

DIAGNOSIS AND TREATMENT OF BACTERIAL INFECTIONS | PART 2



Editors:

Mukesh Kumar Singh
Gurdeep Singh
Amrendra Pratap Yadav
Papiya Bigoniya

Bentham Books

Diagnosis and Treatment of Bacterial Infections

(Part 2)

Edited by

Mukesh Kumar Singh

*School of Pharmaceutical Sciences
Faculty of Pharmacy, IFTM University
Moradabad, Uttar Pradesh
India*

Gurdeep Singh

*School of Pharmaceutical Sciences
Lovely Professional University
Phagwara, Punjab
India*

Amrendra Pratap Yadav

*Department of Pharmacy
Meerut Institute of Technology
Meerut, Uttar Pradesh
India*

&

Papiya Bigoniya

*Cancer Biology Project
University of Westminster
London, UK*

Diagnosis and Treatment of Bacterial Infections - (*Part 2*)

Editors: Mukesh Kumar Singh, Gurdeep Singh, Amrendra Pratap Yadav & Papiya Bigoniya

ISBN (Online): 979-8-89881-348-2

ISBN (Print): 979-8-89881-349-9

ISBN (Paperback): 979-8-89881-350-5

© 2026, Bentham Books imprint.

Published by Bentham Science Publishers Pte. Ltd. Singapore, in collaboration with Eureka Conferences, USA. All Rights Reserved.

First published in 2026.

BENTHAM SCIENCE PUBLISHERS LTD.

End User License Agreement (for non-institutional, personal use)

This is an agreement between you and Bentham Science Publishers Ltd. Please read this License Agreement carefully before using the ebook/echapter/ejournal (“**Work**”). Your use of the Work constitutes your agreement to the terms and conditions set forth in this License Agreement. If you do not agree to these terms and conditions then you should not use the Work.

Bentham Science Publishers agrees to grant you a non-exclusive, non-transferable limited license to use the Work subject to and in accordance with the following terms and conditions. This License Agreement is for non-library, personal use only. For a library / institutional / multi user license in respect of the Work, please contact: permission@benthamscience.org.

Usage Rules:

1. All rights reserved: The Work is the subject of copyright and Bentham Science Publishers either owns the Work (and the copyright in it) or is licensed to distribute the Work. You shall not copy, reproduce, modify, remove, delete, augment, add to, publish, transmit, sell, resell, create derivative works from, or in any way exploit the Work or make the Work available for others to do any of the same, in any form or by any means, in whole or in part, in each case without the prior written permission of Bentham Science Publishers, unless stated otherwise in this License Agreement.
2. You may download a copy of the Work on one occasion to one personal computer (including tablet, laptop, desktop, or other such devices). You may make one back-up copy of the Work to avoid losing it.
3. The unauthorised use or distribution of copyrighted or other proprietary content is illegal and could subject you to liability for substantial money damages. You will be liable for any damage resulting from your misuse of the Work or any violation of this License Agreement, including any infringement by you of copyrights or proprietary rights.

Disclaimer:

Bentham Science Publishers does not guarantee that the information in the Work is error-free, or warrant that it will meet your requirements or that access to the Work will be uninterrupted or error-free. The Work is provided "as is" without warranty of any kind, either express or implied or statutory, including, without limitation, implied warranties of merchantability and fitness for a particular purpose. The entire risk as to the results and performance of the Work is assumed by you. No responsibility is assumed by Bentham Science Publishers, its staff, editors and/or authors for any injury and/or damage to persons or property as a matter of products liability, negligence or otherwise, or from any use or operation of any methods, products instruction, advertisements or ideas contained in the Work.

Limitation of Liability:

In no event will Bentham Science Publishers, its staff, editors and/or authors, be liable for any damages, including, without limitation, special, incidental and/or consequential damages and/or damages for lost data and/or profits arising out of (whether directly or indirectly) the use or inability to use the Work. The entire liability of Bentham Science Publishers shall be limited to the amount actually paid by you for the Work.

General:

1. Any dispute or claim arising out of or in connection with this License Agreement or the Work (including non-contractual disputes or claims) will be governed by and construed in accordance with the laws of Singapore. Each party agrees that the courts of the state of Singapore shall have exclusive jurisdiction to settle any dispute or claim arising out of or in connection with this License Agreement or the Work (including non-contractual disputes or claims).
2. Your rights under this License Agreement will automatically terminate without notice and without the

need for a court order if at any point you breach any terms of this License Agreement. In no event will any delay or failure by Bentham Science Publishers in enforcing your compliance with this License Agreement constitute a waiver of any of its rights.

3. You acknowledge that you have read this License Agreement, and agree to be bound by its terms and conditions. To the extent that any other terms and conditions presented on any website of Bentham Science Publishers conflict with, or are inconsistent with, the terms and conditions set out in this License Agreement, you acknowledge that the terms and conditions set out in this License Agreement shall prevail.

Bentham Science Publishers Pte. Ltd.

No. 9 Raffles Place

Office No. 26-01

Singapore 048619

Singapore

Email: subscriptions@benthamscience.net



CONTENTS

FOREWORD	i
PREFACE	ii
LIST OF CONTRIBUTORS	iv
CHAPTER 1 FROM TRADITIONAL KNOWLEDGE TO MODERN MEDICINE: INTEGRATING PHYTOTHERAPY INTO ANTIBACTERIAL TREATMENT REGIMENS	1
<i>Anju Goyal, Mamta Bhatia and Shaziya Yasmeen Sayeed</i>	
INTRODUCTION	1
Overview of the Rise of Antibiotic Resistance	2
<i>The Need for Alternative and Complementary Therapies</i>	4
TRADITIONAL KNOWLEDGE OF PHYTOTHERAPY	4
Historical Context and Ethnobotanical Studies	4
MODERN PHYTOTHERAPY	6
Advances in Phytochemical Research	6
<i>Identification of Active Compounds with Antibacterial Properties (Table 3)</i>	7
SYNERGY BETWEEN PHYTOTHERAPY AND ANTIBIOTICS	11
Synergistic Effects and Enhanced Efficacy	11
<i>Case Studies and Clinical Trials</i>	13
PHYTOTHERAPY COMPONENTS IN ANTIBACTERIAL REGIMENS	13
Essential Oils (Oregano, Tea Tree, and Eucalyptus)	13
Oregano Essential Oil	13
<i>Reduction of Antibiotic Doses and Side Effects</i>	15
Tea Tree Oil (TTO)	15
Eucalyptus Essential Oil	16
<i>Polyphenols (Green Tea and Grape Seed Extract)</i>	16
Green Tea Polyphenols	16
Grape Seed Extract Polyphenols	17
Alkaloids: Goldenseal, Berberine	18
.....	19
Flavonoids in Antibacterial Regimens	20
CHALLENGES AND CONSIDERATIONS	21
Standardization and Quality Control of Plant Extracts	21
<i>Potential Interactions and Contraindications</i>	21
CLINICAL APPLICATIONS AND CASE STUDIES	22
Success Stories and Practical Applications	22
<i>Specific Infections and Corresponding Phytotherapy Options</i>	22
FUTURE DIRECTIONS	22
Emerging Research and Innovations in Phytotherapy	22
<i>Integration into Mainstream Healthcare</i>	23
<i>Potential for New Drug Development from Plant Sources</i>	24
CONCLUSION	26
REFERENCES	26
CHAPTER 2 IMMUNOMODULATORY STRATEGIES AGAINST BACTERIAL INFECTIONS	39
<i>Prashant Upadhyay, Shweta Mishra and Sukirti Upadhyay</i>	
INTRODUCTION	39
FUTURE ASPECTS	45
Microbiome-Based Immunomodulation	46

Anti-inflammatory and Anti-sepsis Therapies	46
Biomaterials that Modulate Immunity	47
Genetic and Epigenetic Modulation	47
Artificial Intelligence (AI) in Immunomodulatory Drug Discovery	47
CHALLENGES AND CONSIDERATIONS:	48
CONCLUSION	48
REFERENCES	48
CHAPTER 3 HARNESSING GENE EDITING TO ERADICATE BACTERIAL INFECTIONS	52
<i>Dimple Kothari and Niralee Patel</i>	
INTRODUCTION	52
GENE EDITING MECHANISMS	54
CRISPR Cas 9	54
Zinc Finger Nucleases (ZFNs)	55
Transcription Activator-Like Effectors (TALEs)	55
Nickases	56
Base Editing	57
Prime Editing	57
Peptide Nucleic Acids (PNAs)	58
THERAPEUTIC APPLICATION OF GENE EDITING	58
HIV	59
Hepatitis Virus	59
Autoimmunity	60
Non-viral Genes	60
APPLICATION OF NANOPARTICLES IN GENE EDITING:	61
CORRELATION BETWEEN CRISPR-CAS AND GENE MANIPULATION	62
COMPARISON OF THE TRADITIONAL METHOD WITH CRISPR TECHNOLOGY ...	63
CRISPR – CAS 9 IN TYPE 1 DIABETES: A CASE STUDY	64
CONCLUSION	64
CONSENT FOR PUBLICATION	65
ACKNOWLEDGEMENT	65
REFERENCES	65
CHAPTER 4 FROM DIAGNOSIS TO CURE: A MULTIFACETED APPROACH TO BACTERIAL INFECTION WITH EMERGING TECHNOLOGY	73
<i>Shiv Shankar Shukla, Ravindra Kumar Pandey, Monika Bhairam, Neha Dubey, Shilpa Sahu and Bina Gidwani</i>	
INTRODUCTION	74
Bacterial Infections and Their Global Impact	75
Challenges in Treatment: Antibiotic Resistance and Limitations of Traditional Methods	76
<i>Mycobacterium Tuberculosis</i>	76
<i>XDR Bacteria</i>	76
Examples of MDR and XDR Strains	77
<i>Impact on Treatment</i>	78
<i>Spread in Hospital and Community Settings</i>	78
<i>Global Public Health Threat</i>	78
<i>Importance of Emerging Technologies: Transforming the Diagnosis and Treatment of Bacterial Infections</i>	79
<i>Infection Control and Prevention</i>	80
<i>Challenges and Future Directions</i>	81
ADVANCEMENTS IN DIAGNOSTIC TECHNOLOGIES	81
Rapid Diagnostic Tools	82

