

## CHAPTER 2 THE NATURE OF FUNGI WITH SPECIAL EMPHASIS ON MUSHROOMS

### *Synopsis*

This chapter aims to give a basic understanding of fungi, their structure and mode of growth with specific emphasis in the mushroom fungi. The role of mushrooms in nature is outlined with reference to the main forms of nutrition. The historical uses of psychotropic mushrooms in early forms of religion are outlined together with the use of other mushrooms as items of food and medicine.

### ***Introduction***

Mycology is concerned with the study of the Fungi, the term being derived from the Greek word *mykes*, meaning a fungus. The Fungi were, until comparatively recent times, regarded as members of the Plant Kingdom but are now recognized as a very distinct and separate group of organisms. They are eukaryotes having well-defined membrane-bound nuclei with a number of definite chromosomes and, as such, clearly distinguishable from bacteria. They are heterotrophic, requiring organic carbon compounds of varying degrees of complexity which distinguishes them from plants which manufacture their own organic food by photosynthesis. All but a few fungi have well-defined cell walls through which all their nutrients must pass in a soluble form and, in this respect, they differ from animal cells which lack defined cell walls.

The number of species of fungi is a matter of speculation but recent estimates have strongly suggested that their numbers could be well in excess of 1.5 million. The fungi show immense differences in size, structure and metabolic activities. The smallest, such as the yeasts, grow as loose aggregates of single detached microscopic cells while most fungi exist as microscopic filaments or hyphae which extend at the tip, branching and fusing (anastomosing) to form a complex mycelium or network. As such mycelial networks increase in size they become visually

apparent and, indeed, in some cases the mycelia form large complicated structures exemplified by the large fruit bodies known colloquially as mushrooms. While many fungal species do grow and function in aqueous environments, the vast majority, by the nature of their apical growth patterns, are best adapted to growth over and through solid substrates, especially in terrestrial environments. Fungi function extensively in the soil environment breaking down dead organic matter but can also extensively grow in plants, animals and man causing decay and disease. Many fungi negatively attack manufactured products of all kinds including foodstuffs, fabrics, leather, timber, cosmetics, pharmaceuticals, aviation fuel etc., while, on the other hand, they make a huge contribution in biotechnology producing wines, beers, spirits, fermented food products such as cheeses, antibiotics, industrially-important organic acids and now many other important medicinal compounds. In themselves many edible mushrooms form the basis of huge commercial processes.

