

An Introduction to
**INDUSTRIAL
MYCOLOGY**

GEORGE SMITH

AN INTRODUCTION TO INDUSTRIAL MYCOLOGY

BY

GEORGE SMITH

M.Sc., F.R.I.C.

LECTURER, DEPARTMENT OF BIOCHEMISTRY, LONDON SCHOOL OF
HYGIENE AND TROPICAL MEDICINE

FOREWORD BY

HAROLD RAISTRICK

Sc.D., F.R.S.

UNIVERSITY PROFESSOR OF BIOCHEMISTRY, LONDON SCHOOL OF
HYGIENE AND TROPICAL MEDICINE

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INDUSTRIAL MYCOLOGY

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FOREWORD

It is a truism to say that were all types of micro-organisms suddenly to die out, human and animal life as we know it to-day would be impossible. Dead vegetable and animal remains are continuously being broken down by biochemical reactions brought about by micro-organisms, until their constituent elements are returned to the economy of nature as carbon dioxide, ammonia, nitrates, etc., to recommence the synthetic cycle for which the green plants are responsible. The part played by the lower fungi, or "moulds" as they are more commonly known, in this chain of degradative processes is one of paramount importance.

Further, in all industries handling organic materials, e.g. those concerned with food production, leather, textiles, wood, pharmaceuticals, etc., the danger of spoilage through growth of moulds is one of which all those engaged in these industries are acutely aware. Thus the control and prevention of mould growth becomes a major problem to which, in the interests of increased efficiency, more and more attention is being given.

The harnessing of moulds for beneficial purposes, long established in some industries, as for example in the manufacture of Stilton, Gorgonzola and other types of cheese, has in recent years followed some very interesting lines. Thus citric acid, until this century obtained exclusively from the juice of citrus fruits, is now being made in thousands of tons per annum and in many different countries by growing chosen strains of the common black mould *Aspergillus niger* on sugar solutions, under carefully controlled conditions. The study of the biochemical changes, almost bewildering in their diversity, which can be brought about by moulds, is now a rapidly developing branch of biochemistry, and is attracting the attention of scientific workers in different parts of the world.

To those who are actively concerned in any of the industrial or scientific pursuits I have mentioned—and many more examples could be given if these were needed—it is scarcely necessary for me to point out the paramount importance of some knowledge of the moulds themselves, and the more detailed and accurate this knowledge is, the better. Thousands of different species of moulds have been described and their differences in response to a particular

environment, their tolerance of adverse conditions, and their biochemical characteristics, are almost as varied as their numbers are great. There are in existence many admirable text-books on mycology which will probably meet the needs of the student who has had an adequate training in botany. But for those with little or no botanical knowledge, and particularly for those who are faced for the first time with an industrial problem of "mould" control, the lack of an adequate text-book setting forth in simple language the facts of the subject is a very real lack. To these and to any others who wish to acquire a first-hand knowledge of the common "moulds" I must warmly recommend this book written by my colleague, Mr. George Smith. The subject-matter of the book forms the basis of a course of lectures and practical work given by the author as part of the course to students working in this School for the post-graduate Academic Diploma in Bacteriology of the University of London. Readers of Mr. Smith's book will, I think, find it easy to read and stimulating to study, and will, I hope and believe, particularly appreciate, as I do, the really beautiful photomicrographs which form a very important part of the book.

H. RAISTRICK.

LONDON SCHOOL OF HYGIENE
AND TROPICAL MEDICINE.

july 1938.

PREFACE TO THE FIRST EDITION

This book is intended to assist those who are commencing the study of "moulds" rather than of fungi in general. There is already an extensive literature of systematic mycology, plant pathology and medical mycology, but there has been up to the present no book in English, apart from highly specialized monographs, dealing particularly with the fungi which are of importance in industry.

Sufficient general mycology is included to enable the student to follow up the subject in the standard text-books. The major portion of the book, however, consists of descriptions and illustrations of most of the genera of moulds which are of regular occurrence in industrial products, with more detailed consideration of the genera which are of greatest importance. Chapters on laboratory methods are sufficiently detailed to enable those who have had no previous biological training, and who are unable to get personal instruction, to work from the beginning along the right lines.

Many, probably the majority, of those who are called upon to undertake the solution of problems connected with moulds in industry are chemists, most of whom have had no training in botany and who find it difficult to learn the special terminology of mycological literature. Throughout the book, therefore, I have endeavoured to explain all such terms and usages as are like to be unfamiliar to the non-botanical reader.

All the figures, except Fig. 91, are from original photomicrographs, this type of illustration being, in my opinion, more suitable than line drawings for the use of beginners. With few exceptions they are all at certain precise and selected magnifications and are readily comparable one with another. I am grateful for permission to include certain of my illustrations which have previously been published—Figs. 87, 90, 94, 95, 97, 102, 106, 109, 111 and 116 in *The Journal of the Textile Institute*; Figs. 8, 128 and 129 in *Transactions of the British Mycological Society*.

