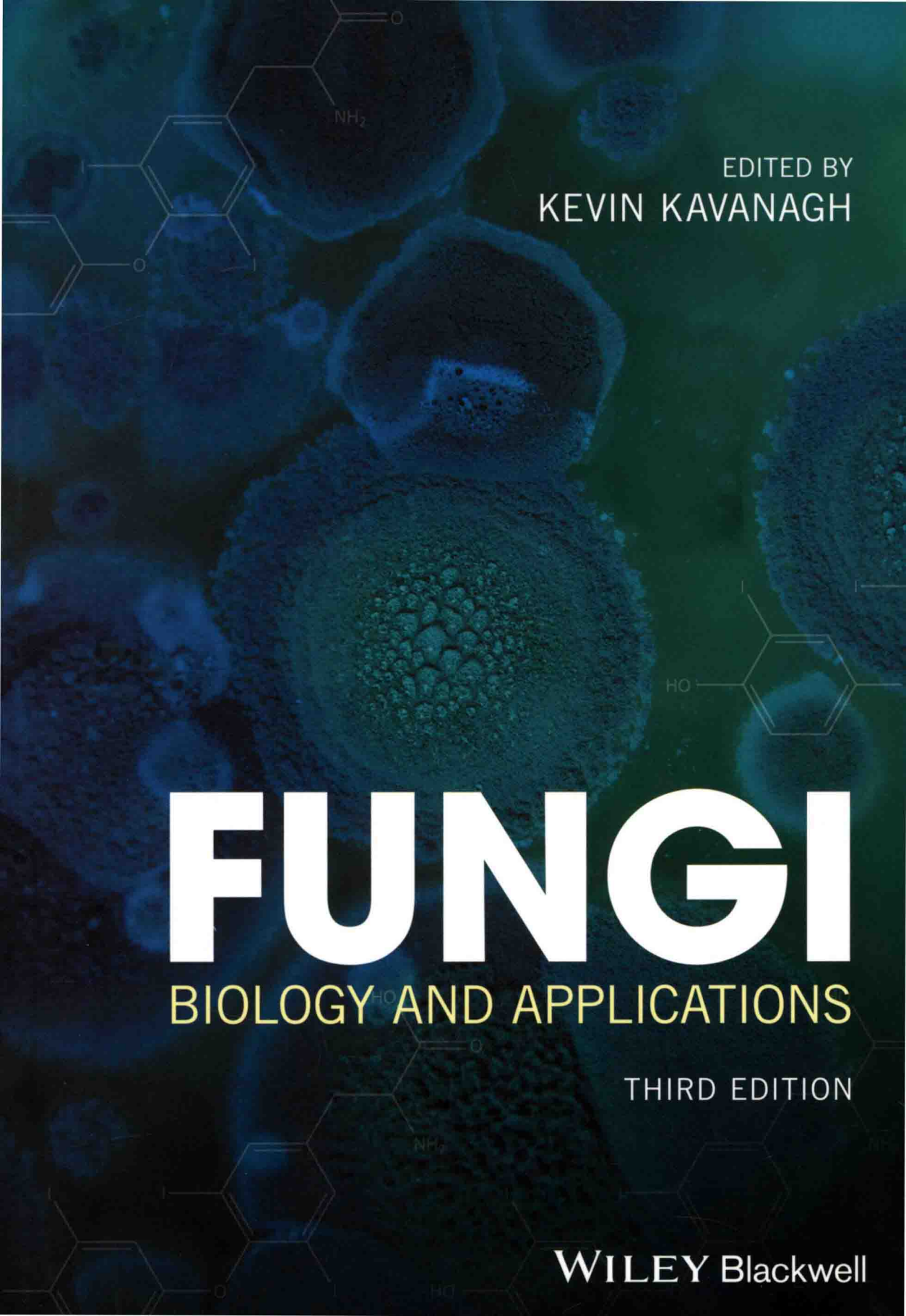

EDITED BY
KEVIN KAVANAGH

FUNGI

BIOLOGY AND APPLICATIONS

THIRD EDITION

WILEY Blackwell

FUNGI BIOLOGY AND APPLICATIONS

THIRD EDITION

This newly updated edition covers a wide range of topics relevant to fungal biology, appealing to academia and industry

