Introduction to Fungi SECOND EDITION

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Preface to the first edition

There are several available good text-books of mycology, and some justification is needed for publishing another. I have long been convinced that the best way to teach mycology, and indeed all biology, is to make use, wherever possible, of living material. Fortunately with fungi, provided one chooses the right time of the year, a wealth of material is readily available. Also by use of cultures and by infecting material of plant pathogens in the glasshouse or by maintaining pathological plots in the garden, it is possible to produce material at almost any time. I have therefore tried to write an introduction to fungi which are easily available in the living state, and have tried to give some indication of where they can be obtained. In this way I hope to encourage students to go into the field and look for fungi themselves. The best way to begin is to go with an expert, or to attend a Fungus Foray such as those organised in the Spring and Autumn by mycological and biological societies. I owe much of my own mycological education to such friendly gatherings. A second aim has been to produce original illustrations of the kind that a student could make for himself from simple preparations of living material, and to illustrate things which he can verify for himself. For this reason I have chosen not to use electron micrographs, but to make drawings based on them.

The problem of what to include has been decided on the criterion of ready availability. Where an uncommon fungus has been included this is because it has been used to establish some important fact or principle. A criticism which I must accept is that no attempt has been made to deal with Fungi Imperfecti as a group. This is not because they are not common or important, but that to have included them would have made the book much longer. To mitigate this shortcoming I have described the conidial states of some Ascomycotina rather fully, to include reference to some of the form-genera which have been linked with them. A more difficult problem has been to know which system of classification to adopt. I have finally chosen the 'General Purpose Classification' proposed by Ainsworth, which is adequate for the purpose of providing a framework of reference. I recognise that some might wish to classify fungi differently, but see no great merit in burdening the student with the arguments in favour of this or that system.

Because the evidence for the evolutionary origins of fungi is so meagre I have made only scant reference to the speculations which have been made on this topic. There are so many observations which can be verified, and for this reason I have preferred to leave aside those which never will.

The literature on fungi is enormous, and expanding rapidly. Many undergraduates do not have much time to check original publications. However, since the book is intended as an introduction I have tried to give references to some of the more recent literature, and at the same time to quote the origins of some of the statements made.

Exeter, 27 April 1970 J.W.

Preface to the second edition

In revising the first edition, which was first published about ten years ago, I have taken the opportunity to give a more complete account of the Myxomycota, and to give a more general introduction to the Eumycota. An account has also been given of some conidial fungi, as exemplified by aquatic Fungi Imperfecti, nematophagous fungi and seed-borne fungi. The taxonomic framework has been based on Volumes IVA and IVB of Ainsworth, Sparrow & Sussman's *The Fungi: An Advanced Treatise* (Academic Press, 1973).

Exeter, January 1979 J.W.

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Contents

Introduction

WHAT ARE FUNGI?

It is difficult to give a precise definition of a fungus, largely because organisms which are regarded as fungi are very variable in form, behaviour and life cycle. Ainsworth (1973) has listed their main characteristics.

Nutrition: heterotrophic (photosynthesis lacking) and absorptive (ingestion rare).
Thallus: on or in the substratum and plasmodial amoeboid or pseudoplasmodial; or in the substratum and unicellular or filamentous (mycelial), the last, septate or nonseptate; typically nonmotile (with protoplasmic flow through the mycelium) but motile states (e.g. zoospores) may occur.
Cell wall: well-defined, typically chitinised (cellulose in Oomycetes).
Nuclear status: eukaryotic, multinucleate, the mycelium being homo- or heterokaryotic, haploid, dikaryotic, or diploid, the last being usually of limited duration.
Life cycle: simple to complex.
Sexuality: asexual or sexual and homo- or heterothallic.
Sporocarps: microscopic or macroscopic and showing limited tissue differentiation.
Habitat: ubiquitous as saprobes, symbionts, parasites, or hyperparasites.
Distribution: cosmopolitan.

WHY STUDY FUNGI?

The absence of photosynthetic pigments enforces upon fungi a saprophytic or a parasitic existence. As saprophytes they share with bacteria and animals the rôle of decay of complex plant and animal remains in the soil, breaking them down into simpler forms which can be absorbed by further generations of plants. Without this essential process of decay, the growth of plants, upon which life is dependent, would eventually cease for lack of raw materials. Soil fertility is thus in part bound up with fungal activity. The roots of most green plants are infected with fungi and absorption of minerals may be enhanced following infection. Such infected root systems are termed mycorrhiza, and they are an example of a symbiotic relationship between green plants and fungi. In infertile natural soils the success of the higher plant may depend on infection (Harley, 1969). Harmful effects of saprophytic fungi on human economy are seen when food, timber and textiles are rotted. Fungi are also of importance in industrial fermentations as in brewing, production of antibiotics, or citric acid fermentation. Food processing such as baking, cheese making, or wine fermentation is also dependent on fungi. Increasing use is made of fungi in carrying out chemical transformations in the pharmaceutical industry. These activities of fungi have been ably reviewed by Christensen (1965), Gray (1959) and Emerson (1973).

As parasites, fungi cause disease in plants and animals. Although fungal pests of crop plants have been known since human records began, it was the impact of potato blight on the population of Ireland in the mid-nineteenth century which gave the impetus to the scientific study of plant pathology (Large, 1958). As agents of disease in animals and man, fungi are commonly less severe than bacteria and viruses, although some are lethal. As the control of other diseases improves, the importance of fungal disease is being recognised (Ainsworth, 1952).

