MICROBIOLOGY OF FOODS

Ayres/Mundt/Sandine

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Preface

The purpose of *Microbiology of Foods* is to serve as a text for the advanced undergraduate and the beginning graduate student preparing to enter the foods industries or involved with allied disciplines. Rather than present the reader with exhaustive source data, we have sought to present the material in sufficient detail for the beginning microbiologist and, to some extent, the lay reader to grasp. For those readers interested in more exhaustive treatment, we provide at the end of each chapter a list of the references cited in the chapter text.

Our text represents the first serious attempt since that of Tanner's *Microbiology of Foods,* first published in the early 1930s, to comprehensively embrace the available information about food microbiology. Tanner's text, authoritative as it was during the first half of the century, is obsolete today. Our text updates the treatment of food microbiology to make it useful in this latter part of the century. We also examine areas little touched upon by other food microbiology texts—for example, the importance of molds in the production of mycotoxins and antibiotics and the involvement of yeasts and molds in various fermentations and spoilage. We also essay—as other general references do not—to evaluate or interpret the confusing data on the role of chemicals, radiation, and microorganisms in benefiting or harming foods and their users.

Microbiology of Foods is divided into four parts. In Part I, Chapter 1 presents the classification of bacteria, yeasts, and molds. The remaining five chapters describe the major nonmicrobiological methods of preserving foods. Part II, composed of four chapters, describes the desirable alterations of cereals, milk, and vegetables by fermentation, to produce beverages and foods for human enjoyment and to effect preservation. Chapter 10, the final chapter of the section, identifies fermentations, most employing fungi, that are little known in the United States but much used in other parts of the world, particularly in the Far East. The 10 chapters of Part III treat the microbiology of specific food products: in the first five chapters, those obtained from spices, sugars and starches, cereals, flours, fruits and vegetables; in the last five chapters, those of animal origin—milk and fermented milk products, meats, fish and shellfish, poultry, and eggs. The three chapters of the last part describe the nonmicrobial and microbial foodborne infections and the bacterial and some fungal toxemias.

Although the principles of microbial spoilage and of nonmicrobiological methods of preservation are concentrated in the opening chapters, they are also interwoven throughout the remainder of the text. In other respects, however, each chapter is independent of preceding chapters, and may be rearranged into any sequence desired in a teaching program. Thus, if the time constraints of academic quarters must be accommodated, chapters deemed less essential to the teaching of food microbiology may be omitted without sacrificing the overall principles.

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Part I

General Considerations

1

Classification of Microorganisms

Every form of life can be assigned membership in one of five kingdoms: **Plantae** (plants), **Animalia** (animals), **Protista, Fungi,** and **Monera.** The basic structural unit of living things is the cell, in which genetic information is replicated and stored, cellular components are synthesized, energy is generated, and, in some cells, a mechanism for movement is located. Both the plants and animals are multicellular. Plants have cell walls composed of cellulose, whereas animal cells do not have cell walls. Plants perform photosynthesis, whereas animals ingest and then digest their foods. To perform a variety of specialized functions the cellular matter of every plant and animal is differentiated into tissues, organs, and organ systems. All members of the kingdom Protista are single-cell life forms that perform all functions without specialization. (Some members, however, occur in well-developed colonial aggregates that resemble multicellular structures.) The kingdom Fungi is made up of single-cell forms, such as the yeasts, and other forms composed of masses of filaments. The kingdom Monera comprises single-cell life forms: the bacteria and the blue-green algae (see Table 1–1).

Table 1-1
Protista

Eucaryotes (having nucleus and nuclear membrane)		
Kingdom:	Animalia	
	Plantae	
	Fungi	
	Protista	
Procaryotes (lacking nucleus and nuclear membrane)		
Kingdom:	Monera	
Division I.	Phototrophic procaryotes (photobacteria)	
Class I.	Blue-green photobacteria	
Class II.	Red photobacteria	Part 1. Phototropic
Class III.	Green photobacteria	
Division II.	Procaryotes indifferent to light (scotobacteria)	
Class I.	The bacteria, Parts 2 to 17; chemotropic	
Class II.	Obligate intracellular scotobacteria in eucaryotic cells, rickettsias, Part 18	
Class III.	Scotobacteria without cell walls, Mollicutes, Part 19	

Sources: After Haeckel, 1894; Stanier and van Niel, 1962. Eucaryotae, after Allsopp, 1969.

These five kingdoms can be divided into two groups: the plants, animals, Fungi, and Protista are **eucaryotes;** the Monera are **procaryotes.** The two groups differ by type of nucleus. In the eucaryotic cell the nucleus is a discrete body surrounded by a membrane; the nucleus divides according to the classical Mendelian description. Each cell possesses spindles, golgi apparatus, and mitochondria. Cells of plants and some protists also contain plastic bodies. Eucaryotic ribosomes are of the large 80S type (Taylor and Storck, 1964).

The procaryotic cell contains none of these structures, having instead a long, double-stranded nucleus that weaves throughout the cell. This nucleus is not a discrete body and is not surrounded by a nuclear membrane. During cell division the double-stranded nucleus separates, each strand becoming a template for the formation of new, complementary strands. Procaryotic ribosomes are of the small 70S type.

