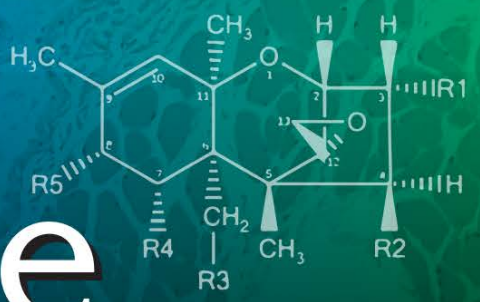
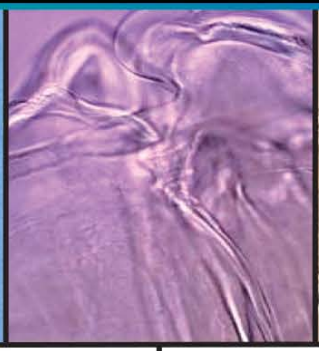
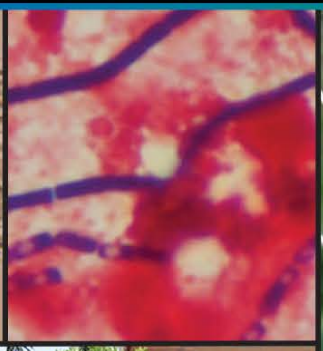
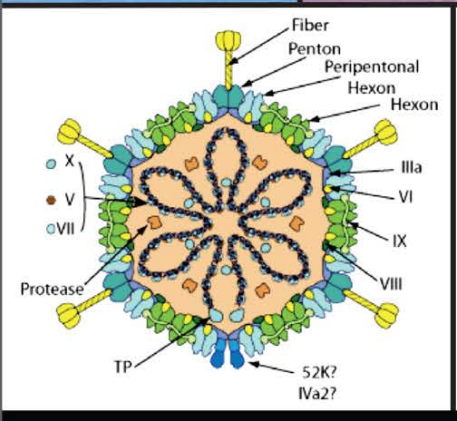
FOOD MICROBIOLOGY SERIES

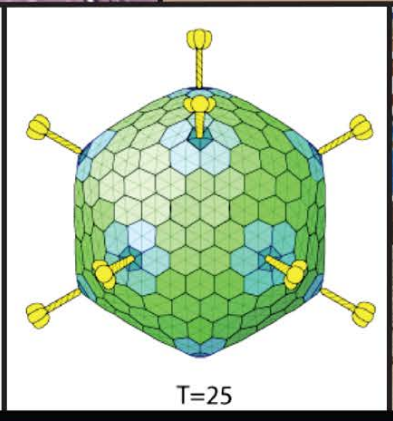
Handbook of Foodborne Diseases











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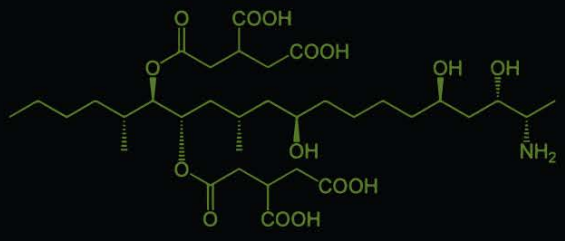

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Handbook of Foodborne Diseases

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Handbook of Foodborne Diseases

Edited by
Dongyou Liu


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This volume is dedicated to an international panel of experts on foodborne diseases, whose willingness to share their in-depth knowledge has made a comprehensive coverage possible.

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Series Preface

Microorganisms (including viruses, bacteria, molds, yeasts, protozoa, and helminthes) represent abundant and diverse forms of life that occupy various ecological niches of Earth. Those utilizing food and food products for growth and maintenance are important to human society due not only to their positive and negative impacts on the food supply, but also to their potential pathogenicity to human and animal hosts.

