commercially; (2) it will encourage and stimulate interest in others qualified to succeed in this work; and (3) at the same time, it is equally desired that it will prove discouraging to those who have erred in analyzing their interest, and positively disheartening to those wholly inexperienced persons, who, misled by extravagant and deceitful advertisers, are willing to invest their savings in a venture regarding the status of which they do not take time to investigate.

To those who might have wished a more detailed discussion of certain scientific problems intimately related to mushroom growing, it may be said that it has not been found practicable to include such matter in the present volume.

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Mushroom Growing

CHAPTER I

INTRODUCTION

THE word "mushroom" is diversely employed. When we speak in a general way of birds no impression of a particular kind of bird is intended, and no one is misled; but when "mushrooms" are mentioned some persons get one impression and some another. Our best usage sanctions "mushroom" as a comprehensive term applicable to most if not all of the fleshy fungi, whether good, bad, or indifferent with respect to edible qualities. On this basis it is then proper to speak of edible, inedible and poisonous mushrooms of all types. From a certain quarter there is an inclination to restrict the term somewhat, some persons regarding only the agarics, or more especially the centrally stalked of these "gill"-bearing fungi, under this name; so that we would have the Field Agaric, or Field Mushroom, the Fly Agaric or Fly Mushroom, and so on, as correct terms; but then the Horn of Plenty and the Edible Hydnum among others would not qualify, and a new term would be needed for these. In a commercial sense, of course, the cultivated mushroom, *Agaricus campestris,* and the allies of this form are everywhere in America the dominant species of interest, and usually the only species of interest; so that among certain classes of persons it is not strange to find a tendency toward such restrictions of the word as to include merely these commoner cultivated forms. Moreover, this restricted use of the term is sanctioned, and it is generally clear when we speak of "mushrooms" in this specific sense.

The use of "mushroom" as the opposite

of "toadstool" with respect to edibility is unfortunate,—"mushroom" in this sense denoting any edible species, and "toadstool" all the poisonous ones, or sometimes, indeed, any of the fungi which are not eaten. With this as our criterion we would collect and assemble in the "mushroom" basket all species as fast as they might in some way or other receive our approval as edible, and we would cast away as "toadstool" all uncertain, untried, suspicious, or admittedly dangerous forms. Mushrooms for A might be toadstools for B; or, to take a specific case, there might be on the markets of Munich, Germany, about fifty species of mushrooms, since this number of edible species is approved by the market authorities; but in Berlin, at the dictation of stricter rules, or tastes, the number of recognized "mushrooms" would be scarcely half that of Munich. "Toadstool" is apparently becoming a nondescript term which might well be abandoned in so far as it may be the intention of indicating any natural or physiological group of the fleshy fungi. In general, I shall use the word "mushroom" in its broader significance, applying it alike to the thousands of species which in form, texture, and habitat may be most diverse,—varying in size from the huge giant puff ball to the almost microscopic Marasmius, and in texture exhibiting such a variety of qualities as gelatinous, fleshy, cartilaginous, leathery, corky, and woody.

Wherever and whenever a measure of success has been attained mushroom growing has proved a fascinating occupation or recreation, and this in spite of the fact that the requisite conditions would not seem to be so pleasing as those attaching to flower-garden work. Doubtless the fascination resides in the value of the product as a table delicacy and somewhat also in purely psychological considerations, as in the surprises experienced, the growth contrasts afforded, the profuse production, and a certain atmosphere of mystery.

Books of reference. Among scores of books and pamphlets dealing with mushrooms and mushroom growing it is practicable to list only the following, the list being largely American:—

Atkinson, Geo. F. Mushrooms edible, poisonous, etc. pp. 1–276. *pls. 1–75. figs. 1–211.* 1900.

Atkinson, Geo. F. Studies and illustrations of mushrooms I, II. Cornell Agr. Exp. Sta. Buls. 138: 337–366. *figs. 87–112.* 1897; 168: 490–516. *figs. 83–97.* 1899.

Atkinson, Geo. F. and Shore, R. Mushroom growing for amateurs. Cornell Agr. Exp. Sta. Bull. 227: 161–174. *figs. 151–154.* 1905.

Chatin, A. La truffe. pp. 1–370. *pls. 1–15.* 1892.

Clements, F. E. Minnesota mushrooms. pp. 1–169. *pls. 2. figs. 124.* 1910.

Duggar, B. M. The cultivation of mushrooms. U. S. Dept. Agr., Farmers' Bul. 204: 1–24. 1904

Duggar, B. M. The principles of mushroom growing and mushroom spawn-making. U. S. Dept. Agr., Bur. Pl. Ind. Bul. 85: 1–60. *pls. 1–7.* 1905.

Dumée, P. Nouvel atlas des champignons comestibles et vénéneux. pp. 1–45. *pls. 1–64.* Paris. 1905.

Falconer, W. Mushrooms: how to grow them. pp. 1–169. *pls. 1–29.* 1900.

Farlow, W. G. Some edible and poisonous fungi. U. S. Dept. Agr., Div. Veg. Physiol. & Path. Bul. 15: 449–470. *pls. 21–30.* 1898.

Gibson, W. H. Our edible toadstools and mushrooms. pp. 1–337. *pls. 1–30.* 1895.

Hard, M. E. Mushrooms, edible and otherwise. pp. 1–609. *pls. 1–65.* *figs. 1–504.* 1908.

Houghton, W. Notices of fungi in Greek and Latin authors. Ann. Mag. of Nat. Hist. 15: 22–49. 1895.

McIlvaine, C., and Macadam, R. K. One thousand American fungi. pp. 1–701. *pls. 1–182* and many text figures. 1900.

Marshall, N. L. The mushroom book. pp. 1–167. *pls. 1–48.* 1901.

Michael, E. Führer für Pilzfreunde. 3rd. Ed. *69 col. figs.* 1898.

Patterson, Flora W., and Charles, Vera K. Mushrooms and other common fungi. U. S. Dept. Agr. Bul. 175: 1–64. *pls. 1–38.* 1915.

Peck, C. H. Edible fungi of N. Y. Mem. N. Y. State Mus. 3 (No. 4): 131–234. *pls. 44–68.* 1900.

Veihmeyer, F. J. The mycogone disease of mushrooms and its control. U. S. Dept. Agr. Bul. 127: 1–24. *figs. 1–5.* 1914.

CHAPTER II

Characteristics of the Common Edible Mushroom, Agaricus campestris

Doubtless many consumers of mushrooms and even some persons with country-life interests would scarcely recognize the common mushroom as it grows naturally in lawns or pastures. Their conception of mushrooms is often merely the picture of the market product *en masse,* or of the partly bleached buttons which constitute many grades of the canned material. It is, however, almost as easy to distinguish the common Agaricus from other fleshy fungi as it is to distinguish the wild rose from the bramble, once a definite concept of it is obtained. Children quickly learn to tell one species of bird or butterfly from another if their interest in the habits of these animals is aroused. In the same way, when attention is directed intelligently to the salient characteristics and habitats of the different mushrooms, they will not be confused or easily forgotten. The point is that if we develop careless habits in the observation of any growing things, we shall need a special effort to dislodge our early and hazy impressions. It may therefore be well at the outset to note some of the important characteristics of a typical form of the cultivated mushroom, and at the same time acquire the terminology necessary to discuss any group of these organisms.

Cap, stem, and ring. The field mushroom is interesting not only in appearance, but in life history as well. The full grown mushroom (sporophore) is of the stout-stemmed umbrella type (Plate I, a). It consists, then of a centrally placed stalk or stipe, 2 to 5 inches in height, usually not more than 1 inch in diameter, and upon this stipe there is supported the relatively large expanded part known as the cap or pileus. The latter is in reality a very essential part, producing, as noted later, the spores, or propagative structures. The diameter and thickness of the pileus vary considerably in the different varieties, and with the conditions of the environment under which the plant is grown; but usually the diameter of the cap is about equal to the height of the stalk, and the thickness of the cap is about equal to the diameter of the stalk. The upper surface of the cap gives the main color tone to the plant, and this, too, varies in the different varieties from almost pure white or cream to purplish gray or dark brown.

The stem is usually cream or white and near the upper or cap end it is encircled by a ring or collar of tissue, known as the annulus. The annulus is the remnant of that tissue which in the younger plants connects the stem with the periphery of the cap, thus forming a covering over the delicate structures on the under surface of the cap. The collar is formed when the rapid expansion and maturity of the cap ruptures the tissue described. The lamellæ or gill-like structures occurring on the under surface of the cap reach for the most part from the stem to the periphery. In the white or cream varieties these gills are distinctly pink until after the formation of the collar, then in a day or two they turn a deep brownish black. Among some of the varieties possessing a brown upper surface of the cap, the gills may be only grayish pink when young, but these turn dark with age. We shall see that this darkening of the gills is most significant.

An examination of immature mushrooms shows that no ring is to be found and that instead of this there is a "veil" stretching from the stem to the periphery of the cap, thus wholly shielding the developing gills. Since the cap rapidly expands with the maturity of the plant, the veil is broken and the greater portion of this structure usually remains adherent to the stem as the ring above indicated. In some varieties of the common mushroom a larger or smaller portion of the veil may maintain its union with the margin of the pileus. In fact, of two plants growing side by side, the one may show a perfect annulus and the other only large veil remnants suspended from the cap.

With the attention once called to these chief features of the cultivated mushroom it is quite incredible that any one should mistake it for poisonous or suspicious species. These characters of the common mushroom may be briefly recalled: Pileus white to brown, with central stem and pileus convex; gills pink or pink-brown, becoming brown-black; a characteristic annulus, ring or collar, near the upper portion of the stem, and no other stem appendages.

The production of spores. If one should take a full-grown mushroom after the under surface of the cap has become exposed by the breaking away of the annulus, twist the stem until it breaks away from its attachment to the cap, or cut it off short, and then place the cap, gill surface downward, on a sheet of white paper, there will be found in the course of twenty-four hours, more or less, a print as illustrated (Plate I, b). In order to avoid drafts of air a vessel may be inverted over the preparation. The print obtained is a fairly good reproduction of the projected form of the gills, being composed of a mass of brownish-black powder which has fallen from the gills themselves. The color of this powder corresponds to the color of the gills and its development is a very important phase in the growth of the mushroom. It is, we may say, for the production of this powdery mass that the mushroom, as we know it, is formed.

The brown powder consists of innumerable minute simple cells in the form of ovate bodies, termed "spores." These serve for the reproduction of the mushroom. They are equivalent to the green powdery substance produced by moulds which grow upon bread, cheese, and the like. Their function is that of reproducing the mush-

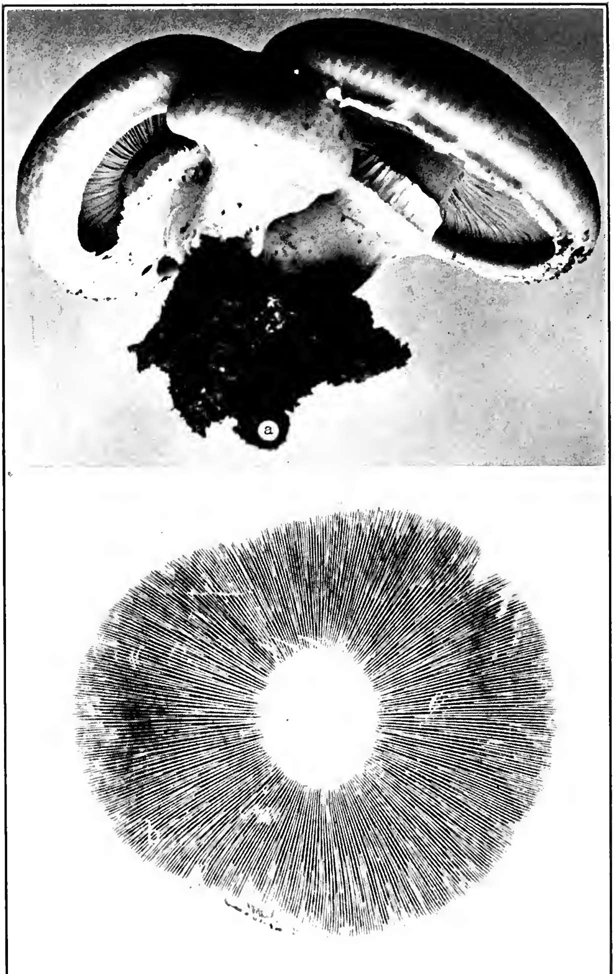

Plate I. (a) Cluster of Agaricus campestris, variety "Columbia."
(b) Black Spore Print of Agaricus campestris.

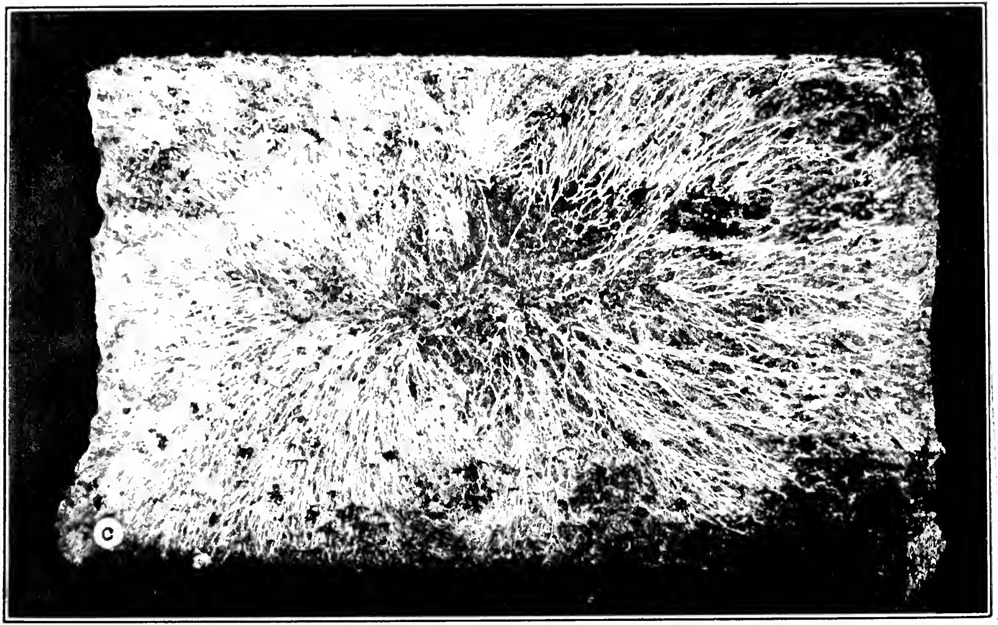

Plate I[1]. (c) Spawn of Agaricus campestris, Pure Culture Grown in Tin Box.

room, but they should not be termed seeds. Their structure is so simple, and they are in their development so distinct from seeds, that the proper botanical term should come into general popular use to express this form of reproductive body. "Spore" is the designation for the reproductive bodies of all mushrooms, and other fungi. In the common, cultivated mushroom the spores are produced over the gill surface only. These surfaces are studded with erect cells in palisade arrangement, each cell (called a "basidium") bearing 2 or 4 spores. The entire gill surface is the "hymenium," or spore-bearing layer.

Mycelium, spawn. Although the spores are normally the propagative bodies and undoubtedly serve in the open for the distribution of the species, growers cannot employ these directly in the production of mushrooms. In fact, it is difficult to germinate them in the laboratory, even though the conditions are as favorable as our knowledge permits us to make them. Under certain favorable conditions each of these minute cells is, however, capable of germinating and producing first a germ tube, ultimately a filamentous or thread-like growth, known as the mycelium. This mycelium arises from the first small germ tube by subsequent branching and continued ramifications, and under favorable conditions it grows until the rapidly elongating filaments penetrate the substratum in every direction. The growth of the mycelium in any suitable substratum yields a characteristic "spawn," and "spawn" refers merely to this phase of the mushroom growth in visible or extensive quantity (Plate I^1, c). It is appropriately called the vegetative phase. Spawn may also be produced from fragments of the living tissue, if pure culture methods are employed, but this is discussed at length later.

In this connection it may be said that the mycelia of other fleshy or woody fungi invade a great variety of substrata. Rich earth, moist leaves of the forest floor, fallen timber, and even the trunks of living trees are all invaded by numerous species, each species having certain general habitat requirements.

Perhaps it is well here to emphasize a certain point discussed at greater length later; namely, that some puff balls and representatives of many other groups of fleshy fungi may occur along with the field mushroom in pastures and meadows; that, similarly, hundreds of wild mushrooms of most diverse form, texture, and color may be found on the ground in the woods; and that an equally diverse flora inhabits trees or timber, producing decay. When, therefore, "spawn" is found in any particular location it may not be easy to name the species from this spawn alone; that is, the "mushroom," or sporophore, is required. True, one may become expert in recognizing kinds of spawn, but the important thing at first is to recognize the mushrooms.

The fresh, undried spawn of *Agaricus campestris* has a pleasing aroma of fresh mushrooms combined, to a slight degree, with that of powdered almonds, while that of *Agaricus fabaceus* is of a far more pronounced almond or amygdaline type. The odor is largely lost with drying. It would scarcely be practicable to attempt to describe in detail the appearance of "spawn" since that is best gained by experience with it, for once mushrooms are grown and the fresh spawn in the bed examined carefully, there will be no further difficulty in recognizing Agaricus spawn.

Stages of the mushroom. When, in any favorable compost or other substratum the spawn has developed sufficiently and the conditions for fruiting are satisfactory, minute cushion-like areas of growth appear on the large threads. These become spherical in form and thus there arise the snow-white pin heads, the first umistakable signs of mushroom production. In a suitable environment, these pin heads grow fairly rapidly in size and are soon recognized as "buttons," ultimately as mature mushrooms (see frontispiece). Under the best conditions for commercial mushroom production a week or ten days will elapse between pin heads and maturity. Commercial mushrooms are graded highest if picked just before the veil breaks.

The mycelium, or spawn, pervading the substratum in all directions absorbs the necessary water, as well as the organic and inorganic food materials required for its growth; and at the same time there accumulates a considerable surplus. This accumulation of food materials is shown by the rapidity with which mushrooms are produced, once the process is started.

CHAPTER III

Market and Production

Agaricus campestris and related species are grown and marketed more or less in all civilized countries. The greater part of the product is sold on local markets or shipped relatively short distances and disposed of as fresh mushrooms. This is entirely as would be expected, since it is only when mushrooms are used fresh that the full flavor may be brought out in cooking—the case likewise with many other delicate products. Nevertheless, the canned product continues to represent a considerable part of the consumption in some countries, and this article reaches many markets to which the fresh mushrooms do not find access. A comparatively small amount of the cultivated mushroom product is dried, and as such finds sale for purposes of seasoning gravies, etc.

Mushroom growing in Europe. It would appear that mushroom culture had its origin in France, so from the beginning France has been, and still remains, the chief home of the industry; yet mushrooms have long been extensively grown in England, and to a much more limited extent in Belgium, Germany, the United States and other countries. On the Continent of Europe, Italy has, in proportion to her other mushroom interests, paid least attention to the cultivation of Agaricus. The only available data bearing upon the present extent of mushroom production in countries other than the United States are those which have been obtained for the Central Market (Halles Centrales) of Paris. These figures are probably approximately correct, and although the sum of the amounts for the different months during the year 1901 are somewhat less than the amount reported for the year, yet the yearly estimate is probably very nearly correct. The figures are as follows:

Year	*Total Production—Kilograms*	*Immediate Consumption—Kilograms*	*Amount Preserved Kilograms*	*Mean Price per Kgm. Wholesale*
1898	1,800,000	1,000,000	800,000	1.35 francs
1899	3,100,000	1,860,000	1,240,000	1.35 "
1900	3,900,000	1,900,000	2,000,000	1.30 "
1901	4,400,000	1,700,000	2,800,000	1.25 "

Month	*Total Production Kilograms*	*Month*	*Total Production Kilograms*
Jan.	410,000	July	334,000
Feb.	407,000	Aug.	296,000
Mar.	428,000	Sept.	297,000
Apr.	417,000	Oct.	295,000
May	448,000	Nov.	298,000
June	399,000	Dec.	330,000

It appears that from 1901 to 1906 there was no material advance in production. The amount passing through the central markets of Paris is believed to be no greater than the output in France which does not reach these markets. The production by months in the vicinity of Paris indicates that an all-year use is made there of the wonderful cave facilities of that section, mentioned elsewhere. The price varies from 1.20 francs to 2.20 francs per kilogram ($2\frac{1}{5}$ lbs.) wholesale. In 1911 the average price was 1.50 francs wholesale, indicating a total value of about 7,500,000 francs, and a retail value of about 12,500,000 francs (about $2,500,000). In 1907 the total yield was less, and the average price was approximately two francs per kilogram wholesale.

The above data indicate to what an enormous extent mushroom growing has developed in France, and especially in the vicinity of Paris. The canned product is very largely exported, and much of this exported material comes to America. For the year 1900 it was ascertained from the American importers that approximately 3,000,000 pounds of canned mushrooms were consumed in the United States. It is evident, therefore, that Americans have used a large proportion of the amount shipped from France. A prominent importer estimates that for the year 1906 between four and five million pounds of canned mushrooms were shipped to the United States. Since that time the increased growth of mushrooms in this country has sufficed to hold the importation of the canned product at a stationary figure.

Mushroom growing in the United States. Practically all of the mushrooms grown in the United States are marketed fresh. This will continue to be the case so long as the industry is so limited and is confined to the vicinity of great centers of population where good prices prevail. The time has not arrived when canning deserves to be encouraged in this country. One could fifteen years ago almost count upon one's fingers the important and successful growers of the country, and any one planting 5,000 square feet of beds was considered an extensive grower. To-day the largest mushroom planters report areas of 100,000 square feet or more.

Again, florists formerly furnished a considerable and often dominant portion of the mushroom supply. By them the work was, of course, conducted as a side line, utilizing the available space under the greenhouse benches during the colder months.

Formerly, those who attempted mushroom growing here were, for the most part, English or French gardeners, or persons who had come in contact with such work in Europe, or who had at least come under European influence. The production for home consumption was very small, and altogether there was nothing to be spoken of as a mushroom industry. Furthermore, the amount of wild mushrooms (*Agaricus campestris*) collected and sold in the autumn was not a very important item. It may be that at that time the market would not have handled a much greater supply. There was then a tendency in this country to look upon mushroom growing as a great secret; a mystery which few could fathom, and it was not often possible to secure consent to visit the houses in which they were grown. This was, of course, largely due to the traditions that had come over with this culture from Europe, emphasized, no doubt, by the conspicuous record of failures experienced by many amateurs who, with plenty of enthusiasm, but with no conception of mushroom requirements, and often with inferior or useless spawn, proceeded blindly in this precarious field.

In the United States unusual interest has become evident during recent years, and the work has been undergoing a wholesome development. The number of inquiries now received by various educational (especially agricultural) institutions show that this interest is common throughout the country, and that it comes from practically all classes. The production of satisfactory grades of American spawn under the stimulus of the pure culture method is directly responsible for this development and increased attention. One of the largest growers in the country, emphasizing this point, says: "If we had to depend upon foreign spawn, as in the past, mushrooms would still be scarce and high." The very fact of its being widely known that mushrooms are now successfully grown in larger quantities every year is sufficient indication that no other "boost" for the industry is required.

It is not easy to estimate the total amount of mushroom production in the United States, since no account whatever can be taken of small growers in those cities where there is no well developed market for mushrooms. Basing an estimate, however, on the amount produced in the vicinity of the larger cities, it seems certain that not less than 5,000,000 pounds were marketed during the season of 1913–14. From a personal investigation of the matter, the writer has been able to ascertain that on the Atlantic coast all of the larger cities and fashionable resorts for tourists from Palm Beach, Florida, to Portland, Maine, were fairly well supplied with fresh mushrooms during the past winter. In the majority of cases the principal hotels used the greater part of the supply. Except in a few of the larger cities, the retail market has not been adequately developed.

Shipment and price. Mushrooms may be shipped considerable distances during the winter months. If properly packed, and shipped immediately after being gathered, there is little danger from shipment during 36 to 48 hours. They should never be packed in very large quantities, since the heat developed in a basket of more than 10 pounds of mushrooms will be considerable. In large quantities they would undergo a "sweating" process; this encourages the development of bacteria and molds, leading rapidly to loss of flavor and ultimate injury. It will well repay the grower to take cognizance of the results achieved by California fruit growers, with whom the neatness of the package has been shown to be most important. Pack in small baskets, as you would pack grapes, give aeration, and study the demands of the market as to sorting and selection.

The small grower frequently experiences great difficulty in handling his product, due to the fact that the market is flooded at the time when his beds are yielding most heavily; that is to say, he finds that he has mushrooms only when mushrooms are plentiful. This is a certain indication that the conditions have not been satisfactory, and that the beds have produced when the outside conditions were favorable. Where mushrooms are grown in sheds, cold cellars, or makeshift houses, the beds may fail to bear until spring, and it is a common experience that the first continued warm weather at this time finds the markets of most of our large cities flooded with the product. The large grower will do well to anticipate this inevitable condition, but a well established high class trade will not be materially injured by it.

The price paid for mushrooms was formerly most variable, ranging from 25 cents to considerably more than $1 a pound. The time has passed, however, when during the winter season, one may expect to sell mushrooms at the fabulous prices advertised by a few unscrupulous vendors of mushroom spawn and mushroom information. In many cities the fancy trade of hotels will not net more than 50 cents per pound and frequently only 40 cents. Sold to commission men, or market, the wholesaler cannot expect to average so much as this, and during the season of heaviest production many large producers are forced to accept 25 cents or less per pound—sometimes less than the cost of production. The private consumer pays ordinarily from 60 to 75 cents per pound. There is abundant opportunity for the development of the retail trade and the direct distribution of mushrooms. The great future development must be in this direction.

Historical account. The earlier history of the field agaric in cultivation remains, so far as can at present be ascertained, to be worked up from the scattering references which are obtainable. It is well known that this species was cultivated in France during the reign of Louis XIV, and it is certain also that it was considered a luxury a century or two earlier. Tournefort has left an interesting note,* under date of 1707, of the cultural operations of his period. While little was then known of the life relations of the organism, it appears that the requisite conditions for successful culture were clearly appreciated. No mention is made of the cultivation in caves at this time. In fact, it does not appear that the underground quarries in and near Paris, which are now the famous mushroom gardens of the world, were commonly used for growing prior to the beginning of the 19th century. Among the references which can be had from early Greek or Roman authors, however, no evi-

* Reproduced in "La culture des champignons comestibles," June, 1913, pp. 139–143.

dence has been brought to my attention indicating that any special consideration was accorded this species in those times.

The methods involved in the cultivation doubtless became more precise as caves were employed, but no progress whatever was made in the matter of maintaining varieties found, or in the development of varieties until about 1900. It seems rather strange that a product so long successfully grown in France and England should have remained a rarity in the United States, in spite of the great progress made in agricultural pursuits generally.

Until very recently the seed trade everywhere has handled spawn as "mushroom spawn," professing to give no indications regarding varieties. That is to say, after several centuries of cultivation it was not possible to take varieties into consideration. In recent years, however, owing to the development of pure culture work both in France and in the United States, the different varieties of mushrooms—just as of other plants—may be propagated, and the spawn made from any particular variety desired, as described in a later section. It is certain that there exist many varieties, or forms, of *Agaricus campestris* and related species, but up to the present we cannot say that there has been any general improvement of any form for cultural purposes.

CHAPTER IV

Situations Favorable for Mushroom Growing

It is easy to specify in a general way the situations in which mushrooms may be grown. This is best done by describing the conditions necessary for growth, since then adequate light is shed upon the type of situation required. Upon reading this and later sections, it will be observed that, after all, the main factors which are to be regulated are those of temperature and moisture, and consequently any situation in which these conditions may be so controlled as to accord with the requirements specified should be satisfactory.

In France. In France the mushroom industry has fallen heir to the subterranean quarries which now constitute a very extensive array of artificial caves, especially under Paris or in its environs. These caves are indeed responsible for the enormous development of the mushroom industry in that country. Parisian buildings have been constructed, in the main, of a limestone which has been mined under the city itself, or in the adjacent suburbs and country. The mining operations have been so conducted as to leave vast labyrinthian systems of caves. The caves now lying under the city proper, known as the catacombs, are not used for mushroom propagation.

The suburban caves are from a few feet to 50 feet beneath the surface. They vary usually from 5 to 25 feet in width, exceptionally 50 feet, and from 5 to 20 or more in height. The extent of these cave areas is very great; and in many suburbs, such as Montrouge, Vitry, Chatillon, Isny, Nanterre, Rosny-sous-Bois, Pasey, etc., mushroom growing is one of the really important industries. It has been estimated that in the caves of the suburbs referred to, there are upwards of 2,000 kilometers (about 1,200 miles) of mushroom beds (Plate II[1], d). In the caves of the suburbs mushrooms are so commonly grown that *"champignonière"* (mushroom cave) is practically synonymous with *"carrière"* (cave). The cave systems are very well ventilated by means of chimneys or chutes. The change of air is often facilitated by small charcoal fires beneath these air chutes and occasionally by the use of special ventilating devices.