Fungi are extremely important microorganisms in relation to human and animal wellbeing, the environment, and in industry. The latest edition of the highly successful *Fungi: Biology and Applications* teaches the basic information required to understand the place of fungi in the world while adding three new chapters that take the study of fungi to the next level. Due to the number of recent developments in fungal biology, expert author Kevin Kavanagh found it necessary to not only update the book as a whole, but to also provide new chapters covering Fungi as Food, Fungi and the Immune Response, and Fungi in the Environment.

Proteomics and genomics are revolutionizing our understanding of fungi and their interaction with the environment and/or the host. Antifungal drug resistance is emerging as a major problem in the treatment of fungal infections. New fungal pathogens of plants are emerging as problems in temperate parts of the world due to the effect of climate change. *Fungi: Biology and Applications, Third Edition* offers in-depth chapter coverage of these new developments and more—ultimately exposing readers to a wider range of topics than any other existing book on the subject.

- Includes three new chapters, which widen the scope of fungi biology for readers
- Takes account of recent developments in a wide range of areas including proteomics and genomics, antifungal drug resistance, medical mycology, physiology, genetics, and plant pathology
- Provides extra reading at the end of each chapter to facilitate the learning process

Fungi: Biology and Applications is designed for undergraduate students, researchers, and those working with fungi for the first time (postgraduates, industrial scientists).

About the Editor

KEVIN KAVANAGH is Professor of Microbiology in the Department of Biology at Maynooth University, Maynooth, County Kildare, Ireland.

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Fungi

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Preface

Fungi make an enormous contribution to our life. The role of yeast in the production of alcohol and bread is well characterized. We consume fungi directly in the form of edible mushrooms and in "blue cheeses" which get their characteristic flavor and aroma from the presence of fungi. Fungi are also used for the production of antibiotics, such as penicillin, and enzymes for use in the food industry. Since the 1990s, fungi have been utilized for the production of recombinant proteins, some of which have great therapeutic potential. Although infrequently recognized as important decomposers of organic detritus, fungi play a significant role in degrading biological matter, such as fallen leaves. On a more negative note, some fungi (for example members of the genus *Candida* and *Aspergillus*) are capable of causing serious life-threatening infections in immunocompromised patients, and other fungi can be serious plant pathogens.

This is the third edition of *Fungi: Biology and Applications* which was first published in 2005. Since that date there have been enormous strides in our understanding of the biology of fungi, and their contribution to our life is becoming increasingly important. The aim of the current edition is to provide a detailed description of the biology, biotechnological applications, and medical significance of fungi. The book commences with an in-depth description of the physiology of fungi in which the structure, metabolism, and growth of fungi are described. This is followed by a chapter dedicated to the genetics of fungi in which the lifecycles of a number of representative fungi are described and the use of fungi for genetic analysis is outlined. The advent of genomics and proteomics has revolutionized our study of the cell. Chapters 3, 4, and 5 describe how genomics, transcriptomics, and proteomics, respectively, have increased our knowledge of fungi and made available new opportunities for exploiting fungi for the good of humanity. Chapter 6 describes the importance of fungi as food and highlights the different techniques for the commercial production of edible fungi. Chapters 7 and 8 describe how fungi can be utilized for producing commercially important antibiotics, enzymes, and a range of chemical

products such as citric acid. Chapter 9 focuses on the exploitation of fungi for the production of heterologous proteins and illustrates how yeast has been used for the production of hepatitis B antigens. Chapter 10 describes the main fungal pathogens of humans and Chapter 11 outlines the human immune response to fungi that restricts infection. Chapter 12 describes the main classes of antifungal drugs and their modes of action. Chapter 13 outlines the role of fungi in the environment where they play a significant role in recycling nutrients. Chapter 14 describes the main fungal pathogens of plants and assesses the impact of such pathogens on the global supply of food.