Role in Identifying Bacterial Strains and Resistance Genes	82
Biosensors and Lab-on-a-Chip	83
<i>Biosensors</i>	83
<i>Lab-on-a-Chip (LOC)</i>	84
<i>Advantages over Traditional Diagnostics</i>	84
Artificial Intelligence in Diagnostics	85
<i>Predictive Analysis in Diagnosing Infections</i>	85
<i>Pattern Recognition in Diagnosing Infections</i>	86
<i>AI in Personalized Medicine</i>	86
INNOVATIVE TREATMENT APPROACHES	87
Antimicrobial Peptides (AMPs)	88
Phage Therapy	90
<i>Use of Bacteriophages</i>	91
CRISPR-Cas Systems	92
<i>The Mechanism by which CRISPR-Cas Systems Function in the Process of Gene Editing</i>	92
<i>Use of CRISPR-Cas Systems Against Pathogenic Bacteria</i>	93
Nanotechnology in Drug Delivery	93
<i>Nanotechnology in the Treatment of Infectious Diseases</i>	94
<i>Application of Nanotechnology in Vaccine Technology</i>	95
ROLE OF PERSONALISED MEDICINE	95
Tailored Therapies	96
<i>The Role of Genetics in Personalized Medicine</i>	96
Pharmacogenomics	97
<i>Pharmacokinetics</i>	98
<i>Pharmacovigilance</i>	99
Factors to Consider Regarding the Microbiome	99
<i>Balancing Bacterial Eradication with Maintaining a Healthy Microbiome</i>	99
<i>Signs or Symptoms of Gut Health</i>	100
EMERGING TRENDS IN INFECTION CONTROL	100
Vaccination Strategies	100
<i>New Vaccines for Bacterial Infections</i>	100
<i>Prevention of Vaccines in Bacterial Infections</i>	101
Use of Beneficial Bacteria to Outcompete Pathogenic Strains	101
<i>Probiotics have Several Important Impacts on the Immune System</i>	101
<i>Application of Probiotics</i>	102
Environmental Control Measures	102
CHALLENGES AND FUTURE DIRECTIONS	103
Obstacles: The Phenomenon of Antibiotic Resistance	104
Biofilm Formation	104
Pathogenic Methods	104
Emerging and Re-emerging Infections	105
Future Directions for Treatment of Bacterial Infection	105
Regulatory Hurdles: Challenges in approving and implementing new technologies.	106
COST AND ACCESSIBILITY	109
Cost Barriers	109
Solutions	109
<i>Accessibility Issues</i>	109
<i>Solutions</i>	110
<i>Awareness and Education</i>	110
<i>Solutions</i>	110

Ongoing Research	110
<i>Antibiotic Alternatives</i>	110
<i>Bacterial Resistance Mechanisms</i>	111
<i>Successful Implementation of Emerging Technologies</i>	112
Case Study: Targeting Antibiotic-Resistant Bacteria	112
<i>Antimicrobial Peptides (AMPs) or Host Defence Peptide</i>	112
Nanotechnology	113
<i>Case Study: Nanoparticles for Treating Tuberculosis</i>	113
<i>Rapid Diagnostic Technologies</i>	113
Phage Therapy	114
<i>Case Study: Phage Therapy for Chronic Wounds</i>	114
Lessons Learned from Recent Outbreaks and Treatment Challenges	114
<i>Antibiotic Resistance Crisis</i>	114
<i>Overuse of Broad-Spectrum Antibiotics</i>	114
<i>Global Disparities in Technology Access</i>	114
<i>Integration of Technology with Clinical Practice</i>	115
<i>Regulatory and Ethical Challenges</i>	115
FUTURE OUTLOOK	115
CONCLUSION	116
REFERENCES	117
CHAPTER 5 CRISPR-CAS VS SUPERBUGS: A NEW ERA IN COMBATING ANTIBIOTIC RESISTANCE	123
<i>Saloni Jain, Rajveer Singh Rajput and Vinay Jain</i>	
INTRODUCTION	123
The CRISPR-Cas System's Organization and Method of Action	124
The Function of the CRISPR-Cas System in the Growth of Antibiotic Resistance	125
Use of the CRISPR-Cas System to Reduce Superbug Infection Risk	126
Case Study of Superbugs and CRISPR/CAS	130
CONCLUSION	130
REFERENCES	131
CHAPTER 6 ROLE OF ARTIFICIAL INTELLIGENCE IN TRANSFORMING ANTIBIOTIC STEWARDSHIP	136
<i>Yogesh Vaishnav, Tarun Dhar Diwan, Vaishali Sarde, Pankaj Sarde and Arvinder Kaur</i>	
INTRODUCTION	137
Antibiotic Stewardship	137
Importance in Combating Antibiotic Resistance	137
Overview of Traditional Antibiotic Stewardship Practices	138
AI IN HEALTHCARE	139
Brief Explanation of AI Technologies Relevant to Healthcare	139
Importance of AI in Modern Medicine	140
UNDERSTANDING ANTIBIOTIC RESISTANCE	141
Overview of Antibiotic Resistance	141
Current Challenges in Antibiotic Stewardship	142
<i>Inconsistent Prescribing Practices in Antibiotic Stewardship</i>	143
<i>Lack of Real-time Data Analysis</i>	144
<i>Patient Non-Compliance in Antibiotic Stewardship</i>	144
AI TECHNOLOGIES IN ANTIBIOTIC STEWARDSHIP	146
Machine Learning and Predictive Analytics in Antibiotic Stewardship	146
<i>How Machine Learning Algorithms Analyze Prescribing Patterns</i>	146

<i>Predicting Patient Outcomes Based on Historical Data</i>	146
Natural Language Processing (NLP)	147
<i>Utilizing NLP to Extract Data from Clinical Notes in Antibiotic Stewardship</i>	147
<i>Improving Communication among Healthcare Providers in Antibiotic Stewardship</i>	148
Clinical Decision Support Systems (CDSS) in Antibiotic Stewardship	148
<i>Integration of AI in CDSS to Guide Antibiotic Prescribing in Antibiotic Stewardship</i>	149
IMPLEMENTATION OF AI IN STEWARDSHIP PROGRAMS	149
Data Collection and Management	149
<i>Role of AI in Collecting and Managing Patient Data in Antibiotic Stewardship</i>	149
Real-Time Monitoring and Feedback	150
<i>AI Systems for Real-Time Monitoring of Antibiotic Prescriptions in Antibiotic Stewardship</i>	150
Customization of Treatment Plans	151
<i>AI's Role in Personalizing Antibiotic Therapy in Antibiotic Stewardship</i>	151
Benefits of AI in Antibiotic Stewardship	151
<i>AI Improved Patient Outcomes in Antibiotic Stewardship</i>	151
<i>AI in Reducing Adverse Effects and Hospital Readmissions</i>	152
Enhanced Compliance with Guidelines	153
Cost-Effectiveness	153
<i>Economic Implications of Optimized Antibiotic use</i>	153
CHALLENGES AND ETHICAL CONSIDERATIONS	154
Data Privacy and Security	154
<i>Ensuring Patient Confidentiality in AI Applications</i>	154
FUTURE DIRECTIONS	155
Emerging AI Technologies and their Potential Impact on Antibiotic Stewardship Programs	155
CONCLUSION	157
REFERENCES	158

CHAPTER 7 ECONOMIC AND ACCESSIBILITY CHALLENGES IN THE BATTLE AGAINST ANTIBACTERIAL RESISTANCE	162
<i>Priti Singh, Dulendra P. Damahe, Lokesh V. Patil, Shetal B. Desai and Sachin B. Narkhede</i>	
INTRODUCTION	162
Bacteria	162
Bacteria as Pathogens	163
<i>Mechanisms of Bacterial Pathogenicity</i>	163
<i>Impact of Bacterial Pathogens</i>	164
EMERGENCE OF ANTIBACTERIAL RESISTANCE (ABR)	164
ECONOMIC BURDEN [11]	165
IMPLICATIONS FOR HEALTHCARE SYSTEMS	165
Why It Matters	166
Direct Costs	167
Indirect Costs	167
Rising ABR: A Global Overview	168
Global Efforts to Combat ABR	169
<i>Key Objectives of the WHO Global Action Plan on AMR</i>	169
Collaborations and Partnerships	170
Progress and Future Directions	170
Global Efforts	171
ECONOMIC CHALLENGES IN COMBATING ANTIBACTERIAL RESISTANCE	171
Longer Hospital Stays	171

More Expensive Treatments	171
Need for More Intensive Care	172
Cost Estimates	172
Breakdown of Costs	172
THE WORLD BANK REPORT	172
RESEARCH AND DEVELOPMENT COSTS FOR NEW ANTIBIOTICS	174
PUBLIC VS. PRIVATE SECTOR INVOLVEMENT IN DRUG DEVELOPMENT AND IMPACT ON THE ECONOMY	174
Indicators of Public-Sector Involvement	176
Economic Consequences for Low- and Middle-Income Countries	176
ACCESSIBILITY CHALLENGES IN THE FIGHT AGAINST ABR	178
Inequitable Access to Effective Antibiotics	178
Healthcare Infrastructure and Access to Care	180
Global Initiatives for Improving Access	181
Russian Examples	181
<i>Building Infrastructure</i>	182
Altering the Policy Environment	182
Scaling up Improvement	182
ADDRESSING THE ECONOMIC AND ACCESSIBILITY CHALLENGES	182
Policy Recommendations	182
Improving Accessibility: A Global Call to Action	185
CONCLUSION	186
REFERENCES	187
SUBJECT INDEX	195

FOREWORD

This is a wonderful opportunity for me to provide a foreword for part II of the Diagnosis and Treatment of Bacterial Infections. The world is currently facing a significant global health challenge due to antibiotic resistance. This part contains many innovative and advanced approaches to the diagnosis and treatment of bacterial infections.