On the one hand, foodborne microorganisms are known to play a critical role in fermentation and modification of foods, leading to a variety of nutritious food products (e.g., bread, beverage, yogurt, and cheese) that have contributed to the sustainment of human civilization from time immemorial. On the other hand, foodborne microorganisms may be responsible for food spoilage, which, albeit a necessary step in keeping up ecological balance, reduces the quality and quantity of foods for human and animal consumption. Furthermore, some foodborne microorganisms are pathogenic to humans and animals, which, in addition to creating havoc on human health and animal welfare, decreases the availability of meat and other animal-related products.

Food microbiology is a continuously evolving field of biological sciences that addresses issues arising from the interactions between food- and waterborne microorganisms and foods. Topics of relevance to food microbiology include, but are not limited to, adoption of innovative fermentation and other techniques to improve food production; optimization of effective preservation procedures to reduce food spoilage; development of rapid, sensitive, and specific methods to identify and monitor foodborne microbes and toxins, helping alleviate food safety concerns among consumers; use of omic approaches to unravel the pathogenicity of foodborne microbes and toxins; selection of nonpathogenic foodborne microbes as probiotics to inhibit and eliminate pathogenic viruses, bacteria, fungi, and parasites; and design and implementation of novel control and prevention strategies against foodborne diseases in human and animal populations.

The Food Microbiology series aims to present state-of-the-art coverage of topics central to the understanding of the interactions between food- and waterborne microorganisms and foods. The series consists of individual volumes, each of which focuses on a particular aspect or group of foodborne microbes and toxins in relation to their biology, ecology, epidemiology, immunology, clinical features, pathogenesis, diagnosis, antibiotic resistance, stress responses, treatment and prevention, and so on. The volume editors and authors are professionals with expertise in respective fields of food microbiology, and the chapter contributors are scientists directly involved in foodborne microbe and toxin research.

Extending the contents of classical textbooks on food microbiology, this series serves as an indispensable tool for food microbiology researchers, industry food microbiologists, and food regulation authorities wishing to keep abreast of the latest developments in food microbiology. In addition, the series offers a reliable reference for undergraduate and graduate students in their pursuit to becoming competent and consummate future food microbiologists. Moreover, the series provides a trustworthy source of information to the general public interested in food safety and other related issues.

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Preface

Once considered rare and insignificant malaises, foodborne diseases (colloquially foodborne poisonings) have emerged as an increasingly common and serious threat to human society in recent decades. Several factors may have been driving this remarkable change of fortune for foodborne diseases. These include the ready availability of refrigerators and freezers in home settings that has pushed up the demand for convenient, ready-to-eat, or heat-and-eat manufactured food products; a dramatic reduction in the costs of air, sea, and road transportation that has facilitated frequent international trade, business, and pleasure travels; an exponential growth of the world population that has stretched the boundary of human activity; and a notable increase in life expectancy that has created an ever larger group of individuals with heightened susceptibility to infections and poisonings. Consequently, some pathogens that previously had restricted distribution are now widespread; some pathogens that were formerly regarded as veterinary concerns are routinely identified in human cases; some pathogens that were known to cause mild clinical syndromes are now involved in severe and sometimes fatal diseases; and some agents that were previously unheard of are now implicated in human poisonings.

In front of these crises, scientists, medical establishments, research organizations, and government agencies around the world have put up a valiant fight that may have temporarily halted the attack of foodborne diseases, but they are far from being in a winning position. Based on World Health Organization (WHO) estimates, annual casualties (mostly children) from foodborne and waterborne diarrheal diseases stand at 2.2 million. Our struggle against foodborne diseases is clearly being compromised by the diversity of causative agents (ranging from viruses, bacteria, yeasts, filamentous fungi, protozoa, helminthes, toxins, to toxic agents), which render a control measure that works for one disease hopelessly ineffective for another; and also by the ingenuity of microbial pathogens, which have the capacity to evolve through genetic resortment, horizontal gene transfer, or random genetic mutation, making a previously highly efficient drug or vaccine suddenly lose its magic power. Obviously, there is still much to be learned about foodborne diseases and their causative agents.