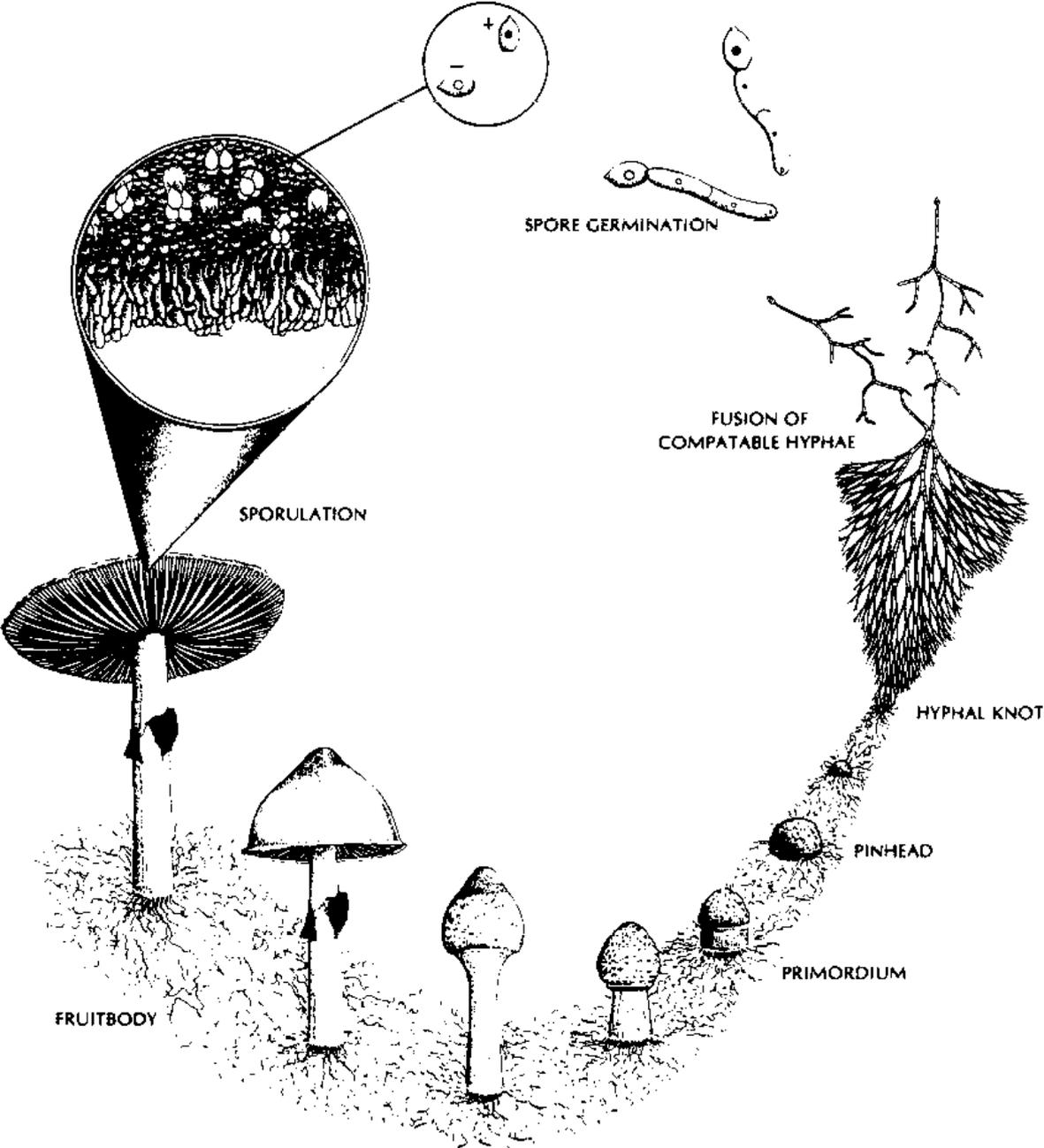
In mycology, as in other sciences, increased knowledge has resulted in complexity and, eventually, the division of the science into a number of branches with the resultant increase in specialization. What is termed pure mycology concerns the detailed structure, cytology and modes of development of fungi while taxonomic studies examine structure with a view to classifying fungi so as to show relationships and facilitate identification of the myriad of types. Medical mycology deals with the fungi which cause diseases in man and as well as the toxic effects of mycotoxins, fungal metabolites formed by filamentous fungi growing mainly in cereal grains and oilseeds. Several of these mycotoxins are now recognized as powerful carcinogens of man. *Such cancer-forming mycotoxins present in the human diet deserve greater awareness in the medical profession.* Field mycologists are particularly concerned with fungi found in fields and woods, particularly the larger forms, the mushrooms,

the mycelium of which colonises the field and forest litter. Some attack and colonise standing trees, producing large outgrowths or bracket fungi.

In the context of this report, attention will be drawn mainly to the larger fleshy fungi or mushrooms since almost all of the important edible and/or medicinal fungi are to be found within these species. In mycological terminology such mushrooms belong almost exclusively to the Basidiomycete and Ascomycete subdivisions. In both the Basidiomycetes and Ascomycetes there is a process of sexual reproduction occurring originally in the underground mycelial stage and finally manifesting in the large above-ground macroscopic fleshy fruit-bodies – the mushrooms (Fig. 1).

Such mushroom structures in their multifarious forms and colours are there primarily to disseminate the spores or units of propagation. The main difference between the two types is in the final mechanism of sexual spore release. In the Ascomycetes, often termed 'sac fungi' as within the mushroom mass they produce sac-shaped capsules (the asci) that actively release the spores to the atmosphere to be dispersed by the wind. In contrast the Basidiomycetes or 'club-fungi' produce spores attached to club-shaped structures, the basidia (Latin name for club). Some of the mushrooms are prized by the epicure, others are shunned as amongst the deadliest of poisons but, most important of all, there is the increasing recognition that many contain a Pandora's box of intriguing medicinally important compounds. Some of the important British species of edible, poisonous, hallucinogenic mushrooms are listed in Tables 1-3, and medicinal mushrooms, mostly Oriental, are listed in Table 4 (Philips, 1994; Miles and Chang, 1997).