The chapters in the part II of Diagnosis and Treatment of Bacterial Infections cover an expansive area, including integrating ancient herbal medicine into modern treatment regimens, the use of immunotherapy, the application of innovative genetic engineering techniques such as CRISPR-Cas to eliminate superbugs, and the innovative application of artificial intelligence in the use of antibiotics, while addressing the major barriers to economic and accessibility of managing bacterial resistance.

In addition to providing scientific insight, the second part of Diagnosis and Treatment of Bacterial Infections is unique for its multidisciplinary framework, utilizing traditional knowledge from herbal medicine, modern biotechnologies, and computer-assisted technologies to provide comprehensive approaches to resolving one of medicine's most pressing concerns. I would like to extend my heartfelt congratulations to the authors and editors for putting together such a wonderful resource and extending to them my brightest wishes for continued success in educating and inspiring researchers, practitioners, and students.

Ranjit Singh
Shobhit University
Gangoh, Uttar Pradesh, India

PREFACE

Bacterial infections remain a large and growing worldwide problem as healthcare services continue to be challenged by ongoing changes in the types of organisms causing infections, the increase in resistance of organisms to antibiotics, and the fact that not all patients have equal access to available therapies for treating bacterial infections. While advances have been made in developing better methods for diagnosing and treating bacterial infections, due to the ongoing threat posed by drug-resistant bacteria, new integrated sustainability strategies are required. Part II of *Diagnosis and Treatment of Bacterial Infections* looks at current challenges in diagnosing and treating bacterial infections from an innovative and integrated perspective by exploring new scientific information and new technologies that are changing the way we view and conduct antibacterial research and clinical practice.

This part expands beyond conventional therapeutic paradigms by integrating culturally acquired knowledge with modern medicine's scientific method. The review of phytotherapy demonstrates how certain natural products have the potential of being useful as either adjunctive or alternative antibacterials. At the same time, the use of immunomodulatory techniques is presented as a potential means to improve or enhance the host's ability to counteract infections through enhanced immune responses, allowing us to focus our attention away from only treating infections and towards enhancing the host's ability to protect itself.

Recent advances in genetics and molecular biology have led to the development of new infection control strategies. The chapters that focus specifically on CRISPR-Cas and other gene editing technologies are especially relevant because they offer potential for precisely targeting disease-causing bacteria and treating multidrug-resistant (MDR) organisms, commonly referred to as "superbugs." This book also takes a holistic view of managing bacterial infections, looking at everything from diagnostic testing to successful treatment, with an emphasis on the potential for developing interdisciplinary and emerging technologies.

This book also takes into account the effects of digital innovations, including artificial intelligence (AI), on the future of antibiotic stewardship. This part will evaluate how AI can improve the effectiveness and applicability of antibiotic stewardship tools like clinical decision support systems (CDSs) and reduce the inappropriate use of antibiotics.

In addition to addressing the technology aspects of the diagnosis and treatment of bacterial infections, this second part will examine both the economic and accessibility-related challenges that are posed by bacterial resistance to antibiotics and the need for equitable healthcare strategies and government-sponsored programs, particularly in low-income areas.

This second part of *Diagnosis and Treatment of Bacterial Infections* is intended for clinicians, researchers in the field, pharmacy scientists, and policymakers. By connecting traditional treatments with emerging technological advances and digital health innovations, this part seeks to meaningfully contribute to global efforts to combat bacterial infections and reduce the impact of antibiotic resistance.

Mukesh Kumar Singh
School of Pharmaceutical Sciences
Faculty of Pharmacy, IFTM University
Moradabad, Uttar Pradesh
India

iii

Gurdeep Singh
School of Pharmaceutical Sciences
Lovely Professional University
Phagwara, Punjab
India

Amrendra Pratap Yadav
Department of Pharmacy
Meerut Institute of Technology
Meerut, Uttar Pradesh
India

&

Papiya Bigoniya
Cancer Biology Project
University of Westminster
London, UK

List of Contributors

Anju Goyal	Faculty of Pharmacy, Department of Pharmaceutical Quality Assurance, Bhupal Noble's University, Udaipur, Rajasthan-313001, India
Arvinder Kaur	KLE College of Pharmacy, Rajajinagar II block, Bengaluru, Karnataka-560010, India
Bina Gidwani	Department of Pharmaceutical Quality Assurance, Columbia Institute of Pharmacy, Raipur, India
Dimple Kothari	Department of Microbiology, Marwadi University, Rajkot, India
Dulendra P. Damahe	Department of Pharmaceutical Chemistry, Smt. B.N.B. Swaminarayan Pharmacy College, Salvav-Vapi, 396195, Gujarat, India
Lokesh V. Patil	Department of Pharmaceutical Chemistry, Smt. B.N.B. Swaminarayan Pharmacy College, Salvav-Vapi, 396195, Gujarat, India
Mamta Bhatia	Faculty of Pharmacy, Department of Pharmaceutical Quality Assurance, Bhupal Noble's University, Udaipur, Rajasthan-313001, India
Monika Bhairam	Department of Pharmaceutical Quality Assurance, Columbia Institute of Pharmacy, Raipur, India
Niralee Patel	Department of Microbiology, Marwadi University, Rajkot, India
Neha Dubey	Department of Pharmaceutics, Columbia Institute of Pharmacy, Raipur, India
Prashant Upadhyay	Faculty of Pharmacy, IFTM University, Moradabad-244102, (U.P.), India
Pankaj Sarde	Department of Mathematics, Rungta College of Engineering and Technology, Bhilai, India
Priti Singh	Department of Pharmaceutical Chemistry, Smt. B.N.B. Swaminarayan Pharmacy College, Salvav-Vapi, 396195, Gujarat, India
Ravindra Kumar Pandey	Department of Pharmacognosy, Columbia Institute of Pharmacy, Raipur, India
Rajveer Singh Rajput	Department of Pharmaceutics, ShriRam College of Pharmacy, (M.P.)-476444, India
Shaziya Yasmeen Sayeed	Faculty of Pharmacy, Department of Pharmaceutical Quality Assurance, Bhupal Noble's University, Udaipur, Rajasthan-313001, India
Shweta Mishra	Faculty of Pharmacy, IFTM University, Moradabad-244102, (U.P.), India
Sukirti Upadhyay	Faculty of Pharmacy, IFTM University, Moradabad-244102, (U.P.), India
Shiv Shankar Shukla	Department of Pharmaceutical Quality Assurance, Columbia Institute of Pharmacy, Raipur, India
Shilpa Sahu	Department of Pharmaceutical Quality Assurance, Columbia Institute of Pharmacy, Raipur, India
Saloni Jain	Department of Pharmaceutics, ShriRam College of Pharmacy, (M.P.)-476444, India
Shetal B. Desai	Department of Pharmaceutical Chemistry, Smt. B.N.B. Swaminarayan Pharmacy College, Salvav-Vapi, 396195, Gujarat, India

Sachin B. Narkhede	Department of Pharmaceutical Chemistry, Smt. B.N.B. Swaminarayan Pharmacy College, Salvav-Vapi, 396195, Gujarat, India
Tarun Dhar Diwan	Department of Computer Science and Information Technology, Atal Bihari Vajpayee University, Chhattisgarh-495001, India
Vinay Jain	Department of Pharmaceutics, ShriRam College of Pharmacy, (M.P.)-476444, India
Vaishali Sarde	Department of Computer Application, Govt. J. Yoganandam, Chhattisgarh College, Raipur (C.G)-492001, India
Yogesh Vaishnav	Department of Pharmacy, Guru Ghasidas Vishwavidyalaya (A Central University), Koni, Chhattisgarh-495009, India

CHAPTER 1

From Traditional Knowledge to Modern Medicine: Integrating Phytotherapy into Antibacterial Treatment Regimens

Anju Goyal^{1,*}, Mamta Bhatia¹ and Shaziya Yasmeen Sayeed¹

¹ Faculty of Pharmacy, Department of Pharmaceutical Quality Assurance, Bhupal Noble's University, Udaipur, Rajasthan-313001, India

Abstract: Antibiotic resistance has become a critical global health threat, as bacteria evolve to withstand standard treatments, leading to persistent infections. This chapter examines the rise of antibiotic resistance, focusing on its historical development, mechanisms, and contributing factors. The present chapter explores the integration of phytotherapy—plant-based medicines—into antibacterial treatment regimens, bridging traditional knowledge with modern medical practices. The chapter investigates key antimicrobial compounds found in secondary metabolites like essential oils, polyphenols, alkaloids, terpenoids, and flavonoids, which show potential against resistant bacteria. Examining synergistic effects demonstrates how combining phytotherapy with conventional antibiotics can enhance treatment efficacy, reduce side effects, and mitigate the development of resistance. Challenges such as the standardization of plant extracts, potential drug interactions, and regulatory hurdles are addressed, alongside successful examples of phytotherapy in treating infections. Through clinical applications and case studies, the chapter highlights the role of plant-based therapies in improving modern medical treatments. This analysis emphasizes the need for more research into phytochemicals and their potential in combating antibiotic resistance, encouraging innovative approaches to integrating traditional knowledge with contemporary medicine to enhance patient health and protect global well-being.

Keywords: Antibiotic resistance, Conventional therapies, Phytotherapy, Polyphenols, Plant-based therapies.

INTRODUCTION

The rising incidence of drug-resistant pathogens has created an urgent demand for the discovery and isolation of new bioactive compounds from medicinal plants using standardized modern analytical techniques. Plant-derived compounds offer promising, novel approaches to combat pathogenic bacteria. This chapter

* Corresponding author Anju Goyal: Faculty of Pharmacy, Department of Pharmaceutical Quality Assurance, Bhupal Noble's University, Udaipur, Rajasthan-313001, India; E-mail: goyalanjugoyal@yahoo.co.in

examines the antimicrobial properties of some plant-based components, their potential mechanisms of action, and their chemical potential [1].