Forming part of the Food Microbiology series, this volume documents and summarizes the most recent findings on foodborne diseases and their causative agents. Written by experts with relevant experience in foodborne pathogens, toxins, and toxic agents' research, each chapter presents a state-of-the-art overview on a causative agent in relation to its classification, biology, epidemiology, clinical presentation, pathogenesis, diagnosis, treatment, and prevention. Apart from providing a contemporary reference for undergraduates and postgraduates in food, medical, and veterinary microbiology, this volume offers a valuable source of information for medical professionals, health authorities, and the general public.

Given the diversity of causative agents, and the breadth and depth of research data on each foodborne disease, a comprehensive volume such as this is clearly beyond an individual's capacity. I am fortunate and honored to have an international panel of experts as chapter contributors, whose in-depth knowledge and technical insights on foodborne diseases have greatly enriched this volume. In addition, the professionalism and dedication of senior editor Stephen Zollo have made the publication of this volume a seamless operation. Finally, the understanding and support from my family—Liling Ma, Brenda, and Cathy—have been crucial to helping keep my focus during the compilation of this all-inclusive volume.

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Editor

Dongyou Liu, PhD, studied veterinary science at Hunan Agricultural University, China, and conducted postgraduate research on the generation and use of monoclonal antibodies for improved immunodiagnosis of human hydatidosis at the University of Melbourne, Australia. Over the past two decades, he has worked at several research and clinical laboratories in Australia and the United States, with focuses on molecular characterization and virulence determination of microbial pathogens such as ovine footrot bacterium (*Dichelobacter nodosus*), dermatophyte fungi (*Trichophyton*, *Microsporum*, and *Epidermophyton*) and listeriae (*Listeria* species), as well as development of nucleic acid–based quality assurance models for security sensitive and emerging viral pathogens. Additionally, during the period from 1995 to 2001, he established and performed molecular tests at clinical laboratories for a range of human genetic disorders and cancer, including BRCA1, BRCA2, c-kit, B- and T-cell receptor gene rearrangements, t(11,14) chromosomal translocation, k-ras, fragile X syndrome, factor V Leiden, hemochromatosis, and prothrombin mutations. He is the primary author of more than 50 original research and review articles in various international journals, the contributor of 176 book chapters, and the editor of *Handbook of* Listeria monocytogenes (2008), *Handbook of Nucleic Acid Purification* (2009), *Molecular Detection of Foodborne Pathogens* (2009), *Molecular Detection of Human Viral Pathogens* (2010), *Molecular Detection of Human Bacterial Pathogens* (2011), *Molecular Detection of Human Fungal Pathogens* (2011), *Molecular Detection of Human Parasitic Pathogens* (2012), *Manual of Security Sensitive Microbes and Toxins* (2014), *Molecular Detection of Animal Viral Pathogens* (2016), and *Laboratory Models for Foodborne Infections* (2017), all of which were released by CRC Press. He is also a coeditor of *Molecular Medical Microbiology, Second Edition*, which was published by Elsevier in 2014. Further, he is the author of recent CRC Press books: *Pocket Guides to Biomedical Sciences*: *Tumors and Cancers—Central and Peripheral Nervous Systems* (2017); *Pocket Guides to Biomedical Sciences: Tumors and Cancers—Head, Neck, Heart, Lung, and Gut* (2017); *Pocket Guides to Biomedical Sciences: Tumors and Cancers—Skin, Soft Tissue, Bone, and Urogenitals* (2017); and *Pocket Guides to Biomedical Sciences: Tumors and Cancers—Endocrine Glands, Blood, Marrow, and Lymph* (2017).