Fig. 1 The Basidiomycete mushroom life cycle (Stamets, 2000)



**Table 1 Edible mushrooms in Britain**

|                                 |                       |
|---------------------------------|-----------------------|
| <i>Agaricus compestris</i>      | The field mushroom    |
| <i>Boletus edulis</i>           | Cep                   |
| <i>Cantharellus cibarius</i>    | Chanterelle           |
| <i>Coprinus comatus</i>         | Shaggy inkcap         |
| <i>Cratarellus cornuopiodes</i> | Horn of Plenty        |
| <i>Hydnum respondum</i>         | Hedgehog fungus       |
| <i>Laetiporus sulphureus</i>    | Chicken of the Woods  |
| <i>Lepiota procera</i>          | Parasol mushroom      |
| <i>Lepiota saeva</i>            | Field blewit          |
| <i>Marasimus oreandes</i>       | Fairy Ring Champignon |
| <i>Morchella esculenta</i>      | Morel                 |
| <i>Sparassis crispa</i>         | Cauliflower fungus    |
| <i>Tuber aestivum</i>           | Truffle               |

**Table 2 Some poisonous mushroom species in Britain**

|                                   |
|-----------------------------------|
| <i>Amanita phalloides</i>         |
| <i>Amanita virosa</i>             |
| <i>Amanita pantherina</i>         |
| <i>Inocybe patouillardii</i>      |
| <i>Cortinarius speciosissimus</i> |
| <i>Cortinarius orellanus</i>      |
| <i>Gyromitra esculenta</i>        |

**Table 3 Some of the main psychoactive mushrooms**

|                           |
|---------------------------|
| <i>Lycoperdon</i> spp.    |
| <i>Psilocybe</i> spp.     |
| <i>Paneolus</i> spp.      |
| <i>Gymnopilus</i>         |
| <i>Conocybe</i> spp.      |
| <i>Amanita muscaria</i>   |
| <i>Amanita pantherina</i> |

**Table 4 Important medicinal mushrooms**

|                                       |
|---------------------------------------|
| <i>Auricularia auricula</i>           |
| <i>Trametes (Coriolus) versicolor</i> |
| <i>Flammulina velutipes</i>           |
| <i>Ganoderma lucidum</i>              |
| <i>Grifola frondosa</i>               |
| <i>Hericium erinaceus</i>             |
| <i>Lentinus edodes</i>                |
| <i>Schizophyllum commune</i>          |
| <i>Tremella fuciformis</i>            |
| <i>Poria cocos</i>                    |

## ***How mushrooms grow in nature***

From an ecological and also an eventual cultivable perspective, mushrooms can be considered in three distinctive modes of growth, viz. as saprophytes, parasites or in a mycorrhizal association (Stamets, 1993).

The saprophytic mushrooms belong to the group of primary recyclers in nature, enzymatically breaking down the complex organic matter of dead organisms, especially those with a woody structure, and setting in motion the ultimate return of the organic building blocks to the ecosystem for reuse. Within this group there are three separate but overlapping groups characterized by their enzymatic capabilities. In nature, the *primary decomposers* are largely decomposers of woody structures and are characterized by possessing enzymes able to degrade the complex macromolecules such as lignin and cellulose. Decaying logs and tree stumps are most often colonized by colourful mushroom types. Many of the Oriental medicinal mushrooms, such as *Lentinus edodes* have their historical origin from such locations. Once such mushroom mycelium has been established and with the initial breakdown of the raw material, other microorganisms, including bacteria and other mushrooms, can further exploit the partially broken down nutrient environment. These are the *secondary decomposers* and are exemplified in the mushrooms by *Agaricus campestris* – the button mushroom. Finally, as the organic material is extensively broken down or decomposed, the *tertiary decomposers* are now able to grow. In nature, the three groups are not clearly separated but rather occur in the same location or habitat. Thus, in any one particular site, there can be a succession of mushroom types depending on the state of decomposition. The recognition of the growth needs of a mushroom in nature can hasten an eventual large-scale commercial cultivation procedure.

True *parasitic mushrooms* can attack living trees causing immense ecological damage and huge financial losses in forestry. While in most cases the mycelial growth within the body of the tree will be limited, in some cases it can lead to death of the trees. However, most parasitic mushrooms can also exist on dead tree material as *facultative parasites*. The medicinal mushroom *Pleurotus ostreatus* is a good example. The spread of such mushrooms from tree to tree and through the soil can be quite extensive. It is interesting to note that American scientists have calculated, using DNA measuring technology, that a single pure colony of the parasitic mushroom *Armillaria bulbosa* covered 37 acres, weighed at 222,000 lbs and had an estimated age of 1500 years – and is still growing. With the exception of certain Sequoia forest trees this is the largest living organism on the planet!