To the many colleagues and workers in other institutions who have supplied infected materials and cultures, or who have made practical suggestions, I tender my thanks. I am also greatly indebted to Messrs. Boardman & Baron, Ltd., of Great Harwood,

for permission to make free use of the large number of photomicrographs taken in their laboratories.

July 1938.

G. S.

PREFACE TO THE FOURTH EDITION

In preparing this edition a number of changes have been made in the layout of the book, all of them designed for convenience of reference. It has been decided that the printing of illustrations on one side of the paper only (as was done in the First Edition) has little advantage as regards quality of reproduction and a serious disadvantage in separating illustrations from the relevant descriptions. The illustrations have now been put, as far as possible, on the same pages with, or facing, the appropriate text.

The etymology of all names of fungi and of technical terms, with very few exceptions, is given. It is hoped that this will be of assistance, particularly to beginners, in becoming familiar with the nomenclature of mycology.

The text of the book has been completely revised and much of it rewritten. There are two new chapters, one on Nomenclature, this being an extension of a short section in previous editions, and the other an Appendix dealing with Microscopy of Moulds.

I have received numerous requests to include descriptions and photographs of many more genera. Whilst appreciating the fact that any user of the book is almost sure to isolate species of fungi which I have not described, I have had to limit the number to those which are of fairly common occurrence. Even if the size of the book were trebled it would still be impossible to cover all eventualities. However, a few genera, which were not included in previous editions, but which for various reasons have assumed increased importance, are now described and pictured.

The number of new illustrations is 22 and, in addition, 6 photographs which were not satisfactory have been replaced by new and, it is hoped, better ones. Three old illustrations are deleted entirely.

Once again I tender my thanks to all the colleagues and correspondents who have kindly offered suggestions for improvement.

LONDON SCHOOL OF HYGIENE
AND TROPICAL MEDICINE.

G. S.

December 1953.

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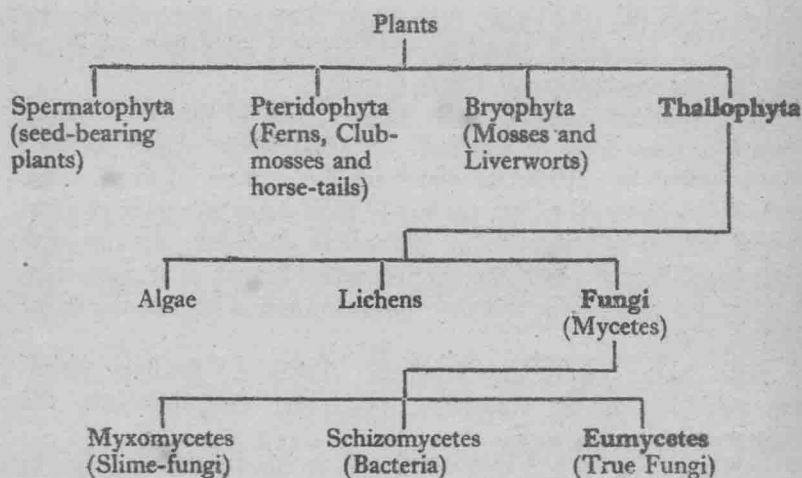
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CHAPTER I

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, and certainly, in general aspect, the majority of them bear a superficial resemblance to plants. Even at the present day nearly all the teaching in mycology in this country is carried out as part of courses in botany in our schools and universities, and the great majority of research workers in mycology have been trained as botanists. The supposed relationship of the Fungi to the various types of true plants (and some other groups of organisms) is usually set out somewhat as in Table I.

TABLE I



The Thallophyta (Gr. *thallos*, a young shoot; *phyton*, a plant) are plants which show no differentiation into root, stem, leaf, etc., the vegetative structure being known as a *thallus*. This may be unicellular, as in some of the simplest fungi, or may show considerable specialization of structure with corresponding specialization of function.

The Fungi are distinguished from the Algae in that they lack chlorophyll, the green colouring matter which enables plants to bring about photosynthesis, that is, the building up of complex organic compounds from carbon dioxide and water in the presence of sunlight.

The Lichens are compound organisms, consisting of algae and fungi in intimate association. Their study is a special branch of botany, since the alga-fungus association is so close that the Lichens may be classified into genera and species just as if they were single organisms, and many of the fungi are unknown apart from their algal associates. Those who are interested in this group should consult the excellent monograph by Miss A. L. Smith (1918, 1926), or her text-book (1921).

The Myxomycetes (Gr. *myxa*, slime; *myketes*, pl. of *mykes*) are a puzzling group of organisms, nowadays usually regarded as belonging to the Animal Kingdom and called Mycetozoa (Gr. *mykes* and *zoön*, an animal). Whether or not they are to be regarded as related to the true fungi, their study does not come within the province of industrial mycology. There is a good monograph of the British Mycetozoa by Lister (1925).