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Introductory Remarks

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CONTENTS

1.1 Preamble

Foodborne diseases (also known as foodborne illnesses, or colloquially, foodborne poisonings) are pathological conditions that result mostly from ingestion of raw, or improperly prepared or stored foods contaminated by microbial pathogens, toxins, or other toxic agents. After establishing in their predilection sites, some pathogens (e.g., parasites) cause direct physical and mechanical damages to the host, while others (e.g., viruses, bacteria, and fungi) produce various virulence factors and toxins that provoke host innate and acquired immune responses, leading to gastrointestinal (e.g., nausea, vomiting, diarrhea, and abdominal cramps) and other clinical symptoms (e.g., fever, joint aches or backaches, and fatigue). Being noninfectious and nonreplicating, toxins (of bacterial, fungal and algal origins) contained in food or water and other toxic agents act rapidly and induce clinical symptoms if sufficient quantities are ingested.

Despite the fact that foodborne diseases have been with us for time immemorial, they were generally considered an insignificant health concern until the early 1980s, when several large outbreaks of food-related illnesses suddenly came to the spotlight. Perhaps, the emergence or reemergence of foodborne diseases reflects several notable changes that have occurred in the preceding decades. These include increasing consumption of manufactured, ready-to-eat food products that allow ready entry of some robust, temperature-insensitive organisms (e.g., *Listeria monocytogenes*) into the human host, frequent international trade and travel that facilitate the spread of pathogenic organisms to where they were once absent, and aging populations whose weakened immune functions provide a fertile ground for opportunistic pathogens to thrive and expand [1,2].

Faced with these unprecedented challenges, governments and health organizations around the world have stepped up research efforts on and implemented control measures against foodborne diseases. This has not only contributed to a better understanding of the causal agents, but also helped to gain an upper hand over foodborne diseases. Nevertheless, there is still much to be learned before highly effective mitigation strategies against foodborne diseases can be devised for their ultimate elimination. By documenting and summarizing the most recent findings on foodborne diseases in relation to their etiology, biology, epidemiology, clinical presentation, pathogenesis, diagnosis, treatment, and prevention, the current volume provides a sound foundation on which new discoveries on foodborne pathogens and toxins will be made.

1.2 Foodborne Pathogens, Toxins, and Toxic Agents

From both individual and collective experiences, sometimes uneventful, but more often disastrous, human society has been long aware of the possible involvement of certain agents in the spoilage of food products as well as in the causation of foodborne malaises. This has provided impetus for developing and refining various food preservation techniques (e.g., salting, smoking, and drying) to prolong the shelf life of fresh produces and maintain the quality of stored foods. Following the pioneering work of Antony Van Leeuwenhoek (1632-1723), it became possible for the first time to view causal agents of human diseases under a microscope, which had been largely invisible through naked eyes. Studies by the succeeding generations have pinpointed the roles of a diverse range of foodborne pathogens, toxins and toxic agents in the initiation and development of food-related illnesses in humans.

Foodborne pathogens of viral, bacterial, fungal, or parasitic origins demonstrate the ability to survive or grow in various food matrices (e.g., pasteurized carrot juice, peanut butter, frozen pot pies, canned chili sauce, hot peppers, white and black pepper, raw cookie dough, and raw frozen scraped ground tuna), plants and produces (e.g., cereals, hazelnuts, fenugreek sprouts, papayas, pine nuts, lettuce, and cantaloupe), surfaces (e.g., food processing facility and hospital benches), dust and soil, and water (e.g., run-off water from farms and sewage), and have the capacity to induce pathological changes in the human host after entry via contaminated food or water (Table 1.1) [3].