Undoubtedly, one of the largest groups of mushroom species are the *mycorrhizal mushrooms* (myco = mushroom, rhizal = roots) which contain many of the important gourmet mushrooms, viz. the Truffles, Matsutake, Ceps and Chantarelles (Table 1). In these cases the underground mycelium of the mushroom grows extensively around the root tips of specific trees forming a protective sheath with some mycelium penetrating into the root tissue. The mycelium grows also in the soil mass and, eventually, appears at the surface as typical mushroom fruit-bodies or underground as solid fungal masses, i.e. the truffles. The fungal sheath greatly increases the absorption of essential nutrients, especially minerals, into the tree improving its vigour and disease resistance. In return, the mycorrhizal mushroom receives organic material of unknown composition. Many mycorrhizal mushroom species have been cultured on selected media as saprophytes but others such as the Truffles and the Chantarelles have, so far, defied true axenic, artificial cultivation. A huge commercial market awaits their inevitable cultivation. In many parts of the

world the collection, distribution and sale of such gourmet mushrooms from natural habitats is a multi-million pound industry.

The health of most forests is directly related to the presence, abundance and variety of mycorrhizal associations. Most mycorrhizal medicinal mushrooms still need to be gathered from the wild. As will be discussed later, fermenter cultivation of mycorrhizal mycelium may help to overcome the difficulty of successful total cultivation.

### ***Mushrooms and historical uses***

Many mushrooms have long been valued as tasty, nutritious food by different societies worldwide. To the ancient Romans they were “the foods of the Gods” resulting from bolts of lightning thrown to the earth by Jupiter during thunder storms; the Egyptians considered them as “a gift from the God Osiris”; while the Chinese viewed them as “the elixir of life”.

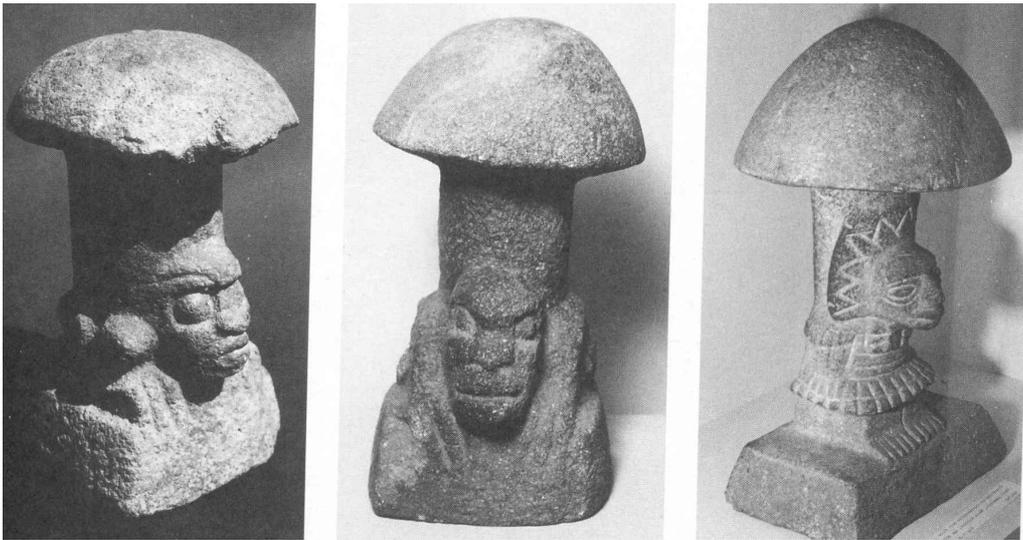
Throughout history many cultures have built-up a practical knowledge of which mushrooms were suitable to eat and those that were poisonous. Many cultures, especially in the Orient, identified that certain mushrooms could have profound health-promoting benefits (Hobbs, 1995).

