Chapter 1

Introduction

It is generally believed that the wars are single most destructive socio-political events with greatest impact on the society. A glance at the estimates of casualties resulting from the major wars in the 20th century can have a chilling effect:

- Number of persons killed during World War I: approximately 12 million.
- Number of persons killed during World War II: approximately 55 million.
- Combined total of persons killed in all other wars in the 20th century: approximately 1 million.

Thus, the total number of war casualties in the 20th century is estimated to be approximately 68 million.

If one takes into account all war-related deaths in the world during the past 500 years, the total would most probably be less than 100 million. In contrast, during the past century alone more than 500 million people have died of infectious diseases and nearly 5 billion have suffered from debilitating infectious diseases. Arguably, the numbers were much higher before the advent of the antibiotics era and before prophylactic vaccines became available.

Besides causing the social and emotional strain, infectious diseases profoundly affect economy and productivity of societies. There is no exact figure, but it is estimated that the worldwide health care cost during the past decade alone was several trillion dollars—much more than the total annual budget of the United States, the world’s richest nation. Yet, neither nations nor societies seem to take infectious diseases as seriously as wars! Why? The answer does merit some serious consideration.

Table 1.1 is based on reports published during the past 10 years. One can very well imagine that the mortality rates were much higher in pre-antibiotics and pre-vaccine eras.

The focus of this book is on a select group of microorganisms that cause common diseases, with relatively less emphasis on the clinical aspects, though still covering the essentials. Each section deals with a group of taxonomically related microorganisms with an emphasis on the following:
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Table 1.1 Annual Mortality Due to Some of the Infectious Diseases That Mostly Affect a Large Segment of the Population of Poor Countries (Source: WHO, affiliated organizations, and authors’ own experience)

<table>
<thead>
<tr>
<th>Disease</th>
<th>Annual Mortality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tuberculosis</td>
<td>Most widespread, over 2 million deaths annually</td>
</tr>
<tr>
<td>Malaria</td>
<td>Quite widespread, 2 to 3 million deaths annually</td>
</tr>
<tr>
<td>Cholera</td>
<td>Over half a million deaths annually</td>
</tr>
<tr>
<td>Typhoid</td>
<td>Over half a million deaths annually</td>
</tr>
<tr>
<td>Diarrhea and dysentery</td>
<td>Caused by a wide range of microorganisms, over 2 million deaths annually</td>
</tr>
<tr>
<td>Pneumonias and respiratory tract infections</td>
<td>Almost 5 million deaths annually</td>
</tr>
<tr>
<td>Mumps, measles, polio</td>
<td>Almost a million deaths annually</td>
</tr>
<tr>
<td>HIV/AIDS</td>
<td>Over 2.5 million deaths annually</td>
</tr>
<tr>
<td>Diseases classified as sexually transmitted</td>
<td>Nearly 0.5 million deaths</td>
</tr>
</tbody>
</table>

- Biology of disease-causing microorganisms (types of microorganisms)
- Natural habitats of the causal agents
- Diseases they cause and mode of dissemination
- Laboratory diagnosis
- Antibiotic sensitivity (control and prevention)

Koch’s postulate forms the very basis of the pathogenic microbiology. The causality of almost all infectious diseases is based on the postulate and theories developed by Robert Koch, who is rightly called the “father of pathogenic microbiology,” and his contemporaries. Developed in the late 19th century, it has stood the test of time. The postulate can be summarized as follows:

1. A microbe suspected as the causal agent of a particular disease must be found in all subjects suffering from a similar disease but must be absent in clinical specimens from healthy individuals.
2. The suspected microorganism can be isolated from the diseased individual and grown in pure culture.
3. When this isolated suspect microbe is injected into healthy, susceptible animals (some human volunteers were also reportedly used by Robert Koch), signs and symptoms of a disease similar to the disease under investigation must develop in the infected animal.
4. The microbe cultured from the infected animal must be morphologically and physiologically identical to the strain initially isolated from the patient (in Item 1).
TERMINOLOGY

Cide: Chemical or physical agent that kills microorganisms.

- Bactericides: Agents that kill bacteria.
- Fungicides: Agents that kill fungi.
- Viricides: Chemical agents that kill viruses.
- Microbicides: Physical or chemical agents that are lethal to a broad group of microorganisms.
- Biocide: Substances lethal to all forms of life.

Communicable/contagious diseases: Diseases that are easily transmitted from person to person (e.g., tuberculosis).