Entrance to the *champignonières* may be, on the one hand, through an open quarry more or less readily accessible, or it may be through a hole only a few feet or more in diameter by means of a ladder, with a windlass for lifting or lowering materials. It may be added that in England mushrooms are grown either in specially constructed houses, in cellars, or in caves, and sometimes even in the open air,—usually protected more or less, as described later.

In the United States. The production is thus far wholly confined to special houses,

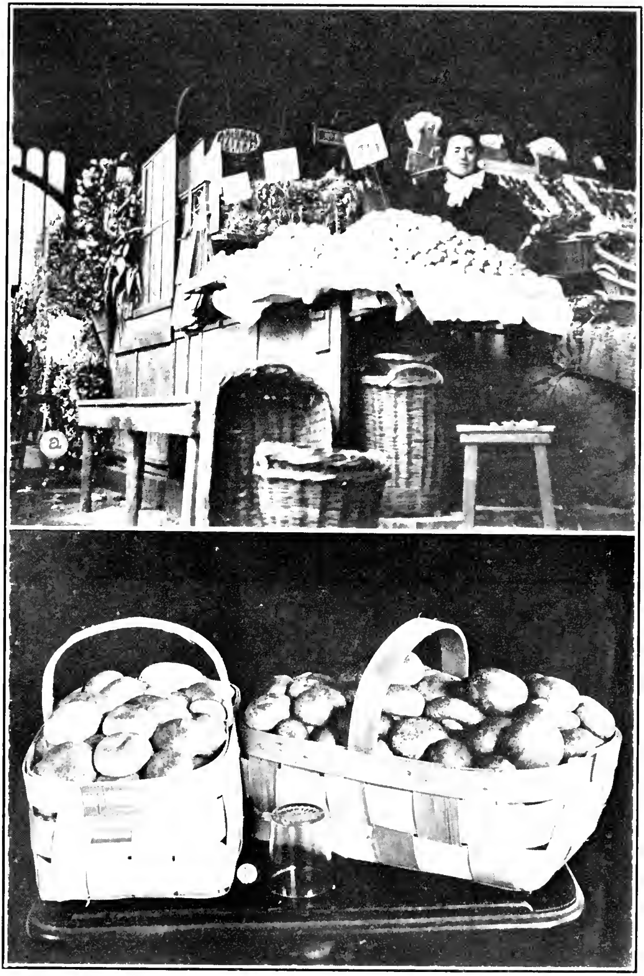

Plate II. (a) Agaricus campestris on Sale, Central Market, Paris.
(b) Mushrooms in Bulk, for Local Trade.

Plate II[1]. (c) Aerated Boxes, for Private Consumer.
(d) Mushroom Culture in Caves near Paris.

caves, and cellars. In such places the temperature, moisture, and other environmental factors may be more readily regulated, or made favorable, and this is the only possible biological reason for designating such places as peculiarly fitted for mushroom propagation. Near Philadelphia, Chicago, Boston, and some other production centers, mushrooms are grown wholly in special mushroom houses. Unquestionably, the major part of the product in the American market is grown in this way. Some few commercial growers in Minnesota, Ohio, Indiana, New York, and Missouri especially, have been so fortunate as to secure underground quarries, caves, or storage cellars of considerable extent. Such places are excellent when readily accessible, provided there is no danger from the possibility of flooding, or of becoming too wet from seepage water.

Seldom would the grower be able to tunnel out caves for his purpose, though in some instances the product mined might pay for the work, as in the case of rock for Portland cement, the finer grades of sand, etc. Many antiquated beer storage cellars of limited capacity are in use in various cities. Abandoned coal mines are certainly unsuitable as usually left, but it is possible that there are hill coal mines in some sections which would repay investigation from the standpoint of commercial mushroom production. Natural caves in the limestone section of Missouri have been used successfully for a time. Often poor arrangements have been made for removing the old beds, and after an accumulation of bedding material has continued for several years, with an attending increase in mushroom enemies, the old cave garden has too often been abandoned for a new one. Again, such caves are not always accessible, and the cost of having manure delivered from a distance may be prohibitive. Natural caves occur in Kentucky, Indiana, Ohio, Virginia, and Arkansas, and perhaps some of these may in time be available. Caves or deep cellars have always the advantage of permitting mushroom production during a long period; indeed, frequently throughout the year, but they must offer the possibility of adequate ventilation.

Mushroom houses. In many sections of the United States mushroom houses and cellars under dwellings might be used for mushroom work from six to nine months in the year. For temporary use a mushroom house may consist of a very simple boarded shed or unused barn. It is necessary to provide a heater of some type, since the winter is the important season for mushroom work. Many commercial mushroom houses which pay well are not particularly elaborate.

As a permanent investment for mushroom growing, the house should, however, be built with due consideration for convenience, durability and economy. No one going into the work on an extensive scale should build before looking over a successful plant. Perfect drainage is a factor of the first importance. To obtain this may be complicated by the fact that for convenience in heating, as well as for more uniform temperature considerations during the warmer parts of the season, it is often convenient to construct the house over an excavation which may be at least several feet lower than the natural surface. In building houses of this type, however, arrangement should be made for the utmost convenience in unloading the compost and for cleaning out the old beds. The greatest economy is attained by the construction of houses high enough to accommodate the beds in tiers of from two to five.

It is necessary to allow about 2-2½ feet free space between the beds in tiers, since the bed is at least 8 to 10 inches deep; somewhat more than 3 feet in height must be allowed for each bed. For some time it has been the custom in building the better class of mushroom houses to make the walls double, and to pack fresh shavings between these. More expensive houses may be made of hollow tile or concrete. Hollow tile has much to recommend it where the outlay is justified. In the house there will always be a moist atmosphere and the contact of this moisture-laden air with cold walls may, of course, produce constant precipitation of moisture or "sweating." A sufficiently sloping roof provided with air space will correct, to a large extent, this difficulty. Arrangement should always be made for ventilation, and it is usually advisable to place the ventilators in the roof, the main point being that the purpose desired is then accomplished, as a rule, with less inconvenience from direct drafts.

When beds are to be prepared in caves, cellars, or merely on the floors of the buildings used, the matter of preparing for the beds is a very simple one. When for commercial production every foot of available space is to be used, and especially in houses built for mushroom growing, the construction of supports for the different tiers will require particular attention. Do not make the mistake of using inadequate supports. The upright supports for beds in tiers of four or five should be scantling not less than 2 x 6 inches, and these should be placed about 4 feet apart. Experienced commercial growers are now using large gas piping for the supports (Plate III, b), and these have, of course, the advantage of great permanency, and they are perfect also from a sanitary standpoint. Wall beds should seldom be more than 3 feet across, but beds approachable from either side may be 6 feet across. Ample space should be left for the aisles, 3 feet, however, being usually sufficient. One or more wider aisles may be employed where the houses are very large, but, as stated above, everything depends upon convenience in the installation and removal of beds. In general, it may be stated the exact form of the house, materials to be used, the method of heating, and all such details will depend entirely upon conditions. Have in mind always the purpose for which the house is used and the conditions to be maintained.

Open air culture. In Southern England

the extremes of temperature during the winter are not so great as to prohibit culture in modified hot beds or cold frames. Simple culture frames of the usual type are employed, except that no glass is used, and they are covered with sheet iron or boards, upon which finally a layer of straw is placed, if necessary. Fresh manure may be used under the compost, if it seems desirable to force somewhat the early growth of the spawn. This form of culture is often very successful. Properly speaking, however, this is not open air culture.

Open air culture for mushrooms cannot be regarded as having great possibilities of success in most regions. There are many difficulties suggested by the fact that commercial mushroom growing demands a more or less uniform temperature. The variation in daily temperature is usually considerable, drying winds are not infrequent, and at best, it is difficult to regulate the moisture factor. In Southern England I have seen successful open air beds during the late autumn and winter. Probably under the most favorable conditions it would prove necessary to make the beds deeper than they are ordinarily made, and to use some fresh manure at the bottom, so as to maintain some degree of bottom heat. Mulching with clean straw is required, and it is probable that cloth covers would be desirable. The nature of the covers needed would be determined by the daily range of temperature. It is believed that there are sections of California in which open-air culture might be profitably practised; but there is no available experimental evidence on a scale worthy of consideration. It is of interest to note that both *Agaricus campestris* and *A. arvensis* are found in parts of California during the winter months. The mean monthly temperature of the city of San Francisco and of an important section of the State is normally from 50° to 60° F., and the daily range is not pronounced. There is consequently a considerable territory thus favorably located as to temperature. If the experience in England may serve as a guide, a mean temperature rather below than above the requirements is desirable, say 48° to 56° F. It is self evident that open-air beds must be protected from drenching rains.

Inquiries are frequently sent in asking if it is possible to spawn pastures and lawns and thus establish natural cultures to increase the "spontaneous" autumn supply. I have had no permanent success in this kind of work, and the failures were under a variety of conditions. Upon communicating with persons who have been reported successful in such experiments it was usually ascertained that everything seemed to depend upon the season, and that the results are wholly inconstant. English correspondents give a similar version of this natural or field culture idea. It is, therefore, at present not to be depended upon.

From what has been said, however, it should not be assumed that success may not be attained under field conditions. The spreading of spawn about lawns or pastures may involve so little labor that in the long run it may be well worth while to make the experiment whenever spawn is available. In favorable seasons occasionally one may be well repaid. Similarly one might spread about the premises the spawn of other edible varieties which would be expected to grow under the conditions.

CHAPTER V

The Compost

There is no substitute known for stable manure as a compost for commercial mushroom production. Wherever *Agaricus campestris* and related species are cultivated this is the nutrient substratum employed. The best results are obtained only when the manure is hauled fresh from the stables and permitted to undergo a definite type of fermentation, as subsequently described.

Stable manure essential. In selecting manure for mushroom work only that which is recognized as of the highest quality should be taken. It is the general experience that considerable bedding straw should be present with the manure, and if good straw it is not likely to contain too much, but even a small quantity of "weeds" is a nuisance. The straw of the various grains seems to possess distinct advantages over that of other grasses, perhaps on account of a certain resistance to complete fermentation, or decay, yielding a highly porous substratum which maintains an excellent physical condition in the beds. Unfortunately, it is becoming increasingly difficult in some cities to obtain straw manure; for animals are bedded with straw less and less, sawdust and shavings being the cheaper substitutes now commonly used.

These bedding substitutes do not, of course, render the manure unfit for mushroom work, and in fact compost containing these substances is extensively used. In order to exclude poor material in the selection of compost, it is also well to avoid any manure from veterinary hospitals, or from stables which use freely any type of disinfectants. It is quite probable that the poor producing quality of the compost obtained when the bedding material employed is refuse hay, weeds, etc., is the result of the "shortness" of the product after fermentation. Experience indicates clearly that any short, trashy compost does not make the best substratum for mushrooms. It is probably less retentive of moisture for one thing. Manure from animals fed largely upon grass has not proved satisfactory in such tests as have been made, and French experience rules out that obtained from stables employing chiefly leguminous fodders. The French ideal is manure from grain-fed animals bedded with rye straw. A few years ago when in France it was decreed that, to save expense, other cereal straws should be substituted for rye in the cavalry stables, there was a strong but futile outcry on the part of French mushroom growers. It has been demonstrated satisfactorily that the manure from grain-fed animals yields a more vigorous bed of spawn than any other, although I am also convinced that many growers insist on a type of stable manure containing too little straw for the best results.

The fermentation process. In the fermentation of manure the same end may be obtained by a variety of methods, so it is necessary to understand the principles involved, and then one may go ahead intelligently. Beginning with good materials the essentials are adequate moisture all the time and sufficient forking over, or turning, to effect equal ferment action and uniformity throughout—also sometimes to force a temperature decline.

The manure contains many soluble organic substances which invite a vigorous development of mould fungi, if it is not fermented. During the fermentation process the common mould fungi do not, as a rule, develop profusely, but bacterial and direct chemical action is facilitated. The end result is such a stage in the decomposition of the material as will favor the growth of mushroom spawn rather than the mycelia of moulds.

If fresh stable manure is secured it should be thrown into piles not more than 4 feet high and of any extent desired. It is unsatisfactory to make one great pyramid, or many nondescript heaps. At first the manure should be thoroughly wet throughout. Subsequently it will be necessary to maintain it in a moist state, and to turn, or fork over, the pile three or four times, or oftener, depending upon the conditions. Under ordinary circumstances if the manure is well moistened it may be properly fermented in three weeks or somewhat less, being turned at intervals of from three to five days. The presence of shavings or sawdust may necessitate a longer fermentation interval, and the longest fermentation period will be required when there is much resin in the shavings. At each turning it should be seen that there is sufficient moisture throughout the pile, and it is usually necessary to water during the turning process, in order that the moisture may reach all parts. With the maintenance of adequate moisture, the attainment of a temperature of 140° to 150° F. between the first three turnings may be considered advantageous. If there is little moisture, the manure will "burn" easily and it will require a much longer period of fermentation. Again, if the pile has been compressed by tramping or by long standing when more than 4 feet high, the fermentation will be retarded. It is the practice of some who grow mushrooms in large quantities to have the manure thrown into huge piles, then moistened, and no further attention given it for two or three weeks, meanwhile collecting more material day by day from stables for the product of which the grower has contracted. Ultimately this manure is turned once or possibly twice, and then made into beds. The fermentation continues to some extent after the beds are made, but as they are well compressed and moist there are no disadvantageous consequences, if spawning is delayed until there is no danger of over heating.

The difficulty of fermentation is increased if only a small quantity of compost is to be prepared. In this case it dries out quickly, and a certain amount of burning is scarcely to be avoided. Special attention to the moisture and compactness of the material is then required; but whether it "burns" or not, the best type of fermentation, as my experiments have repeatedly shown, is obtained only when the temperature remains for several days at a time above 125° F. "Burning" is indicative of a fairly high temperature combined with a rapid drying out. In a properly arranged compost pile the greatest "burning" will occur just beneath the surface, but it is still a question as to what extent "burning" injures the compost. Certainly a reasonably good yield may be obtained from such material.

During composting the manure should lose practically all objectionable odor, and with material properly prepared there is no unpleasant feature after the preparation of the beds. Other unmistakable signs of sufficient composting are the oleaginous "feel," the pliability, and the uniform brown color of the straw. Commonly the temperature declines to about 120° or 130° F. As soon as the compost is ready it is desirable to make the beds and to have the spawning follow as promptly as possible, as subsequently shown.

It is, of course, preferable to have the compost made under cover when this is feasible, particularly if prepared during mid-summer or during freezing weather. It should also be stated that manure which has been piled in a barn lot or otherwise subjected to leaching will have lost much of its value. In short, never use for compost anything but the best fresh stable manure, and thus you will eliminate many difficulties.

The quantity of compost required. The practical grower should be able to compute in a fairly accurate manner the quantity of manure he requires for a certain area of beds, assuming that beds of the usual depth are made. I estimate that a full (coal) carload will usually suffice for about 3,000 square feet. A carload of manure is about 12 or 14 large wagon loads — I refer to the regular two horse manure wagons used on good roads by truckers in the vicinity of cities — that is to say, a load of this type is about 225 square feet. The average wagon body will hold enough for perhaps 100 square feet. In estimating the amount needed, however, it should be remembered that the age, moisture content, and compactness of the product, as well as the amount of straw present, are factors to be considered. The more straw there is present, the greater the loss of bulk after composting.

A quick method. Where it is not possible to ferment the manure, and yet it is desired to grow mushrooms in a very small way for home consumption, some measure of success may be attained by the following procedure: Free the fresh manure from long straw, mix thoroughly with one-third as much light garden loam, moisten if required, then let it stand three or four days before preparing the bed. Spread the material in the space for the bed, or in a box in layers of about two inches deep, tamping down each layer firmly until a bed eight inches deep is prepared. Observe the temperature at intervals, and for spawning and subsequent care of the bed follow the directions given later for beds of the usual type.

Is there a substitute for compost? A large number of inquiries have been made regarding the possibility of employing other vegetable products, such as decayed leaves, sawdust, woods mould, etc., in mushroom growing. Experiments were accordingly made a few years ago to determine if certain of these products are of any importance. The detailed results may be omitted here, and it is enough to say that they were decisive in one particular, that is, that none of these products approaches the value of stable manure for mushroom growing. Even when an equal quantity of manure was combined with sawdust or with well fermented leaves of deciduous trees the size of the mushrooms was reduced, and the yield of the beds was lessened, as compared with normal compost. A few experiments were also made in which fertilizers were added to these materials, but unfortunately these tests were made late in the season and the results are inconclusive as to absolute values. Sawdust and decaying leaves are undoubtedly improved by the addition of phosphates and nitrates, but so far as my experience goes, no combination of fertilizers has been able to bring up these products to the point of being a worthy competitor of stable manure. Further experimental work in this direction is highly desirable. It is quite possible that certain forest species of Agaricus, notably *A. silvicola* and *A. placomyces,* might be more amenable to successful culture on such substrata, and it is proposed to continue experiments with these forms.

Substitutes for stable manure would not at present be a matter of great importance to the commercial grower, but it would mean much to those in towns who wish to grow mushrooms for home consumption. It would not be possible on small town premises to ferment the manure without objectionable consequences, and it is wholly undesirable to attempt such an operation in the cellar or basement of a dwelling-house. Moreover, fermented manure properly prepared and ready for mushroom work may not be readily obtained, although there is no inherent reason why a product of this nature should not be offered for sale where the demand might justify it.

CHAPTER VI

Nutrition

General experiments have long ago shown that mushrooms grow best in fermented stable manure. This fact does not make the matter of mushroom nutrition either a simple one or an unimportant one. Indeed it makes the fundamental facts connected with nutrition more difficult to ascertain, for stable manure is complex and variable. Why is fermentation necessary? What are the effects of fermentation? What are the real nutrients in manure from the standpoint of the mushroom? The finer mycological methods of work offer us a means of answering some of these questions.

Fermentation a biological requirement. In the first place it may be definitely stated that while under the usual conditions, or with the natural environment, the manure must be fermented for mushroom culture; yet chemically this fermentation is probably more injurious than beneficial. Grown in sterilized fresh manure in pure cultures the mushroom mycelium grows as rapidly and more profusely than in fermented manure similarly treated. This indicates conclusively that fermentation is not chemically essential. It is essential for biological reasons, which, briefly stated, are apparently as follows:— Fresh manure contains some very readily soluble and relatively unstable organic products. These products are ordinarily the seat of pronounced and abundant bacterial activity, perhaps also of some important direct chemical rearrangements. In the presence of rapid bacterial activity (which occurs during this first stage of fermentation) the mycelium of the mushroom will not grow,—and that this is not due merely to the usually accompanying increased temperature is shown by the failure of the mycelium to grow even when the manure is in such small quantity that noticeable temperature increase does not occur. Fermentation acts generally, therefore, not by improving the quality of the manure, but by effecting a complete change in the bacterial activity.

The effect of the fermentation serves apparently, to remove or transform rapidly fermentable products. Again, it induces certain changes in the insoluble material and straw whereby the mushroom mycelium is then able to grow slowly and to compete with the micro-organisms next involved. The nutrients used by the mushroom are, of course, both the gradually soluble organic products as well as the necessary inorganic salts. The once prevalent belief that the "ammonia" of the manure might constitute the only important fertilizer in mushroom culture is certainly erroneous; but manure so treated as to effect the loss of much free ammonia is injured for manurial purposes.

Growth on "synthetic" media. The mycelium of *Agaricus campestris* grows quite well upon synthesized media, that is, nutrient media prepared from known chemical substances, such as the ordinary nutrient "fertilizer" salts with the addition of casein, peptone, etc. In fact, laboratory experiments indicate that all of the nitrogen may be supplied as inorganic salts, if a suitable organic compound as a source of carbon is furnished.

Is it possible to improve the manure by the addition of mineral nutrients, or fertilizers? While experiments thus far seem to indicate that cotton seed meal fermented with manure will increase the yield, the experiments with mineral nutrients have been in the main contradictory, the addition of phosphorous (as a phosphate), and of lime, however, being often advantageous. The variable quality of manure and spawn, and thus far the impracticability of co-operating with extensive growers, have prevented an adequate study of nutrition on a practical basis, although much attention has been given to laboratory experiments preliminary to such practical tests on a large scale. The results of these laboratory experiments cannot be included here.

Temperature, Moisture, and Light

We usually speak of the relation of a plant to the different factors of its environment—such as to temperature, moisture, and light—as if the effects of these factors were very simple; hence easily evaluated, or distinguished one from another. In reality, this is only in the smallest degree true. It has, however, been most thoroughly demonstrated that under the present methods of mushroom growing a more or less uniform temperature of the air in the mushroom house is highly desirable; the optimum, or best, is judged to be from about 54° to 56° F. If, instead of making reference to the optimum, we consider merely a good range of temperature for the work, we might extend the limits indicated from 50° to 65° F. It is certain that mushroom growing (as at present conducted) at a temperature more or less continuously above 60° F., or below 50° F., is not commercially successful; yet much depends upon other factors than temperature.

High temperature more injurious. With respect to the extremes, however, it may be said that the mushroom bed will not be rendered useless by being heated to 70°, or more, for brief periods, and it will withstand a low temperature, or even being frozen for a considerable period of time. The amount of heat and the amount of cold which may permanently injure the bed will be determined very largely by the extent of the growth already made, and by the conditions of moisture. Any severe changes, however, either retard growth or act more injuriously. As above suggested, a high temperature long continued, say 72° F. for 24 hours, is fatal to the pin heads and injurious to the spawn. This effect, as will be shown later, is not due to the fact that the mushroom spawn is directly killed by the temperature of a warm day, but rather is it due to the great stimulus given to the growth of other organisms at the higher temperature. These other organisms may be insects, fungi, and bacteria, and many of these either crowd out, or directly attack the mushroom mycelium or the young pin heads. The high temperature, therefore, operates by making some other condition of the environment injurious. Indeed, if other organisms could be largely eliminated from the mushroom bed, we might find that mushroom production were possible at a considerably higher temperature.

At any rate, by experiments with pure cultures, it has been shown that mushroom mycelium is not directly injured at from 70° to 85° F. Pure cultures of *Agaricus campestris* grow well up to 85° F. so long as sufficient moisture is present. This is positive proof that the conditions for growth in pure cultures are different from what they are in the mushroom bed, and this difference is due in large part, at least, to the elimination of certain "biological" factors and enemies. The presence, by accident, of contaminating organisms in the culture causes an immediate suppression of the mushroom mycelium, and this shows in a measure what happens in nature. The sporophores of the mushroom have been produced in Mason jar cultures in our laboratory at a temperature constantly at or above 70°, and in pot cultures under practically sterile conditions at a temperature constantly between 60° and 70° F. We have not had an opportunity of testing on a large scale the possibility of growing mushrooms during warmer weather under essentially pure conditions, that is, in manure sterilized on a large scale, as the soils of greenhouses are frequently sterilized. This might be done merely to throw light on the causes of injury at high temperature, as I doubt if the general sterilization of compost in mushroom work is a remote practical possibility. All kinds of sanitary precautions may and should be taken, as a matter of course. It might be more practicable to employ refrigeration for summer production. Reference will be made later to the control of insects injurious in this work, but in this connection it is worthy of note that in an experiment which I made at Cornell University in 1912 it was clearly demonstrated that a complete fumigation of the compost permits continuous cultivation at a temperature somewhat above normal.

Under ordinary conditions a high temperature has an unfortunate effect upon the form of the mushroom. The sporophores then expand and elongate so rapidly that the large, heavy buttons, which make up the highest quality on the market, are not produced. On the contrary they are like the mushrooms produced when the bed is nearly exhausted. This effect, however, is partially due to a decrease in the humidity of the atmosphere as the temperature is raised. We have fortunately had an opportunity to test on a large scale the effect of cold or freezing on mushroom beds which were "well run." I refer to beds which happened to be spawned in November. The spawn developed well for a month, then from that time until about March the temperature was never above 52° F. On several occasions it was 32°, or below, and the beds were frozen. Continuously higher temperature in March caused the beds to bear abundantly, and the mushrooms were of unusual size. The temperature was soon above normal and the "life," that is, the period of production of the bed was relatively brief. Nevertheless, these beds produced heavy mushrooms much later in the warm weather than beds which were spawned in January, then held at a growing temperature until the mushrooms appeared, and finally subjected to the warmer conditions above noted.

The grower who wishes to produce heavy mushrooms will do well to remember that for this type it is not well to "push" the beds by regulating to the highest permissible temperature; and if there is no necessity of hastening the bearing period, a temperature below 50° F. for a week or two before the buttons begin to form will be advantageous.

In connection with the relation of mushroom growing to temperature, it should be stated that there are unquestionably species of edible mushrooms which are found in their native habitats maturing readily at temperatures unfavorable for *Agaricus campestris,* some at higher temperatures, some at lower. It remains to be determined whether any of such species are capable of being grown economically.

Moisture. From what has been said already, it is evident that the moisture factor is one which should be considered as next in importance. With an atmosphere saturated with moisture, and with water dripping from the walls everywhere, the environment would be anything but favorable. On the other hand the atmosphere should always contain a fairly high relative humidity, 60 to 75 per cent. being satisfactory. A gradual but slow evaporation from the surface of the beds is altogether desirable, and as a rule this can be easily regulated by controlling ventilation. The undesirable extremes, so far as moisture and ventilation are concerned, therefore, would be on the one hand caves in which there could be no circulation of air, and, on the other, exposure to drying winds. The question of watering the beds will be fully treated in a later section (p. 75, 80).

Light. Since mushrooms are ordinarily grown in cellars or other light-proof houses, it has been assumed by many that light is an injurious factor in the cultivation of this fungus. A moment's thought, however, would doubtless suggest that in pastures or fields, where mushrooms are ordinarily found, the young buttons are exposed to direct light as soon as they begin to burst forth through the sod. As a matter of fact, light has obviously no directly injurious effect upon the quality or productiveness of the cultivated mushrooms. Sunlight is, of course, accompanied by heat, and where the sun shines directly into a window, the temperature is appreciably raised. In cellars, therefore, which admit the sunlight through many windows, the temperature factor might be variable, and, during bright weather, too high for successful work. If the temperature can be regulated, light can do no harm. It is clear that the "injurious" effects of light on mushrooms under glass is wholly a matter of temperature. Mushrooms can be, and, indeed, are grown in greenhouses, both under the benches and on the benches, under proper conditions of temperature and moisture.

CHAPTER VII

Installation, Spawning, and Care of Beds

Nearly every one who has had much experience in mushroom growing has his own favorite method when it comes to the small details of making the beds and looking after them during the period of growth. The type of bed will be determined by conditions. The two types to which all others may be referred as modifications are the flat bed, commonly known as the English type, and the ridge bed, the favorite with the French. The flat bed is more generally employed in this country, and less labor is required in its construction. The surface area, generally, will be slightly less than an equal space devoted to the ridge bed system.

The flat bed. The flat bed system may

be used either in ordinary cellars or mushroom houses where the beds are made on the floor only, or it is equally applicable in mushroom houses or deep cellars where it is desirable to make use of the floor space and at the same time to arrange shelves in tiers. It will readily be seen from Plate III, b, that the shelf-bed system will often permit one to multiply the amount of available space four or five times. This multiplication of bed space is, to a certain extent, at a sacrifice of convenience. It is frequently the only practicable plan, in order to operate on a paying basis, since a single tier of beds would make it necessary to invest perhaps twice as much in the plant as for the same amount of bed space when arranged in three tiers.

The ridge bed. In the relatively low-roofed caves of Paris the ridge bed system alone is practised, and there it has its distinct advantages. This system means more labor both in the preparation of the bed and in the subsequent care of it. It permits of a more effective sanitation, and aside from slightly increasing the floor space, it seems to increase the yield possibilities. In the writer's experience, however, the first and last parts of the crop harvested from ridge beds have a tendency to run lighter in weight as compared with the product from the continuous flat bed.

Installation. Whatever may be the type of bed employed, the compost is pitched into the area designed for the beds, and it is immediately arranged and somewhat compressed with the blows from a shovel, or "firmed" with a compressing board, in order that it may not become loose and dry. The flat bed should be made about 8 to 10 inches deep, that is, after suitable compression it should be of this depth. The ridge beds may be arranged in groups of two, and it is customary to leave between each group of two a floor space of 10 or 12 inches, but this will be reduced to about 9 inches after the process of casing; but the two beds in the group may come in contact throughout their length. By compression it is not meant that the bed should be hammered with a mallet. On the other hand, it should be firm enough even before spawning to support a person without his sinking, say, more than 1 or 2 inches.