This book gives a comprehensive introduction to fungi in terms of their biology, genetics, medical significance, and biotechnological potential. Each chapter is written by internationally recognized experts, so the reader is given an up-to-date and detailed account of our knowledge of the biology and various applications of fungi.

Kevin Kavanagh

Contents

1

Introduction to Fungal Physiology

Graeme M. Walker and Nia A. White

1.1 Introduction

Fungal physiology refers to the nutrition, metabolism, growth, reproduction, and death of fungal cells. It also generally relates to interaction of fungi with their biotic and abiotic surroundings, including cellular responses to environmental stress. The physiology of fungal cells impacts significantly on the environment, industrial processes, and human health. In relation to ecological aspects, the biogeochemical cycling of carbon in nature would not be possible without the participation of fungi acting as primary decomposers of organic material. Furthermore, in agricultural operations fungi play important roles as mutualistic symbionts, pathogens, and saprophytes, where they mobilize nutrients and affect the physicochemical environment, or can be exploited as agents of biocontrol or as biofertilizers. Fungal metabolism is also responsible for the detoxification of organic pollutants and for bioremediating heavy metals and other recalcitrant chemicals in the environment (including wastewaters and groundwaters). The production of many economically important industrial commodities relies on the exploitation of yeast and fungal metabolism and these include such diverse products as whole foods, food additives, fermented beverages, antibiotics, probiotics, pigments, pharmaceuticals, biofuels, enzymes, vitamins, organic and fatty acids, and sterols. More negatively, fungi can cause considerable disease, spoilage, and decay of important artefacts, commodities, and materials, buildings, and of course food supplies.

In terms of human health, some yeasts and fungi represent major opportunistic life-threatening pathogens, while others are life-savers as they provide antimicrobial and chemotherapeutic agents. In modern biotechnology, several yeast

Fungi: Biology and Applications, Third Edition. Edited by Kevin Kavanagh.

species are being exploited as hosts for the expression of human therapeutic proteins following recombinant DNA and gene editing technologies (see Chapter 9). Recently, the application of gene editing using CRISPR/Cas is leading to a revolution in fungal genetic engineering (see Chapter 2). Furthermore, an international synthetic biology research consortium, called Sc-2.0, has embarked on the construction of a completely synthetic version of *Saccharomyces cerevisiae*. This would represent the world's first fully synthetic eukaryotic genome! In addition to the direct industrial exploitation of yeasts and fungi, it is important to note that these organisms, most notably the yeast *S. cerevisiae*, play increasingly significant roles as model eukaryotic cells in furthering our fundamental knowledge of biological and biomedical science. This is especially the case now that numerous fungal genomes have been completely sequenced and the information gleaned from fungal genomics and proteomics is providing valuable insight into human genetics and heritable disorders. However, knowledge of cell physiology is essential if the functions of many of the currently unknown fungal genes, including "synthetic" ones, are to be fully elucidated.

It is apparent, therefore, that fungi are important organisms for human society, health, and well-being, and that studies of fungal physiology are very pertinent to our understanding, control, and exploitation of this group of microorganisms. This chapter describes some basic aspects of fungal cell physiology, focusing primarily on nutrition, growth, and metabolism in unicellular yeasts and filamentous fungi.

1.2 Morphology of Yeasts and Fungi

There are a diversity of yeast and fungal cellular morphologies. Most higher fungi are filamentous, yeasts grow as unicells, and some primitive fungi such as the Chytridomycota grow as individual rounded cells or dichotomous branched chains of cells with root-like rhizoids for attachment to a nutrient resource. Here we consider the most common growth forms, the filamentous fungi and unicellular yeasts.

1.2.1 Filamentous Fungi

The gross morphologies of macrofungi and microfungi are varied and often apparent throughout the environment (Plate 1.1). For example, we can easily recognize a variety of mushrooms and toadstools, the sexual fruiting bodies of certain macrofungi (the higher fungi Ascomycota and Basidiomycota and related forms), during a walk through pasture or woodland. Microfungi (the molds) are also diverse and are often observed on decaying foods and detritus, whereas many, including the colored rusts, smuts, and mildews, are common plant pathogens. Closer inspection of these visible structures, however, reveals that all are