Disease: Disease can be defined as a state of altered homeostasis, that is, being in a state of dis-ease. Causes and factors relating to a disease may be:

- Metabolic
- Psychiatric
- Environmental
- Infectious
- Immunological

Endotoxins: Lipopolysaccharides, produced by certain Gram-negative bacteria, for example, Escherichia coli.

Epidemic: Excessive frequency of a disease.

Etiologic agent: Causal agent of a disease (same as pathogen).

Exogenous: Pathogens that come from external sources (outside the body).

Exotoxins: Toxic proteins produced by a wide range of bacteria.

Facultative pathogen: A part-time pathogen, which needs to infect a host in order to complete its life cycle.

Infectious diseases: Diseases caused by microorganisms.

Mode of dissemination: Medium through which causal agents of infectious diseases are transmitted from person to person (e.g., airborne diseases).

Obligate pathogen: A pathogen that cannot live outside the host and is mostly dependant on host for the ATP.

Opportunist: Microbes that infect a host when the host’s immune system is weakened.

Pathogen: A microorganism that causes a disease.

Portal of entry: The route through which a pathogen enters human body.

Reservoir: Source of infection or natural habitat of the pathogen.

Resident microbiota: Microorganisms normally present at a specific anatomical site. This is due to local physiological factors (pH, presence of iron-binding proteins, lysozyme, etc.) and the resultant species selection.

Saprobe: Microbes that grow on nonliving entities. This term mostly refers to nonpathogenic microorganisms.
Static: A chemical agent that stops cell multiplication. They can be bacterio-
static or fungistatic, for example.

Transient microbiota: Microorganisms that are not normally present at a spe-
cific anatomical site, but are introduced deliberately or inadvertently.

Virulence: Pathogenic potential of a microorganism.

Virulence factors: Morphological, physiological, or genetic traits of a micro-
organism that enables it to overcome the host’s immune defenses. Examples include
capsules, proteolytic enzymes, and toxins.

MAJOR CATEGORIES OF PATHOGENIC
MICROORGANISMS

Viruses

Believed to be a bridge between the living and the nonliving, viruses have either
DNA or RNA, seldom both. Their genome is surrounded by a protein coat, called
capsid. Certain viruses have an envelope, often derived from the host cell membrane
during lysis and release. Multiple characteristics, including type of nucleic acid,
single or double strands, and presence or absence of envelope, are taken into account
in the classification of viruses.

Bacteria

Bacteria are prokaryotes, which means they lack nuclear membranes and other
membrane-bound organelles, such as mitochondria, Golgi apparatuses, and endoplas-
mic reticula. Most bacteria have a cell wall, but some are devoid of a cell wall (e.g.,
Mycoplasma spp.). Bacteria are divided into two major groups, cocci and bacilli.
Cocci (singular coccus) are spherical and may occur as single coccus, as a pair called
diplococcus as in the case of Neisseria gonorrhoeae, as a cluster as seen in the case
of Staphylococcus aureus, or a chain as seen in the case of Streptococcus spp.
The bacilli (singular bacillus) are rod-shaped bacteria and they are often referred to
as “rods.” They exhibit a considerable variation in their size and shape. Some are
straight rods, other slightly curved, and some are comma-shaped vibrios as in the
case of Vibrio cholerae. Another variation in the shape is represented by the spiral
bacteria called Spirochetes (e.g., Treponema pallidum, the causal agent of syphilis).
Certain “evolved” forms of bacilli tend to have rudimentary filaments, as in the case
of Corynebacterium and Mycobacterium, and others have a fully developed filament
with true branching, as seen in the case of Streptomyces. Based on their reactions to
Gram staining (color), both cocci and bacilli are further divided into two groups,
Gram-positive (stain purple) and Gram-negative (stain red). The Gram-positive bac-
terial cell wall is made of a thick layer of peptidoglycan with some embedded teichoic
acid. The outer layer of the Gram-negative bacterial cell wall is made of a thick layer
of lipopolysaccharide, some phospholipids, and a small amount of peptidoglycan.
Both groups of bacteria have aerobic (oxygen dependent) and anaerobic (oxygen
independent) members. There are also several bacteria that can grow under either condition and they are called facultative anaerobes. For a detailed discussion on bacterial taxonomy, readers are referred to Bergey’s Manual of Determinative Bacteriology and numerous other authoritative sources listed in the bibliography.