Each ridge bed should be about 20 to 24 inches wide at the base, tapering gradually to a top which should not be more than 6 inches across. These beds may be from 12 to 14 inches high. The dimensions indicated will give to the ridge beds a gentle slope from crest to floor, which will permit of the production of heavy clusters. If the slope is much steeper, the mushrooms developed will be smaller, since they will not only be subject to more rapid drying out, but the clusters will also pull away more or less readily from their attachment to the spawn below, and thus will not reach the maximum size possible. The same matter of gentle slope applies to the flat bed when this is not "sided" by boards. To the American commercial grower, however, the sort of flat bed which is the center of interest is almost invariably sided. In my opinion, this type of bed—other conditions being the same—encourages the formation of heavier mushrooms. The desirability of growing all varieties of mushrooms in the same type of bed is frequently questioned. Undoubtedly there are different requirements to be met between such species as *Agaricus campestris* and *A. fabaceus,* or *A. arvensis* and *A. silvicola.* Much experimental work is required before any definite rules can be laid down governing the practices with these diverse forms.

I have never been able to see the necessity of giving the beds such depth that a bottom heat may be temporarily maintained; indeed it is, I believe, preferable that with uniform conditions the temperature of the beds should very soon approximate that of the air. When, however, beds are prepared in cold frames, or in situations where the temperature is likely to fall below that required, it might be well to give greater depth, and to use a small amount of fresh manure at the bottom, with the hope of maintaining a slight and fairly uniform bottom heat. This method of procedure is often followed in the open-air cultures in England, as noted earlier.

Between making and spawning beds. With the installation of the beds of compost, vigilance is again required in the matters of moisture content and temperature. The compost must remain moist. If there is rapid drying at the surface, it must be sprinkled; but in a suitable cellar or mushroom house little attention to watering should be necessary during this interval. However, the one practical test of sufficient moisture is a simple one: it is merely to compress some of the compost in the hand; and under such pressure it will not be easy to squeeze from a properly prepared compost any drops of water, yet the hand will be distinctly moistened. This usually denotes a water content of about 65 per cent., a quantitative statement which means much less for practical purposes than the hand test.

The beds must be observed from day to day with regard to temperature, since it is often well to spawn them as soon as the temperature will permit. For a few days after the preparation of the beds the temperature may rise, but if so, it will promptly decline again. Spawning should not be carried out until there is a fall to 70° or 75° F.; in fact, spawning at 75° F. is permissible only when the temperature is unquestionably declining. My recent tests indicate that 65° to 70° F. is generally preferable when one is prepared to maintain during the growing period a temperature of 55° in the houses. It does no harm to spawn at 50° to 65° F.; but below 50° growth will be very slow. In some earlier mushroom guides certain growers have advised spawning at 85° to 90° F. This temperature is fatal if maintained for some time.

Often, one finds that while waiting to

spawn the beds, or to case them, a profuse development of mould occurs, and also later the smaller species of ink caps, or *Coprinus fimetarius*. This is more frequent where shavings or sawdust constitute a considerable part of the compost. This growth will do no harm, but where it occurs profusely before spawning it is just as well to wait a few days. If the mould continues abundant after spawning, it may be eliminated by further compression of the compost, or by early "casing," as subsequently described.

Spawning and casing. Attention is directed elsewhere to the kinds of spawn and the procedure of spawn-making; so that here the use of the spawn will alone be discussed. When brick spawn is used the bricks may be broken into about 9 to 12 or more pieces (each piece about the size of a hen's egg) and one piece will be required for each square foot of bed space; of flake spawn an amount half as large as one's fist is not excessive. In spawning, lift the compost and insert the piece deep enough with the right hand, so that it may be covered fully 1 inch with manure, the compost being then pressed firmly over it with the left hand. When the right hand is removed an aerating passage will be left to one side of the piece of spawn inserted. With the compost firm about it the spawn will begin growth in a week or 10 days. It is not well to "case" or cover the bed with soil until it may be seen that the spawn is running well, unless conditions in the house make casing necessary in order to maintain satisfactorily the moisture of the beds. Casing consists in covering the bed throughout with a layer of earth from 1 to 1½ inches deep. Any fairly rich loam is good for this purpose. It should be secured some time in advance, and will require screening only if it contains numerous sticks and stones. French growers use considerable calcareous soil mixed with the loam, and if for no other reason, this is certainly desirable from the standpoint of sanitation. Neither a pure sand nor a heavy clay is desirable; the former loses moisture too easily, and the latter (especially where artificial heat is employed) is subject to baking. Moreover, a woods-mould would also be objectionable, partially on account of the abundance of other fungi in this material, but especially because of the tendency to increase the number of fruits at the expense of size. Either a good garden loam, a potting soil, or such a soil as is usually found just beneath a grass sod is excellent.

Care after casing. One of the chief difficulties in mushroom growing is encountered in caring for the beds after spawning, although the only factor to be considered besides temperature is that of moisture of the bed and air. Many amateurs drench the bed with water and destroy the spawn, others are afraid to water even when there is rapid drying out; in consequence, the spawn will not grow near the surface of the bed, and hence will not bear mushrooms. When the casing material is applied the compost should be exactly correct as regards the amount of moisture. The casing soil should be well moistened by repeated sprinkling, and not by a sudden drenching, as soon as the beds are cased. The amount of water to be given the beds subsequently should be as little as possible in order to keep the bed *merely moist.* Usually it is best to water frequently, rather than heavily, applying sufficient water each time to slightly more than counterbalance evaporation, for if the casing soil is kept moist, there will be little danger of drying out. It is not well to tear a hole in the bed every day to see if it is moist, or to ascertain if the spawn is growing; but an occasional thorough examination may be made. When the mushrooms begin to appear, more water may be given. It is not possible to say how much water should be applied per square foot or per square yard of bed, since the conditions of evaporation are so different. A dry room may require sprinkling twice a day; a favorable cellar no oftener than once a week. Surface indications are generally satisfactory criteria, if followed closely.

The Growing Period

UNDER favorable conditions a bed of straw-manure compost should come into bearing in from six to eight weeks, and one must begin to look for the source of the trouble if after ten weeks there is no sign of fruiting. On the other hand, if shaving-manure compost is employed, the beds may bear in eight weeks, but it is just as likely that twelve weeks will be required. In the same way, even with the best spawn, the growth will be slow if the manure is inadequately fermented, if the temperature is low, or if the moisture conditions are unsatisfactory. In those instances where "green" spawn is used a small mushroom or two may arise directly in about three weeks from the piece of spawn inserted. This is not a desirable occurrence, and such mushrooms are small of body and of less commercial value. At 58° to 60° F. the bed will come into bearing, as a rule, earlier than when kept at 54°, but with other factors equal, the length of the period of production will usually be shorter and the mushrooms smaller at the higher temperature.

Flushes of growth. When the mushrooms begin to form, they invariably appear first almost directly over the inoculum of spawn inserted, so that under uniform conditions the first patches of buttons will be as regularly distributed as the spawn pieces. As these groups or clusters all push toward maturity simultaneously, it may be called a "flush" of fruiting (Plate III[1], d; IV, a). When these are picked, a little fresh earth placed where necessary, and the bed sufficiently watered, it may be a week or more before a second flush of buttons occurs. By this time the mushrooms are better distributed over the bed, and subsequently there may be less regularity in the flushes. If the temperature is irregular, flushes may characterize the whole bearing period.

Period of production. The period of productiveness of a bed will vary from a few weeks to several months, depending upon the conditions. A satisfactory bed will bear continuously from two to three or four months. After a bed has apparently ceased to bear it should not immediately be discarded; but rather an examination should first be made, since sometimes an application of water heavier than usual may cause it to yield an additional supply. It has been advised to water at such times with a dilute saltpeter solution, or with liquid manure, but the writer has not found these methods sufficiently beneficial to justify a general recommendation of this sort. It is possible that watering with some complete fertilizer might be of service, although this has not been well demonstrated. If the examination reveals fresh-looking spawn in the bed, the removal of the old soil and the substitution of a thin layer of fresh, rich earth may be a stimulus to renewed productiveness.

Care during production. Beds which are yielding heavily will, of course, require considerable water, and no grower can make a greater mistake than to follow the now almost discarded custom of adding no water to the beds so long as mushrooms are evident. I have witnessed several cases in extensive cultures where the sole cause of failure to get adequate returns was in the dearth of water at the right time. Preferably, the water applied should be of about the temperature of the beds. Obviously, one must beware of water if ventilation is poor and evaporation practically nil; indeed, there is then nothing more disastrous than too much water.

When hot water or steam heat are employed it is comparatively simple to control conditions, but with dry heat the moisture conditions will be irregular at best. Forcing the stoves or heating plant in cold weather will necessitate more water, and at the same time the changes from a moist to a dry atmosphere will induce a cracking of the upper surface of the mushrooms—much to their market injury. Under such circumstances some type of covering may be necessary. The simplest cover method, and one which especially commends itself when the unfavorable condition is temporary, is to spread newspapers over the bed. When the condition is likely to be permanent, a framework may be made to extend 6 or 12 inches above the bed, with cheese cloth or unbleached cotton over the frame. This may be arranged to be readily removed for harvesting. In this connection it is necessary to call attention again to the fact that such coverings are never to be employed where they retain so much moisture that the effect is to induce a " stemmy " development of the mushrooms at the expense of caps. In open air culture matting is often employed over the frames—performing the double duty of retaining moisture and preserving a more uniform temperature.

Between crops. Directly after the beds in any house or cellar have ceased to be productive or remunerative, they should be removed and the house thoroughly cleaned and ultimately fumigated or sprayed, as mentioned later. Beds which come into bearing in mid-winter will usually cease to be productive with the warm weather of May or early June; those coming into bearing earlier may not last until the warm weather. None of the old compost, soil, etc., used in the beds should be employed in any subsequent mushroom crop. It would be a source of great danger, probably increasing many times the amount of disease and insect injury. It is, however, excellent compost for flowers, lawns, and gardens. When the beds have been dumped and the old compost removed all wooden supports and boards, as well as the walls and floors of the house should be thoroughly cleaned. Preferably the boards may be taken from the house or cellar, and as soon as dry whitewashed with a lime-wash made from good stone lime, or thoroughly sprayed with strong copper sulphate solution. Where possible the walls of the cellar should also be sprayed with one of these washes, or the cellar may be fumigated with hydrocyanic acid or sulphur fumes.

CHAPTER VIII

Mushroom Spawn-making

In an earlier section of this book (pages 13–16) I have drawn attention to the nature of mushroom "spawn." It was also indicated that spores cannot be used directly in propagation and that spawn of commerce is the only "seed" material practically employed in growing these fungi. Pure cultures are effective, but too expensive for practical purposes. "Brick" spawn (Plate IV[1], d) is commonly used in England and the United States, and very few growers find it advisable to make their own; while in France "flake" spawn has a monopoly of the market, and most of the large growers prepare, by means of a "starter" of "virgin" spawn, all of the material they use.

Foreign spawn. For a period of several years subsequent to 1901 I undertook to investigate the reliability of the mushroom spawn (English "brick" and French "flake") sold at that time by American seed dealers. Indications had pointed strongly to poor spawn as a cause of many of the failures commonly experienced by amateurs. From 1901 to 1904 samples of commercial spawn were purchased in various cities and subsequently tested at Columbia, Mo. (as reported, in part, in Bulletin 85, Bureau of Plant Industry). These samples were either tested in regular mushroom beds, or they were placed under conditions favorable for determining if growth would start. In an unexpectedly large majority of cases, the spawn proved to be dead. The conclusion drawn was that for American growers the most important consideration was a source of reliable spawn. Moreover, through observations in England and France I was convinced that growers in those countries experienced no such difficulties with poor spawn as the American growers had suffered. With imported spawn it seemed probable that the additional time involved conditions of shipment, and the subsequent storage methods in the United States all tended to weaken or ruin the products. Worst of all, it was found that spawn was sometimes carried over from one season to the next under the assumption that it was "quite as good" as the fresher product.

Spawn-making in the United States. Meanwhile our attention was gradually focused sharply upon the possibility of spawn-making in the United States. By English growers the information had been offered that spawn-making in the United States would not be successful on account of climatic conditions, just as I had been assured in France that the extreme conditions would render mushroom culture unsatisfactory. Through the development of a method of securing pure cultures of *Agaricus campestris* and other mushrooms, originated by the writer while at the Bureau of Plant Industry, U. S. Department of Agriculture, in 1902, the way was opened not merely for the production of a high grade mushroom spawn in the United States, but also for its production by a selection method. The perfection of the method and its application by spawn growers required a few years; and still further time was required for this to react upon commercial mushroom production.

The experimental pure culture spawn made and distributed under the auspices of the Department of Agriculture was very successful, so that certain irresponsible firms took advantage of the new movement to advertise and sell quantities of poor product —to the utter confusion of the amateur. In time several reliable and painstaking growers mastered all necessary bacteriological (pure culture) and mechanical details, ultimately launching highly successful enterprises.

Poor spawn has been, to a considerable extent, driven from the markets, and the quality of the English spawn imported has of necessity advanced, as a result of the successful competition. French flake spawn was never in very great demand, and time has convinced most growers that this type rapidly loses vitality under the conditions of importation. It is still desirable that the grower should insist upon receiving fresh, vigorous spawn; but the improvement in conditions is obvious to any one of experience. The success of spawn of pure culture origin has been so great that from 80 to 90 per cent. of the mushrooms grown during the season of 1913–1914 are reported to have been from American spawn of this type. Some spawn was actually exported to Europe.

Spawn-making a special enterprise. The present day production of mushroom spawn is based on a selection principle, and it also involves a certain knowledge of laboratory "pure culture" methods, or bacteriological technique. Spawn-making is, in fact, a special industry, and at the present time it is not practicable for every mushroom grower to make his own spawn satisfactorily unless he is prepared to get the necessary training, and look complacently upon his first failures. A brief description of methods is included here, not with the idea of teaching the reader how to make spawn, but rather with the view of giving him some general information about the process, so that he may perhaps better appreciate both the necessity of good spawn and the reasons why he is justified in demanding good quality and tested varieties. Before discussing the newer methods it may be well to indicate first, however, the empirical procedure which prevailed in England, France, and elsewhere before pure culture methods were introduced.

A chance method. From the earliest records obtainable regarding mushroom culture, it appears that the grower depended upon a "spontaneous" or "native" occurrence of spawn in pastures, in compost piles, or elsewhere as a means of starting his cultures. He was forced to use this spawn without an opportunity of adequately testing its productiveness, and often without even knowing the appearance of the form secured. The spawn thus obtained was known as "virgin" spawn and presumably it came from the accidental germination of spores. As mushroom growing developed, the demand for virgin spawn increased to such extent, that the location and sale of this product became almost a special industry. In England "mill-track" virgin spawn was at one time much sought, this being originally the spawn found in the well-trodden soil and manure of the horse path, or course, of the animal-driven mill; later it became merely a trade name.

The maker of spawn or grower of mushrooms whose source of spawn was the pasture proceeded in the following manner: Finding a natural occurrence of mushrooms —or assuming their occurrence—in a favorable locality, the sod was removed, small trenches were prepared and filled with a good quality of stable manure, and the sod returned. Into the manure of these trenches the spawn would grow and spread vigorously in an interval of some weeks. This material was then available for spawn-making or mushroom growing. Since the method is based, usually, on first locating a few mushrooms in the open, it has at least the advantage of affording in a general way a knowledge of the variety grown. In any case virgin spawn was used either (1) directly to inoculate, or spawn, the mushroom beds, or (2) more frequently to spawn compost which was intended to yield a large amount of crop spawn. Crop spawn was made (a) on the part of the grower (especially the French grower) by spawning heavily with virgin spawn a small bed of compost in which it was permitted to spread, but not to proceed to the production of mushrooms, the bed being taken down and used to make flake spawn for crop purposes; or, (b) this virgin spawn was used by the commercial spawn-maker (in England) in the inoculation of the compost bricks now so much employed. It is said that in the vicinity of Paris some persons make a business of searching for this virgin spawn, which they sell to the growers at a high figure. It is claimed that they become so adept in detecting the differences in the character of growth, the quality of odors, etc., that they can distinguish not only *Agaricus campestris,* but also some of its varieties.

It might be asked: What is the necessity for virgin spawn? Why not transfer the spawn continually from one bed to another? The answer to these questions is found in the fact that experience shows this to be an unprofitable method if carried too far. The feeling is that a practice of this kind results in a complete "running-out" or deterioration of the spawn if persisted in for about three years. To a limited extent the idea of transfer is applicable, as we shall see in a moment, but under certain restrictions. It is to be regretted that definite experiments are lacking regarding the extent to which successive propagation is permissible, but it seems fairly certain that no transfer of spawn should be made from a bed which has begun to bear mushrooms vigorously. By transfer in this case I mean either direct transfer of the growing spawn into fresh beds, or transfer to other beds, after drying and preserving the spawn until the next season.

Any method of spawn-making which involves the use of an unknown strain or variety of mushrooms is essentially haphazard, and by such chance procedure there can be no progress in the selection and maintenance of desirable strains or varieties, and no accumulation of benefits. Moreover, it is not possible even to know the worth of the strain unless the finder were able to await the result of a preliminary test. On this ground, therefore, the writer determined that for the general success of mushroom growing in America it would be desirable, first of all, to attempt to develop a method by which one might select and maintain in culture the varieties which might prove to be most suitable.

The tissue culture method. While studying in my laboratory in 1899 Miss Ferguson was able to determine certain of the conditions governing spore germination, and as a result of this, it was hoped that a method of using spores in spawn-making would be practicable. Certain difficulties arose which we were not able satisfactorily to overcome, and the use of spores was temporarily abandoned. Meanwhile, the writer ascertained, as might well have been anticipated, that fragments of growing mushrooms, obtained under aseptic conditions, may be made the starting point for pure cultures of spawn. This is based on the fact that a small piece of the inner tissue of a fresh mushroom will, when placed on any suitable sterile nutrient medium, promptly develop a mycelium, thus yielding a culture of the spawn. In making cultures in this way, however, it should be recalled that a special technique is required, since otherwise the presence of foreign moulds or bacteria will cause the pieces of tissue to undergo prompt decay, rather than to grow into a vigorous mycelium. The use of these pure culture methods indeed necessitates a knowledge of sterilization precautions, and of the distribution of bacteria and moulds in nature.

Making pure cultures. The method of making pure cultures is described in bulletin 85, Bureau of Plant Industry, United States Department of Agriculture as follows:

"The materials, or media, and all the vessels employed must be sterilized, which implies being heated at a temperature sufficient to kill all germs present in the vessels or materials used. If the vessels used are test tubes or other pieces of glassware with small mouths, they should, previous to sterilization, be plugged with cotton batting. This cotton batting prevents, when carefully manipulated, the entrance of germs from the air, and therefore keeps the vessel or medium in a pure or sterile condition. If such a vessel is opened, this should be done in a room free from currents of air or falling dust particles; and, while open, tubes and other apparatus should be held in a more or less horizontal position, so that they will be less liable to contamination. It follows, of course, that the cotton plug, if removed, should not come in contact with any unsterilized substances. If, now, a small quantity of the growing mycelium of a mushroom from a pure culture is transferred to such a sterilized tube, using for this transfer sterile needles, or scalpels, there will be little danger from foreign organisms, and the piece of mycelium inserted will therefore grow as a pure culture free from all other fungi or bacteria." . . .

"In making pure cultures of mushrooms, large test tubes or wide-mouthed bottles may be used. These should be carefully cleaned, and if possible, a sterilization should be given by means of dry heat as a preliminary precaution. In this event the tubes are plugged with cotton plugs and placed in a dry oven made for the purpose. They are heated to a temperature of about 150° C., and this temperature should be maintained for nearly an hour. Ordinarily, however, in rough work it is not essential to employ this preliminary sterilization. In either case the tubes are next partially filled (about two-thirds) with the manure, or half-decayed leaves, upon which it is desired to grow the virgin spawn. A plug is inserted in each tube, and the tubes are then sterilized in a steam boiler or under pressure. If sterilized under steam pressure, as in an autoclave, it is necessary to use about 15 pounds pressure and to allow the tubes to remain at this pressure for from 15 minutes to half an hour. If the sterilization must be effected in a boiler or in an open water bath, it can only be done at 100° C., of course; and it is then desirable to boil the tubes for at least an hour on each of two or three successive days.

"With the tubes thoroughly sterile, the next step is to make the cultures or inoculations. By the tissue-culture method it is implied that the inoculations are made from pieces of the tissue of a living mushroom. It is at this stage that selection may be made. One should procure from a bed of mushrooms in full bearing mushrooms which represent the most desirable qualities that are to be found. Size, quality, and general prolificness must all be considered, as well also, as other characteristics in any special selections. One may desire, for instance, to select from a variety which yields throughout a long period or one which is resistant to higher temperatures, etc. Having found the mushroom from which it is desired to propagate, plants as young as possible may be used, and those which show the veil still intact are especially desirable. With a scalpel, or a pair of forceps, which has been sterilized by passing the blade through a gas flame, or even the flame from an alcohol or ordinary lamp, small pieces of the internal tissue may be removed, and these pieces transferred to the tubes, without, of course, coming in contact with any object whatever which has not previously been sterilized. It is a good idea to wash the mushroom first, so that no dust will be made. The plant may then be broken open longitudinally and bits of the internal tissue readily removed without fear of contamination when one becomes adept in this kind of manipulation. Immediately upon inoculation the cotton plug is replaced in the tube, and after all the tubes are inoculated they should be put out of the dust, preferably in a situation where the temperature is about that of an ordinary living room. In the course of several days a slight growth may be evident from the tissue if the conditions have been perfectly sterile. In the course of a week or more the growth should become very evident, and in three weeks the mold-like development of mycelium should spread to practically all parts of the medium in the tube." . . .

"When the tubes are thoroughly 'run' the contents may be removed and used in spawning brick. The contents of a single large tube may spawn several bricks when carefully employed. If no transfers are made of the growing mycelium from one lot of tubes to another, the writer has not found it at all impracticable or unfavorable to utilize this first lot of bricks later in spawning others. No further transfers, however, should be made from these bricks to others under any circumstances in spawn making. As elsewhere indicated, such a continuous transference is injurious to the vigor of the spawn, and diminishes the quantity of mushrooms produced."

I now regard it as the wiser course to use larger containers for the spawn and to make no transfers whatever. Where these containers are more than about one inch in diameter, it will be found that steaming for the time mentioned above, will be inadequate to effect thorough sterilization. With such vessels it will be necessary to increase the time of steaming, and the length of time required to effect the complete sterilization should be carefully determined in advance. It also appears that a more rapid growth is obtained if leaf mould and well fermented manure are mixed together as a substratum for the cultures.

To secure a fresh growth of the mycelium or spawn of any desired mushroom, the obvious way would be to collect and sow the spores in a nutrient substratum, employing for the latter, let us say, stable manure, decayed leaves, or any of the special nutrient media used in the laboratory. This method is successsful with the morel, the oyster mushroom, and certain other species. Contrariwise, the same treatment does not effect the germination of the spores of *Agaricus campestris,* or, at most, they only germinate sporadically. Nevertheless, these spores are capable of germination, and suitably stimulated, a considerable percentage may grow. Many attempts have been made by practical growers to develop spawn from spores, sowing the gill portions of mature mushrooms in specially constructed beds; but the results, so far as the writer is aware, have not been satisfactory, and until recently, growers had been compelled to rely upon virgin spawn. After the tissue method above described, the writer has grown thousands of cultures, and there is no hesitation in stating that it is entirely practicable as a source of pure cultures for spawn-making.

Pure cultures and selection. The advantages of the pure culture methods are obvious. Wherever the species may be found or whatever it may be—provided the specimens are growing vigorously, and free from parasitic attacks—a culture may be made. One may therefore get specimens from the fields, or the woods, or from the beds of mushroom growers. In another chapter it is shown that there are numerous strains and varieties of the cultivated mushroom. Whether these varieties vary as to color, whether they differ in quality or productiveness, or show diversity in other characters, the method permits a perpetuation of the kinds which promise something of interest or of value. Any individual difference indicating the possibility of a permanent desirable departure may be selected, and henceforth, if this quality is stable, this particular characteristic may be propagated. It is believed that this method may be fully relied upon for further progress in selective mushroom growing.

At one time there was the feeling that even with the tissue culture method there might be more or less "running out." I have, however, tested for five years one strain by continuous propagation from season to season through tissue cultures, and this has consistently shown a high yield and quality. It is likely that "running out" would be in part due to improper care of the pure cultures. Analogous cases are well known, as when continuous culture of certain pathogenic fungi in the laboratory suffices to materially lower their pathogenicity.

Spore germination. Some will no doubt wonder why there should be any serious difficulty in germinating mushroom spores, and in thus producing spawn by a direct and natural process. The difficulty lies in the fact that the spores do not germinate readily, and such methods of stimulating germination as have been made known are far less easily applicable than the tissue culture method already described. Some years ago Costantin and Matruchot reported that they had been able to produce mushroom spawn from spores. Their work was reported in such manner that only the results, and not the methods, were made known, and it has remained a secret. Since they distinctly refer to the use of spores, it is to be assumed that they found a practicable method of stimulating spore germination, but even this is not certain. At any rate their method of making spawn found practical application for a time in a department of the Pasteur Institute, and recently it appears to have been taken over by a corporation in Paris interested in mushroom growing. By the process mentioned the spore culture tubes of spawn are grown and sold to growers who are expected to multiply the volume of the product by preparing beds which yield the crop spawn required. The grower who so desires, therefore, purchases spore cultures and makes his own general supply of spawn. This method with tissue cultures may also develop in the United States in time.

Another secret method of effecting spore germination has been referred to by Repin in a circular on the subject, and his method appears to have been practically applied in the making of "plate" spawn by one of the large seed firms of Paris. As far as can be ascertained, this spawn has not come into very general use. Details regarding Dr. Ferguson's investigations on spore germination will be found in Bulletin 16 of the Bureau of Plant Industry, and my own studies are reported in Bulletin 85 of the same series. I have not abandoned the hope that a practical spore method may be developed in this country, but even should such a method be found, it is not at all certain that it would be more practicable than the tissue culture method which has been the first cause of the rapid development of mushroom growing in this country in recent years.

Commercial "brick." As will be indicated in some detail later, the compact commercial brick spawn seems to exhibit a better keeping quality than any other product on the market. This spawn has also the advantage of being easily handled. In making the bricks, manure or compost is compressed into a compact form, which, when dry, ordinarily measures about $5\frac{1}{2} \times 8\frac{1}{2} \times 1\frac{1}{2}$ inches. It will be necessary to make the brick in moulds somewhat larger than these dimensions in order to make allowances for shrinkage upon drying. It will not be possible to give detailed directions governing spawn-making under all conditions; indeed, the methods of spawn-making may be diverse, and no one system is preeminently best.

Materials and methods. The compost used is customarily a mixture of stable-manure, cow-manure, and sometimes a small quantity of loam. The mixing of these materials is done after composting. It is believed that at least two-thirds of the material used should be stable manure free of heavy straw, and good success for home use has been obtained when this material was used alone. However, a considerable admixture of cow manure gives a more compact brick and encourages a mould-like rather than a thread-like texture of the mycelium. Several machines have been successfully used in the making of brick. In general, however, hand moulds are employed; then subsequently repressing may be given with a brick machine if one is available. The ordinary hand moulds may be made of iron or may be in the form of a strong oak frame, or the latter may be lined with steel plates. From a previous description of two methods employed in hand-moulding, I may quote as follows:—

(1). "The compost may be thoroughly wet or puddled; then, with the mold upon a board of suitable width, the manure is compressed into it, the mold removed from the brick then formed, and the board pushed along for a succession of such impressions. The boards supporting the bricks are then disposed in racks and the bricks dried for a few days, or until they may be turned on edge for further drying out. (2) The compost may be used in a condition which is quite moist but not puddled. It is compressed into the brick with some force, a mallet being often employed. The brick thus obtained is sufficiently rigid to be immediately handled if necessary."

Inoculation, growth and drying. With the bricks properly made the procedure is then to dry them on racks, and not too quickly, to the stage demanded for inoculation or spawning. With regard to the inoculation of the bricks, one of two methods may be adopted: (1) The bricks are dried rather slowly to a point when they are but slightly moist throughout. This is to be determined not by the condition of the exterior, but by the internal moisture content of the brick. They are then piled or stacked in a situation favorable for mushroom growing, and between each pair of bricks in successive layers are distributed four or five bits of the spawn from pure cultures or other sources of inoculation used. (2) While the bricks are still fairly moist the pieces of spawn used for inoculation may be inserted in the brick, one or two towards each end. To effect this a cut is made in the soft brick, the spawn inserted, and a stroke of the knife is made to nearly close the slit opened. Drying is then continued slowly until the bricks are about in the condition mentioned under the first method, when they were stacked in piles in a well drained, ventilated room or cellar for growth.

