

# Chapter 1

# Introduction to Antimicrobial Resistance: A Modern Plague

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## **ABSTRACT**

*The discovery of antibiotics revolutionized the field of medicine, but their overuse and misuse have fueled the emergence of antimicrobial resistance among pathogens. Antibiotic resistance has been aptly described as a modern plague since it has resulted in a public health crisis and jeopardized human, animal, and environmental well-being. This chapter provides a comprehensive overview of antibiotic resistance, its biological mechanisms, and the devastating consequences for world health and the economy. The findings also highlight the need for a multifaceted approach to deal with this crisis. Generative AI offers a promising path toward understanding resistance mechanisms, developing novel antibiotics, and optimizing treatment strategies. This chapter gives a brief introduction to the transformative potential of AI in combating AMR.*

## **1.0 INTRODUCTION**

The discovery of antibiotics marked a significant milestone in medicine, offering potent solutions to infections once considered deadly (Muteeb et al., 2023). Antibiotics have improved medical outcomes, supported complex medical procedures, and contributed to an increase in human life expectancy (Hutchings et al., 2019). However, the misuse and overuse of antibiotics have led to antibiotic resistance among multiple pathogens, compromising these benefits (Muteeb et al., 2023). As a result, several antibiotics have become ineffective, leading to prolonged hospitalizations, increased healthcare costs, and higher mortality rates (Chinemerem et al., 2022). Antimicrobial resistance (AMR) can occur in fungi, viruses, parasites, and bacteria (Prestinaci et al., 2015). Bacteria pose a unique problem because of their ability to quickly acquire resistance genes through horizontal transfer and their profound impact on public health (Larsson & Flach, 2022). There are several examples of bacteria causing significant morbidity and mortality and probably the most debilitating diseases (Davies & Davies, 2010). Antibiotic-resistant bacteria can persist

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in the environment and spread between humans and animals when they come in contact with contaminated sources (Pandey et al., 2024). This chapter focuses on AMR in bacteria, detailing the historical perspective of antibiotic discovery, the biological mechanisms driving resistance, and its implications for public health and the economy. Our understanding of antimicrobial resistance (AMR) allows us to take the necessary steps to mitigate its devastating effects. Further, this chapter gives an overview of the emerging role of artificial intelligence (AI) in expediting the discovery of novel antibiotics, diagnostics, surveillance, and treatment strategies to outpace the evolution of antibiotic-resistant pathogens.

## **1.1 Historical Perspective: The Antibiotic Revolution**

### **1.1.1 Pre-Antibiotic Era**

Before the dawn of the 20<sup>th</sup> century, several infectious diseases like smallpox, cholera, tuberculosis, typhoid, etc. were the leading causes of death. Puerperal fever, a devastating disease, claimed the lives of several women who contracted it during childbirth (Hallett, 2005). The plague sparked three pandemics and claimed the lives of 150 million people worldwide (Sebbane & Lemaître, 2021). During the pre-antibiotic era, treatment methods were rooted in superstitious beliefs, folk remedies, and trial and error. Bloodletting, purging, and poultices were the practiced techniques that yielded little success (Hajar, 2012). As a result, the mortality rates were high, and the average life expectancy for an individual was a mere 47 years (Adedeji, 2016). The situation was exacerbated by World War I. The staggering number of casualties overwhelmed the available medical services. A significant delay in the retrieval of wounded soldiers from the battlefield reduced the chances of successful treatment. Additionally, the crowded and unsanitary conditions in field hospitals made them perfect breeding grounds for microbes. Several pathogens remained unidentified and uncharacterized, making it difficult for physicians to devise effective treatment strategies (Runcie, 2015).

### **1.1.2 The Rise and Fall of Antibiotics**

The discovery of antibiotics in medicine was perhaps one of the most significant developments, allowing unprecedented control over infectious diseases. The serendipitous discovery of penicillin in 1928 by Alexander Fleming marked the start of what could be referred to as ‘the golden age of antibiotics’ (Boyd et al., 2021), and the subsequent decades witnessed a rapid rise in antibiotic discoveries, such as streptomycin, chloramphenicol, tetracycline, and erythromycin (Figure 1) (da Cunha et al., 2019). The indiscriminate use of antibiotics resulted in a selective pressure rendering microbes resistant to various antibiotics (Prestinaci et al., 2015). In addition, me-too drugs derived from a modification of existing antibiotics exacerbated this problem. Although they provided moderate relief, they promoted the development of resistance among bacteria (Dhingra et al., 2020). Literature indicates that bacteria are developing resistance to even the last resort antimicrobials such as linezolid and daptomycin (Markwart et al., 2021). The pharmaceutical industry assumes funding research involving novel antibiotics is risky because it is expensive to comply with regulatory requirements, and the market is not very lucrative (Klug et al., 2021). The World Health Organization (WHO) declared in its report that there is a ‘discovery void’ in the antibiotic development pipeline and warned against multidrug-resistant infections (Iskandar et al., 2022). Without antibiotics, even common diseases such as pneumonia (Stamm & Stankewicz, 2024), urinary tract infections, and sepsis can become fatal (Sabih & Leslie, 2024). It is predicted that we will

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