However, there does exist an insidious fear of mushroom poisoning in many cultures which can even approach phobic levels. Such profound mycophobic reactions are evident in the UK, Ireland and much of North America while, in sharp contrast, mycophilic or fungus-loving societies can be witnessed throughout Asia, much of Europe, Poland and Russia where wild mushrooms are extensively collected or purchased for food to be incorporated into soups, stews and teas. Catholic countries, in general, are more mycophilic and it has been suggested that this may have arisen because they are not allowed to eat meat on Fridays and mushrooms

could be a good alternative (Taylor-Hawksworth, 2001). Notwithstanding, in some societies where gourmet mushrooms were regularly consumed at feasts and banquets, it was relatively easy to add in a few deadly poisonous mushrooms e.g. *Amanita phalloides* (Table 2) with dire consequences ensuing. Claudius II and Pope Clement VII are strongly believed to have died in this way. Symptoms and death normally came many hours later which allowed the perpetrator to be many “leagues” away before the onset of the symptoms. Some legends even suggest that the Buddha died in this way.

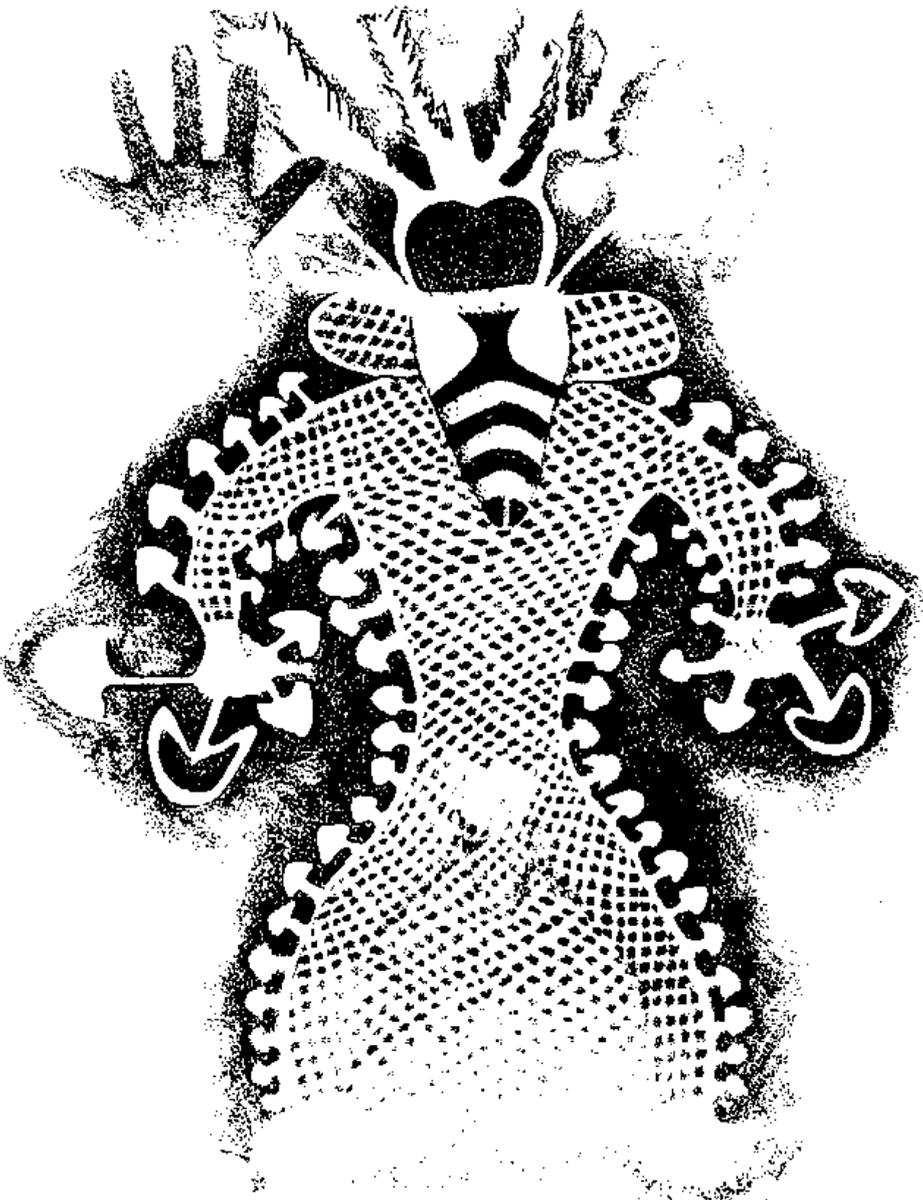
Perhaps the most fascinating aspect of ancient mushroom usage is related to the psycho-active, hallucinogenic properties of some mushrooms (Table 3). There is an extensive literature implicating certain mushrooms in ancient religious beliefs and practices (Arora, 1985). Investigations have demonstrated extensive past use of the tiny psycho-active hallucinogenic mushrooms *Psilocybe* spp. and *Panaeolus* spp. in Meso America and *Amanita muscaria* in Northern Europe/Siberia and in the Sahara region dating back to Paleolithic times. The accumulated, detailed data gathered to date strongly implicates the use of powerful hallucinogenic mushrooms in primitive forms of religion. There are numerous Meso American mushroom stones which date back to 3000 BC (Fig. 2). These stones were found at Mayan excavation sites in Guatemala and it is known that these “mushroom cults” were strongly persecuted by the Spanish when they arrived in the New World. These may represent the sacramental mushroom called Teonanc-tl (meaning flesh or food of the Gods) by the ancient Aztecs (Wasson, 1978).