Whatever may be the method of spawning the brick, the size of the stacks made will depend upon circumstances. When a thorough fermentation of the manure has not been given, or when relatively little loam is used an after-fermentation may result. The bricks should then under no circumstances be put in large stacks. The bricks are usually stored for growth at a temperature about the same as that most favorable in mushroom growing (Plate IV[1], c). They should be examined occasionally, and the moisture relation should be carefully controlled. It is desirable to have the spawn grow throughout the brick, and to attain this end the surface must be kept slightly moist. Therefore spraying the brick or the walls of the storage cellar with water may be required, but extremely moist

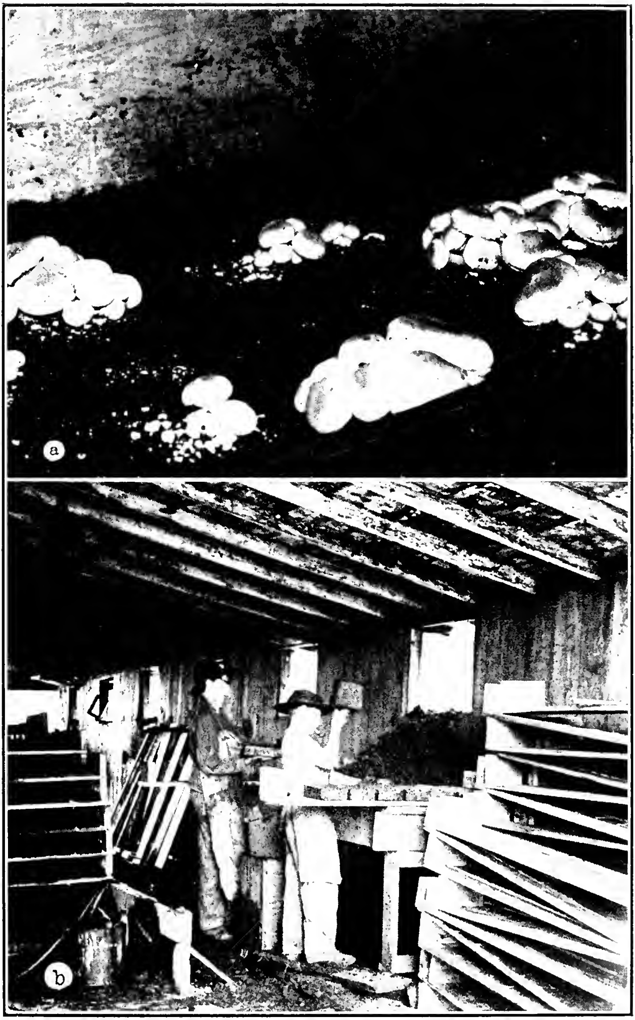

Plate IV. (a) First Flush of "Columbia."
(b) Spawn Making, Old Process.

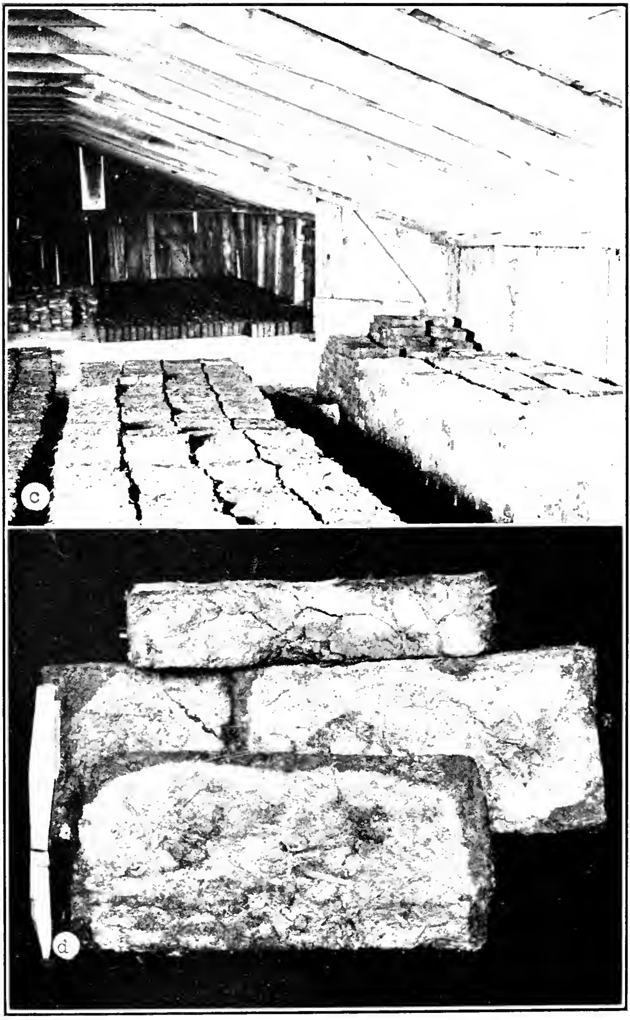

Plate IV[1]. (c) Brick Inoculated and Stacked.
(d) Brick Mushroom Spawn.

conditions are to be avoided. Moreover, for the last stages of growth it may be necessary to place the bricks on edge, and so spaced as to allow free circulation of air. Sometimes it is necessary to shield the stacks with good clean straw or cheese cloth. Above everything else the spawn maker should realize that vigorous spawn, free from insects and disease, is required. Any practical method of manure fumigation which can be employed would be a step in advance.

If the spawn runs well, it will show throughout the brick as a mold-like growth. Even in good spawn there may be some coarser thread-like elements, but an abundance of these heavier threads alone is usually indicative of undesirable quality. Furthermore, evidences that the bricks have begun to produce a quantity of small mushrooms are not favorable. Spawn of this character when planted in the beds will frequently produce mushrooms directly, without spreading throughout the beds.

The well penetrated bricks should be dried gradually, but considerably, and to the extent that no more growth may occur. This is preferably accomplished under cover; and the spawn should subsequently be stored where it is both cool and dry. A cool, moist cellar would encourage a production of little mushrooms upon the bricks and it seems that a very warm situation is more injurious to the vitality of the product.

Vitality of spawn. During the past few years I have made many tests of spawn of various ages, and of material which had been stored in various ways. The results indicate that under ordinary circumstances mushroom spawn is unquestionably so badly injured after being stored for a period of one year as to be unfit for commercial purposes. There are persons who claim that they have successfully carried spawn over from one season to another. This may be true, but the conditions must have been unusually favorable. I have never had the opportunity of testing commercial spawn kept at a uniformly low temperature, say, 50° or 60° F., but in only one single instance have I obtained a satisfactory yield from such spawn over one year old, and in no instance have any mushrooms whatever been thus far obtained in our experimental beds by the use of spawn two years old. In fact, we believe that it is preferable for seedsmen and growers to use spawn not more than six or eight months old. It would seem certain that under the same conditions the vitality of brick spawn is greater than that of flake spawn.

Experiments made with the view of reducing the weight of the brick by employing a more spongy material in its preparation gave unsatisfactory results from the vitality standpoint. It is probable that to this fact is to be attributed the early general use of brick or English spawn rather than of flake spawn in America. Formerly, the imported French product was flake material only, and this proved unsatisfactory time and again. A rather anomalous state of affairs existed. We imported canned mushrooms from France, the country of great mushroom production, but most of the mushroom spawn came from England.

The price of spawn. The price of mushroom spawn varies considerably, depending upon quality. The table below is a fair index of current prices to growers of what is known as standard spawn.

1 brick, postpaid	$ .40
5 bricks, not prepaid	1.00
10 bricks, not prepaid	1.80
50 bricks, not prepaid	8.00
100 bricks, not prepaid	15.00
160 bricks, not prepaid	22.40

Spawn of even higher quality may be obtained, in which case the excuse for the higher price is the fact that the bricks have all been inoculated directly from the pure culture. English brick spawn may also be purchased from importers and the price of this is a few cents less per brick than the American. The imported spawns have, however, been subjected to longer shipment and storage.

It is a mistake on the part of the grower to purchase his spawn in a hurry whereby he may be forced to take whatever the market affords. If spawn is needed in quantity it is well to place the order with the manufacturer several months before it is needed, and this should secure the best quality which he is capable of furnishing.

CHAPTER IX

Success and Failure, Expenses

Can success in mushroom work be counted upon? Not at all. Indeed there have been innumerable failures; but at the same time there are conspicuous successes. If you will examine into the record of those who have failed with poultry work, with orange groves, with carnation culture, or in any other agricultural or floricultural enterprises requiring constant, intelligent attention you will find that the main factor has been that of lack of information, or incapacity, on the one hand, and deception or extreme bad luck on the other. It is undoubtedly true that a large number of the failures in mushroom growing have been the direct result of crediting irresponsible or deceptive advertisements. It is fair to say that no one should be advised to undertake mushroom culture on a commercial basis who can not present good evidence of his special competence to go into this work. It is true that relatively little capital may be required where it is unnecessary to build houses for the purpose. It should be remembered, however, that practically all capital invested in materials aside from houses is used up in the production of the crop; that is, it is recoverable only through successful yield. We may consider a person qualified to undertake this work (1) because he is interested and not merely because it is supposed to offer a fortune in a few years; (2) after successful experience on a small scale and after serious study of the conditions required for commercial work; (3) after careful observation of the market demands or possibilities and an equally careful computation of all costs involved.

I do not depart from the spirit manifest in many letters received when I say that the following excuses are frequently offered for undertaking mushroom growing: I am broken down in health, wealth, or temperament, and this pursuit appeals to me as an "Aladdin's Lamp" whereby I may obtain the independence desired.

Even after one has made a careful study of the conditions of mushroom growing, there remains, of course, the possibility of failure through accident or through the selection of a poor quality of spawn. The latter difficulty, at least, may be in a measure obviated by appealing to the director of the experiment station of the state in which one lives, or to the U. S. Department of Agriculture for information. In this way one may ultimately be put in touch with reliable dealers or manufacturers of spawn. So much false advertising has been practised that while it may seem a misfortune to the reliable spawn makers we would frame the general rule that no inexperienced grower should depend upon advertisements alone in order to determine where he shall purchase his spawn. It is greatly to be hoped that this condition will soon be remedied.

Mushroom growing is, however, an established industry and the figures regarding its development in recent years indicate that when freed from fake advertisers and fake growers it will succeed throughout the United States just as it has succeeded throughout France.

In computing the probable expenses of mushroom growing one should include such items as rent or depreciation, compost, soil, implements, labor, delivery of product, heat, water, and facilities for lighting, as well as all such minor expenses as spray materials, boxes, baskets, and numerous other incidentals. One should also bear in mind that if he is in a position to undertake this work as an independent enterprise occupying his whole time the scale of operations should be great enough to make certain a definite (assumed) income. For example, if only 3,000 square feet are planted, an average crop would yield not more than 3,000 pounds of mushrooms, and these if sold to commission men might not yield more than $1,000 gross. These figures are intended merely to make the suggestion that on going into this work one should not count upon more than average returns, and he should at least be sure that average returns would insure a sufficient profit to make the undertaking worth while. I would advise no person experienced in mushroom growing to undertake this work on a basis of less than 7,500 square feet, unless, of course, it is merely experimental: experiment by all means, only experiment on a small scale and with a definite end in view.

Mushrooms for the Table

The impression is perhaps too prevalent that the use of mushrooms (and I refer here particularly to *Agaricus campestris* and related forms) in the home is restricted by the fact that they must be consumed immediately—not being easily kept even for a day or two. It is well to err on the side of freshness and safety with all foods; but it should be pointed out that when mushrooms are properly gathered, and marketed in relatively small containers, fairly well aerated, they keep two or three days even in warm weather. In a cold dry place or open in a properly kept refrigerator they keep much longer. Under no circumstances should mushrooms be kept long in a tight box in warm weather, a precaution which clearly applies also to almost any fresh fruit or meat.

Mushrooms grown in small quantity for home consumption may be gathered in a condition so neat and clean that cutting off the stem end is the only precaution required. Sprinkling the beds, however, will often result in spattering a little soil on the caps, and it is usually desirable to brush the mushrooms as they are gathered. Mushrooms purchased on the market will require washing, but never soaking—the latter resulting in a loss of flavor.

In using puff balls, boleti, and the full-grown *Agaricaceæ,* peeling will usually be required, and the stems of pileate forms should usually be scraped or peeled, depending upon the texture. It is entirely unnecessary to peel buttons of *Agaricus campestris* and other delicate species, and in this connection it may be pointed out that in the most successful mushroom culture the buttons are often of giant size. Such buttons may be lightly peeled or scraped, not peeling by stripping the skin with the fingers from the margin inward toward the center, as should be done with older specimens. Morels, clavarias, and the branched forms of Hydnum and the like, cannot, of course, be peeled under any circumstances, and all parts of these mushrooms are edible.

Many of the recipes given below call for the use of mushroom caps, and frequently no mention is made of the use to which the stems may be put. It is to be noted, however, that in the higher qualities of commercial mushrooms the stems are not so elongated as to be tough and they may at all times be used in dressings, stuffings, etc., and moreover, in making soups they are more desirable than the gill surfaces on account of the fact that they do not yield a dark colored broth. The flavor of the stem, however, is inferior to that of the cap after the mushroom has attained some size, or after the veil has broken. In referring to the preliminary preparation for cooking under the recipes, it will be assumed that the mushrooms have been cleansed and where necessary peeled in accordance with the suggestions made above. It is impossible in the space here at command to give more than a selection of the various recipes which may be employed in the preparation of mushrooms for the table. In addition to the suggestions made, the best cook books are, of course, to be consulted. In general, it may be said that mushrooms are susceptible of being used in countless ways, for example, as hors d'œuvres; in various entrées, or with meats; as side dishes (baked, creamed, etc.); also in connection with tomatoes as a salad course; and finally they may be used in dressings, stuffings, or sauces, as well as cooked with certain farinaceous foods, especially spaghetti.

The recipes here presented have been selected from a variety of sources, and only this general acknowledgment of the fact can be made.

Stuffed. Prepare 12 large cleansed caps by removing stems and peeling. Melt 3 tablespoons of butter in a stewpan, add a small piece of bacon fat, ½ teaspoon finely chopped onion together with about ¼ pound chopped stems and small buttons, then cook 10 minutes. Cool and add ½ teaspoon finely chopped parsley and salt and pepper to taste. Fill the caps well rounded over, cover with buttered cracker crumbs and bake 15 minutes in a hot oven.

À l'Algonquin. Prepare as many large mushrooms as required, remove stems and sauté the caps in butter. Arrange in a buttered shallow pan with cap side up. On each cap place a large oyster, sprinkling with salt and pepper and adding a bit of butter. Cook in a hot oven until the oysters are plump.

Baked. Cleanse and prepare large caps as for broiling. Arrange the caps on buttered, two-inch squares of bread sliced thin (and sprinkled with pepper if desired). Arrange in a baking pan and cook in a hot oven for 5 minutes, then quickly place on each cap a piece of butter the size of a hazel nut, sprinkle the cap with salt and pepper, then continue baking until they appear soft and tender.

Panned on cream toast. Use cleansed buttons or large mushrooms in slices ¼ inch thick. Place in a hot buttered pan, with a little melted butter, salt and pepper, then cook in a hot oven for 20 minutes. Meanwhile prepare toasted bread, and when the mushrooms are ready, dip the toast in hot milk, cover with the mushrooms, and serve hot.

Baked in cream. Arrange 8 large firm caps (gill side up, or 1 pound of small mushrooms) in a shallow, buttered pan, sprinkle with salt and pepper and dot with butter. Add about ½ cup cream and bake 10 minutes in a hot oven. Place the caps on pieces of toast and just before serving pour over them cream remaining in pan. (An excellent simple method.)

Under glass. Prepare circular pieces of toasted bread and as many firm mushroom caps of medium size. Arrange the mushrooms on the toast in individual dishes, sprinkle with salt and pepper, dot over with butter, and pour over each a small quantity of heated cream. Cover with bell-shaped glasses and bake 20 minutes. Send to the table hot with covers on, so that the fine flavor of the mushrooms may be retained.

With sweetbreads. Cook 1 slice onion for 5 minutes in 3 tablespoons butter, then add ½ cup bread crumbs, ½ teaspoon salt, 1 cup milk, yolks of 2 eggs well beaten, together with whites of the same beaten until stiff and a little red pepper, together with 1½ cups of finely chopped mushrooms and 1 small parboiled finely chopped sweetbread. Fill buttered moulds or ramekins, set in a pan of hot water and bake 15 minutes.

Stuffed tomatoes with mushrooms. One pound of mushrooms will suffice to stuff 8-10 tomatoes. Cleanse, peel, and slice the mushrooms, then cook 5 minutes in a stew pan with 2 tablespoons butter, adding 1 level teaspoon salt. Scoop out the centers of the tomatoes, stuff with the mushrooms prepared, cover each with buttered crumbs, season to taste with pepper, olive oil, and lemon juice. Arrange in a baking dish and cook in a hot oven about 15 minutes.

Beefsteak smothered with mushrooms. Bake ½ hour in a buttered pan containing 1 tablespoon water, 1 pound of buttons, or of large mushrooms sliced. Broil the steak almost to point desired, pour the juices over the mushrooms, then cover the steak with mushrooms and juices and place in the oven for 10 minutes.

Creamed. Prepare ½ pound mushrooms (those in which the veil has not broken are preferable) and break in pieces. Melt 3 tablespoons butter in a sauce pan, add the mushrooms and cook 2 to 3 minutes; sprinkle with salt and pepper, dredge with flour, and add ¾ cup of cream. Cook slowly for about 5 minutes. Serve hot on small pieces of toast.

Creamed (2). Cleanse and prepare 10 medium caps, place them whole in the pan with 2 glasses of fresh cream, ¼ teaspoon of salt and a bit of shallot and some chopped parsley, cook slowly a half hour. Then beat up 3 yolks of eggs with 1 ounce of butter, a little grated nutmeg and a pinch of chopped parsley. Add these to the cream and let simmer a short time without boiling. Serve hot.

Chafing dish. Prepare 1 pound of small mushrooms or larger forms sliced, cook in 2 tablespoons butter 5 minutes, add one cup of hot milk, cover and cook 3 minutes, add the yolks of 2 eggs beaten, keep hot to serve but do not boil.

Broiled. Cleanse large mushrooms, peel, remove the stems, and place the caps in a buttered broiler, broiling for 5 minutes with cap side down during first part of the interval. Turn the caps, place a small piece of butter in each, sprinkle with salt and pepper and as soon as butter is melted and caps appear tender serve on circular pieces of buttered toast.

Broiled (2). Select fine, flat specimens, dip in salt water to cleanse, drain on cheese cloth, peel thinly (or skin if the specimens are older) upper surface of caps, and cut off stems with silver knife. Arrange gills upward in a gridiron rubbed with sweet butter. Place on each cap a small piece of butter and sprinkle over with salt and pepper. Broil until butter is melted, or not over five minutes on a quick fire. Serve hot on thin buttered toast.

Allamande. Peel the prepared caps and sauté in butter. Arrange in pairs with gill surfaces in contact and cover with

Allamande sauce, dip in egg and crumbs and fry in deep fat. (Allamande sauce: Melt 3 tablespoons butter, add 1/3 cup flour and gradually pour on a cup of white stock. Mix in yolk of 1 egg and season with salt, pepper, and lemon juice.)

Fried. Cleanse, remove stems, and slice the larger specimens. Heat sufficient butter to the boiling point, in a frying pan, then drop in mushrooms and fry 3 minutes on a quick fire. Serve hot on toast with a little sauce of melted butter, lemon juice, salt, and red pepper.

Sauté. Melt 2 tablespoons of butter in a hot frying pan and as soon as melted, add 1 cup small mushrooms (if large break in pieces), dredge with flour, add a few drops of onion juice, 1/4 teaspoon salt and a few grains of pepper and cook 5 minutes. Then add 1 teaspoon finely chopped parsley and 1/4 cup boiling water. Cook 2 minutes and serve on dry toast.

Sauté. Prepare the mushrooms, large or small as desired, and cook with butter a quarter of an hour, season with a little salt, pepper, and fine herbs, and serve hot.

À la Sabine. Prepare and peel 1/2 pound mushroom caps, sprinkle with salt and pepper, dredge with flour and cook 3 minutes in a hot frying pan with 2 tablespoons of butter; then to 2 tablespoons of browned butter and 3 of browned flour add salt and pepper and 1 cup milk. Combine the two and cook slowly 5 minutes. Sprinkle with 3 tablespoons of grated cheese and as soon as cheese is melted arrange the caps on toast and pour over the sauce.

Mushroom-tomato salad. Peel medium size tomatoes, cut thin slices from the top of each and remove seeds and some of the pulp. Sprinkle the interior with salt and pepper, also add a few drops of olive oil and vinegar. Cut up the cleansed mushrooms and mix with the dressing prepared as follows: To the yolk of one egg add a little oil and onion juice and a few drops of Anchovy sauce (if convenient) and vinegar, salt and pepper and capers; beat these all together but without forming a mayonaise, and add this sauce to the mushrooms and with the dressing thus prepared fill the tomatoes. Prepare the day before serving.

Chicken à la Bressanne. Put a dozen large cleansed mushrooms in a casserole with the same weight of chicken, add 2 ounces of butter, and salt and pepper to taste. Cover and let cook for 1 hour. When the chicken is tender add 1 cup of cream and 1 tablespoon of flour. Reheat and serve with mushroom croustades. The latter are made by cutting stale bread in strips 1½ by 1 inch and frying in butter. Chop some mushrooms, and sauté in butter. When the croustades are golden brown drain and cover with the chopped mushrooms.

Stewed, for breakfast. Use all sizes including younger stems, cleanse and peel where necessary, cover with cold water containing a little vinegar. After standing half an hour, drop the mushrooms into a stew pan containing a tablespoon of butter at the boiling point. Cook for a minute or two and season with salt and black pepper. Cook again slowly for 8 minutes while shaking the pan, then pour in cream to cover, and let cook 8 or 10 minutes longer.

Hors d' œuvre. Cleanse ½ pound of button mushrooms, sprinkle with a spoonful of salt and let stand for 1 hour. Add 2 soup spoons of white vinegar and let macerate for 12 hours. Pour on ½ tablespoon olive oil, and a little pepper and a trace of mustard. Serve as desired.

Cream soup. ½ pound mushrooms cut up fine, 2 cups water, 1 teaspoon salt, cook in double boiler 30 minutes, strain (or rub through sieve, if desired); rub together 2 tablespoons butter and 3 of sifted flour, then add this and 1 pint full milk to the stock above, cook 20 minutes, season to taste, and serve with or without whipped cream.

Cream soup (2). ½ pound mushrooms (young), 4 cups chicken stock, 1 slice onion, ½ cup butter, ¼ cup flour, 1 cup cream, salt, pepper, 2 tablespoons Sauterne. Chop the cleansed mushrooms. Pour in the chicken stock, add the onion; cook 20 minutes and rub through a sieve. Reheat, bind with butter and flour, cook together, then add cream, salt, and pepper to taste. Just before serving add the wine.

CHAPTER X

MUSHROOM ENEMIES

WHEN the conditions are favorable and the surroundings sufficiently sanitary the grower is not likely to experience any great amount of difficulty in restraining the usual mushroom pests. It is necessary, however, to be constantly on the alert since several of the common pests are invariably present in untreated compost and these may at any time become a great nuisance or a cause of failure. It is not feasible to include in this discussion all organisms which attack mushrooms, but there will be included both those which cause the heaviest losses and those generally present. The pests may be conveniently divided into two classes, insects and fungi. In the order of importance the chief insects are (1) small flies or gnats, (2) mites, (3) springtails, and (4) crustaceans or sowbugs.

Small flies. Several species of small flies are common about mushroom houses, but as the different ones are not readily distinguished one from another except by the specialist they may all be spoken of generically. The mushroom is injured by these gnats in the larval or maggot stage. It is unnecessary here to give a complete account of their life history, as thorough descriptions of the insects mentioned are given in circular 155, Bureau of Entomology U. S. Dept. of Agr. This circular may be obtained upon request. These little insects may appear in enormous quantity in the mushroom house following the preparation of the beds—when the temperature is on the decline. They multiply with great rapidity during any period when the temperature is high enough, depositing their eggs at the base of the mushroom stem. From this point the larvæ may pass up the stem and ultimately riddle the cap. In the open fields and woods larva-infested mushrooms are frequent, but in a properly regulated mushroom cellar this condition is most infrequent. This is due to the fact that these insects are practically inactive at temperatures below 55° F. In fact, if they cause damage at this temperature it is more to the spawn than to the mushrooms. If the eggs have been deposited in the compost while the temperature is still high the flies will emerge in time, but little damage will be done. From what has been said it is obvious that proper control of conditions will usually result in perfect control of this pest. On the other hand, when spawn is planted in late summer with the idea of having the crop come into production early in the autumn these pests may be a serious consideration. The adult flies are readily killed by fumigation with tobacco or any of the various trade nicotine fumigants, employing the amount of material commonly recommended for greenhouses, the indications for which are furnished with the material. It is also claimed that fumigation with carbon bisulphide (2 to 4 pounds per 1,000 cubic feet of space) is effective against these insects. This is rather expensive, and may be considered a last resort. Again, sulphur or hydrocyanic acid fumigation may be used before spawning. If a thorough fumigation is carried out it is best done just prior to making the beds. Following up the suggestions made here the commercial mushroom grower should make a special study of fumigation methods adapted to his space and other conditions.

Mites. The common mushroom mite (*Tyroglyphus lintneri*) is a minute insect which is found invariably in manure. It becomes very abundant if much time is consumed in the preparation of the compost and of the beds, particularly if the temperature is high. This minute creature feeds not only upon the mushrooms themselves, but more particularly upon the mushroom spawn, so that when they are present in large numbers they may entirely prevent mushroom production, or even the growth of spawn. It is one of the undoubted sources of failure when the conditions are unfavorable. Just as in the case of the gnat, the mite is less active at the lower favorable temperatures and unless it has become exceptionally abundant before the beds are made, it will not be an important factor with the growth conditions satisfactory. The writer has tried many types of fumigation in an endeavor to eliminate this insect from the manure, but has failed to find any practical means whereby it may be killed. Fumigation with the deadly hydrocyanic acid fumes four times the strength usually employed has served to kill the majority, but a sufficient number survived this treatment to make it seem scarcely worth while. It would, of course, be possible to kill all insects as well as fungi by steam sterilization of the manure, but for a variety of reasons I am unable to hold out the hope that this operation will simplify the problems as a whole. The best that can be said is that the various processes in the preparation of the compost should be carried through as promptly as possible and the conditions kept favorable. If the mushroom house has been cleaned to begin with, and the other precautions mentioned are observed, it is unlikely that this insect will be a cause of failure. However, mites have been treated fairly successfully by placing upon the beds scraps of cooked meat and then occasionally collecting these and dropping them into boiling water, afterwards returning them again to the bed.

Springtails. These little insects sometimes appear upon the surface of the beds in colonies so populous that affected areas seem literally alive with the tiny gray-black creatures, hopping in every direction, when disturbed, more actively than "wrigglers" in a tub of water. I have found these insects particularly numerous—and frequently a cause of failure—where mushrooms are grown in damp caves, and where the rules of sanitation are grossly violated. These insects occur in the manure, but with a proper treatment of materials and control of conditions they are seldom a serious pest. They attack the mushrooms primarily through the region of the gills, or gain an entrance from injuries, and a "flush" of mushrooms may be completely destroyed in two days. The best practical remedy is to ventilate thoroughly and dust the beds and floors with quick lime. Pyrethrum powder is serviceable if the conditions are not too wet. A spray of lysol, 2 to 2½ per cent., is also effective, but cannot be applied without some injury to the growing mushrooms.

Sowbugs. The common gray crustaceans of the woods and greenhouse, a "bug" fully a half-inch in length, and elliptical in outline, commonly known as sowbugs or woodlice, are sometimes brought in with the manure, or permitted to multiply in rubbish left in the houses. They eat into the mushrooms as would snails or mice, and a relatively small force of them may destroy many pounds of buttons. To a certain extent they may be hand-picked; but they are more effectively destroyed by paris green, which they will eat if smeared over slices of raw potato distributed about the beds. Spraying their favorite haunts with lysol is also fairly effective.

An important fungous disease. The most important fungous disease of mushrooms is one known as "la Môle," or the Mycogone Disease. This disease has been known in France for several generations at least, and the same or similar diseases are widely distributed wherever mushroom culture is practised. It has been extensively studied in France by Costantin and Dufour, and in the United States by Veihmeyer. A bibliography of the more important work is contained in a paper by the author last named. Costantin and Dufour have described minutely the forms of injury produced by this parasitic fungus, and they discussed two characteristic types of the disease. In the one case the mushrooms are somewhat deformed, but maintain the general form of the species. Cap, stipe and gills may all exhibit enlargements or tubercles, and the gills in particular show a flaky surface and sometimes considerable reduction in depth. Commonly the mushrooms are more or less invested with a mold-like coating, but this may not be apparent if the disease occurs in very mild form. This stage of the disease, through more seriously deformed specimens, grades into the second or puff-ball type, in which the stem is greatly enlarged, irregularly at times, and the cap poorly, if at all, developed. The mushrooms in this type are soft in texture and frequently decay before they have reached half the size of a normal unopened button. On the other hand giant forms of these abnormal structures occur.