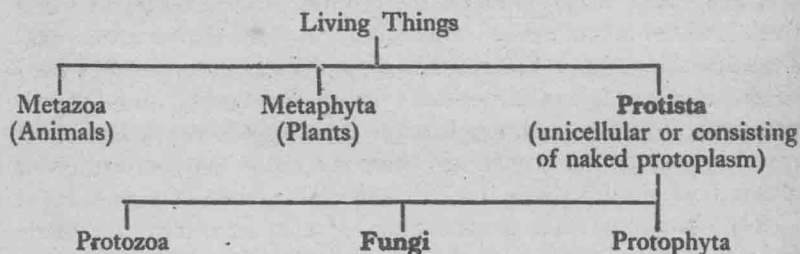
The Bacteria, comprising in Table I, one of the three classes of fungi, bear little resemblance to true fungi. Until modern developments in microscopic technique have advanced to the stage of enabling us to get a clear picture of their structure, their position in any scheme of classification will remain doubtful. In any case, their study is now a separate and important branch of science, with a technique of its own, and their consideration is outside the scope of this book.

The only organisms, listed in Table I, coming within the province of the industrial mycologist are, therefore, the Eumycetes, or true fungi.

The modern view is that the Fungi do not belong to either of the Plant and Animal Kingdoms, but constitute a third, co-equal Kingdom. One fundamental difference from plants is that none of the fungi produces chlorophyll, and none, so far as is known, is capable of effecting photosynthesis. Plants, in general, utilize simple substances and build them up into substances of greater complexity. On balance they absorb carbon dioxide, using it to build up starch, cellulose, fats and the like, and liberate oxygen. Also their nitrogen requirements are met by the presence in the

soil of simple inorganic salts, nitrates and ammonium salts. Animals differ fundamentally from plants in that they are entirely unable to utilize carbon dioxide as a source from which to build up tissue but, on the contrary, require oxygen and liberate carbon dioxide as a waste product. They cannot utilize inorganic compounds of nitrogen but require this element in the form of proteins, or at least the constituent amino-acids. Fungi resemble animals in that they require oxygen and invariably liberate carbon dioxide as a final metabolic product. On the other hand, very many species are able to utilize inorganic nitrogen, in this respect resembling plants.

According to Langeron (1945) a further fundamental difference between plants and animals on the one hand and fungi on the other is that the latter never form tissue, all structures, including the highly organized fruit-bodies of the larger fungi, consisting entirely of a system of tubes. Even when the tubes are apparently divided into individual cells by cross-walls, these, except when they are formed to cut off dead portions of the organisms, always have a central pore, through which both cytoplasm and nuclei can freely pass. Langeron maintains that fungi are thus essentially unicellular and the following classification is based on his arguments.



The term "protista", derived from Gr. *protistos*, superlative of *protos*, first, was coined by the German philosopher Haeckel.

The number of species of fungi is probably about 100,000. This is less than the number of species of true plants, but in number of individuals the fungi surpass plants, for their range of habitat is wider and many species are of world-wide distribution. As is to be expected of such a large group of living things, the fungi show great differences in size, structure, and metabolic activities. Some, such as the Yeasts, grow as loose aggregates of single detached cells, whilst others, such as the mushrooms and toadstools, form

large fruit-bodies of complicated structure, with elaborate mechanisms for propagation. Some of the larger fungi are prized by the epicure whilst others are shunned as amongst the deadliest of poisons. The majority of the known fungi live on dead organic matter, performing a useful service in returning to the soil nutrients originally extracted by plants, but there is a large group of species which are inimical to man's activities through their habit of parasitizing plants which are grown for food and clothing, and a smaller group which are parasitic on animals, including man himself. Many fungi attack manufactured products of all kinds, including foodstuffs, fabrics, leather, timber, cosmetics, pharmaceuticals, and even glass. On the other hand, a number of species are capable of synthesizing, under suitable conditions, substances useful to man, with an economy of effort which the chemist cannot emulate.

In mycology, as in other sciences, increased knowledge has resulted in complexity, and eventually the division of the science into a number of branches in which individual workers tend to specialize. What is usually termed pure mycology concerns the detailed structure, cytology, and modes of development of fungi. Field mycologists are interested in the fungi which are to be found in fields and woods, both the larger forms, known as mushrooms and toadstools, which grow on the ground or as parasites of forest trees, and the microscopic forms found on plant debris or as parasites of wild plants. The taxonomist studies structure with a view to classifying fungi, so as to show relationships and facilitate identifications by others. Although plant pathology is not a branch of mycology, since it is concerned with the study and prevention of all kinds of abnormalities in cultivated plants, the plant pathologist nevertheless must have a good knowledge of mycology, for many important diseases of plants are caused by fungi, and there are now a number of workers who specialize in the mycological side of the subject. Medical mycology deals with a small, highly specialized, and difficult group of fungi which cause human and animal diseases. Another somewhat restricted branch of the science is the study of the wood-destroying fungi, both those which attack standing trees and those which rot felled and worked timber.

The field of industrial mycology includes both the harmful activities of fungi in rotting or spoiling industrial raw materials and manufactured goods, and the uses of fungi in industrial fermentations. The fungi concerned are commonly known as "moulds".