Antibiotics are chemical substances produced by living organisms, typically microorganisms, that are harmful to other microorganisms. They are commonly produced by soil-dwelling microorganisms and likely serve as a mechanism for controlling the growth of competing species in complex environments like soil. Microorganisms that produce antibiotics useful for preventing or treating diseases include certain bacteria and fungi [2].

Overview of the Rise of Antibiotic Resistance

Antibiotic resistance has emerged as one of the most critical global threats to the effective treatment of bacterial infections. It negatively impacts both clinical and therapeutic outcomes, leading to treatment failures, the need for costly and safer alternative drugs, increased morbidity and mortality rates, prolonged hospitalizations, and elevated healthcare costs. (Fig. 1) effectively illustrates why antibiotic resistance is so challenging to combat, and for each mechanism of antibiotic action, bacteria have evolved corresponding resistance mechanisms. Antibiotics target vital processes like cell wall synthesis, protein production, and DNA/RNA replication. In response, bacteria develop resistance through strategies such as drug inactivation, efflux pumps, target modification, and bypass mechanisms. This interplay illustrates the challenge of treating bacterial infections. The urgent search for new antibiotics and antimicrobial agents remains crucial in the fight against bacterial infections. However, antibiotic resistance seems inevitable, compounded by a persistent lack of interest from the pharmaceutical industry in investing in new antibiotic research [3].

Over the past decades, resistance has escalated due to several factors, leading to infections that are harder to treat, increased healthcare costs, and higher mortality rates. (Fig. 2) effectively illustrates the interconnected factors that drive antibiotic resistance.

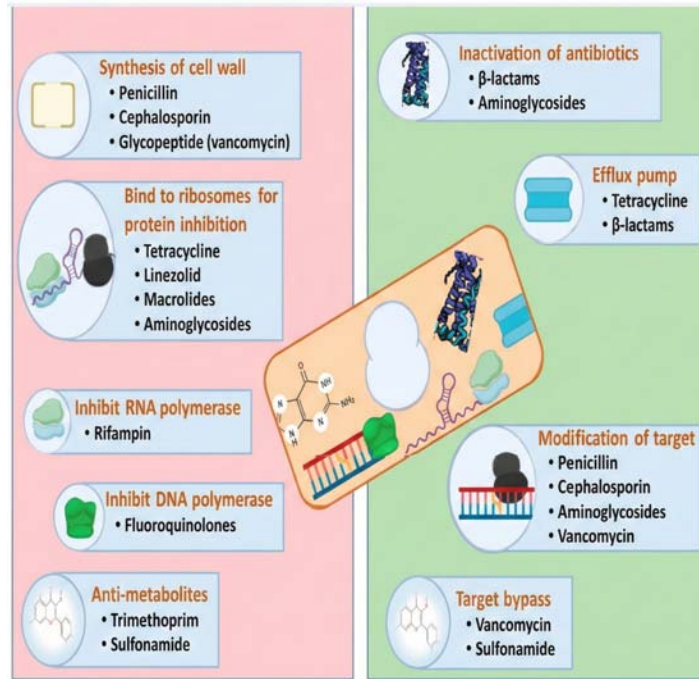


Fig. (1). Differentiating the antibiotic action and antibiotic resistance through different aspects within a bacterial cell [4].

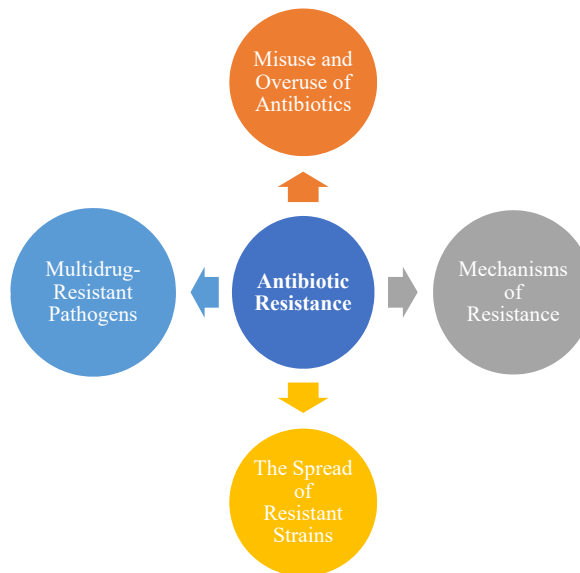


Fig. (2). An overview of the key aspects contributing to the rise of antibiotic resistance.

CHAPTER 2

Immunomodulatory Strategies Against Bacterial Infections

Prashant Upadhyay^{1,*}, Shweta Mishra¹ and Sukirti Upadhyay¹

¹ Faculty of Pharmacy, IFTM University, Moradabad-244102, (U.P.), India

Abstract: Bacterial infection remains a universal threat that worsens with the development of antibiotic resistance. It is estimated that 10 million people will die annually due to bacterial antibiotic resistance by the year 2050. Immunomodulatory approaches are novel modalities to augment host defenses and combat bacterial infections. The ultimate goal of immunomodulation is to activate innate and adaptive immunity to fight bacterial pathogens. This chapter discusses various immunomodulatory strategies, which can be broadly categorized as cytokine therapy, monoclonal antibodies, neutralising bacterial toxins, Toll-like receptor agonists, enhancement of phagocytosis, activation of host defense peptides, modulation of immune checkpoints, probiotics usage, T-cell therapy, phage therapy, stem cell therapy, *etc.*

Keywords: Antibodies, Agonists, Bacteria, Cytokines, Resistance, Stem cells.

INTRODUCTION

Bacterial infections remain a significant worldwide health concern, particularly in light of the growing threat of antibiotic resistance. The demand for alternative therapeutic strategies is increasing because drug-resistant strains continue to limit the success of traditional antibiotics [1].

One possible tactic is immunomodulation, which is defined as the practice of changing the immune system to increase or reduce its response. This is an important issue because such immunomodulatory approaches are more effective in combating infections and do not involve the problem of antibiotic resistance. This chapter presents several immunomodulatory approaches that can be used to treat bacterial infections, as shown in Fig. (1). These methods include targeted cytokine therapy, monoclonal antibodies, and microbiome manipulation [2].

* Corresponding author Prashant Upadhyay: Faculty of Pharmacy, IFTM University, Moradabad-244102, (U.P.) India; E-mail:prashantupadhyay@iftmuniversity.ac.in,p23upadhyay@yahoo.com

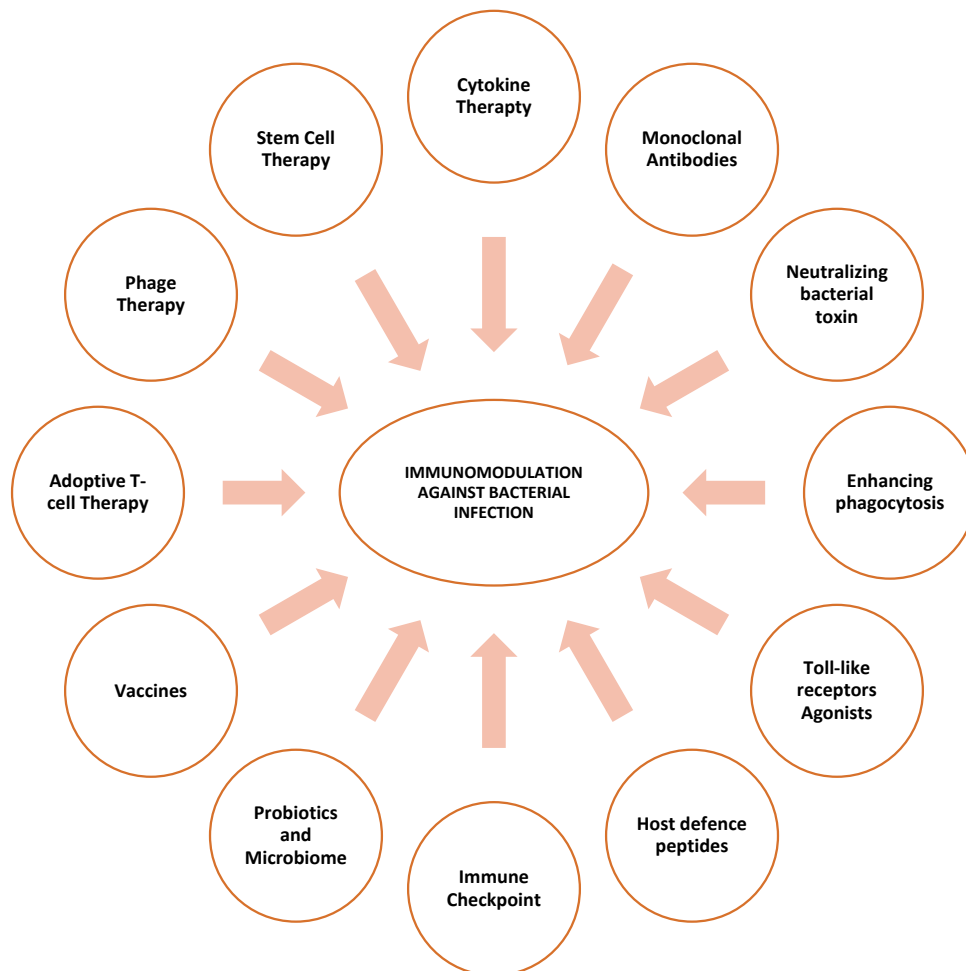


Fig. (1). Immunomodulation against Bacterial Infection.

Various strategies for attaining immunomodulation against bacterial infection are discussed below.

• **Cytokine Therapy: Orchestrating the Immune Response**

Given the significance of internal cellular proteins, cytokines appear to have a significant impact on many diseases. They are signaling molecules that regulate inflammation, immune cell activity, and all the host defense mechanisms. Given the bacterial infection, the focus may need to be either on boosting the immune response or on controlling excessive reactions that could result in tissue damage. [3].