The extent of the injury in France was estimated in 1897 to be about $200,000 annually. It is difficult to determine what the loss may be in the United States, but it has been very serious at times in the more important centers of production. The writer has found specimens with a milder form of the disease offered for sale on most of the larger American markets. It is not possible to state positively at the present time that there is but one fungus concerned, but there is every reason to believe that the chief types of the disease are due to one species. The fungus may be provisionally called *Mycogone perniciosa,* and it possesses two known spore stages. The fungus grows not only upon the mushrooms, but also upon the spawn; and the sporophores of the parasite are produced in large number, especially where diseased mushrooms are permitted to remain on the beds. It is very difficult to stamp out this disease since it has been determined that the spores remain alive even under unfavorable conditions for a period of more than one year, and probably for several years under favorable conditions. Once the disease is established in a part of the house, it may be quickly spread by gathering mushrooms, by the implements used around the beds, or even by currents of air.

Careful experiments have been made to determine the means of control. For details of this work the reader should consult the paper by Veihmeyer mentioned above. Costantin and Dufour recommend spraying the affected bed or the diseased areas with a 2½ per cent. solution of lysol. Many of the sanitary fluids used as dips or sprays in poultry work are of the same nature and might be employed. The possibility of carrying over such a disease from one season to the next and having it occur with increasing intensity is one of the reasons for complete fumigation after the house has ceased to bear for the season. The house also may be thoroughly sprayed with a lysol or sanitary fluid, yet even more effective would be complete fumigation with the vapors of formaldehyde as described in the next section.

Fumigation. The best time for the fumigation of mushroom houses, having in mind particularly the destruction of the Mycogone Disease as well as of insects, is shortly before the new beds go in. Long before this all remains of the previous crop should have been removed from the vicinity. In preparation for the fumigation, thoroughly clean and sweep the houses, spray with water one or two days in advance, to insure a moist condition, and select preferably damp weather. Also make the house as air-tight as possible, pasting paper over all cracks.

For every 1,000 cubic feet of space allow three pints of commercial formalin (40 per cent. formaldehyde) and 1½ pounds of permanganate of potash. Vessels to contain the fumigation materials are required, and for relatively large quantities these may be such as tubs, or very large earthenware containers. When the houses are over 50 feet long two or more containers are needed. Prepare the amounts of the materials with respect to the number of vessels, pour the required amount of formaldehyde into each and weigh the permanganate into paper bags to be placed beside the containers until ready. The formalin will suffice to cover the permanganate when this is dropped in. With everything in readiness the operators begin farthest from the exit and quickly and successively drop the bags of permanganate into the formalin, leaving the building before the fumes can cause discomfort to the eyes. A vigorous action is set up when these ingredients come together, so that the material boils over the sides of the vessel if the latter is small.

Keep the house closed for at least twenty-four hours, then open all windows, ventilators and doors from the outside and let the house air and dry out. Be careful that no lighted lamp comes near the house during the fumigation, for while the liquid formalin is non-explosive, the gas in a confined state is.

Fumigation by burning sulphur is also effective against both insects and fungi, and has been used to fumigate both the houses and the compost. Two ounces of the powdered sulphur for each 1,000 cubic feet of space are required.

CHAPTER XI

THE CLASSIFICATION OF MUSHROOMS

THE scope of this volume will permit of only the briefest survey of some of the greater groups of fleshy fungi. It is a well-known fact that in this country mushrooms are not known and appreciated as they are in Europe. Among the thousands of persons who spend their vacations in regions abounding in these interesting plants, it is the exceptional person who can speak intelligently of mushrooms, or point out the commonest edible and poisonous species of the region. It is hoped that these references will at least serve to indicate how diverse and interesting the mushrooms are; suggesting the advisability of knowing some of the technical characters used to distinguish families, genera, and species; and perhaps also stimulating confidence to take up the study of books designed particularly to guide one in the identification of mushrooms.

The *Basidiomycetes* are the predominant fleshy fungi. They are all characterized by the development of a sporophore or fruit-body (that which is called the "mushroom," "toadstool," "punk," etc.), frequently of large size and of most diverse form, size, and color. In certain areas the sporophore is differentiated into a spore-bearing surface. If sectioned and examined microscopically this fruiting surface is found to consist of a close layer from which arise ordinarily in a palisade manner certain clavate branches called basidia, each basidium producing, as a rule, four spores.

This is but one of the orders of the fungi. It comprehends numerous families, but for our purpose it is enough to indicate briefly and successively the characteristics of five of these, namely, *Agaricaceæ* (gill fungi), *Polyporaceæ* (pore-bearing), *Hydnaceæ* (with tooth-like structures), *Clavariaceæ* (often much branched), and *Lycoperdaceæ* (puff balls).

The *Ascomycetes* constitute another very large class of the fungi and they are characterized by having asci, or spore sacs, in which the spores are produced. The sporophores, or fruit bodies, are frequently microscopic, but in a certain number of genera they are of sufficient size to be properly characterized as fleshy fungi. It would not be feasible here to indicate the general characteristics of the different groups, but it may be stated that among the fleshy forms of this order there are included the saddle fungi and the morels (*Helvellaceæ*), the sporophores of which appear above the surface, and the exceedingly interesting truffles (*Tuberaceæ*) and terfas (*Terfeziaceæ*), both of which are subterranean in habit.

AGARICACEÆ.

THE *Agaricaceæ* are characterized by the possession of gills, usually blade-like structures, almost invariably on the under side of the pileus, the surface layer of which constitutes the spore-bearing surface, or hymenium. The gills radiate from a stem which is central, or sometimes excentric. In this family the parasol shape is the most common, and the spores may be black (purple-black or brown-black), ochraceous, pink, or white. The *Agaricaceæ* constitute the majority of the conspicuous fleshy fungi. More than five thousand species have been described. It is not possible in this account to mention all of the important genera which contain edible species, but a few of the more important of both the black and the white spored genera will be described.

Agarics with Black Spores

Agaricus campestris. It is rather generally maintained that the only species of mushroom in cultivation is *Agaricus campestris,* and doubtless this species is more commonly cultivated than any other. However, it should be recognized that there are several species of Agaricus which vary so little in their characteristics that especially when grown under the forced conditions of mushroom production it is an extremely difficult matter to find distinguishing characteristics. Some would maintain that cultivation has modified the natural species to such an extent that they are not readily recognized. It should be pointed out, however, that until recently the grower has obtained his "virgin" spawn almost annually from "spontaneous" occurrences of mushrooms in the field and pasture, or from spawn appearing in the compost heap. Therefore if there are many "varieties" in cultivation, these same varieties must in large part exist also in the open. I find it difficult to agree with those who adhere to the view that cultivated varieties have originated from wild varieties by mutation.

I am convinced that there are from a half dozen to a dozen distinct forms frequently used in cultivation, and that these must rep-

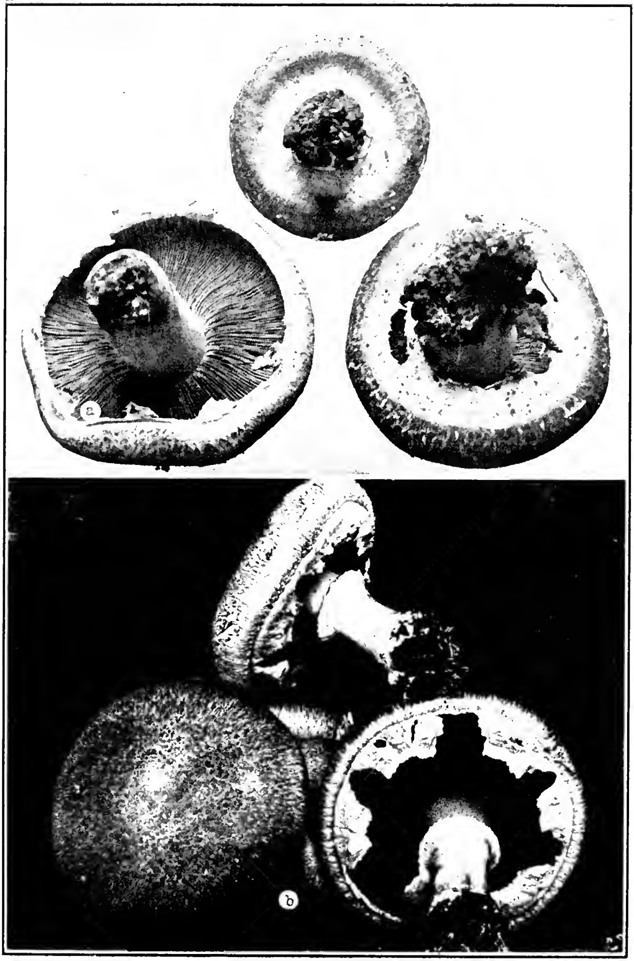

Plate V. Species of Agaricus:
(a) Stout Brown Form, Short Stem.
(b) Gray-Brown Form of A. campestris.

Plate V¹. (c) Agaricus villaticus.
(d) A. silvicola.

resent several species. Among the species common in the United States botanists have distinguished, of course, "typical" *Agaricus campestris,* the Field Mushroom, from *A. arvensis,* the Horse Mushroom. Undoubtedly characteristic forms of both these species are widely cultivated. Intergrading forms or varieties also occur, and it is often very difficult to determine whether these may be more properly regarded as varieties of the two species mentioned or as constituting forms perhaps closely related, but to which others would assign specific rank. Some botanists would assign specific rank, for example, to such forms as *A. magnificus* and *A. Rodmani* among others.

In Europe *A. pratensis* (*A. praticola*) and *A. villaticus* are among those recognized as related species. Types corresponding to these last mentioned also occur in the United States. Referring, in an earlier publication, to the forms of Agaricus in cultivation, it was suggested that in the absence of any possibility that the grower would distinguish the different species on structural grounds, a classification based on color might be at least temporarily serviceable. Accordingly it was recommended that for trade purposes the smaller, practically pure white form, in cultivation be called "Alaska," the large cream colored form (sometimes grayish) be called "Columbia" (Plate I, a), and that the typical brown variety of the English brick spawn be called "Bohemia" (Plate V, a). This simple classification has undoubtedly been of assistance in directing the attention of growers to the necessity for distinguishing between varieties. The classification is, however, no longer adequate, and there is at the present time great need for a careful study of varieties and species.

For a comprehensive study of this nature a thorough knowledge of European forms as well as of those found in America would be essential. Moreover, it could not very well be attempted unless the various forms were grown at the same time under similar conditions; so that the differences between specimens produced under both favorable and unfavorable conditions might be contrasted. At the present time the writer has in cultivation some ten or twelve forms which appear to be more or less distinct. Some of these, however, belong to species other than the two above referred to. We commonly understand that the typical form of *A. campestris* possesses gills which are at first bright pink, changing to bright reddish brown, and finally to brown-black; that the annulus is single and relatively not much thickened as a rule; that the cap is convex or plain, varying from white to brownish; and that the stem is equal and solid. It has been found, however, that under the conditions of vigorous production in cellars or mushroom houses spawn derived from the typical field species may yield specimens in which the color and ring characteristics are not distinguishable from those commonly identified as *A. arvensis*.

Specimens produced when the spawn is just beginning to "run" (therefore not so vigorous) may be more like the typical form; and those produced at the end of the season may again seem more typical. It is obviously necessary to follow carefully the effects of conditions and vigor of mycelium on the general appearance of the plant. I have found that *A. campestris* grown on composted leaves exhibits very little pink in the gills, and the color changes rapidly from pale brown to a gray-brown. Color of the cap is subject to more or less change, and experiments have clearly shown that exposure, including the action of light and wind, intensify the color up to a certain point. Forms which produce perfectly white mushrooms in moist places, especially when protected by an inverted flower pot, may produce in the open, or near the door of the mushroom house, plants which would not be recognized as being the same species or variety.

Agaricus arvensis, formerly more com-

Plate VI. Agaricus fabaceus:
(a) Young Specimens.
(b) Spawn.

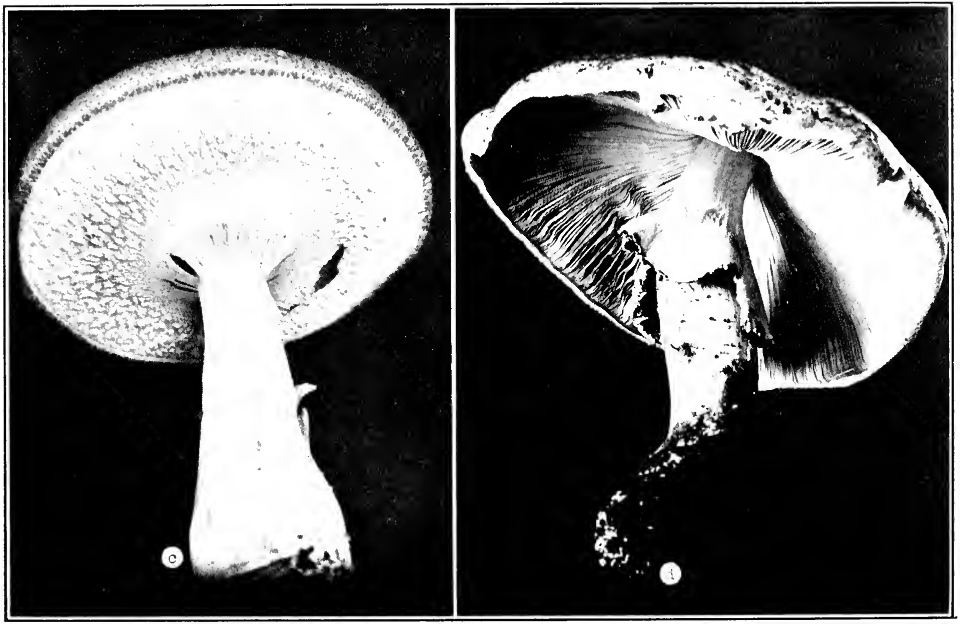

Plate VI[1]. (c, d) Agaricus fabaceus, Mature Specimens.

monly known as the Horse Mushroom, is found in situations similar to those mentioned for *A. campestris.* Typical forms of the Horse Mushroom in the field are larger and stouter than the Field Mushroom, and are particularly distinguished from the latter by the possession of a double ring. Descriptions differ regarding pileus (color) characters; but in any event there would appear to be several varieties in cultivation which may be properly referred to this species. Especially interesting has been one thin capped brown variety, possessing what was clearly a double ring, yet one much more delicate than usual. Under cultivation the writer has been unable to find *A. campestris* better in flavor than *A. arvensis.*

Agaricus fabaceus (*A. subrufescens*) is the almond-flavored and almond-fragrant mushroom (Plate VI [1]). This species is reported as springing up in greenhouses and in flower beds. It is readily distinguished from any of the allies of *A. campestris* by (1) the long-persistent membranous veil, the lower surface of which is covered with soft frosty scales; (2) the red-brown to gray-brown pileus, paler gills, and the enlarged lower part of the stem. It has been cultivated, but requires more completely fermented compost, a higher temperature, and may not come into bearing in several months. It is also less gregarious and less prolific. It deserves further extended trial under special conditions. The spawn grows vigorously in the usual cultures and also in bricks.

Agaricus placomyces is a woodland species, found from early summer until late fall (Plate VII, a). As the name implies, the cap is large, flat, and thin. It appears smoky above from the presence of numerous small, dark scales, more closely aggregated near the center. The veil is double, like that of *A. arvensis,* but not so stout, and the base of the stem is enlarged. This species, like *A. fabaceus,* is readily distinguished from the usual cultivated types. The writer has made spawn of this species and cultivated it in small quantity.

Agaricus silvicola (Plate V[1], d), also an inhabitant of woods, is almost pure white except as to gills. It is described as sometimes tinged with yellow. This is a rather small species, and it occurs in the summer. So far as I am aware, this form has not been intentionally brought into cultivation. I have, however, obtained from commercial spawn, and have continued to propagate, a form which may prove to be this species. If so, cultivation induces considerable change in size and texture.

Coprinus, "Ink Caps." Besides Agaricus, there are many other genera of the *Agaricaceæ* with brown-black or purple-black spores. Very few of these are sufficiently large to be important from an economic standpoint. Accordingly, one genus alone, Coprinus, will here receive consideration. This genus is characterized more particularly by the deliquescence of gills and other parts of the pileus, and sometimes of the stem, when fully mature, to an inky black liquid. Besides numerous small evanescent species there are three interesting edible forms of common occurrence, appearing usually in lawns and along roadways in the spring and fall.

The largest is *Coprinus comatus,* the Shaggy Mane Mushroom (Plate VII, b), considered by many to be one of the best of the fungi. The plant, including stem, is often 6 to 8 inches in height, with an almost cylindrical cap frequently not less than 3 inches long and 1½ inches in diameter. The common name is derived from the shaggy scales which are conspicuous on the pileus. With approaching maturity the gills assume a salmon color and then the pileus begins gradually to deliquesce from the margin towards the region of attachment to the stem. In this species there is also a free, or movable ring. This plant has an excellent flavor, but the soft texture of this, as well as of the other coprini men-

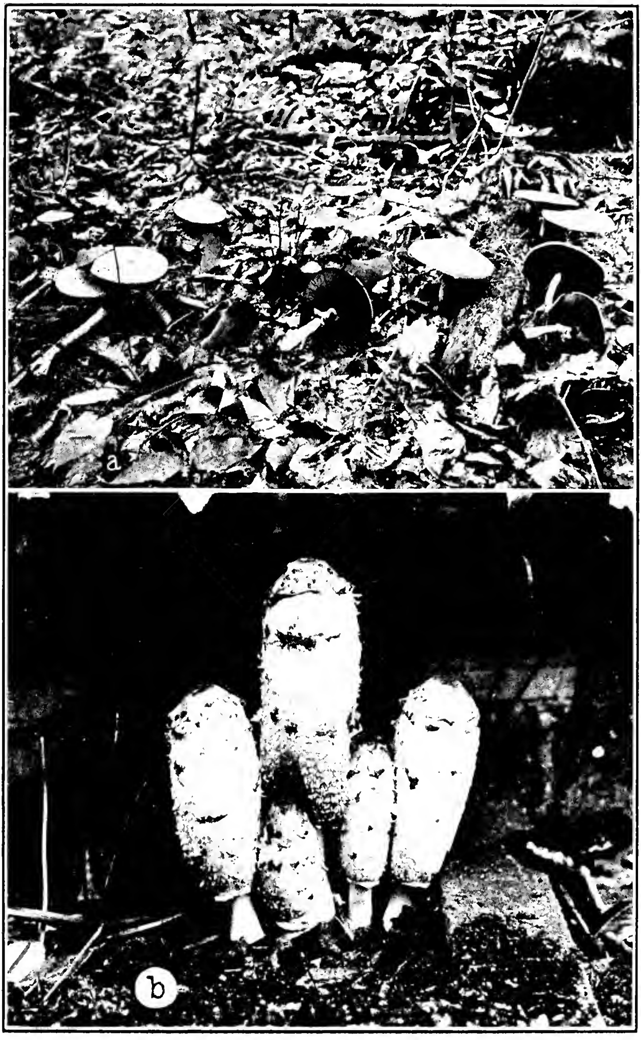

Plate VII. (a) Agaricus placomyces.
(b) Coprinus comatus, Shaggy Mane, from Buller's "Researches on Fungi."

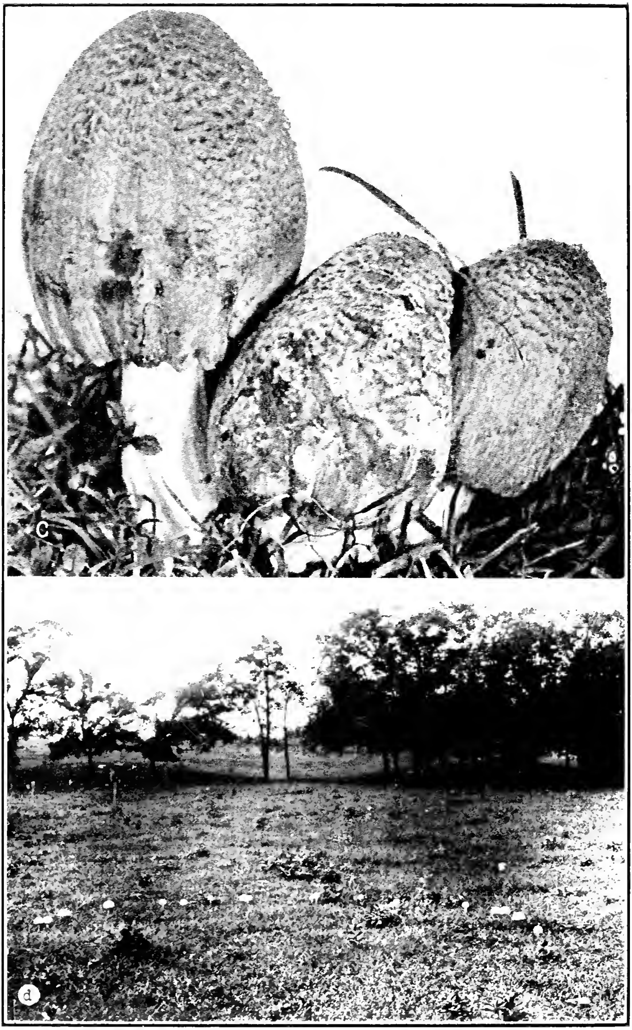

Plate VII[1]. (c) Coprinus atramentarius, Ink Caps, from Atkinson's "Mushrooms, Edible, etc."

(d) Fairy Ring of Lepiota Morgani, not edible.

tioned below, does not lend itself for satisfactory use in all mushroom recipes.

The true Ink-Cap (Plate VII[1], c), *Coprinus atramentarius,* is usually a smaller form than *C. comatus,* with a cap distinctly shorter. The cap is at first oval in form, but later opens wider than in the previous species. It is invariably slaty gray in color, due to the background of the dark gills showing through the hygrophorous tissues. The plants are commonly found in clusters, especially about sidewalks and paths. This species is so rapidly deliquescent that it should be put on ice as soon as gathered, and promptly used.

Coprinus micaceus is much smaller than either of the preceding, and it occurs often in solid phalanx covering several square feet of space about old stumps or over decaying roots, although it may be found in smaller clusters about the lawn or meadow. When young the tan-colored, obtusely conical cap is covered with temporary, glistening scales, like minute particles of mica. With age the cap becomes convex or almost plane. This species is not so rapidly deliquescent as the larger forms mentioned. Some of the other species of Coprinus possess an unpleasant earthy flavor, but all three here discussed are to be recommended.

Agarics with White Spores

Lepiota. The genus Lepiota resembles Agaricus in many structural features. It is, in fact, the white-spored equivalent, differing chiefly in that it possesses white spores, also in that the various species are usually less stocky than those of Agaricus. Lepiota possesses therefore the usual cap and stem, a definite ring, and white gills. The species differ widely in size and color. Among the larger edible species are *Lepiota procera* (the Parasol Mushroom) and *L. naucinoides.* Both occur throughout the country in lawns, fields, or meadows. Among the edible agarics none is perhaps more conspicuous than the Parasol Mushroom. It is frequently 10 inches high, with a pileus 5 to 6 inches in diameter, appearing reddish brown in tone, owing to the presence of numerous brown "scales," against a cream-colored background. The stem is slender above, tapering upward from the bulbous base. The ring is usually quite free. *Lepiota naucinoides* is a clean-cut, pure white species. It is about as large as the average cultivated mushroom, but the cap is always thinner and the stem more slender, thickening slightly towards the base. *Lepiota Morgani* (Plate VII[1], d), a species with gills becoming greenish-tinted with age is reported inedible, causing severe indigestion. Before using any forms with white spores one should learn carefully to distinguish them from species of Amanita.

Armillaria. The Honey Agaric, *Armillaria mellea,* is commonly brownish yellow in general appearance. This species occurs in clusters about stumps and the bases of trees, or may emerge through the sod over decaying roots. It is one of the more abundant mushrooms in wooded sections in the late summer and autumn. This plant differs from Lepiota largely in the fact that the gills are attached to the stem. The spores are white, but the gills, although white or pale when young, become discolored with age. This species is an injurious parasite on a number of trees. The mycelium develops a characteristic cord-like, or rhizomorphic stage. The mushroom is acrid and disagreeable raw, but cooked it has at least the merit of possessing a characteristic flavor.

Amanita. The genus Amanita is particularly interesting because it contains some handsome species which are quite likely to attract the attention of every collector (Plate VIII, a, b), and among these species there are several which are the most deadly poisonous of all mushrooms. The genus also contains, it is true, several edible species; and when one knows the amanitas there is, of course, no danger; but all amanitas should be kept away from the kitchen if there exists the least doubt or suspicion. Bear in mind, however, that the poisonous fungi are not injurious to the touch, so that all may be examined with impunity. Amanita possesses the general characters of Lepiota, likewise certain additional ones which serve clearly to distinguish it. The white spores (and usually white gills), the annulus, and gills free from the stem are just as in Lepiota; but there is in Amanita also a volva or universal veil, which in the mature mushroom appears usually as a cup at the base of the stem, and sometimes remnants of it are carried up by the pileus as frosty scales. In the button stage this universal veil is an outer skin or envelope, and as the plant expands it bursts through this envelope, leaving more or less of a cup, or at least a broken ring, at the base; and if the upper part of the envelope adheres to the cup, it is broken into many scales, or frosty patches, as the pileus grows. Now if one pulls up an Amanita carelessly, the volva might not be detected, thus suggesting

Lepiota. On the other hand, the ring, or veil, might be broken, and then with only a volva the plant might be mistaken for an Amanitopsis—also a genus with edible species. Young stages in meadows have been mistaken, indeed, for buttons of *Agaricus campestris*.

The Deadly Amanita, *A. phalloides*, occurs in favorable situations throughout the United States. It grows in woods or meadows, and the attractive plant may attain a height of about 6 inches and a pileus diameter of about 4 inches. Usually the upper surface of the pileus is smooth, at least no small scales occur, and it is ordinarily grayish, brownish, or greenish in tone, yet a form of the species with white cap is described. The casual observer might mistake the latter for a Lepiota, *L. naucinoides*, for example. The Destroying Angel, *Amanita verna* (Plate VIII, b), is also a pure white plant regarded by some as a white form of the preceding.

Second only to those just mentioned, in

Plate VIII. (a) Amanita, Form with Basal Volval Ridges.
(b) Amanita verna, Poisonous, from Atkinson's "Mushrooms, Edible, etc."

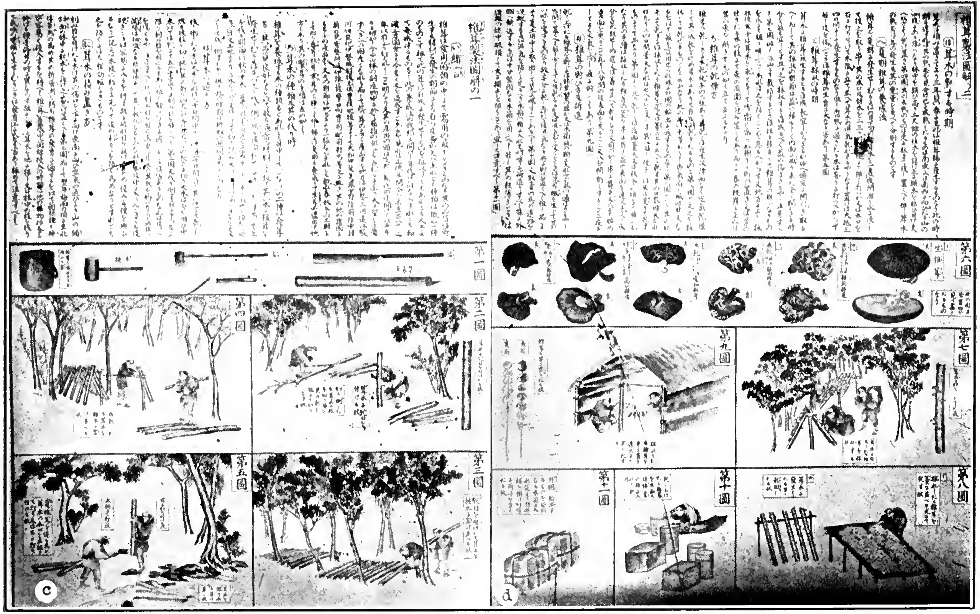

Plate VIII[1]. (c, d) The Cultivation of Shiitake as Explained by a Japanese Chart.

poisonous quality, is *Amanita muscaria,* the Fly Agaric, perhaps the handsomest mushroom of the forest. The plant may be considerably larger than *A. phalloides,* with a cap varying from yellow to orange red, frosty with soft creamy-white scales or patches. These scales on the cap indicate that the upper portion of the volva breaks into many areas as the plant emerges, and moreover it generally ruptures transversally into a number of small incomplete rings which remain at the base of the stem as interrupted volval rings or ridges. The gills and stem are white. The Royal Agaric, *Amanita Cæsarea,* possesses likewise an orange red cap, but the gills are yellow and the volva cup-like. This species is regarded as a great delicacy, but it is obvious that it should be omitted by the amateur collector.