TABLE 1.1

Characteristics of Foodborne Viral, Bacterial, Fungal and Parasitic Pathogens

Type	Category	Key Features	Examples
Viruses	RNA virus	Single- or double-stranded RNA of 4–33 kb; positive sense, single-stranded RNA is identical to viral mRNA, and can be translated directly into proteins by host ribosomes; negative sense, single-stranded RNA is complementary to viral mRNA, and requires transcription by RNA-dependent RNA polymerase into positive sense mRNA before translation into proteins; relatively unstable (showing high error rate during transcription, and high rate of recombination/reassortment during co-infection)	Norovirus, hepatitis E virus
	DNA virus	Single-stranded DNA of 3–6 kb, or double-stranded RNA of 5–375 kb; relatively stable (showing low error rate during transcription, and low rate of recombination/reassortment during co-infection)	Human bocavirus
	Prion	Prion (proteinaceous and infectious virion) is composed of protein that has the ability to change the normal shape of host protein into the prion shape, which converts even more host proteins into prions	Creutzfeldt–Jakob disease (CJD)
Bacteria	Gram positive	Classified in the kingdom Bacteria, Gram-positive bacteria possess a cell wall that comprises a thick layer (or several layers) of peptidoglycan (which retains crystal violet during Gram staining to produce purple color) attached to an inner cell membrane via lipoproteins and lipoteichoic acids (which are formed by teichoic acids and lipoids); an outer membrane is notably absent	*Listeria, Staphylococcus, Streptococcus*
	Gram negative	Classified in the kingdom Bacteria, Gram-negative bacteria possess a cell wall that has a thin layer of peptidoglycan (which fails to retain crystal violet during Gram staining to produce red or pink color after restaining with basic fuchsin) sandwiched between an inner cell membrane and an outer membrane; the outer membrane contains lipopolysaccharides (LPS, made up of lipid-A, core polysaccharide, and O-antigen) in its outer leaflet and phospholipids in the inner leaflet; teichoic acids and lipoids are notably absent	*Helicobacter, Pseudomonas*
Fungi	Yeasts	Classified in the kingdom Fungi, yeasts are single-celled organisms that reproduce by budding or binary fission; of ∼700 species identified, 200 are implicated in superficial/cutaneous, subcutaneous, and systemic infections (mycoses)	*Candida, Saccharomyces*
	Filamentous fungi	Classified in the kingdom Fungi, filamentous fungi (∼100,000 species identified so far) generate tubular, elongated, and threadlike (filamentous) cellular structures (hyphae), which contain multiple nuclei and extend at their tips; filamentous fungi often cause superficial/cutaneous, and subcutaneous infections (mycoses) and produce mycotoxins that lead to food poisoning	*Aspergillus, Fusarium*
	Microsporidia	Microsporidia (previously regarded as protozoa) are relatives of zygomycetes (possession of chitin and trehalose; sequence similarity in α- and β-tubulin as well as Hsp70 genes), display features reminiscent of both prokaryotes (small genome, 16S and 23S RNA) and eukaryotes (nucleus, mitotic spindle-separated chromosome, cytoskeleton, polyadenylation on mRNA), and produce highly resistant oval or pyriform spores; of ∼1200 species identified, 12 are associated with human diseases	*Encephalitozoon, Enterocytozoon*
Parasites	Protozoa	Classified in the kingdom Protista, protozoa are small (∼50 μm), unicellular eukaryotes (∼50,000 species identified); human pathogenic protozoa are mainly found in the phyla Sarcomastigophora (amoebae and flagellates, generally reproducing by asexual binary fission) and Apicomplexa (sporozoa, reproducing by both asexual sporogony/schizogony and sexual gamogony)	*Acanthamoeba, Giadia, Cryptosporidium*
	Cestodes	Classified in the class Cestoda, phylum Platyhelminthes, kingdom Animalia, cestodes (tapeworms) have a head (scolex) with sucking organs, a segmented body, but lack alimentary canal; each segment is hermaphrodite	*Echninococcus, Taenia*
	Trematodes	Classified in the class Trematoda, phylum Platyhelminthes, kingdom Animalia, trematodes (flatworms or flukes) have a nonsegmented, usually leaf-like body, with two suckers but no distinct head; have an alimentary canal (but no anus) and are hermaphrodite; however, schistosomes are thread-like and have separate sexes	*Fasciola, Opisthorchis*
	Nematodes	Classified in the phylum Nematoda, kingdom Animalia, nematodes (roundworms) appear round in cross section, have body cavities, a straight alimentary canal, and an anus; have separate sexes	*Ascaris, Trichinella*