**Fungi**

Unlike bacteria, fungi are eukaryotes, which means they have nuclear membranes and membrane-bound organelle. Almost all have a cell wall, which is usually made of chitin. Based on their sexual reproduction and other structural features, fungi are divided into four major groups called divisions or phylum. Division Zygomycota can reproduce sexually and asexually and most (but not all) have no septum in their mycelium. *Mucor* and *Rhizopus* spp. are examples of zygomycetes. The second division, Ascomycota, is characterized by the production of ascospores during their sexual reproduction. The ascospores are generally housed in an enclosed structure called an ascus. An example of an ascomycete is *Pseudallescheria boydii*. The third division, Basidiomycota, produce special cells called basidia during their sexual reproduction. The sexual spores, called basidiospores, develop on the basidia. An example of a basidiomycete is *Filobasidiella neoformans*, which is the sexual stage of an important human pathogen, *Cryptococcus neoformans*. Common mushrooms are also members of division Basidiomycota. Fungi which are not known to reproduce sexually are called Fungi imperfecti (fourth division). They multiply vegetatively, but show considerable variation in their structure. As their sexual stages are discovered, they are generally categorized as either Ascomycota or Basidiomycota. A great majority of common airborne fungi, including members of the genus *Aspergillus*, *Alternaria*, and *Penicillium* are examples of Fungi imperfecti. Many fungi are also known to produce powerful toxins, such as aflatoxins, ochratoxins, aminitins, and ergot alkaloids.

**Protozoa and Multicellular Parasites**

Protozoa are unicellular eukaryotic microorganisms that belong to kingdom Protista. Protozoa and multicellular parasites called helminths lack a cell wall. Classification of protozoa and helminths is complex and the system is not without controversies. Therefore, the authors have chosen a simple and practical approach which is summarized in the respective chapters on unicellular parasites and multicellular parasites.

**TRANSMISSION OF INFECTIOUS DISEASE (MODE OF DISSEMINATION)**

**Airborne (Inhalation of Bioaerosols)**

A bioaerosol contains bacteria in its center, surrounded by air and a small amount of liquid, generally saliva. Bioaerosols may be produced due to sneezing, coughing,
or talking. Depending on the force of sneezing or coughing, the bioaerosol-borne microorganism can travel up to several meters in air. Almost all respiratory tract infections are airborne; some can also pass from person to person through the inhalation of bioaerosols. Some of the examples of airborne infections include tuberculosis, strep throat, diphtheria, pertussis, legionellosis, influenza, and chicken pox, and a wide range of mycotic diseases such as aspergillosis, zygomycosis, cryptococcosis, histoplasmosis, and coccidioidomycosis.

**Food- and Waterborne**

These diseases are acquired through the ingestion of food or water contaminated with fecal bacteria or other infectious agents. The usual portal of entry is mouth or gastrointestinal tract. Examples include cholera, typhoid, botulism, shigellosis, gastroenteritis, leptospirosis, hepatitis A, and a number of parasitic diseases.

**Zoonosis**

The term “zoonosis” refers to a wide range of diseases that are transmitted via a vector, a carrier, or an infected animal. Such animals may also be infested with insects, which in turn harbor the pathogen. Examples are malaria, Lyme disease, rabies, plague, Rocky Mountain spotted fever, and some of the parasitic diseases.

**Sexually Transmitted**

These diseases are acquired through close contact, usually sexual intercourse. Examples include syphilis, gonorrhea, HIV, hepatitis B, herpes, and nongonococcal urethritis. Exchange of biological fluid through oral sex should be included in this category.

**Nosocomial Infections**

Nosocomial infections are infections contracted during a patient’s medical care and they can include diseases contracted through fomites. Fomites are inanimate or nonliving objects, such as doorknobs, telephones, and computer keyboards, which facilitate dissemination of infectious diseases. Fomites contribute to many hospital-acquired infections. Examples include Clostridium difficile-associated diarrhea, urinary tract infections, and pneumonia.

**UNIVERSAL PRECAUTIONS**

At a minimum, universal precautions, that is, common-sense safety measures, must be followed when dealing with potentially infectious materials or persons suffering from infectious diseases. The universal precautions require an investigator to:
• Wear protective apparel (lab coat, gloves, etc.)
• Not mouth pipette
• Not talk while handling or culturing a clinical specimen
• Minimize socializing in the lab
• Not consume food or apply cosmetics in the lab
• Always disinfect work area, before and after work
• Use proper safety cabinets for the laboratory work:
  ◦ Class I: For media preparation
  ◦ Class II: For handling average pathogens (normally present in the area and community)
  ◦ Class III: For handling highly pathogenic microorganisms
  ◦ Class IV: For handling deadly pathogens (mostly used at designated labs, such as at the Centers for Disease Control and Prevention [CDC]).