Cortinellus. In Japan one or two species of fungi are commercially grown, and the most important is called the "Shiitake," *Cortinellus Shiitake.* It is grown on wood and is the one mushroom of considerable economic importance, apparently, now cultivated on this substratum, and the production of which actually attains the dimensions of an industry. According to the indications available, the fungus occurs more luxuriantly upon *Carpinus laxiflora* and *Quercus glandulifera* (Plate IX, a). It would appear that the conditions for the growth of this fungus have been carefully worked out. The wood is cut in the form of poles, then permitted to weather for some time. Subsequently cuts are made through the bark into the wood with an ax, holes are bored with an auger for the insertion of the spawn if artificially inoculated, and the poles are placed in situations favorable for the growth of the fungus (Plate VIII[1], c, d). Apparently more than two years are required after the cutting of the poles before the first mushrooms are secured. The sporophores, however, appear in quantity and the operation seems to be well recognized as a financially successful one.

The fungus has been cultivated in this manner for several centuries. It is sold as fresh product and is also preserved for the export trade. It is said that China offers a good market for dried mushrooms shipped both from Japan and New Zealand. The Japanese "Shiitake" is likewise cultivated to some extent in China, where it is known as Hoang-Mo. The writer secured through the Bureau of Plant Industry some tins of spawn of the Japanese Shiitake, but no experimental work worthy of mention has as yet been done in this country. The spawn seems to be prepared by growing the mycelium in the wood of Carpinus and then chipping or grinding this so that it can be readily inserted into the small holes made in the poles.

In addition to the Shiitake there occurs another species of Cortinellus, *C. edodes.* This species, however, is found on the ground, and while of much the same flavor as the more important one, it has not yet been cultivated extensively. The last named species is known in Japan as "Matsutake."

Tricholoma, Blewitts. The genus Tricholoma embraces a very large number of species of mushrooms, nearly all of which are of considerable size. Seldom is a species met whose cap measures less than two inches in diameter and often it is as much as five inches. The genus is not so strikingly distinguished from other mushrooms by easily recognizable characters as is the case with Coprinus or Agaricus. For those who wish to try the edibility of practically all mushrooms within reach it is of interest to note that only a single species among the 200 or more now embraced in the genus Tricholoma has been marked even suspicious. Moreover, this inedible one is uncommon and could never be mistaken for any of the larger species, much less for the one or two members of this genus which are here described and recommended. Before any general use of the species of Tricholoma, one should, however, be sure that he knows the milk-producing fungi (Lactarius), mentioned later, as well as the related genus Russula.

The genus Tricholoma has a central fleshy stem, homogeneous with the cap. The gills are nearly white, though frequently somewhat dingy, or having the appearance of being slightly stained. Caught in quantity, the spores are always white or grayish lilac. A section through the cap shows that the gills terminate with a sinus, or notch, before being attached to the stem. There is no ring on the stem, nor is there any basal cup out of which the plant has developed. With regard to edibility and wide range of habitat, the two best species are doubtless *Tricholoma personatum* and *Tricholoma nudum*. The former is known as the Masked Tricholoma, so called owing to the slight variation in color, while the latter is known as the Naked Tricholoma, the name being derived from the smooth surface and margin of the cap. *T. personatum* is, in general, nearly white, but both stem and cap are usually somewhat relieved by a light purplish or lilac tint, sometimes more nearly ashen. The flesh is thick, firm and white; and the gills, while often violet tinted when young, may become pallid or brown-stained. The other species, *T. nudum,* does not seem to be readily distinguished, in many cases, at least, from the one just described; but those who regard *T. nudum* as distinct figure it as being somewhat smaller and as becoming reddish tinted with age. The flesh is also said to partake somewhat lightly of this same color.

More than ten years ago Costantin grew the mycelium of *T. nudum* in cultures and attempted the cultivation of this form. His statements justified the hope that this plant might be grown under cultivation. The writer has grown the mycelium of *T. personatum* in pure culture since 1903. It grows with readiness upon sterilized leaves or leaf-mould as well as upon stable manure. A large pot of sterilized leaves inoculated with pure cultures was completely penetrated with the mycelium in about six weeks, and numerous small sporophores had begun to form when the experiment was lost through accident. Subsequently, Mr. L. F. Childers, who was assisting me in mushroom growing, made a small quantity of spawn of this species and prepared a bed under ordinary conditions, using, however, more completely fermented stable manure than for Agaricus. The bed, unfortunately, was made in a room in which *Agaricus campestris* would not grow on account of the variable temperature. Nevertheless, in the course of two months fruiting of the Tricholoma had begun on one side of the bed, that farthest from the drying effects of the steam radiator, and the production of fine heavy mushrooms (Plate IX, b) in the small area indicated was enough to demonstrate the fact that this form may be, under certain conditions, a valuable plant for home production. The quality of the mushrooms thus grown was pronounced by some superior to *Agaricus campestris,* but I cannot agree with this view. I have since grown the Tricholoma satisfactorily in a small bed of well fermented leaves—maple, birch, and beech. During the past year or two Matruchot, in Paris, has also announced the successful culture of this species. From none of the experiments made, however, is there any indication that this species will excel *Agaricus campestris* in yield, and it is not so satisfactory for marketing and shipping. The fact that it may be grown upon leaves—which as a substratum are free from all the objections to compost—and the further capacity to fruit at a wider range of temperatures, suggest its possibilities.

The two species above mentioned may frequently be found upon the markets of Europe, as also of Asia (notably in China and Japan, I am informed) and where they occur in sufficient quantity to be of any economic importance they are invariably considered edible.

On the markets of Munich, *T. gambosum* was sold in 1901 to the extent of about 25,000

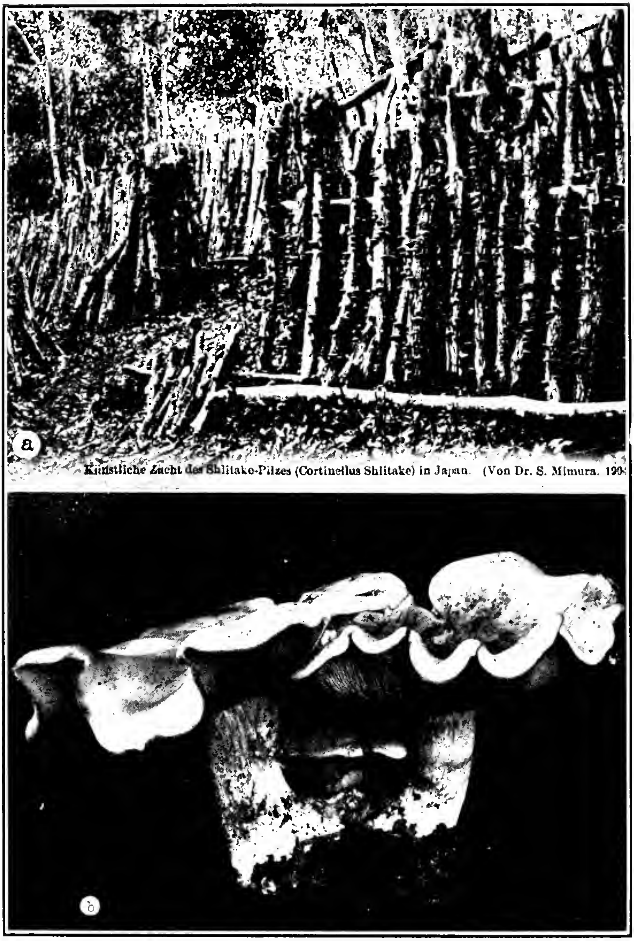

Plate IX. (a) Cultivation of Shiitake in Japan, after Dr. S. Mimura.
(b) Tricholoma personatum.

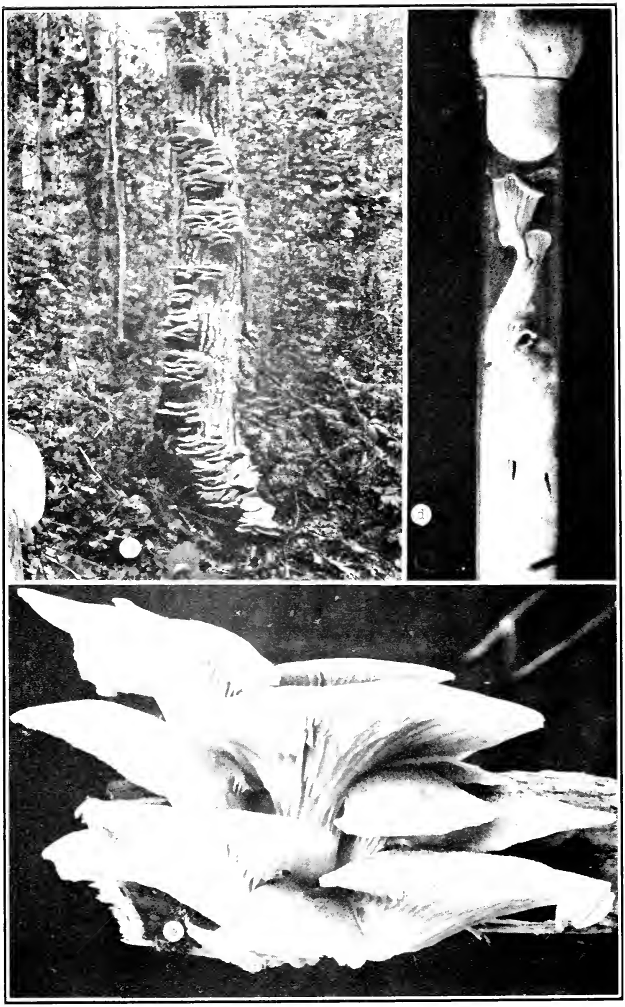

Plate IX[1]. (c) Pleurotus ulmarius on Dead Trunk.
(d) P. ostreatus, Pure Culture.
(e) A Large Cluster of Sporophores.

pounds. This same species is also generally used in many other regions. In England it is known as St. George's mushroom, appearing usually in the spring. It is cream white, often somewhat darker at the middle and may appear in definite "fairy rings" in pastures and meadows. It has thick flesh and a very strong odor. The fresh mushrooms become objectionable in a closed room, but in cooking all objectionable characters are said to be lost.

Pleurotus. As a type of this genus we may name *P. ostreatus,* the Oyster Mushroom, a fungus widely distributed and often abundant throughout moist temperature regions. These plants are produced in clusters, or aggregates of individuals constituting an attractive complex bracket (Plate IX[1], e) or "comb." Its special habitats are the decaying trunks and fallen logs of many deciduous trees. The upper surface varies in color, from white to grayish (the latter ordinarily when conditions are less favorable) and the gills are also white and strongly decurrent, that is, they course down the stem. The cluster is made up of many individuals, each with pileus and fairly distinct stem, the latter excentric, or clearly at one edge. This plant may be found through the season from early spring until frost, but early autumn is generally the season of heaviest fruitage. The mycelium grows vigorously in pure culture on a variety of substrata. There is, however, no particular reason for attempting the artificial cultivation of this form. By most persons, it would not be regarded as one of the better flavored species, but possesses obvious advantages in its frequency, size, and unmistakable form characters. There are no species of Pleurotus which are even suspicious. Just why *P. ostreatus* is the "Oyster Mushroom" is not clear unless it be that the form of the plant, looking down upon it, the wavy outline of the pileus, and the grayish tint sometimes observed, are collectively responsible.

Related to the preceding is *P. ulmarius*

(Plate IX[1], c), one of the distinguishing features of which is a somewhat more definite stem, while *P. sapidus* is regarded by many as a synonym of the "Oyster Mushroom." Some would differentiate *P. sapidus* on account of a lilac tint exhibited by the spores when caught fresh in quantity.

Collybia. In this genus there are many edible species, but with one exception they do not occur, as a rule, in such abundance as to make them of horticultural interest. The spores are white and the pileus may be white or variously colored. *Collybia velutipes* is a form occurring in clusters on stumps and roots in the late fall or early winter. The pileus is reddish brown in color; the plants are somewhat tough in texture, but they are pronounced to be of excellent flavor.

Lactarius, including those species of mushrooms which yield a milky juice when the gills are cut or injured, is represented in our woods by several species of which the commoner edible ones are *Lactarius de-*

liciosus and *L. volemus.* In form these plants are much like a Clitocybe, but the gills are not strictly decurrent. *Lactarius deliciosus* is yellow buff or light orange mottled with darker spots or zones, and the juice is colored. The plant is often about three inches high or about equal in height to the diameter of the pileus. *L. volemus,* a somewhat smaller plant, is of uniform color, brown orange, or tawny, with white juice. The Peppery Lactarius (Plate X, b), a large white species, is very acrid. Closely related to Lactarius is the genus Russula. In this genus the milky juice is lacking. Among the various species occur those with pilei white, greenish, violaceous, or red. They are found in our woods in summer and early autumn. Some are edible and some are not.

Cantharellus cibarius, the Chanterelle (Plate X, a), is one of a group the members of which are barely agarics, for the gills are often almost vein-like, rounded on the margin, and often reticulate. The true Chanterelle is uniformly yellow to orange in color, small, more or less unsymmetrical in form. It is also an inhabitant of the woods, and it is much used for food in Europe.

PORE FUNGI, POLYPORACEÆ

THE *Polyporaceæ* have a fruiting or hymenial layer constituting the lining surface of minute tubes, the mouths of which appear as countless pores, located on the under surface of the sporophore or pileus. Many of the fungi of this family are of the usual parasol type (especially the fleshy species), but the majority are shelving, stalkless forms (for example, the common bracket fungi of the woods). The various members of this family differ greatly in texture, being frequently fleshy, woody, or leathery. In form, size and color they are likewise diverse. Among the genera containing edible species are the more fleshy representatives, Boletus and Fistulina; while of the less fleshy forms the genus

Polyporus furnishes a few edible species. Thus *P. sulphureus* forms immense clusters of sulphur yellow and orange bracket-like sporophores on a variety of trees and stumps. The family possesses no species so injurious as the poisonous amanitas, yet a few species of Boletus must be avoided.

Boletus. Among the *Polyporaceæ* the genus Boletus is by far the most important in respect to furnishing edible species. These plants are all characterized by a central stalk, and a pileus often thick and fleshy, with a layer of pores separable from the general tissue of the sporophore. Many species are large, often attaining a diameter of six inches or more. The color of the cap is predominantly red to orange, with pore-bearing surface pale, yellowish, or orange. In many species the flesh changes color rapidly when cut or bruised. The spores are usually white, or chestnut brown in certain species. The normal habitat is wooded areas, and some species are apparently re-

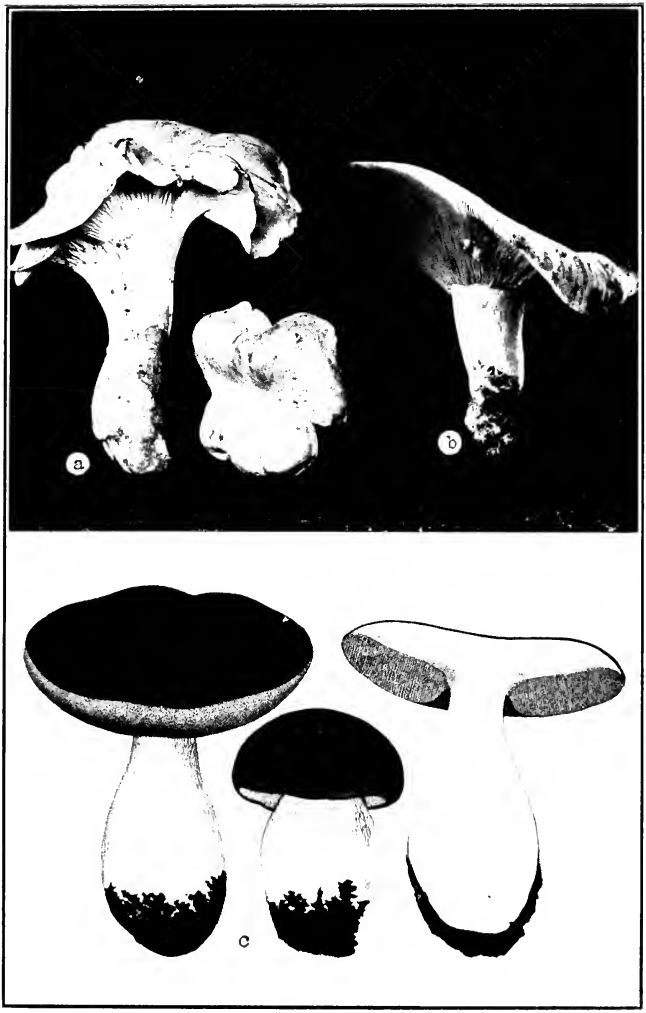

Plate X. (a) Cantharellus cibarius (Chanterelle).
(b) A Species of Lactarius.
(c) Boletus edulis, after Fries.

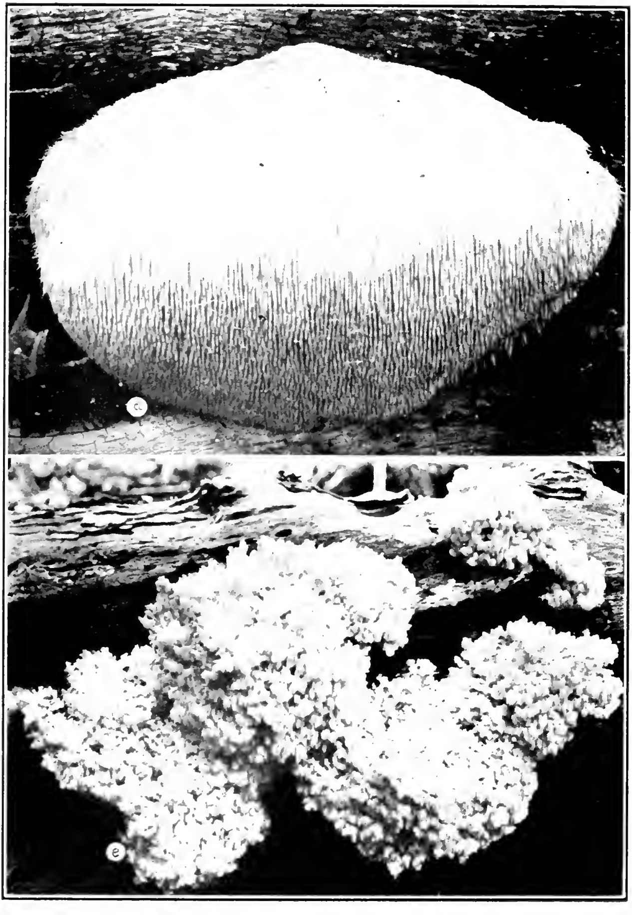

Plate X^1. (d) Hydnum erinaceus.
(e) H. coralloides.

stricted in distribution by the occurrence of particular trees.

Boletus edulis (Plate X, c) is a large form with red-brown or gray-brown pileus, the pore surface white or yellowish, the stem often thickened or slightly bulbous at the base and reticulate above. The flesh of this species changes its color only slightly. It is apparently widely distributed over the world and in Europe it constitutes, as a rule, more of the fleshy product sold in the market than any other species. It is likewise extensively dried and also preserved in oil and butter. For drying the plants are cut into thick slices, strung on stout cord, and suspended about the kitchen or other warm room.

In the United States the typical *B. edulis* does not appear to be so abundant, but one or more of several closely related species are commonly found. Among these are *B. scaber* and *B. granulatus,* both of which are prized in Europe almost equally. In some of the larger markets of Europe *B. scaber* ranks almost with *B. edulis* as a chief mushroom product.

Species of Boletus possessing pores with reddish mouths are to be avoided. *B. luridus* and *B. satanus* are among those which are considered the most dangerous of the *Polyporaceæ*.

Fistulina hepatica, the beefsteak fungus, sometimes called tongue of liver, is found on the trunks and stumps of oak trees. The fungus is widely distributed, but since the amount occurring in any locality at one time is ordinarily small, it is not a plant of much market interest. The flavor and texture of this fungus is said to be best when fully matured, for it is then less astringent. It should be served with meats.

Polyporus. Among the bracket fungi the genus Polyporus furnishes a few species. For the most part these are edible only when young, and in no case may they be recorded as particularly attractive or worthy of experimental cultivation. *Polyporus sulphureus* is common throughout a large part of the United States on a variety of trees, and it often attains a weight of five pounds. *P. tuberaster* is cultivated in Italy, where it is known as *pietra fongaia.* The spawn of the fungus, in the form of a mass of clay held together by profusely interwoven mycelium, is brought in from the fields and forests. Masses of this spawn are found weighing many kilo. Placed in a cellar or other favorable situation and covered with fresh loam the sporophores will often produce for several months. Among other fleshy species of Polyporus sometimes utilized is *P. squamosus,* in most countries a common parasite of the various broad leaved trees. This fungus occasionally attains a diameter of a foot or more and is perhaps the largest of the fleshy polypores.

TOOTH-BEARING FUNGI, HYDNACEÆ

IN the *Hydnaceæ* (tooth-bearing or hedgehog fungi) the hymenium or spore-bearing surface is confined to spines, teeth, or similar structures. The teeth may arise from a true cap or from a tubercular, or much branched structure. In form and texture the members of this family differ greatly and very few species possess a central stem. The majority are tough or woody, but some of the edible species are extremely soft and delicate. No poisonous species of this family have been reported.

Edible Hydnums. Some members of the genus Hydnum have a more or less central stalk and a true pileus. In this subdivision of the genus is found one species of appreciable economic value, *H. imbricatum.* This is a form of considerable size, the cap, which is frequently irregular, being eight to ten inches in diameter in extreme forms. The upper surface is sooty brown or mouse color and as it expands it is differentiated or torn into scale-like areas, sometimes with lighter markings or striations where the flesh shows through or is exposed. The lower surface of the pileus is densely beset with teeth, the color of which, together with the stem, is a hygrophorous white, varying to buff. This species is particularly abundant in mountain woods, where it grows on the ground in the damp places among the mosses and liverworts. It is as abundant in the foothills of the Rockies as farther east.

The species of more peculiar form which will here be considered are the "Satyr's Beard" *Hydnum erinaceus,* the "Coral Hydnum," *H. coralloides,* and the "Bear's Head," *H. caput-ursi.* These are all attractive species. In a sense they are shelving forms in which all definiteness of stem and pileus are lost. These species are common in moist woods and meadows practically throughout the country, growing upon decaying trees and logs, and sometimes ornamenting the larger wound areas left by the fall of decayed branches. These forms are relished by many, but by those to whom a woody flavor is not attractive, although relieved by a certain spiciness, they will not be so diligently sought.

The Satyr's Beard consists of a fleshy unbranched basal mass, from which long straight spines in a solid phalanx grow downward, sometimes attaining a length of an inch or more (Plate X^1, d). Specimens of this species have been collected along the Missouri River weighing fourteen ounces, and measuring seven inches across.

The really beautiful species of this group are the Coral Hydnum (Plate X^1, e) and the Bear's Head. When these species have grown quickly in response to a favorable environment they form elaborate tufts of pure white, branching sporophores, icicled, as it were, by their pendant spine-like, but delicate, appendages. In each of these species a common stem grows from the wood, and this becomes variously and gracefully branched to form the tufts. In the Coral Hydnum the teeth clothe the under surfaces of all branches and branchlets, so that a certain delicacy and simplicity of each part is maintained. This species has been found in clusters which could barely be placed in a peck measure. In the Bear's Head, as the name might suggest, there is a massing of the drooping spines at the ends of the branchlets, and these heads often possess a certain mark of shagginess, due to a wavy or sinuous form assumed by some of the specimens.

Fairy Club or Coral Fungi, Clavariaceæ

THE *Clavariaceæ* are characterized by a spore-bearing surface which may cover practically the entire sporophore. The plants are upright, and most members of the family are rather fleshy, often much branched, or coralloid, however sometimes club-like in habit. All the species which are sufficiently fleshy or delicate are considered edible, and certainly those that are sufficiently attractive to be collected for the table are non-injurious. Clavaria (Plate XI, a) is the most important genus, and it includes many striking species. *Clavaria* *aurea,* the golden coral fungus, *C. flava,* also yellowish in color, *C. formosa,* somewhat ochraceous, and *C. cristata,* whitish to buff in color, are among the commoner conspicuous forms. The two first mentioned are the more fragile and tender.

PUFF BALLS, LYCOPERDACEÆ

THE puff balls are so different in general form and structure from the families already discussed that they may be identified with comparative ease. They are commonly more or less spheroidal or ovate in form, and when young they are white and solid throughout. Within the walls of the solid sporophore practically all of the tissues differentiate, at maturity, into a mass of countless, dry, colored spores, together with some spongy remains of the hyphal tissues,—in some cases literally into a puff of powder, or "snuff box." Some of the smaller puff balls develop at maturity a mouth, or opening at the apex; and these afford moments of pleasure to many barefoot boys who find a certain joy in using their toes to make the puff balls "smoke." Most of the larger species develop no terminal aperture, and the spores are liberated only with the general breaking of the sporophore wall. Besides the wall, the only portion of the sporophore which does not take part in the formation of the spores in the true puff ball is the sterile base; and the latter in certain species persists in characteristic form until the following season. They are not very distinctive in habitat, growing in woods, fields, and pastures. There are species which are minute and others which are relatively gigantic, but in all of these the distinguishing structural feature of the family is the internal spore-forming habit.

When young, and practically up to the time of attaining full size, nearly all puff balls possess white flesh; and so long as this inner tissue is white, the puff balls are to be recommended for the table. When past their prime, or when attacked by insects and bacteria, the flesh becomes yellowish, purplish, or otherwise colored or discolored, and in this condition no species is wholesome. There are only a few small species of the puff ball family which have a brown or black flesh. These are indigestible at least, and may be cast aside as undesirable. White flesh may be considered an all-sufficient indication of edibility, and this is so unmistakable that it is evident one may collect and eat puff balls at will. By the simple rule of using no form with colored flesh no mistake is possible.

Aside from the wild forms of *Agaricus campestris* and the morels, there are probably no other species of fleshy fungi which are now so generally collected and eaten as two species of these puff balls, namely, *Calvatia cyathiforme* and *Calvatia gigantea.* I cannot regard the edible qualities of these two species as entirely comparable with that of many of the agarics, yet they are sufficiently attractive in flavor to meet with general favor. More important for the ama-

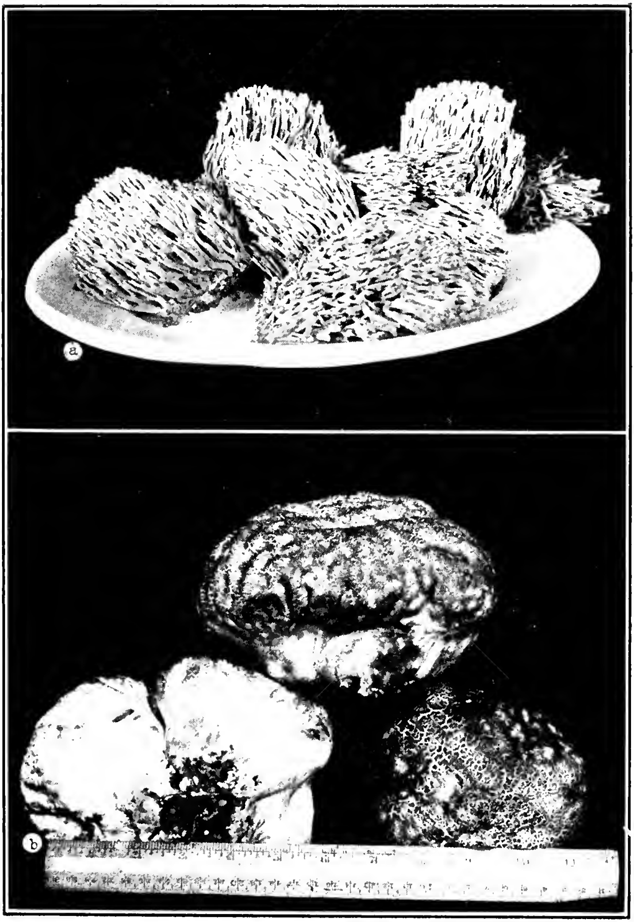

Plate XI. (a) Clavaria
(b) Calvatia cyathiformis.