Apart from these applied aspects of the study of fungi, they have a claim to interest in their own right, and as tools for the physiologist, microbiologist, biochemist and geneticist, who often find them ideally suited for investigations of all kinds. Our general understanding of genetics owes much to investigations with *Neurospora,* and our understanding of respiration to studies on yeast. Investigations into the bakanae disease of rice caused by *Gibberella fujikuroi* led to the discovery of the group of plant growth hormones called gibberellins. These aspects of fungal biology will not be stressed in this book. They have been well described by Cochrane (1958), Fincham & Day (1971), Esser & Kuehnen (1967) and Burnett (1975).

CLASSIFICATION

Organisms do not classify themselves. They are classified by man for convenience of reference. Ideally a scheme of classification should reflect natural relationships, but in considering relationships mycologists may not attach the same weight to the criteria available. It should therefore not be surprising that different authorities do not use the same scheme of classification. I have chosen to adopt the scheme proposed by Ainsworth (1973). Fungi are divided into two Divisions, distinguished by the presence or absence of a plasmodium or pseudoplasmodium. A plasmodium is a mass of naked, multinucleate protoplasm, moving by amoeboid movement and usually feeding by ingesting particulate matter. Nuclear division in a plasmodium is usually simultaneous. A pseudoplasmodium is an aggregation of separate amoeboid cells. Fungi with plasmodia or pseudoplasmodia are classified in the Division Myxomycota, whilst the majority of fungi, which are usually filamentous, are classified in the Eumycota.

Key to divisions of fungi

Plasmodium or pseudoplasmodium present **Myxomycota (p. 5)**

Plasmodium or pseudoplasmodium absent, assimilative phase typically filamentous **Eumycota (p. 55)**

PART ONE

Myxomycota

Slime moulds and similar organisms

Whether the Myxomycota are closely related to the Eumycota is doubtful. Possibly they are more closely related to protozoa. De Bary (1887) used the term Mycetozoa, indicating a relationship with animals. This view is shared by Olive (1970) who has reviewed the classification of the group. The classification below (Ainsworth, 1973), however, places them with the fungi. It is by no means certain that the organisms classified together in the Myxomycota are closely related to each other, and indeed some authorities would classify certain of the groups elsewhere.

Key to classes of Myxomycota

1 Assimilative phase free-living amoebae which unite as a pseudoplasmodium before reproduction **Acrasiomycetes (p. 7)**
Assimilative phase a plasmodium 2

2 Plasmodium forming a network ('net plasmodium') **Hydromyxomycetes (p. 19)**
Plasmodium not forming a network 3

3 Plasmodium saprobic, free-living **Myxomycetes (p. 22)**
Plasmodium parasitic within cells of the host plant **Plasmodiophoromycetes (p. 42)**

1: ACRASIOMYCETES

The characteristic feature of this group is that they have a trophic (i.e. feeding) stage consisting of amoeboid cells, or myxamoebae, (or in a few cases minute plasmodia), which ingest bacteria or other prey. Raper (1973) has given a valuable outline. He has pointed out that even the organisms classified in the Acrasiomycetes may not represent a natural group. It is also uncertain whether the group is best considered as related to fungi or to protozoa. The main justification for considering them here is that they have been traditionally studied by mycologists.

The fructifications of Acrasiomycetes consist of **sporocarps** (delicate tubular stalks bearing one or a few spores) or **sorocarps** (multicellular fruiting structures in which a sorus of spores is borne at the tip of a unicellular or multicellular stalk).

The key below is from Raper (1973).

Key to subclasses of Acrasiomycetes

1 Sporulation not preceded by aggregation of myxamoebae; sporocarps one- to few-spored; trophic stage consisting of myxamoebae or minute plasmodia, both with filose pseudopodia and nuclei with single centrally positioned nucleoli; flagellate stage present in some genera, lacking in others **Protostelidae (p. 8)**

Sporulation preceded by aggregation of myxamoebae to form pseudoplasmodia; sorocarps multispored; trophic stage consisting of uninucleate myxamoebae; pseudopodia filose in some genera and lobose in others; flagellate cells absent 2

2 Aggregating myxamoebae do not form streams in developing pseudoplasmodia; fructifications may or may not show definite sori and sorophores; myxamoebae with lobose pseudopodia and nuclei with single centrally positioned nucleoli **Acrasidae (p. 10)**

Aggregating myxamoebae form convergent streams in developing pseudoplasmodia; sorocarps with well-defined sori and sorophores; myxamoebae with filose pseudopodia and nuclei with two or more peripheral nucleoli **Dictyostelidae (p. 11)**

Protostelidae

PROSTELIALES

This group of organisms has only recently been discovered, probably because they are inconspicuous. They are, however, ubiquitous on decaying plant parts in soil, dung and also in fresh water. Olive (1967) has provided a monograph of the group. They can be cultivated on weakly nutrient agars such as lactose yeast extract agar (0·1% lactose, 0·05% yeast extract, 2% agar) or hay infusion agar (2·5 g hay/litre, 0·2% $K_2HPO_4.3H_2O$, 2% agar) in conjunction with other organisms ingested as food, such as the bacteria *Escherichia coli*, *Klebsiella aerogenes*, and the yeast *Rhodotorula mucilaginosa*.

Protostelium is a typical member of the group (Fig. 1). *Protostelium mycophaga* has been found on still-attached dead parts of plants. It grows and fruits well in culture, feeding at the expense of fungal cells such as yeasts, but not, apparently, bacteria. The fruiting body or sporocarp consists of a long, slender, tubular stalk about 75 μm long, bearing a single spherical spore about 4–10 μm in diameter. The spore is deciduous and readily detached. On germination, a single, uninucleate, amoeboid stage with thin pseudopodia