Among the procaryotes the organisms of most concern to the food microbiologist are the bacteria. Among the eucaryotes the organisms of most concern are the fungi. Of far less importance are the algae and protozoa.

Except for a few siliceous forms, such as the diatoms, the Algae have cell walls composed of cellulose. Being chlorophyllous, the algae are photosynthetic—although occasionally achlorophyllous algae are isolated from untreated waters and foods washed or conveyed in such waters. The achlorophyllous forms are easily mistaken for yeasts. In the past the algae have played no role in the microbiology of foods, but they may be a future source of food for humans and animals. The Protozoa lack cell walls. They ingest and digest complex organic matter. They thrive in moist or wet environments. Some protozoa are food- and water-borne pathogens.

Fungi

Many fungi are multicellular; others, such as the yeasts, are unicellular; and some, called dimorphic, are unicellular in some conditions or stages of their existence but become multicellular in other conditions or stages.

In many varieties of fungi the cells grow end-to-end to form filaments, or **hyphae,** which in turn branch and intertwine into a network, termed the **mycelium.** In other varieties hyphae produce a compact stalk and aerial spore-forming structure, as in the fruiting body of mushrooms. In some fungi the hyphal strands have no crosswalls, or **septa,** and the cytoplasm can flow as the fungus grows. Although these nonseptate, or **coenocytic,** structures are multinucleate, they remain unicellular even when attaining heroic size. Since the same habit also occurs in some of the green algae, this group of fungi is called **Phycomycetes** (*phykos,* seaweed; *mykes,* fungus). The phycomycetes constitute one of the five classes of the true Fungi (Table 1-2). The remaining classes of fungi have a septate, or cellular mycelium; at certain stages of development the cells of some members may contain two or more nuclei.

Fungi are differentiated into classes by their reproductive habits. All except the members of the class **Mycelia Sterila** are able to produce spores asexually, by simple cell division without fusion of nuclei. The members of the classes Phycomycetes, Basidiomycetes, and Ascomycetes also reproduce sexually, by fusion of two similar or dissimilar cells, but asexual spores are produced much more commonly than are the sexual spores.

Table 1-2
Key to the classes and orders of fungi.

I. Reproduce by sexual mechanisms	
A. Mycelium, when present, coenocytic; zygotes produced	Class: Phycomycetes
1. Mycelium scanty or lacking	Subclass: Archimycetes
2. Mycelium present	
a. Sex cells heterogamic	Subclass: Oomycetes
b. Sex cells isogamic	Subclass: Zygomycetes
B. Mycelium septate, or reproduces by budding	
1. Sexual spores borne externally	Class: Basidiomycetes
a. Basidiospores not septate or deeply divided	Subclass: Homobasidiomycetes
b. Basidiospores deeply divided or septate	Subclass: Heterobasidiomycetes
2. Sexual spores borne within a membrane or sac	Class: Ascomycetes
a. Unicellular or rarely filamentous	Subclass: Hemiascomycetes
b. Loosely filamentous to fleshy structures	Subclass: Euascomycetes
i. Produce cleistothecia	
Colonial structures filamentous	Order: Plectascales
Colonial structures compact	Order: Tuberales
ii. Produce perithecia	
Peridium dark in color	Order: Sphaeriales
Peridium bright in color	Order: Hypocreales
iii. Produce apothecia	Order: Pezizales
II. Do not reproduce by sexual mechanisms	
A. Produce neither sexual cells nor vegetative spores	Class: Mycelia Sterila
B. Produce conidia (conidia may be lacking in laboratory cultures)	Class: Fungi Imperfecti
1. Conidia produced in pycnidia	Order: Sphaeropsidales
2. Conidia produced openly, not in enclosed structures	Order: Moniales

Table 1-2, *continued*

a. Conidiophores scattered, not in a sheath or a globose structure	
i. Basal mycelium light in color; reverse not dark or darkening with age	Family: Moniliaceae
ii. Basal mycelium may be dark in color; reverse dark or darkening with age	Family: Dematiceae
b. Conidiophores gathered into sheath	Family: Stilbaceae
c. Conidiophores globose and sessile	Family: Tuberculariaceae

Source: Adapted from Gilman, 1957.

Because it is extremely difficult to induce the sexual, or **perfect,** stage in some fungi, these organisms are often identified by their vegetative growth and by their asexual fruiting structure. Such organisms are placed in an artificial class called the Fungi Imperfecti, or Deuteromycetes, discussed further below.

Phycomycetes

This class of fungi is generally divided into three subclasses: Archimycetes, Oomycetes, and Zygomycetes.

Archimycetes comprises the most primitive of the fungi, being rudimentary aquatic parasites composed of single or irregular masses of cells (**thalli;** singular, **thallus**) or forming, at most, only a rudimentary mycelium. The organisms produce both sexual and asexual spores. The latter form at the tips of hyphae, where they are separated from the rest of the filament by a septum, forming a **sporangium,** a sac containing one or more vegetatively produced spores. After the septum is formed, rapid mitotic divisions produce many nuclei around which the spore coats form to leave an anucleated sporangium. The numerous **sporangiospores** borne within the cell of an Archimycete have a distinguishing feature: they are genetically alike; those of the other two subclasses are not. Since each spore develops two flagella and is able to swim freely when released, it