- **Pro-inflammatory Cytokines (e.g., TNF- α , IL-1, and IL-6):** These substances are essential for inducing the immune system to fight invasive infections. They encourage the recruitment and activation of immune cells, including neutrophils, dendritic cells, and macrophages—all of which are critical for getting rid of bacterial infections.
 - **Example:** Interferon-gamma (IFN- γ) therapy has been shown to enhance macrophage activity in *Mycobacterium tuberculosis* patients, aiding in the management of the infection [4].
- **Anti-inflammatory Cytokines (such as TGF- β and IL-10):** An uncontrolled immune response can damage host tissues, even while inflammation is required to fight infections. Inflammation is regulated and resolved in part by cytokines that decrease it. Therapies that change these cytokines can be useful in conditions like sepsis, where the immune system's overreaction can be fatal. Cytokine blockers can also help reduce excessive inflammation in conditions like septic shock, where the immune system overreacts and results in multiple organ failure [5, 6].
- **Cytokine Modulation:** By altering the immune response using cytokines or cytokine inhibitors, immunological activity can be increased or decreased as needed. While boosting Th1 responses may be beneficial for intracellular bacterial infections, avoiding excessive inflammation (e.g., with IL-1 or TNF- α inhibitors) may prevent sepsis in severe bacterial infections [7].

Monoclonal Antibodies (mAbs): Therapeutic monoclonal antibodies (mAbs) remain one of the best-known methods of immunomodulation. These synthetic proteins can be specifically designed to bind to certain bacterial elements or host immunological mechanisms, enabling the immune system to combat the infection or eliminate virulence factors more successfully [8].

Neutralizing Bacterial Toxins: Bacterial toxins produced by *Clostridium difficile* and *Staphylococcus aureus*, among others, aggravate diseases. Monoclonal antibodies that counteract the effects of these poisons can help avoid tissue damage. For instance, a monoclonal antibody that neutralizes the Pantan-Valentine leukocidin (PVL) toxin generated by *Staphylococcus aureus* has been developed to reduce the severity of skin and soft tissue infections.

Enhancing Phagocytosis: Phagocytes can ingest and kill bacteria. Monoclonal antibodies can bind to a bacterial surface and facilitate that surface's recognition by phagocytes, thereby improving the immune competence of the body against diseases without the use of drugs. There is much to learn, and ongoing studies continue to investigate the use of

Harnessing Gene Editing to Eradicate Bacterial Infections

Dimple Kothari¹ and Niralee Patel^{1,*}

¹ Department of Microbiology, Marwadi University, Rajkot, India

Abstract: Gene editing techniques have revolutionised the treatment of bacterial illnesses, offering promising alternatives to traditional antibiotics, particularly in combating antibiotic resistance. Discoveries highlight the potential of CRISPR/Cas9 gene editing in combating antibiotic-resistant bacterial infections. This technology can specifically target and disrupt drug-resistant genes or directly kill pathogens. To enhance delivery efficiency, nanoparticle-based systems are being explored. The CRISPR-Cas system, particularly type II, shows promise in editing drug-resistant bacterial genomes. Advanced base-editing techniques, such as adenine and cytidine base editors, offer more precise genome modifications without causing double-strand breaks. Genome editing technologies beyond CRISPR, such as zinc-finger nucleases and Transcription Activator-Like Effectors, can target and disrupt essential genes in bacteria and viruses to fight infectious diseases. While CRISPR-Cas systems have revolutionised genome editing, their application in bacteria faces challenges. Alternative approaches include CRISPR-associated transposases, base editors, Cas12a, and CRISPR nickases. Strategies to improve CRISPR-based methods in bacteria involve optimising double-strand break repair pathways and plasmid curing approaches. Genome editing can be accomplished in a laboratory setting (*in vitro*) or within a living organism (*in vivo*) by directly delivering the editing tools to the desired location. Recent case studies and experimental findings are presented to demonstrate the successes and challenges of applying gene editing in practical scenarios. Finally, future directions are discussed, highlighting the integration of synthetic biology, precision medicine, and advanced delivery platforms to develop safe and effective gene-editing-based antimicrobial therapies. This chapter explores the potential of gene editing for eliminating bacterial pathogens and treating infections.

Keywords: Bacterial Infection, CRISPR, Diagnosis, Gene Editing, Nanoparticles.

INTRODUCTION

Genetic manipulation serves as the foundation for researchers to explore the molecular underpinnings of physiological and metabolic functions in various

* Corresponding author Niralee Patel: Department of Microbiology, Marwadi University, Rajkot, India; E-mail:niralee.patel@marwadieducation.edu.in

organisms, especially in scientifically and industrially significant bacteria. Traditional genetic techniques have been established for bacterial species that can be cultured and transformed, such as suicide plasmids. These approaches are typically labour-intensive and often, though not always (as in the case of the Clostron method), necessitate the insertion of an antibiotic resistance indicator into the DNA. This requirement impedes the ability to create precise modifications, such as individual amino acid alterations [1]. The most advanced method for editing the genome in bacteria involves combining homologous recombination of a template sequence with a target DNA utilising genetically engineered nucleases from CRISPR-Cas systems [2]. In the 19th century, doctors faced problems with infectious diseases, which changed public health and financial management [3]. A total of 13.7 million people died in 2019, of which approximately seven million deaths were associated with 33 bacterial pathogens, including *Klebsiella pneumoniae*, *Escherichia coli*, *Staphylococcus aureus*, *Pseudomonas aeruginosa*, and *Streptococcus pneumoniae*, responsible for 54.9% of the mortality rate [4]. The pharmaceutical industry's efforts to create novel antibiotics, a previously successful approach to tackling resistant bacteria, had largely come to a standstill due to financial and regulatory challenges. The development of antibiotics is no longer deemed a financially prudent venture for pharmaceutical companies. Even for firms willing to pursue antibiotic discovery, regulatory approval often presents a significant hurdle. A promising avenue for developing new therapeutic approaches to combat infectious diseases lies in the application of programmable nucleases for genomic modification [5]. The breakthrough of the bacterial CRISPR (Clustered Regularly Interspaced Short Palindromic Repeats), CRISPR-associated protein system (Cas) has ignited the growth of a robust method for targeting DNA through nucleotide base-pairing. The type II CRISPR system's endonuclease Cas9 is precisely directed by a sgRNA (single guide RNA) to bind and produce a DSB (double-strand break) at complementary genomic regions [6]. Specifically, targeting novel sequences utilising CRISPR-Cas is feasible by modifying the crRNA that guides a given Cas nuclease instead of re-engineering the protein. This characteristic distinguishes it from alternative genome editing platforms like meganucleases (MNs), transcription-activating like effectors (TALE), and zinc finger nucleases (ZFN), and has facilitated its rapid and widespread adoption [7]. CRISPR-based antimicrobials offer a unique advantage over traditional methods by targeting bacteria based on their genetic sequence. This capability is particularly valuable in scenarios where selective elimination of specific bacteria within a genus is required, a task that proves challenging with existing approaches. One therapeutic application of CRISPR technology involves delivering various tools into target cells in living organisms. Viral vectors are the most common means of administering these techniques, with many researchers favouring adeno-associated virus (AAV) as their vector of choice [8]. To tackle the issue of administering CRISPR-Cas antibacterial agents to bacteria, researchers have devised a method of genetically encoding CRISPR-Cas9 into phage genomes. These genetically modified, non-replicating phages are engineered to function as precise nano-carriers, transporting payloads that exhibit antibacterial effects beyond merely lysing the cell [9]. CRISPR-Cas9-encoded bacteriophages provide species-specific delivery of novel antibacterial agents and must target infected host cells before being released into the intracellular bacteria [10]. The combination of phage therapy and

gene editing technologies has the potential to revolutionise bacterial infection treatments. This innovative approach primarily targets genes associated with resistance and presents a formidable alternative to conventional antimicrobial therapies.

GENE EDITING MECHANISMS

The microbial community widely uses the CRISPR-Cas system (clustered regularly interspersed short palindromic repeats). It has been discovered that this particular characteristic is present in approximately 40% of bacterial species and as high as 90% of archaea [11, 12]. Still, recent discoveries have shed light on the biological significance of this genetically adaptable defence system in defending against the invasion of genetic elements like transmissible viruses and vectors.

CRISPR Cas 9

CRISPRs were first discovered in *E. coli* in early 1987 and later found in various bacterial species [13]. For many years, the purpose of the brief repetitive sequences remained enigmatic until studies in 2005 identified their resemblance to phage DNA. Following these findings, further research demonstrated that these sequences played a role in the adaptive immune defence of archaea and bacteria against invasive foreign DNA by triggering RNA-guided DNA cleavage [14]. CRISPR-Cas systems are classified into two distinctive groups according to the morphological diversity and organizational configuration of the Cas genes [14]. Class 1 CRISPR-Cas systems contain multiple proteins, whereas class 2 systems have only one effector protein. Around six CRISPR-Cas classifications and at least twenty-nine distinct subtypes have been identified recently, with the ongoing expansion of this classification. The Cas9 system or type II CRISPR is the predominant form of CRISPR, utilising a single Cas protein produced by *Streptococcus pyogenes* (SpCas9) to edit specific DNA sequences, and is a powerful tool for editing genes [15, 16]. Cas9 facilitates interference in Type II systems *via* sequence-specific endonucleolytic activity at the target locus, facilitated by the combined action of RuvC and HNH nickase activities [17, 18]. The multifunctional characteristics of Cas9 facilitate programmable genome editing across various organisms, necessitating the production of its related tracrRNA and a crRNA that matches the target sequence. Pivotal advancement in this approach was the development of a single guide RNA (sgRNA) chimera, which integrates the functionalities of the native crRNA and tracrRNA duplex [14]. Editing of the genome *via* Cas9 can be controlled by designing sgRNAs. Specificity of chromosome split is dependent on the selection of a unique spacer sequence that is distinctive to the target allele and is additionally influenced by the PAM (Protospacer Adjacent Motif), a short conserved sequence that must be close to the protospacer of interest [19, 20]. Cas9 causes the target region's dsDNA to break fatally, serving as a selection strategy against wild-type

CHAPTER 4

From Diagnosis to Cure: A Multifaceted Approach to Bacterial Infection with Emerging Technology