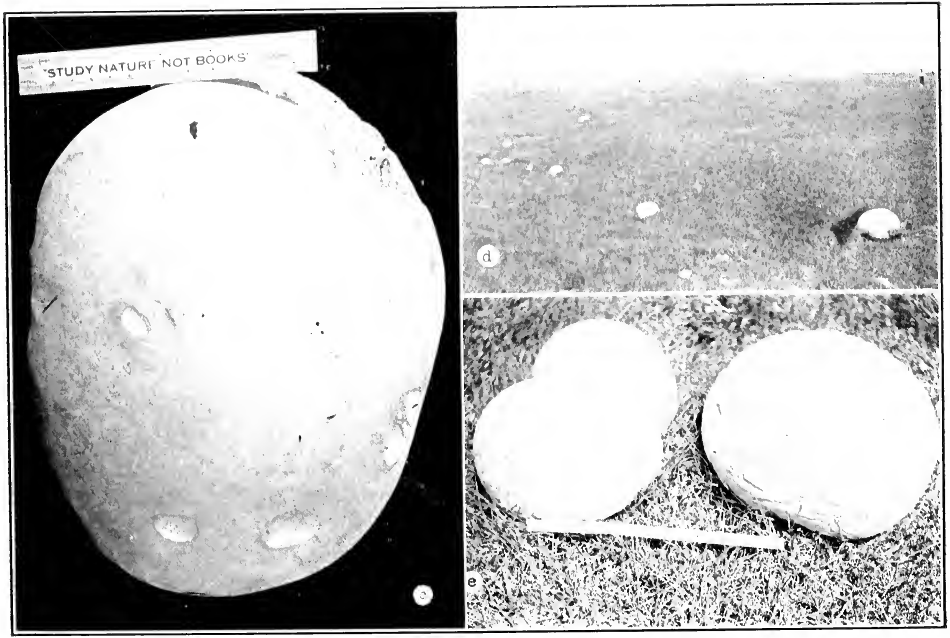

Plate XI[1]. (c) Calvatia gigantea.

(d, e) Calvatia in Semi-arid Region, Yuma, Colorado, from a Photograph by H. L. Shantz.

teur collectors, oftentimes, is the fact above mentioned—that these puff balls can not possibly be mistaken for poisonous species of mushrooms.

Calvatia cyathiforme. The more important of the two species mentioned from the standpoint of its constant appearance and wide distribution in the Eastern and Central States is *Calvatia cyathiforme* (Plate XI, b). The habitat of this species is much the same as that of *Agaricus campestris;* and the pastures usually bring it forth in some quantity when the autumn is cool and moist. The summer of 1914 was particularly cool and moist in central New York, and under these conditions the cyathiforme puff ball appeared in quantity by the middle of August. This species is more nearly broadly pear-shaped than spherical, and the stipe-like part is much reduced. It is usually from two to five inches in diameter. It may be clear white and smooth when young, but it usually becomes pink, brown, or purple-brown when older; and either when in full prime, or somewhat later, the surface becomes distinctly marked into areas as shown in the accompanying illustration. As the plant dries in the field, the outer wall, or peridium, peels off in areas, gradually the mass of purplish spores and tissue wear away, and there persists for months a basal saucer-like, or beaker-shaped, sterile basal part, from which character the name of the species is derived.

Calvatia gigantea (Plate XI[1], c) is, as its name implies, the largest of all the fleshy fungi. It often measures from 12 to 18 inches in diameter, and specimens more than two feet in diameter have been reported. The sporophores are vertically compressed, especially when more than about ten inches in lateral diameter, so that the mature puff ball is ordinarily strongly oblate spheroidal. This species is widely distributed throughout the United States, but it is not so constantly abundant as is *Calvatia cyathiforme*. It may be found in gardens, pastures, or fields, and occasionally in open woods. Externally it is almost pure white, or cream color, until practically full size is attained. While the flavor is good, there is a peculiarity about it which some do not regard as inviting. The texture is rather soft and the flesh pure white. The large size of the species commends it particularly for broiling in thick slices.

As the giant puff ball approaches maturity, the flesh becomes yellowish or olive green in color—due to the formation of spores. The mycelium of this species also grows readily when cultures are made by the tissue-fragment method, the growth being profuse upon decayed leaves or soil. Pure cultures were made by the writer in 1902, and an excellent pure culture in a quart bottle of compost was sent to me by Mr. L. F. Lambert, about 1905. No sufficient attempts have yet been made, so far as I am aware, to cultivate this species, but the size and the importance of the fungus make it desirable that careful trials should be inaugurated. For the present we can offer no suggestions regarding a satisfactory substratum except to say that it does not grow so readily as *Agaricus campestris* in freshly prepared compost. It is possible that a well rotted compost mixed with soil, and well compressed, would be a suitable starting point.

EUROPEAN TRUFFLES

TRUFFLES are subterranean fungi, the various species constituting a coherent family interesting in structure, almost unique in habitat, unequaled in flavor and aroma. It would appear that terfas and not the now famous truffles of southern Europe were the subterranean fungi known to be so highly prized by the early Greeks and Romans. The European truffles came into use in the courts of France and Italy at some time prior to the 14th century, it is believed. Moreover, it is probable that the earliest references to the use of truffles in France are concerned with the so-called summer truffle, *Tuber aestivum.* The truffle which is now the one of world-wide fame, *Tuber melanosporum* (Plate XII, a) often known as the Périgord truffle, seems to have made its entrance into Parisian culinary proceedings towards the close of the 15th century. It is claimed that the superior merits of this form were first discovered by Bruyerin-Champin, medical adviser to Francis the First and Henry the Second. In more modern times it has grown in favor and use to such an extent that one might almost divide French hotels into two groups, those affording *chefs des cuisines* who require and know the value of truffles and those having chefs who do not.

Distribution. In spite of the considerable use of truffles as a condimentary food in France, about one-third the product grown in that country is exported. It should be remembered, however, that France is practically the only country in which truffles constitute an article of commerce, for although truffles are marketed to some extent in Italy and Spain, from these countries relatively few are at present exported. They are found in the temperate and the warm temperate regions of the western part of southern Europe; that is, from Italy westward, and from the 40th to the 48th parallel. From early times it has been recognized that truffles are to be found in close association with the roots of certain trees, especially the evergreen oaks of this region, *Quercus ilex,* and *Q. coccifera* also the velvety deciduous oak of somewhat wider distribution, *Q. sessiliflora.* More recently, through the investigations of careful observers, they have also been found in conjunction with the roots of the chestnut, of the pine, it is claimed, and with a long list of other plants characteristic of temperate regions in Europe. The natural home, or preferred habitat, so to speak, of the truffles, is, however, under the shade of the oak, and no professional truffle hunter would waste time looking elsewhere for these plants in any quantity.

The parasitism of the truffle has been much discussed and disputed, but the prevalent belief to-day is that truffles are to a considerable extent, at least, dependent upon the living roots of the plants with which the mycelium is associated for a portion of the nourishment which they require. Prof. Mattirolo of Turin, who has devoted as much study to these plants as any other botanist, is a strong supporter of this view. It is possible, however, that the organic matter of the soil also plays some part in the nourishment of the mycelium, and certainly the mycelium is found in some quantity at considerable distances from living roots, indeed in close connection with decaying leaves. Nevertheless, truffles are not found in dense, moist woods, and the habitats of mosses would never foster them.

Botanically truffles have been recognized since early in the 18th century, and the mature fruit body, or sporophore, of the various species has been carefully studied. Systematically they are to-day well known, but from the standpoint of development and physiology, our data are scattering.

Species. Employing the term in its narrower sense, the several species of truffles are all members of the genus Tuber, which in turn, is the dominant genus in the family *Tuberaceæ.* The genus Tuber embraces more than fifty known species. The more important of the edible species, or forms, are six, and these latter may be divided into two groups:—(1) Those in which the fruit body is dark brown or black, and the surface covered with wart-like structures; and (2) those in which the fruit body is yellow or yellowish brown, and the surface usually smooth. The black truffles give us the most highly prized and abundant edible species, such as *Tuber æstivum* Vittad., *T. mesentericum* Vittad., *T. uncinatum* Chatin, *T. brumale* Vittad., *T. melanosporum* Vittad.; some might also include *T. gulonum* Cda., *T. montanus* Chatin, etc. Among those of the lighter colored group the only really important species is *T. magnatum* Pico, although two or three others are sometimes seen on the markets. The different edible species vary considerably in size, but none of these would average smaller than the size of a walnut with hull removed.

Counting from the beginning of the ripening period, the earliest of the truffles is perhaps *T. æstivum,* which is found from early summer until early autumn. *T. mesentericum* and *T. magnatum* are found during much the same period, with *T. uncinatum* as an essentially autumn species. *T. brumale* and *T. melanosporum* are species which ripen during the winter months. Two forms may be briefly described, in order that the characters of the plants may be apparent. *T. melanosporum* varies from the size of a small nut to that of a man's fist. Specimens have been found weighing more than one pound. The wart-like surface structures are somewhat pyramidal in form. The fruit body is solid, and a cross section of the ripe or mature fungus shows a brown ground effect marbled by numerous irregularly coursing veins of lighter color. In the dark ground tissue the asci are embedded in quantity, and the brown spores give to this tissue most of its color. The spores are not set free until the fruit body disintegrates. In *T. magnatum* the fruit body is yellow (resembling a spherical yam), smooth, but somewhat irregular, and the tissue within corresponds to that already described, except that it is lighter in color. The fruit bodies of this species average larger than those of any other. The flavor is somewhat onion-like. This truffle is highly esteemed in Italy, where it is known as *fiorini* or *tartufo bianco*. It is particularly abundant in Lombardy, and far southward towards Rome.

Truffle hunting. Truffle hunting is most interesting. It is a hunt, and for the amateur it has the impelling fascination of the chase, but for many it is also a serious business, since in productive regions it brings rich financial returns. All modes of truffle hunting are so distinctively primitive that they seem like picturesque diversions, or mere sport. Man unassisted works to small purpose in the search for truffles, for reason and the sense of sight—his main dependencies—avail little in locating these subterranean fungi. The truffle is aromatic; in consequence, man must make use of those animals which have a keen sense of smell. There are three methods pursued; (1) that with the assistance of the dog, (2) with the assistance of the pig, and (3) with the assistance of certain flies of the woods, which are the natural enemies of the truffle. Truffle hunting is such an important business, and requires such knowledge of the forest and field, that there are men who devote their lives to it. These men are known as rabassiers.

(1) The first method, using the dog as man's guide and assistant, is employed in those regions where the truffle is not unusually abundant. The dog has enduring qualities and can cover a large amount of territory in a short time. For this reason

he is employed exclusively in the garigues of southern France (Plate XII[1], e), in many other sections of France where the harvest is not so rich, and in Italy. The garigues are vast areas of rock and clay grown up almost entirely to the scrubby, prickly-leaved oak, *Quercus coccifera,* dwarfed specimens of *Q. ilex,* and other thorny plants. These deter even the dog at times from his best work. As a rule, the dog is trained to the search from puppyhood, and breeds of naturally keen scent are required. Bird dogs, though keen of scent, are undesirable, however, on account of being readily diverted from their work. Toward his dog, particularly on the hunting field, the rabassier shows his gentlest and most sympathetic side. The dog is encouraged to hunt, but never is he excited, and his master's every action is calculated to inspire in him a feeling for careful search. Upon the anticipation of a truffle nearby, the dog scents the ground carefully, locates it definitely, and may even

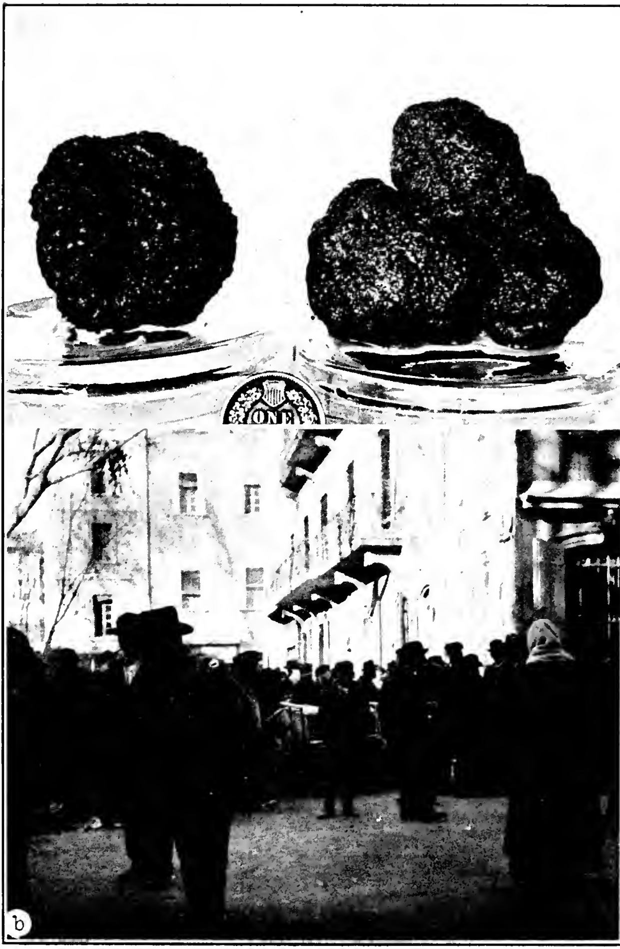

Plate XII. (a) Tuber melanosporum.
(b) Truffle Market, Carpentras, France.

Plate XII[1]. (c, d, e) Truffle Hunting.

mark the place (by scratching the ground with his paw). The rabassier must then use his short grubbing-hoe or pick to uncover the find. The dog remains at hand, and will indicate the exact location of the truffle as the soil is carefully removed. In the rocky soils of the garigue the truffles are found from one to even twelve inches below the surface. When the truffle is secured, the dog is invariably rewarded by the frugal Frenchman with a bit of bread or cheese. It is an interesting fact that the dog, like the man, shows the effects of the hunt. He is brighter and more alert when finds are numerous, careless and dull after an hour's fruitless endeavor.

(2) More picturesque, and at the same time more accurate, is the method involving the assistance of the pig (Plate XII[1], c, d). The female is almost invariably employed on account of her superiority for the work and her greater docility. The pig is fond of the truffle and would seek it naturally in

the woods, but it is said to require a year or two of training to bring it to the proper understanding of its work.

I saw one animal which had earned a competent livelihood for a family of peasants during ten years. In employing the pig care is taken to conserve her strength and energy. If the field is at some little distance, she is hoisted into a cart and driven to the truffières in state. In her search she is in a general way guided by the rabassier, who carries a long stick, its chief purpose being to command immediate obedience. Upon discovering the location of the truffle, the pig begins to root it up. The rabassier is alert to every action, and can tell the moment that the truffle is being uncovered. Usually a touch of the hand on her head is sufficient to remind her that the truffle is not her property; but in cases of necessity, the stick is interposed, then a few acorns are thrown to the animal, who, so recompensed, is content to proceed elsewhere with her hunt. No animal will continue to search without reward. In regions where truffles are abundant, a single pig has been known to net ten kilo of truffles in one day. This refers to the black or winter truffle, for pigs are not so successful during the summer months. Whether the pig or the dog is used, the weather is an important factor in the yield. It is said that during very dry weather or during a drizzling rain fewer can be found; whereas, if the soil is merely moist, conditions are most favorable for their detection.

(3) The third method is of much less importance, yet it is one which must be used when one has neither trained dog nor pig. There is a species of fly prevalent in the Mediterranean region which uses the truffle as a medium in which to deposit its eggs in order that its larvæ may be well nourished. At the time when the perfume of the truffle becomes pronounced, several of these flies alight upon the ground where the attractive odor is perceived, any may thus mark the exact location of the truffle. In

such hunting it is necessary to select a quiet day, and it requires great patience. Moreover, one must frequently dig up the earth without reward. Nevertheless, there are one or two marks by which the skilled rabassier is able to determine a so-called truffière, the small area near a tree or group of bushes in which the truffle mycelium, at least, is growing. Frequently under the borders of such a tree, or around the edge of a clump of such bushes, it will be noticed that the herbage is not so abundant as elsewhere. It may be that the truffle mycelium is more or less destructive to many plants; this relationship has not as yet been scientifically investigated. However, this is one of the signs which enable the hunter to limit his attention to small, well-chosen areas, where his search may be best rewarded.

The Market. Should we follow the truffles to a wholesale market, such as that of Carpentras (Plate XII, b), for example, we would find an animated scene and lively though neighborly competition. Old men, boys, and women, but mostly old men, troop in at nine o'clock with sacks, baskets, and pouches. Before and after each trade a visit is made to the cafés, and they dispose of their wares with little loss of time. Then more cafés, and an all day discussion of politics awaits them.

Among interesting customs regarding truffles in the Department of Vaucluse, there is a regulation or habit of using only four days each week for truffle hunting, and frequently only three in the little villages occupied solely by peasantry. These three are Monday, Tuesday, and Wednesday. Thursday, the day before market, one must prepare for market day in town; Friday is market day, and one must be in town; Saturday is the day after market, and one must recover from having been in town.

Soil relations. As a rule certain plants prefer calcareous soils, while others may occur in silicious soils, the latter soils being usually relatively free from lime. Among plants very common in moist silicious soils are some of the heaths, notably Calluna and Erica. Wherever Calluna and Erica are found, truffles may not be anticipated. Indeed, everything goes to show that the truffles are distinctly calcareous plants and are sharply limited in their distribution by the presence of clay—seldom trespassing upon sand. In this regard they are even more sensitive than the plant with whose roots they are ordinarily associated. In France truffles are most abundant in the so-called *gariques* of the Midi, in the *causses* of the southwest, and in the *cosses* and *galluches* of Poitou, as well also as in the *lauses* of Dauphiny. They are most abundant in the Jurassic formation, especially in the Lias, the Oolithes, and the Neocomian. In this latter formation, the great truffle field of Mont Ventoux occurs. Indeed, up to a height of 800 meters this is practically one continuous truffière.

It is difficult to explain why the European truffles are not found in some quantity in portions of Algeria, where the climate is approximately the same, as there are many soils in Northern Algeria which would be considered truffle soils. In this connection it is also noteworthy that the terfas of Africa and Asia which correspond to the truffle of Europe occur only in silicious soils. These soils sometimes contain a considerable quantity of clay, but often little else than sand can be detected. However, it is claimed that the sands of the Sahara contain a large proportion of lime, and that therefore the difference between the silicious soils of the northern Sahara and the calcareous soils of France is largely chemical and not physical.

Truffle culture and exploitation. Many of the finest truffle areas of France were at one time barren of these fungi, and it is through the perseverance and intelligence of the owners that truffle production has been made possible in them. The trees known to shelter truffles were planted, drainage provided for, and predatory animals shut out. Frequently soil from truffle regions was brought and scattered upon the land. We may therefore say that the cultivation of truffles has been practised. The old adage, "plant acorns if you would have truffles," has been handed down through several generations, but it is recognized today that other conditions must also be considered. The growth of the truffle industry in certain *departments,* particularly in Vaucluse, has encouraged the government to proceed on a large scale with its attempts at reforesting many large and barren areas. The work has often yielded handsome returns through the so-called spontaneous appearance of truffles in such regions. In general, the reforested areas are owned by the *communs,* or villages, near by, and under certain restrictions, or with the imposition of a certain tax, where truffles are abundant, any villager may become a truffle hunter in the village domain.

The Périgord region is a famous truffle ground, yet up to a few years ago the town of Carpentras, in Vaucluse, has been foremost in the truffle trade. The little village of Bédouin, at about eight miles from Carpentras, tucked away under the very shadow of Mt. Ventoux, is the centre of one of the chief truffle sections of France, and Mt. Ventoux is now itself a field of extensive reforesting operations. Through some unknown cause truffles have begun to fail in this region, and it is to be greatly regretted that a thorough study of the conditions has not been made by some botanist and mycologist.

The reports of the truffle regions of France which have reached the American public have left the impression that these fungi are unusually restricted in habitat. This is only in part true, and nothing will illustrate better the distribution of these fungi throughout a large portion of France than the following valuation in francs placed upon the truffle yield in the various departments of France, in 1889, giving only those provinces in which the valuation is 50,000 francs or more.

Departments	*Francs*	*Departments*	*Francs*
Ain	85,000	Indre-et Loire	90,000
Alpes (Basses)	3,800,000	Isère	50,000
Alpes-Maritimes	85,000	Jura	75,000
Ardèche	300,000	Lot	3,600,000
Ariège	70,000	Lot-et-Garonne	360,000
Aube	60,000	Lozère	80,000
Aveyron	460,000	Marne (Haute-)	180,000
Charente	530,000	Nièvre	125,000
Charente-Inférieure	180,000	Bouches-du-Rhone	300,000
Corrèze	200,000	Tarn	180,000
Cote-d'Or	150,000	Tarn-et-Garonne	110,000
Dordogne	1,600,000	Var	300,000
Drome	1,800,000	Vaucluse	4,700,000
Gard	80,000	Vienne	320,000
Garonne (Haute-)	60,000	Yonne	80,000
Hérault	180,000		

It is a curious fact that up to the present time none of these fungi which are of economic importance has been found in North America. There are some small species occurring on the Pacific coast, and one form has been discovered in Minnesota and New York. It is believed that the conditions in many other regions would not be ill-adapted to these edible species, particularly some areas in California, Texas and Southern Arkansas, Georgia and South Carolina. No well-planned or extensive introduction experiments have as yet been attempted.

Truffle spores are not readily germinated, and most, if not all of the cases of germination reported have proved erroneous. The writer has been able to grow the mycelium of *Tuber melanosporum* to a limited extent in cultures emanating from fragments of tissue. The medium employed was sterilized roots of *Quercus ilex*.

The Terfas of Africa and the Orient

THE subterranean fungi properly known to-day as terfas or kames, sometimes also called false truffles, are almost wholly the product of arid Mohammedan countries. These are fungi which were well known to the Greeks and to the Romans of imperial times. Since in the Latin the designation of these organisms is by the word *tubera* they might well be called tubers, or truffles, but since the latter term is now preempted by the homogeneous group of fungi already discussed, it is preferable to employ one of the two terms of Arabic origin, "terfas" or "kames." Moreover, as noted earlier, the terfas were known to the early Greeks, but there is apparently no evidence that the European truffles were.

It is only within the past twenty years that much definite knowledge has been gained concerning the distribution and real value of the commoner species. This is not remarkable, for the habitats of the terfas are not to be visited by western scientists without great consumption of time and considerable expense. Our present knowledge of these plants has the freshness of a recent discovery as yet imperfectly investigated. We must be content to wait some years longer perhaps before any great confidence may be placed in the matter of species limitations, or detailed biological relationships.

Use by the early Greeks. Terfas or kames were evidently always abundant in many parts of greater Greece, east of the Ægean and Mediterranean Seas, and the early references to them are particularly interesting. From the Deipnosophists of Athenæus we learn that Theophrastus spoke of them thus: "the production and generation of these things which seed beneath the earth; as, for instance, of the truffle, and of a plant which grows around Cyrene, which they call *misy*. And it appears to be exceedingly sweet, and to have a smell like that of meat; and so, too, has a plant called *itum,* which grows in Thrace. And a peculiarity is mentioned as incidental to these things; for men say that they appear when there is heavy rain in autumn and violent thunder; especially when there is thunder, as that is a more stimulating cause of them; however, they do not last more than a year, as they are only annuals; they are in the greatest perfection in the spring, when they are most plentiful. Not but what there are people who believe that they are or can be raised from seed. At all events they say that they never appeared on the shore of the Mitylenæans, until after a heavy shower some seed was brought in from Tiaræ; and that is the place where they are in the greatest numbers." In another place it is mentioned that they are found near Lampsacus and in Acarnania and Alopeconnesus and the District of the Eleans. Further, in the same book we are told that Hegesander, the Delphian, says that in the Hellespont there are neither truffles, thyme, nor *γλαυκίσκος* (supposedly a species of fish), and that therefore Mausiclides said that the country had neither spring season nor friends. Pamphilus says, in his book entitled "Languages" that *ὑδνόφυλλον* (truffle-leaf) is a grass which grows on top of the truffles, from which the truffle is discovered. These references, with our present knowledge of the distribution and manner of growth of the Terfas, clearly indicate that these fungi and not species of the truffle are concerned.

At present the terfas are believed to be most common in certain sections of Asiatic

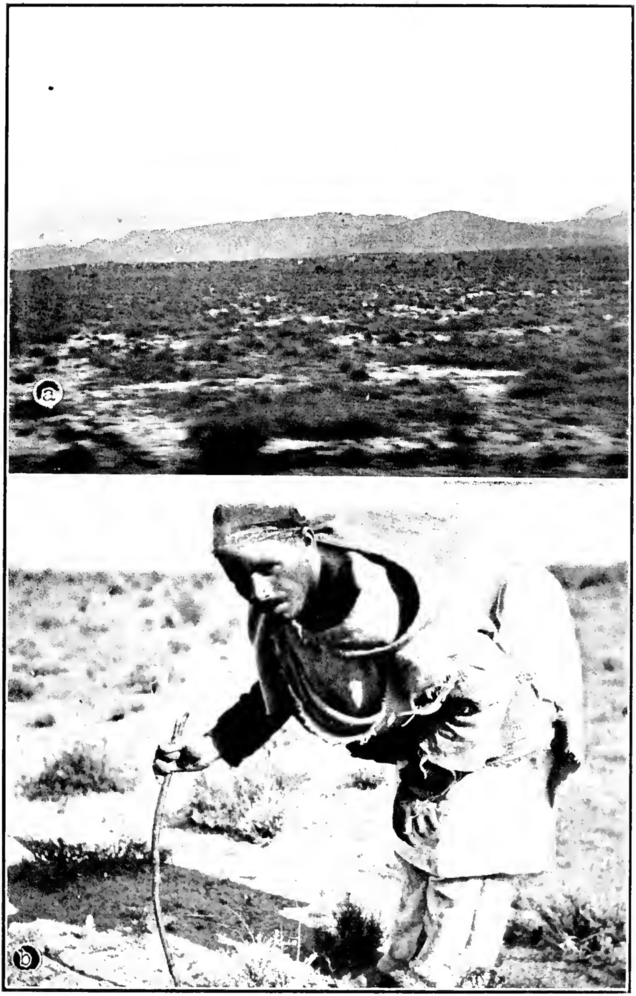

Plate XIII. (a) Near Ain Sefra, Algeria, Where Terfas Abound.
(b) Terfa Collector.

Plate XIII[1]. (c) Terfa and Host Plant.
(d) Habitat of Morel.

Turkey, Persia, and Arabia, perhaps more abundant near Smyrna, Damascus, and Bagdad; and also in many portions of northern Africa, extending well into the Sahara (Plate XIII, a). The writer found them particularly abundant in the vicinity of Ben Zireg and Ain Sefra in Algeria.

Botanically, the terfas constitute a family known as *Terfeziaceæ.* They are certainly allies of the *Tuberaceæ,* but well-marked differences exist. Moreover, the botanist makes two genera of the various forms of kames. These two are Terfezia and Tirmania. There are probably about fifteen valid species of Terfezia known. Of these six or eight at most would include all of the larger edible forms. The smaller species, which are economically valueless, are not uncommon in southern Europe, especially in Spanish Mediterranean region. It is believed, however, that only one edible species invades European borders, and even there it rarely becomes an article of importance. In general, the species of Terfezia have been found under and associated with roots of the herbaceous or shrubby forms of Cistus and Helianthemum, although this is not invariable. Those collected by the writer at Ain Sefra were under *Artemisia herba-alba* (Plate XIII[1], c), and recently several new hosts have been added. These flowering plants may be spoken of with justice, I believe, as hosts, for the parasitism, or at least partial parasitism, of the terfas upon the roots of these plants seems to be beyond question.

The family *Terfeziaceæ* differs from the truffle family, *Tuberaceæ,* especially in the fact that in the former the veins, which break the general internal tissue into distinct areas, have no outlet to the surface; and further, the plants are all provided with a root-like process, or rudimentary stipe, to which the mycelium in the soil is attached. The principal species of the terfas as at present known are as follows:—

Terfezia leonis Tul. is a species which is believed to occur in Northern Africa, particularly in forests of pine and cedar in mountain regions. It is whitish yellow in color and from the size of a nut to that of an orange. In Spain it is said to occur in fields of Cistus, there called *turmera.* In the sands of Sardinia the same species is also found. Again, this seems to be the species which is common near Smyrna, and it is conjectured to be the one of which Theophrastus wrote that it was obtained by the Greeks and Romans from the Island of Lesbos (Mitylene), but not the one which they imported from Libya (Libye). This species is believed to be the least desert-adjusted of all good forms. It is found from March to April, and is said to be in flavor sweet and agreeable enough.

Among the desert species described by Chatin are the following, *Terfezia Boudieri, T. claveryi, T. Hafizi,* and *Tirmania ovalispora.* Recently other desert forms have been described. The species which have been mentioned represent those of southern Algeria, and also those of Asiatic

Turkey. It would seem that the majority are found in the spring, but Tirmania is reported to be ripe in October.

Distribution. The excellent descriptions of Chatin were made from terfaz material sent to him in general from the markets of the countries in which they occur. So far as one can judge several of the finest species have never been collected in place by botanists until a visit to Tunis and Algeria by Patouilliard in 1894. The reported occurrence of these fungi on the roots of certain *Cistaceæ* was doubtless known through the Arab or other native fungus hunters. In the spring of 1906 the writer had the pleasure of collecting and studying these plants in their native habitats in southwestern Algeria. They were found for the most part in the flat grazing lands adjacent to small oueds, or stream beds (Plate XIII, a). The soil in which they occur is invariably sandy, sometimes a rich sandy loam, and the dominant vegetation consisted of the composite weed *Artemisia herba-alba* and other plants of somewhat similar habits.