**Fig. 2 Meso American mushroom stones circa 3000 years BC from the Pacific Slopes of Guatemala**



The oldest archaeological evidence of apparent mushroom use in the African continent can be seen in the Tassili images discovered in rock cave paintings in Algeria, dated at least 5000 B.C. (Fig. 3). The dancer is about 80 cm in height with the mask and stance typical of that historical period of rock paintings. The dancer is probably a shaman and the repetitive mushroom symbols hallucinogenic mushrooms (Samorini, 2001). In Europe, an effigy of a mushroom, not unlike *Amanita*, inserted in a scene with shamanistic connotations, has been found in a rock engraving of Mount Bego, France, dating back to 1800 B.C. Further important archaeo-ethnomycological documentation is to be found in ancient Greek culture (Samorini, 2001).

Fig. 3 Tasseli cave art from Northern Algeria, circa 5000 years BC.



Aristotle, Plato and Sophocles are believed to have participated in religious ceremonies which involved, in part, the consumption of mushroom decoctions. Furthermore, it has been strongly postulated that the mysterious SOMA in the Vedic

literature, a red fruit causing spontaneous enlightenment for those who ingest it could only be the red Fly Agaric, *Amanita muscaria* (Wasson, 1976) (Fig. 4). It is surprising that there has been such limited modern scientific study of the psychoactive compounds produced by such mushrooms. The extensive representation of mushrooms in a religious context would strongly imply their hallucinogenic potential and ingestion could induce mental experiences generally interpreted in terms of enlightenment and mystic-religious visions (Samarini, 2001).

**Fig. 4** *Amanita muscaria* – the Fly Agaric



The recent discovery of the “Iceman” in the Italian Alps, who is believed to have died 5300 years ago, brought further intriguing evidence of ancient mushroom

use. Among his accessories was a string of Birch Polypore Mushrooms (*Piptoporus betulinis*). Such mushrooms have long been used as tinder for starting fires, as medicine for treating wounds, and for producing an invigorating and immune stimulating tea (Hobbs, 1995, Stamets, 2000).

Why, might we ask, do so many British people have this very deep-felt and tenaciously-held fear of mushrooms? Robert Graves in “Food for Centaurs” (1956) has constructively discussed the use of hallucinogenic mushrooms in ancient religious ceremonies. It has been seriously considered that the British phobic attitude may be a deeply ingrained tradition from Druid times that mushrooms contain magical properties and may only be eaten under the control of the Druids themselves. Yet all round us nations relish eating mushrooms of diverse kinds!

## **References**

- Arora, D. 1985. Mushrooms demystified. Ten Speed Press, PO Box 7123, Berkeley CA 94707.
- Graves, R. 1994 (1957). La Conida de los Centauros y Otros Ensayos. Madrid, Alianza.
- Hobbs, C. 1995. Medicinal mushrooms. Botanica Press, 10226 Empire Grade, Santa Cruz, CA 95060.
- Miles, P.G. and Chang, S-T. 1997. Mushroom biology: concise basics and current development. World Scientific, Singapore.
- Philips, R. 1994. Mushrooms and other fungi of Great Britain and Europe. Interlitho S.p.A. Milan.
- Samorini, G. 2001. New data on the ethnomycology of psychoactive mushrooms. *International Journal of Medicinal Mushrooms* 3, 257-278.
- Stamets, P. 2000. Growing gourmet and medical mushrooms. Ten Speed Press, PO Box 7123, Berkeley CA 94707.
- Wasson, R.G. 1976. Soma: divine mushroom of immortality. Harcourt, Brace and Jovanovich, New York.
- Wasson, R.G. 1978. The wondrous mushroom: mycolatry to Mesoamerica. McGraw-Hill, New York