Shiv Shankar Shukla¹, Ravindra Kumar Pandey², Monika Bhairam¹, Neha Dubey³, Shilpa Sahu¹ and Bina Gidwani^{1,*}

¹ *Department of Pharmaceutical Quality Assurance, Columbia Institute of Pharmacy, Raipur, India*

² *Department of Pharmacognosy, Columbia Institute of Pharmacy, Raipur, India*

³ *Department of Pharmaceutics, Columbia Institute of Pharmacy, Raipur, India*

Abstract: Bacterial infections remain a significant global health challenge, exacerbated by the rise of antibiotic resistance and the limitations of traditional diagnostic and treatment methods. This chapter explores the transformative impact of emerging technologies on the fight against bacterial infections, offering a comprehensive approach from diagnosis to cure. This chapter discusses advancements in rapid diagnostic tools, including point-of-care testing, next-generation sequencing, and AI-driven diagnostic platforms, which have revolutionized the speed and accuracy of bacterial identification. In treatment, innovative approaches such as antimicrobial peptides, phage therapy, CRISPR-Cas systems, and nanotechnology-based drug delivery are highlighted as promising alternatives to conventional antibiotics. The role of personalized medicine, with tailored therapies and consideration of the patient's microbiome, is emphasized as a critical component in optimizing treatment outcomes. The chapter highlights emerging trends in infection control, including new vaccination strategies, the use of probiotics, and environmental control measures, which aim to prevent bacterial spread and reduce infection rates. Challenges such as regulatory hurdles, cost, and accessibility are discussed, alongside potential solutions and future research directions. Through case studies and real-world applications, the chapter illustrates the practical implementation of these technologies, offering insights into their effectiveness and the lessons learned from recent experiences. Ultimately, this chapter provides a forward-looking perspective on how the integration of cutting-edge technologies will shape the future of bacterial infection management and improve global health outcomes.

Keywords: Bacterial infections, Diagnosis, Global health, Nanotechnology, Vaccination strategies.

* **Corresponding author Bina Gidwani:** Department of Pharmaceutical Quality Assurance, Columbia Institute of Pharmacy, Raipur, India; E-mail:beenagidwani@gmail.com

Mukesh Kumar Singh, Gurdeep Singh, Amrendra Pratap Yadav & Papiya Bigoniya (Eds.)
All rights reserved-© 2026 Bentham Science Publishers

INTRODUCTION

Bacterial infections result from the invasion and proliferation of harmful bacteria within the human body, causing a spectrum of diseases that can range from minor to severe, potentially fatal situations. These infections have the potential to impact several systems, such as the respiratory, gastrointestinal, urinary, and circulatory systems [1]. On a global scale, bacterial infections pose a substantial challenge to public health, leading to elevated rates of illness and death, especially in underdeveloped areas with inadequate healthcare access [2]. Antibiotic-resistant bacteria like Methicillin-resistant *Staphylococcus aureus* (MRSA) and multidrug-resistant tuberculosis (MDR-TB) are becoming more common. This makes it harder to treat and control, which is a significant problem for healthcare systems around the world [3]. The presence of these resilient infections frequently leads to extended hospitalization, elevated healthcare expenses, and heightened mortality rates, emphasizing the pressing requirement for novel diagnostic tools and therapeutic approaches to successfully tackle bacterial diseases [4].

Bacterial infections arise when pathogenic bacteria infiltrate and proliferate within the organism, resulting in a diverse array of illnesses and medical disorders. Bacteria are unicellular microbes that inhabit many habitats, such as soil, water, and the human body [5]. Although certain bacteria in the gut microbiome are harmless or even beneficial, pathogenic bacteria can lead to diseases by overpowering the immune system when they invade the body [6].

Bacterial infections have the potential to impact every region of the body, resulting in various disorders, such as pneumonia, urinary tract infections, meningitis, and foodborne illnesses like salmonella. The severity of these infections can range from minor to life-threatening, depending on factors such as the specific bacteria involved, the location of the illness, and the overall health of the sick person [7].

Bacterial infections have a major and far-reaching impact on global health, leading to a high number of illnesses and deaths worldwide. In 2019, bacterial infections ranked as the second most common cause of death worldwide, resulting in nearly 7.7 million fatalities [8]. Bacterial infections pose a significant burden in low- and middle-income countries due to inadequate access to healthcare, resulting in elevated rates of infection and mortality [9].

Furthermore, the emergence of antibiotic resistance, defined as the ability of bacteria to develop resistance to the effects of antibiotics, has worsened the global health burden. Antibiotic-resistant illnesses provide more challenges in terms of treatment, resulting in elevated medical expenses, prolonged hospitalisation, and heightened fatality rates. Antimicrobial resistance (AMR) caused nearly 5 million

deaths in 2019, underscoring the urgent need for novel medicines, vaccines, and other measures to effectively address bacterial infections [8].

To tackle bacterial diseases and their worldwide consequences, a comprehensive strategy is necessary. This entails creating quick diagnostic technologies, efficient therapies, and preventive measures such as immunization and enhanced sanitation. Effective global surveillance and synchronized initiatives to mitigate the proliferation of antibiotic resistance are critical for effectively addressing the impact of bacterial infections [10].

Bacterial Infections and Their Global Impact

Bacterial infections are a significant global health problem, resulting in millions of deaths and extensive illness among various groups. Bacterial infections accounted for almost 7.7 million fatalities in 2019, making them the second most common cause of death globally, second only to ischaemic heart disease [11]. These infections have a greater impact on low- and middle-income nations, where healthcare resources are generally restricted, making the situation worse for vulnerable populations [8]. A small number of primary pathogens are primarily responsible for the worldwide prevalence of bacterial illnesses. In the year 2019, a total of five bacterial species, namely *Staphylococcus aureus*, *Escherichia coli*, *Streptococcus pneumoniae*, *Klebsiella pneumoniae*, and *Pseudomonas aeruginosa*, accounted for almost 50% of all fatalities associated with bacterial infections. These disease-causing microorganisms are responsible for a variety of illnesses, such as infections in the lower respiratory tract, infections in the bloodstream, and infections in the abdominal cavity. All of these infections play a substantial role in causing death worldwide [9].

Age and geographic location significantly influence the distribution and impact of these illnesses. *S. aureus* was the primary cause of bacterial fatalities worldwide, with a particular impact on individuals aged 15 and above. Among children under the age of five, *Streptococcus pneumoniae* was the primary cause of mortality, responsible for a significant proportion of fatalities. Sub-Saharan Africa has the greatest fatality rates from bacterial illnesses due to its sometimes inadequate healthcare infrastructure [12].

Bacterial infections not only directly cause deaths but also impose a substantial burden of illness, putting pressure on healthcare systems globally. The emergence of antimicrobial resistance (AMR) adds another layer of complexity to the treatment of these infections, resulting in approximately 5 million deaths in 2019 due to AMR-related diseases. The increasing resistance of bacteria to antibiotics poses a significant concern to global health, resulting in more challenging infections to cure and raising the likelihood of death, especially in areas with

CHAPTER 5

CRISPR-Cas vs Superbugs: A New Era in Combating Antibiotic Resistance

Saloni Jain^{1*}, Rajveer Singh Rajput¹ and Vinay Jain¹

¹ Department of Pharmaceutics, ShriRam College of Pharmacy, (M.P.)-476444, India

Abstract: Superbugs are bacterial strains that are thought to cause deadly infections due to their multidrug resistance. Overcrowding and poor sanitation brought on by migration and urbanization have increased the chances of infections by superbugs within the communities. It has been predicted that the system of CRISPR-Cas, primarily type 2, is a powerful tool for precisely editing bacterial genomes that are resistant to drugs, efficiently tackling bacterial populations using antibiotic resistance. In order to fully realize its promise, further advancements in this system are required to minimize the toxic effects and enhance the effectiveness of gene-editing applications. This could entail point mutations created by base-editing techniques. These techniques modify single base pairs directly, resulting in double-strand breaks (DSBs) by employing engineered Cas9 variants such as (ABE, which is an adenine base editor, and (CBE), which is a cytidine base editor. A target base pair (*e.g.*, G-C to A-T or C-G to A-T) can be modified by CBE and ABE. Here, the constraints of the CRISPR/Cas system will be discussed, and methods to overcome these constraints will be investigated through the use of various base-editing approaches. In addition, this chapter will talk about current studies that demonstrate basic editors' capacity to eradicate germs that are resistant to drugs.

Keywords: Antibiotic Resistance, CRISPR, DNA, Genome, Gene Editing, Superbugs.

INTRODUCTION

Genome editing is a technique for changing the genomic DNA at a particular point in a variety of cells and organisms. The process involves inserting, deleting, or replacing the DNA, which results in inactivating target genes, the creation of new genetic traits, and the repair of harmful gene mutations. Genome editing technology has become the most useful tool for researching the pathophysiology of genetic illnesses, studying gene function, developing new gene therapy targets, and breeding crop varieties, among others, because life sciences have grown

* Corresponding author Saloni Jain: Department of Pharmaceutics, ShriRam College of Pharmacy, (M.P.)-476444, India; E-mail: salonijain455@gmail.com

rapidly in recent years [4 - 7]. Three common genome editing techniques are currently available worldwide: RNA-guided CRISPR-Cas systems (CRISPR-associated), transcription activator-like effector nucleases (TALENs), and zinc finger nucleases (ZFNs) [8 - 10]. Cloned regularly interspaced short palindromic repeats are referred to as CRISPR. Because of the numerous advantages offered by CRISPR-Cas systems, such as their short cycle times, high repeatability, affordability, high efficiency, and straightforward design, they are currently the highly utilized techniques for editing genomes in cell biology labs across the globe [11, 12]. The purpose of our study is to provide an introduction to our systems, involving their advancements and applications in the understanding of diseases associated with humans and gene therapy, along with the opportunities and difficulties associated with using them in practical settings.