Collecting terfas. In hunting for terfas neither dogs nor pigs are used. A native Arab is required to point out the favorable regions, and then careful observation is all that is needed. When the terfas are nearly mature they doubtless absorb water more abundantly through the mycelium, thus increasing rapidly in size, and this expansion causes a slight bulging and breaking of the soil around the roots of the plants under which they grow. By this means they are easily located, yet there are many false alarms, caused generally by little ant hills. With a sharp stick, alpine stock, or trowel, the fungus is readily removed, for it is seldom more than one or two inches beneath the surface. In Algeria the terfas vary in size usually from one to three inches or more in diameter. They may be obtained in surprising quantity during a good season. The fungus is evidently in part parasitic, for not only does it commonly occur in connection with the roots of the same plants, but when found under *Artemisia herba-alba,* the latter proved to be injured almost in direct proportion to the size of the terfas produced. It is probable that in hunting for these plants also the keen scent of the dog would be advantageous.

Use and quality. Terfas are used with meats as one would use mushrooms, or they may be prepared by many of the methods used for white potatoes. The writer was much interested to find that the terfas are indeed considered an important article of food; and in the movements of native tribes in the past terfas fields were given due consideration.

These fungi are unusually rich in proteins and the analyses compare favorably with those of truffles in this regard. The terfas possess a rich flavor and mealy texture, yet they possess only to a degree the deliciousness of the cultivated mushroom or the pervading aroma and fragrance of the truffle. The price which they bring upon the market is more comparable to that of the mushroom,—sometimes, indeed, less than one franc per kilo. They do not often find their way to the markets of Europe, and seldom are they to be had in any of the larger coast cities of Algeria, except, perhaps, Algiers. Nevertheless, from the point of view of flavor I am at a loss to account for the high esteem in which these plants were held by the contemporaries of Theophrastus, unless the species common in Lesbos, Cyrene, etc., is more fragrant than those of the Northern Sahara. That they were held in unbounded esteem in those days will be shown by the following passage from Juvenal: "'Keep your grain, O Africa,' said Aletius, 'unyoke your oxen, provided only you send us truffles.'" And again Juvenal blames the over-indulgent father for encouraging his son in luxurious habits since he teaches him "to peel the truffle and to put up the boletus in spices."

MORELS

THE morels (Morchella), commonly known as sponge mushrooms in parts of the United States, are perhaps the most highly prized of all native wild species, and in Europe they rank next to the truffles. Aside from the truffles and terfas it is one of the few genera of the *Ascomycetes* sufficiently large to be considered satisfactory for table purposes.

Description. A general description of any species with illustration will suffice, perhaps, for the recognition as morels of all the larger species. Even should related genera be mistaken for these morels, no harm would be done, since all are edible cooked. Instead of possessing the usual "parasol" form characteristic of the agarics, we may best describe the morels as stalked sponges, consisting of a stem usually one to three inches high, generally pale to buff in color, bearing an ovoidal or conical cap somewhat greater in diameter than the

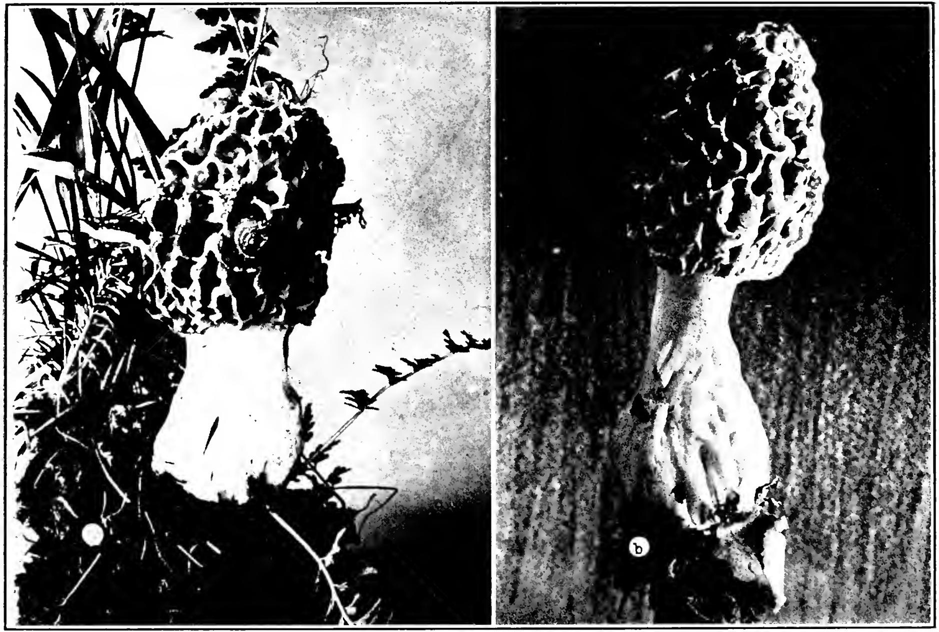

Plate XIV. (a, b) Morels.

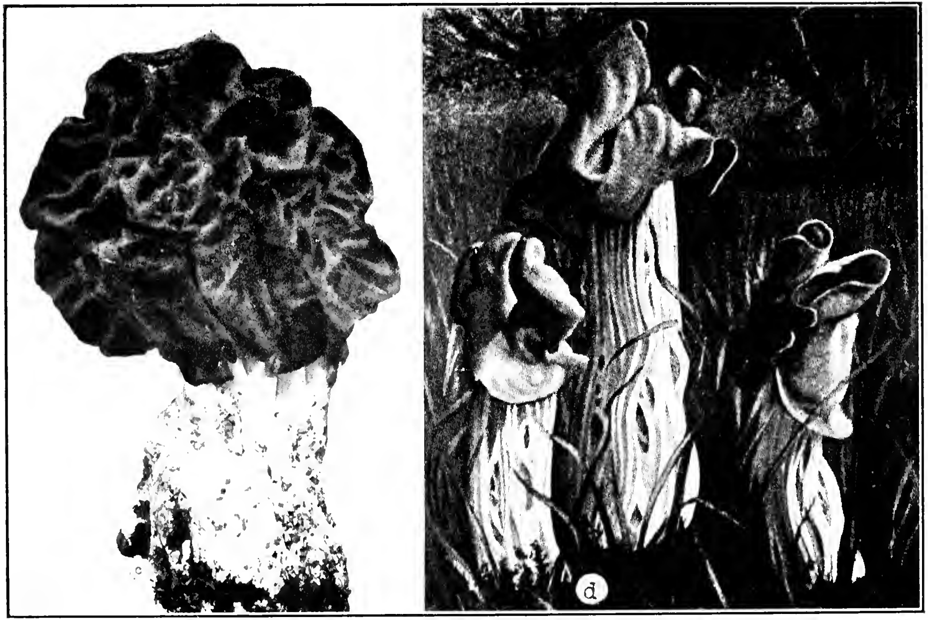

Plate XIV[1]. (c) Gyromitra gigas.
(d) Helvella crispa, from Paul Dumée's "Nouvel atlas des Champignons."

stalk (Plate XIV, a, b). The cap has much the appearance of a sponge, presenting an irregular honeycombed structure; and it is sometimes buff in color, but more frequently darker, often brownish, olivaceous, or smoky.

Occurrence. Next to the wild *Agaricus campestris* the morel is more often sold on the American markets than any other wild species. They are widely distributed throughout temperate climates, at least in the Northern Hemisphere, and are found more frequently, perhaps, in open woods (Plate XIII[1], d), meadows and orchards, but may occur also in dense woods or even in pastures. They appear in the early spring, especially after warm rains. With favorable conditions the whole period of their occurrence in any locality will often be limited to an interval of two weeks. On the other hand, if the season is dry until summer weather prevails, they will occur very sparingly and be of poor quality.

Apparently no careful study has been

made of the species occurring in the United States, but the European forms have received special attention by Boudier. In his *Icones Mycologicæ* nineteen species and three varieties are figured for France, and of these at least half are large enough and sufficiently common in western Europe to be of interest economically. It is quite probable that most of these European forms occur in the United States and certainly four or five of the more important do. From the lists and descriptions which have been published it would appear that the following larger species, or forms resembling them, are rather common, namely, *Morchella vulgaris, M. crassipes, M. rotunda, M. conica,* together, of course, with several smaller forms. It would appear that *M. vulgaris* is more common in the eastern part of the United States and a species which appears to be *M. crassipes* is very abundant in the Central West.

Attempts to grow the morel. In spite of its high quality and wide distribution the morel has never been successfully cultivated. It is an easy matter to prepare pure cultures, and for more than ten years the writer has used these in various laboratory experiments. Pure cultures have also been used by French investigators, both for a further study of the life relations of the species and for the experimental work in attempting to grow the morels. Cultures may be made either from spores or by the tissue method described for *Agaricus campestris* and other fleshy fungi. The spores germinate readily in almost any nutrient medium and yield a vigorous mycelium on sterilized plant products of various kinds, especially on bean stems and pods or pieces of apple. The writer has also grown the mycelium in large quantity on sterile loam. Experiments have been undertaken with the idea of determining the conditions of sporophore formation. Compost of various kinds, leaf mold, and other products variously treated with fertilizers, also modified with respect to acidity and alkalinity, have been employed. In no case thus far have successful results been obtained. In France it is reported that a few small specimens have been grown on the fermented, refuse apple pulp from cider mills. The spawn is brownish in appearance and in loam cultures soon yields sclerotial-like masses which are thought by some to be an important preliminary to fruit production. At one time the view prevailed that the mycelium of the morel is parasitic, or at least closely associated with the roots of higher plants (such as the oak and the sunflower) so that the growth of this mushroom would be limited by the distribution of these associated plants. This view has not apparently been justified in the case of any species. When the morels are found in the spring one can readily observe the mycelium extending through the decaying leaves and into the soil, like that of most mushrooms of the woods.

The fruit bodies undergo much of their development hidden beneath the leaves and other forest cover, rapidly expanding into full size under favorable conditions. On account of the high quality of the mushrooms it is to be hoped that the conditions for sporophore formation will be determined so that one or more of the larger species may be grown commercially. It is scarcely a matter, however, with which the amateur may experiment profitably, since a considerable equipment would be desirable. Meanwhile, it may be said that the morels when cooked properly may be utilized as a food delicacy second to none. They should not be used raw or partly cooked, and the same caution applies to all the morel allies. Any surplus collected may be preserved by drying, although some of the characteristic aroma is lost as a result of preserving them in this way.

Gyromitra and Helvella. Finally, it might be said that the habitats of the related genera Gyromitra (Plate XIV[1], c) and of the larger species of Helvella (Plate XIV[1], d) are much the same as those of the morel, and an illustration of the former must suffice to indicate its appearance. The gyromitras are generally larger than the morels and much less common. The helvellas are smaller and are not, as a rule, found in such great quantity in small areas.

Markets and Seasons for Wild Mushrooms

Wild mushrooms are marketed extensively in many countries, but it is a difficult matter to obtain reliable information regarding the species and quantities sold, except in the case of certain cities of France, Germany, and Switzerland. In the United States, unfortunately, there is practically no market for wild mushrooms. *Agaricus campestris* is in general the only species sold, and more or less of this is offered for sale during the months of September and October in various cities. In California it appears in the open during the winter months, and for a long time constituted the chief source of fresh mushrooms on the market there during the winter season.

When one considers the wide range of flavors and textures which mushrooms possess, and the immense number of species growing wild, there is every reason to regret the failure on the part of Americans to become interested in wild mushrooms as an article of food. There are, of course, individuals who are enthusiastic collectors, and some who may be cranks about eating all sorts of species. A few mycological clubs have been formed, apart from scientific work, designed to interest the public in the use of these plants. Up to the present such efforts have not been far reaching in results, so that much general educational work will be required in order to stimulate a demand for the wild forms. On the other hand, a word of warning is necessary: It is senseless to eat any and all mushrooms just because they are not poisonous. There is no more point to that than that we should eat crows. Wherever wild mushrooms are offered for sale in the markets the regulations or laws of the municipalities should be strict, and competent inspectors should be charged with an examination of all products offered for sale. In European cities the regulations are not always adequate to prevent accidents, even through market sales, but in many cases a resident botanist acts in the capacity of consulting officer or referee of the market to whom doubtful mushrooms are brought.

French markets. Prior to about 1876 only the cultivated mushrooms and certain truffles seem to have been permitted on the markets of Paris. Doubtless there were many persons who collected and ate various species of mushrooms, but public sale was not permitted—even in the case of the morel. Gradually the market has been extended, and now as many as thirty species are fairly common, while the sale of others would also be sanctioned. Besides the truffle and the cultivated mushroom, the two chief species which are dried or otherwise preserved are *Boletus edulis* (la cèpe) and *Amanita Cæsarea* (l'oronge), the total quantity preserved being valued at 250,000 francs. Genevier, writing in 1876 of the market of Nantes, estimated the sale of wild mushrooms at about 30,000 kilo (about 66,-000 pounds), which might be subdivided into three parts of about 10,000 kilo each, one-third being *Agaricus campestris,* another third being represented by three species of edible mushrooms very common in that region, namely *Boletus edulis, B. æreus,* and *Lepiota procera,* while the third part was distributed among ten or more common ones, among which were several species of Lepiota, Morchella, and Amanita.

In France there is perhaps no city located near a forested region which is not a considerable market for many species of wild mushrooms in season. The dominant species vary with the localtiy. It is reported that in 1907 about 26,000 pounds were sold at Lyon, of which the greater part consisted of the chanterelle, *Cantharellus cibarius,* with *Tricholoma terreum* next in quantity. In other markets, *Boletus edulis* or *B. granulatus* is often the dominant species.

At Geneva, Switzerland, there is a special quarter of the market reserved for the sale of mushrooms, and in season this is a veritable fungous exposition. The inspection is carefully organized, and even those who collect for private use are encouraged to have their collections passed upon. Lausanne is another important Swiss market for this product, and there the sale of seventy-eight species is reported to have been authorized, the total amount sold being perhaps 60,000 pounds.

German markets. During the summer of 1899 I observed the markets of Berlin and Leipzig, but at no time were there more than a dozen of the commoner species of wild mushrooms on sale. I was informed that the market inspection in these cities is not yet well enough organized to encourage the use of any large number of species.

As early as 1812 a law restricting mushroom sale in Prussia was very clearly set forth, the early date of this law making it of especial interest. From a report of Professor Giesenhagen (Zeitsch. f. Unters. der Nahrungs-u. Genussmittel. 1 Juli, 1902, pp. 601-602) the exact text of this law may be obtained, and it indicates that the sale of the following species only shall be permitted: *"Morchella esculenta, M. conica, Psalliota campestris, Lactarius deliciosus, Agaricus cebaceus, Merulius cantharellus, Boletus edulis, Clavaria flava."* The same law states that all other species of fungi are to be discarded, since they are in part poisonous and in part easy to be confused with poisonous forms. Referring to Italy, in this connection it may be said that in 1820 the government of Milan declared that certain fungi were edible, naming about half a dozen common species. The same law permits the greatest latitude in kinds for each province, since it is provided that each province shall post a list of those species occurring in the region which have, from experience, been found to be wholly harmless.

The moist woods of southern Bavaria offer an excellent habitat for many species of fungi, and the city of Munich is doubtless the largest market in the world for wild mushrooms (Plate XV, a, b, XV[1], c). According to Professor Giesenhagen, the quantity sold in the provision market of that city in the summer and autumn of 1901 was about 850,000 kilo (about 1,850,000 pounds), distributed as shown in the following table:—

		Kilo.
1.	Clavaria aurea	10,000 — 12,000
2.	Clavaria botrytis	
3.	Clavaria flava	
4.	Craterellus clavatus	500 — 600
5.	Sparassis crispa	
6.	Cantharellus cibarius	70,000 — 90,000
7.	Boletus edulis	300,000 — 350,000
8.	Boletus granulatus	1,000 — 1,500
9.	Boletus scaber	150,000 — 180,000
10.	Polyporus confluens	500 — 600
11.	Polyporus ovinus	15,000 — 20,000
12.	Hydnum imbricatum	13,000 — 15,000
13.	Armillaria mellea	600 — 800
14.	Clitocybe nebularis	50,000 — 60,000
15.	Lactarius deliciosus	200 — 300
16.	Lactarius volemus	8,000 — 10,000

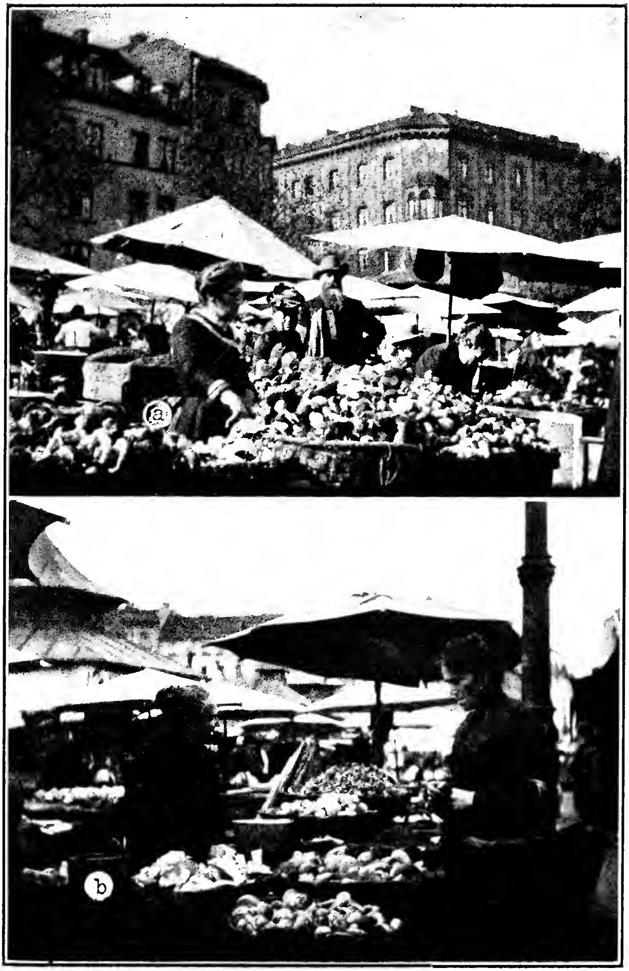

Plate XV. (a, b) Views in the Market Place of Munich, showing Wild Mushrooms on Sale.

Plate XVI. (c) Another View of the Mushroom Market, Munich.
(d) Market at Bozen, Austria.

		Kilo.
17.	Lepiota procera	12,000 — 13,000
18.	Pleurotus ostreatus	1,000 — 2,000
19.	Russula alutacea	30,000 — 35,000
20.	Russula cyanoxantha	
21.	Russula vesca	
22.	Russula virescens	
23.	Tricholoma gambosum	10,000 — 12,000
24.	Pholiota mutabilis	5,000 — 6,000
25.	Psalliota campestris	80,000 — 100,000
26.	Morchella bohemica	5,000 — 8,000
27.	Morchella conica	
28.	Morchella esculenta	
29.	Morchella patula	
30.	Gyromitra esculenta	2,000 — 3,000
31.	Gyromitra gigas	

The sale of thirty-one species was therefore localized on this market. Doubtless this number would be somewhat increased by the fact that several species may be included under *Agaricus* (*Psalliota*) *campestris,* and the same may be true of some other forms. Aside from this it is to be noted that this list is a local one and that many fairly common edible fungi are not included.

Seasons. Except in very few cases—notably that of the truffle—the usual growing season is the time for mushrooms.

However, there is commonly a paucity of the larger fleshy fungi during the early spring. Nevertheless, the springtime brings the morels or sponge mushrooms and some of their allies, the helvellas and gyromitras, likewise under certain conditions most species of ink caps; and certain other edible forms. Of the subterranean species the African terfas are mature in March and April, and the winter truffle of Southern Europe sometimes extends into this season. Neither the morels nor the larger coprini ordinarily extend into summer. The early summer, however, if favorable, brings to fruitage many of the smaller fleshy fungi, certain species of Russula, Lactarius, Lepiota, etc. Since midsummer is a season of high evaporation, the infrequency of rains is promptly felt in the development of the mushroom flora. In most regions of fungous exploitation the late summer and early autumn constitute the chief period of production. Many of these edible species which are able to make out but a mean existence in early summer appear in quantity later. It is, in fact, during the late summer and early autumn that the wild mushrooms flood the European markets. This is the season for the edible species of Boletus, Cantharellus (chanterelle), Pleurotus (Oyster Mushroom), *Agaricus campestris, Agaricus placomyces,* and other species of Agaricus, the various fleshy species of Hydnum, most of the larger puff-balls, and in general the greater number of showy species ordinarily collected, including the poisonous Amanitas. As cold weather begins, the last forms to disappear are some of the tougher types, including, however, Pleurotus, Marasmius, Clitocybe, Armillaria and Collybia. In many regions the suspected Clitocybe, *C. illudens,* and the edible *Collybia, C. velutipes,* are conspicuous at the time of early frost, both occurring about decayed roots or stumps. *Collybia velutipes* is able to withstand considerable frost and may be designated as a typical early winter fleshy species. An explanation of the abundance at this season in most regions is, of course, to be had in the fact that the environmental conditions then more nearly fulfill the requirements for perfect development. A factor in some cases appears to be that their enemies are less abundant, and therefore the mushrooms have an opportunity which has been previously unrealized. This is not to be understood as an indication that the main growth of the mycelium occurs during the late summer or early autumn. It is more probable that under the cover of the leaves and other material of the forest floor, or protected by the grass turf in the pasture and meadow, the mycelium grows more or less abundantly throughout the whole spring and summer, the relative water content of the soil, within certain limits, being at this time often a far less important consideration than later. Rainfall undoubtedly governs to a marked degree the production of sporophores, and as a rule the expert can, from the nature of the season, foretell with considerable accuracy whether or not the season will be favorable for finding any particular species.

These remarks concerning the general abundance of mushrooms in the different seasons does not, of course, apply to regions in which special climatic conditions prevail, as in California, or in other places where the wet season begins in late autumn, attended usually by a period of slow growth of the vegetation throughout the so-called winter. In fact, under such circumstances mushrooms do not begin to appear in quantity until the wet season is at hand, and they may be most abundant in the depth of what is called winter.

Although field and pasture, forest, woodland, and meadow throughout the humid regions of the temperate zone are all favorable habitats, the number of species is greater in wooded areas. In fact, for one who wishes to see a maximum of species and a maximum quantity in a minimum of days, the moist wooded mountain or hilly region is to be recommended. It is immaterial whether we consider the mountains of New York and New England or the various ranges in the far West, a favorable season will ordinarily develop mushrooms more plentifully in such situations than in the plains, prairies, and fields. But the moist forests everywhere abound sufficiently in wild forms, and in taking care of forest preserves in Germany, particularly, financial consideration is made for the mushrooms which may appear. No small part of the keeper's wage is said to accrue from his privilege of harvesting these plants. It is not then surprising to find that the wooded hills of Sweden, of the Tyrol, or of the Pyrenees will yield alike an abundance of forms sufficient to satisfy the interests of any amateur or mycologist. It is more probable that discouragement will come to the amateur who has set out with the idea of learning all of the species of mushrooms in a single late summer outing or vacation. Few mycologists know, to recognize at sight, more than a few hundred species of our fleshy fungi. The amateur might well be content to know a few dozen of the better edible forms, and to confine his desire to experiment upon himself as to edibility to his definite knowledge of species.

Mushrooms in Roman Times

We are in possession of sufficient information to indicate the esteem in which mushrooms were held by the Romans. Apparently they were used more extensively during the time of the Empire, and the principal references are to be found in Horace, Pliny, Juvenal, and Martial. It seems that the Romans may have obtained their knowledge of them through the Greeks, for there is no evidence that they were used at Rome in very early times. A few references may be given merely to indicate their favor. Catius repeats to Horace the substance of a discourse on things to eat, and in this he states that the fungi which frequent the open meadows are those that are to be trusted. Pliny also refers to the use of mushrooms as dainties which had recently come into fashion. That some species were held in high regard is shown from a statement in Martial in which he says that "it is hard to give up the *boleti*" ("boleti" is here supposed to refer to *Amanita Cæsarea*). Again, in referring to the gluttony of Cæcilianus, Martial reproves him in these words "In the presence of an invited assemblage you alone eat boleti." Numerous other references indicate that certain mushrooms, notably the one above referred to as "boletus," are always reckoned among the delicacies or luxuries.

It will be seen from the references which have been given that the Roman writers who referred to these plants were active from less than half a century B. C. to about one century A. D. It is not without interest to note that there is nothing to indicate that the common mushroom *Agaricus campestris* was used at that time, except possibly we may read this into the information that the mushrooms of the open meadow were regarded as trustworthy.

If it can be properly assumed that *Boletus edulis,* now known so well throughout Europe, is the same as the fungus which in the time of the Roman Empire passed under the name of *"suilli,"* then it may be said that this species has through many centuries formed a considerable part of the food of the common people of many sections of Europe. It is clear that the Romans used certain fungi which were constantly referred to under this name, but they were not considered the best of the mushrooms. This is well shown when Martial complains that at a dinner to which he was invited his host feasted upon oysters and *"boleti,"* while he must be content with the *"fungi suilli."* The fungus thus designated was certainly cheap and common. Frequently the intimation is given that the *fungi suilli* were doubtfully edible, and that such untried mushrooms were placed before the poorer persons at the feast. In these cases, however, and possibly always, the name may have referred to various species of the present genus Boletus.

Food Value of Mushrooms

From time to time there is discussion in popular articles of the food value of mushrooms. Unfortunately such discussions seldom take into consideration all of the important factors. In reference to food value it is to be remembered, first of all, that the cultivated mushroom is properly an accessory food, or luxury, deserving particular attention more as a relish or condimentary dish. As such it has a value which cannot adequately be expressed physiologically, much less measured by the figures which express the chemist's data. Food values are of little consideration, as a rule, with products which are essentially a matter of taste. Truffles may bring twenty or thirty francs per kilo in Paris; the common mushroom may sell at two francs, and green beans at less than a franc. As a matter of fact, comparing equal weights, the beans have greater actual food value than the mushrooms, and the mushroom is nearly as valuable in this way as the truffle. Because of their flavor, however, mushrooms command a special price; while the peculiarly attractive flavor and unusual aroma, or perfume, of the truffle stamps this fungus as distinctly a luxury. Exactly the same relation holds with respect to values in fruits. The difference in the price between the Ben Davis apple and the Jonathan, approximately the same composition, is in a way a measure of our judgment of quality.

In the second place, however, it is well to note that the cultivated mushrooms and the wild edible ones as well, actually possess in a chemical sense a food value equal to that of many vegetables, better than some, poorer than others. It is perhaps on this basis that so much is said regarding the great waste in the United States by our failure to use more commonly the edible mushrooms of the fields and woods. In any case, however, it is misleading to speak of this product in general, as vegetable meat, or to imply that mushrooms possess a special food value due to supposedly "animal-like" composition. Wild mushrooms at the prices at which they are sold on the markets of Europe are undoubtedly an important staple food. They contain far less protein than meat, pound for pound of the fresh material. This is apparent from the figures given in the table below, where fresh weight percentages are comparable. On the basis of dry substance the mushroom does contain a relatively high percentage of protein, but it is obvious that many pounds of mushrooms would be required to directly replace one pound of meat. Aside from the indications given it is clear that the chief point for the mushroom is quality and flavor, which are quite sufficient; and there would be no more reason for eating unsavory mushrooms than for eating tasteless legumes.

NUTRITIVE VALUE OF TEN POUNDS OF SEVERAL FOODS

		Proteins	Fats	Carbo-hydrates	Calories	Cost	Calories for one cent
		Percentages of fresh material					
a.	Beef (round) ..	1.87	.88		7200	$2.50	48
b.	Cabbage	.18	.03	.49	1400		
	Potatoes	.18	.01	1.53	3250	.10	325
	Flour (roller process)	1.13	.11	7.46	16450	.25	658
c.	Coprinus comatus	.04	.025	.434	987	2.50	3.9
	Pleurotus ostreatus	.051	.042	.828	1811	2.50	7.2
	Morchella esculenta	.094	.05	.306	955	4.00	6.08
	Agaricus campestris	.18	.03	.46	1316	4.00	8.48
	Oysters	.61	.14	.33	2350	2.00	11.7

Full justice will be done the cultivated and the desirable native mushrooms so soon as the public have had adequate opportunity to utilize them under satisfactory conditions. Satisfactory conditions are to be understood, in the main, as savory and appropriate cooking. This is an essential in the proper appreciation of any highly flavored product, and mushrooms may be made delicious, whether for a picnic in the woods or for a dinner party.

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