CRISPR-Cas Systems Overview: CRISPR-Cas serves as an immune system that is adaptable in the majority of microorganisms and archaea, keeping out viruses, phages, and other foreign genetic material [13, 14]. This structure is comprised of a group of CRISPR-associated(cas) genes, which produce endonucleases [15]. If prokaryotes are exposed to foreign genetic material, the foreign DNA is processed into small fragments and inserted as spacers [16]. Once the same intruder resurfaces, the foreign DNA is immediately recognized by crRNA, which couples with it to direct Cas9 to split the target.

The CRISPR-Cas System's Organization and Method of Action

A collection of CRISPR-involved (Cas) genes and a CRISPR array make up the CRISPR system [17]. Brief repeating patterns separated by pauses make up the CRISPR array [18]. An A-T-rich head, a promoter-comprising sequence that starts the recording of the spacer and repeat sequences, usually comes before the CRISPR array [19, 20]. Based on the proteins that make up the system and how it functions, the CRISPR-Cas system is primarily classified into two groups [21, 22]. Class 1 relies on multi-protein effector complexes and is further categorized into types I, III, and IV. In contrast, Class 2 employs single-protein effector complexes and is subdivided into types II, V, and VI. Class 1 is responsible for the breakdown of nucleic acids. [23 - 26] The bacterial immune response mediated by the CRISPR/Cas systems is divided into three stages [14, 27]. (i) Spacer acquisition, during which spacer sequences are incorporated; [28, 29] (ii) Expression, involving the production of Cas proteins and crRNA; [24] and (iii) Interference, where the crRNA guides the cleavage of target nucleic acid [30, 31, 33].

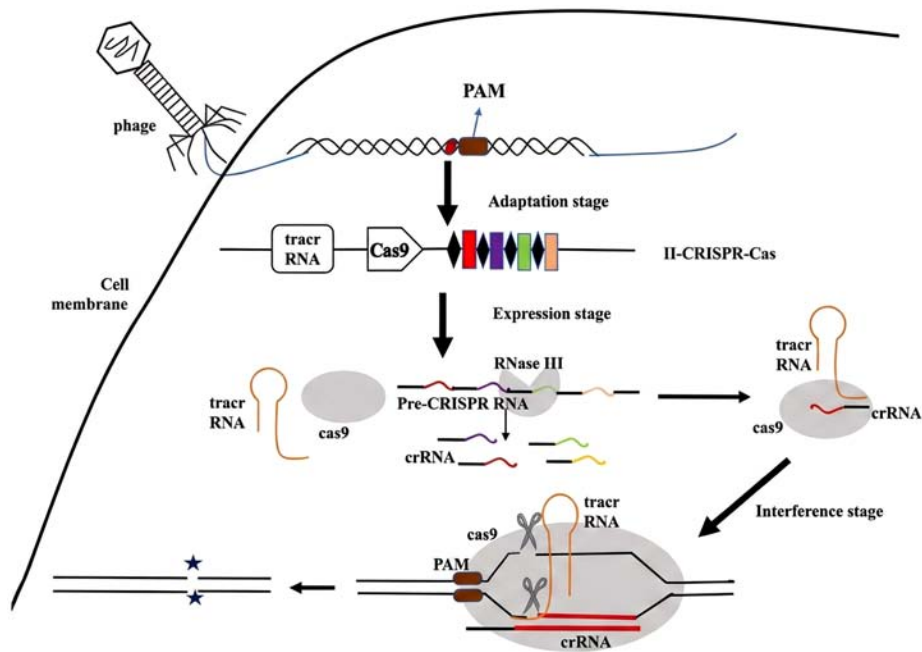


Fig. (1). CRISPR-Cas system's mode of action. Three phases make up the CRISPR/Cas systems' mechanism of defending bacteria: Stage of adaptation: obtaining spacer sequences; Stage of expression: production of Cas proteins and crRNA; Stage of interference: cleavage of a target nucleic acid by crRNA.

The Function of the CRISPR-Cas System in the Growth of Antibiotic Resistance

Human health is at risk due to the progress and growth in antimicrobial resistance [34]. The spread of drug resistance in microorganisms is mostly caused by horizontal gene transfer (HGT), which also enhances antimicrobial resistance [35]. CRISPR-Cas systems function as defence mechanisms for the genome, capable of preventing the entry of foreign genetic material [36]. Bacterial resistance has an impact on the framework and functionality of the CRISPR-Cas system. These mobile genomic components mediate antibiotic resistance. HGT genes can be limited by the CRISPR-Cas system, which can halt the growth of antibiotic-resistant phage and *plasmid genes* [85]. It can be stopped and controlled by utilizing the widely distributed CRISPR-Cas system in prokaryotes [38]. Isolates of the *Escherichia coli* type I-CRISPR system might help support the strain's susceptibility to the attacks of drug resistance plasmids [39]. An intestinal colonization mouse model revealed that CRISPR-Cas systems obtained from the mammalian gut can restrain the transmission of plasmids, which contribute to antibiotic resistance. The presence of CRISPR/Cas and the acquisition of

Role of Artificial Intelligence in Transforming Antibiotic Stewardship

Yogesh Vaishnav^{1,*}, Tarun Dhar Diwan², Vaishali Sarde³, Pankaj Sarde⁴ and Arvinder Kaur⁵

¹ Department of Pharmacy, Guru Ghasidas Vishwavidyalaya (A Central University) Koni, Chhattisgarh-495009, India

² Department of Computer Science and Information Technology, Atal Bihari Vajpayee University, Chhattisgarh-495001, India

³ Department of Computer Application, Govt. J. Yoganandam, Chhattisgarh College, Raipur (C.G)-492001, India

⁴ Department of Mathematics, Rungta College of Engineering and Technology, Bhilai, India

⁵ KLE College of Pharmacy, Rajajinagar II block, Bengaluru, Karnataka-560010, India

Abstract: Antibiotic stewardship programs (ASPs) seek to enhance patient outcomes by maximising the use of antibiotics in the fight against antimicrobial resistance (AMR). Artificial intelligence (AI) developments in recent years have showed significant potential for improving these applications. Artificial intelligence (AI) technologies, such as machine learning (ML) and natural language processing (NLP), are revolutionising antibiotic stewardship through enhanced diagnostic precision, customised treatment plans, resistance pattern prediction, and resource allocation optimisation. The article examines the major contributions of AI to antimicrobial stewardship, assesses the state of present applications, and talks about obstacles and future directions. Because AI can analyse enormous datasets, combine data from various sources, and produce actionable insights, it is a critical weapon in the fight against antimicrobial resistance (AMR).

Keywords: Artificial intelligence, Antibiotics, Antibiotic stewardship programs, Antimicrobial resistance, Machine learning.

* Corresponding author **Yogesh Vaishnav:** Department of Pharmacy, Guru Ghasidas Vishwavidyalaya (A Central University) Koni, Chhattisgarh-495009 India; E-mail:yogesh446688@gmail.com

Mukesh Kumar Singh, Gurdeep Singh, Amrendra Pratap Yadav & Papiya Bigoniya (Eds.)
All rights reserved-© 2026 Bentham Science Publishers

INTRODUCTION

Antibiotic Stewardship

Antibiotic stewardship as observed in Fig. (1) refers to coordinated interventions designed to improve and measure the appropriate use of antibiotics. Its primary goal is to enhance patient health outcomes while minimizing adverse effects, including the development of antibiotic resistance. Effective stewardship programs promote the selection of the optimal antibiotic drug regimen, including the choice of the specific antibiotic, dose, duration of therapy, and route of administration. These initiatives are crucial in preserving the effectiveness of existing antibiotics and ensuring their availability for future generations [1 - 4].

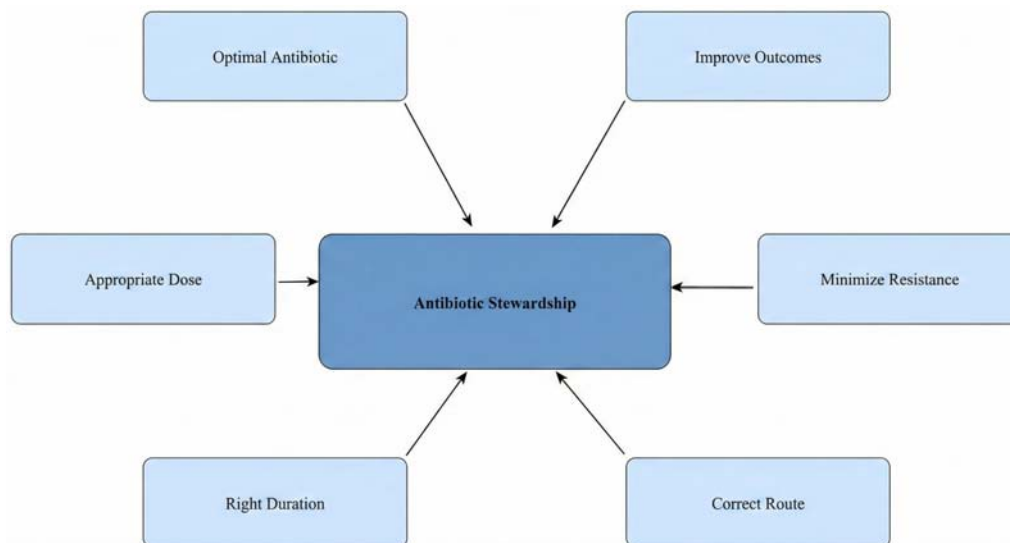


Fig. (1). Antibiotic stewardship program components.

Importance in Combating Antibiotic Resistance

Antibiotic stewardship plays a critical role in combating antibiotic resistance by promoting the responsible use of antibiotics (Fig. 2). Effective stewardship programs help reduce the misuse and overuse of these drugs, which are primary drivers of resistance. By ensuring that antibiotics are prescribed only when necessary and that the correct drugs are selected, stewardship initiatives can minimize the emergence of resistant bacteria. This is essential for preserving the efficacy of existing antibiotics, protecting patient health, and ensuring the sustainability of effective treatments for future generations [5 - 8].

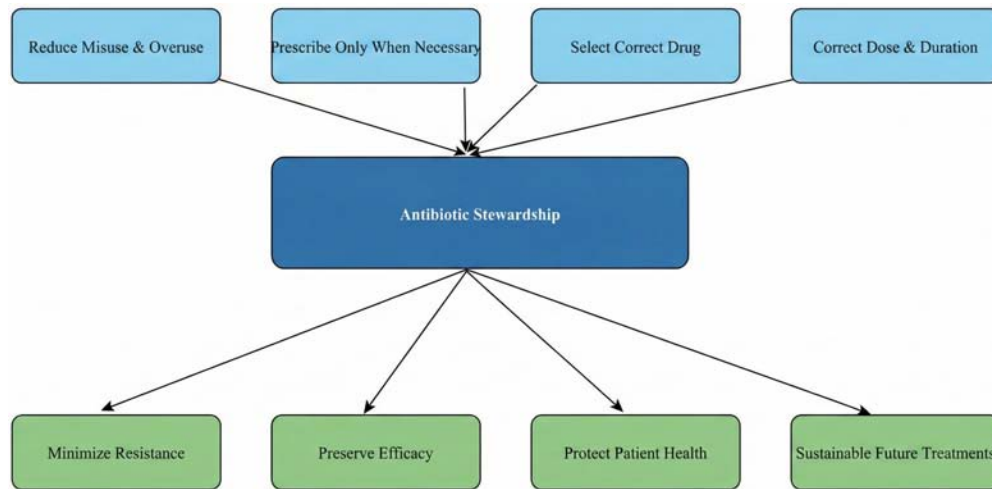


Fig. (2). Role of antibiotic stewardship in combating resistance.

Overview of Traditional Antibiotic Stewardship Practices

Traditional antibiotic stewardship practices aim to optimize antibiotic use and mitigate resistance through structured interventions. Key components include formulary restrictions that limit broad-spectrum antibiotics, thereby encouraging the use of narrow-spectrum agents when appropriate. Evidence-based guidelines are developed to direct clinicians in prescribing practices tailored to specific infections and patient demographics. Educational initiatives are essential for training healthcare providers on the principles of effective antibiotic use and current resistance patterns. Additionally, audit and feedback mechanisms provide clinicians with insights into their prescribing habits, promoting adherence to established guidelines. Infectious disease consultations are encouraged in complex cases, ensuring expert input in antibiotic management. These traditional practices have demonstrated effectiveness in improving patient outcomes and reducing the prevalence of antibiotic resistance [9 - 12], as presented in Fig. (3).

Economic and Accessibility Challenges in the Battle against Antibacterial Resistance

Priti Singh^{* 1}, Dulendra P. Damahe¹, Lokesh V. Patil¹, Shetal B. Desai¹ and Sachin B. Narkhede¹

¹ Department of Pharmaceutical Chemistry, Smt. B.N.B. Swaminarayan Pharmacy College, Salvav-Vapi- 396195, Gujarat, India

Abstract: Drugs that are used for the treatment of bacterial infections are known as antibiotics or antimicrobials. Antibiotics can occasionally cease acting and fail to kill or slow down microorganisms. One cause for this can be antimicrobial resistance (AMR). AMR can be caused by several factors, including natural selection, excessive and inappropriate use of antibiotics, and inferior and fake medications. Drug resistance makes medications ineffective and treating infections challenging or impossible. It leads to the formation of superbugs. The entire world, irrespective of geographical or economic level, is impacted by AMR. Initiatives are urgently needed for equal access to both new and existing treatment. AMR results in significant financial costs, extended hospital stays, and the need for more costly treatment, which has a negative impact on productivity. As a result, economies and health systems bear the financial burden of AMR due to failures in supply and demand, price structures, low innovation, inadequate funding, and unaddressed adverse effects in the agricultural and pharmaceutical industries.

Keywords: Anti-microbial resistance, Economy, Financial costs, Patient productivity.

INTRODUCTION

Bacteria

Single-celled, microscopic bacteria are present almost everywhere on Earth. They exist in a great diversity of sizes, forms, and habitats and are among the oldest living organisms. While some bacteria may infect people, animals, and plants, the

^{*} Corresponding author Priti Singh: Department of Pharmaceutical Chemistry, Smt. B.N.B. Swaminarayan Pharmacy College, Salvav-Vapi- 396195, Gujarat, India; E-mail:sheetu1929@gmail.com

majority are benign or even helpful. They are crucial to several functions, including fermentation, nutrient recycling, aiding food digestion, and protecting against pathogens [1].

Bacteria as Pathogens

While many bacteria are harmless or beneficial, some are pathogenic, meaning they cause diseases in humans, animals, and plants. Pathogenic bacteria invade hosts, evade the immune system, and multiply, often releasing toxins that damage host tissues [2].

Mechanisms of Bacterial Pathogenicity

- ***Invasion of Host Tissues:*** Pathogenic bacteria enter the body through various routes, such as the respiratory tract, digestive system, or wounds. They attach to host cells using structures like pili and then penetrate the tissues [3].
- ***Toxin Production:*** Many pathogenic bacteria produce toxins that damage host cells. These toxins can be:
 - ***Endotoxins:*** Released from the outer membrane of Gram-negative bacteria as they die and break down.
 - ***Exotoxins:*** Secreted by bacteria during their life cycle, causing damage to specific tissues (e.g., *Clostridium botulinum* producing botulinum toxin) [4].
- ***Immune Evasion:*** It is now possible for pathogenic germs to avoid the host's immune system. For example, some bacteria form a capsule around their cell wall that protects them from being absorbed by immune cells.
- ***Biofilm Formation:*** Certain bacteria aggregate into dense colonies called biofilms, which are covered in a defense coating. These biofilms, bacteria may stick to surfaces, such as medical equipment, and withstand the effects of medicines [5].

The following are examples of pathogenic bacteria and diseases [6]:

1. ***Streptococcus pneumoniae:*** Causes pneumonia, meningitis, and septicemia, particularly in the elderly and immunocompromised.
2. ***Mycobacterium tuberculosis:*** Causes tuberculosis, primarily affecting the lungs, and can become resistant to antibiotics.
3. ***Escherichia coli (E. coli):*** While most strains are harmless, pathogenic strains like *E. coli* O157 can cause food poisoning and severe gastrointestinal infections.

4. ***Vibrio cholerae***: Causes cholera, leading to severe diarrhoea and dehydration, which can be life-threatening without treatment.
5. ***Salmonella spp.***: Responsible for foodborne illnesses and typhoid fever.

Impact of Bacterial Pathogens

- ***Human Health***: Pathogenic bacteria are responsible for a range of diseases, from mild infections like strep throat to life-threatening conditions such as meningitis and sepsis. They are also a leading cause of hospital-acquired infections [7].
- ***Antibiotic Resistance***: Pathogens that have become resistant to antibiotics (e.g., MRSA, CRE) are increasingly difficult to treat, posing a serious global health challenge.
- ***Economic Burden***: The cost of treating bacterial infections, especially drug-resistant ones, significantly burdens healthcare systems. This is particularly critical in low-resource settings, where access to effective antibiotics is limited.

Bacteria as pathogens demonstrate the complexity of their interaction with hosts, ranging from commensal organisms to harmful invaders that can significantly impact health and survival.

Financial limitations often impede the low-income government's capacity to adequately address the antimicrobial resistance (AMR) challenge [8]. Funding is necessary for research, monitoring, and the development of new antibiotics to address AMR, yet these initiatives come at a significant financial cost. The underfunding of healthcare systems is exacerbated when antimicrobial resistance (AMR) is not controlled, leading to a vicious cycle of underinvestment in AMR [9].

EMERGENCE OF ANTIBACTERIAL RESISTANCE (ABR)

- **Global Spread**: Antibacterial resistance (ABR) is becoming increasingly common across the world, affecting both developed and developing countries [10].
- **Multidrug-Resistant Organisms (MDROs)**: Multidrug-resistant organisms (MDROs) pose a significant healthcare challenge because they resist common and even powerful antibiotics, making infections harder and more expensive to treat. Hospitals throughout the globe are now facing grave risks from Methicillin-Resistant *Staphylococcus Aureus* (MRSA) and Carbapenem-Resistant Enterobacteriaceae (CRE) [10].

SUBJECT INDEX

A

Acinetobacter baumannii 14, 168
 Active compounds 4, 5, 6, 7, 15, 21, 23
 Adenine base editors (ABEs) 57, 123
 Adeno-associated virus (AAV) 53
 Adherence 14, 138, 145, 148, 149, 155
 Adverse drug reactions (ADRs) 99, 151, 153
 Advancements 63, 64, 81, 82, 116, 117, 123, 124, 127, 131, 152, 155
 Aeromonas hydrophila 14
 Agonists 39, 42, 46
 Agricultural misuse 169
 Algorithms 86, 139, 140, 146, 147, 149, 151, 152, 154
 Alkaloids 1, 5, 6, 7, 8, 9, 13, 18
 Allicin 7
 Allium sativum 5, 7, 23
 Amino acids 55, 89
 Aminoglycosides 178
 Antimicrobial peptides (AMPs) 42, 73, 80, 88, 89, 90, 104, 110, 112, 114, 116, 156, 157
 Antimicrobial resistance (AMR) 74, 75, 83, 87, 100, 101, 136, 162, 164, 165, 166, 168, 169, 170, 171, 173, 179, 182, 183, 187
 Antibiotic resistance genes (ARGs) 14, 93, 126
 Antibiotic stewardship programs (ASPs) 136, 143, 144, 146, 148, 149, 150, 151, 152, 153, 155, 157
 Antibiotic susceptibility 84
 Antibodies 39, 47, 83, 183
 Antigens 90, 95
 Antimicrobials 5, 12, 89, 93, 94, 109, 112, 155, 162, 170, 172
 Aquifex aeolicus 128
 Artificial intelligence 115, 149, 152, 157

B

Bacillus cereus 15, 19
 Bacillus subtilis 7, 11, 23
 Bacterial cell membranes 7, 8, 9, 13, 14, 15, 16, 17, 62, 89
 Bacterial genomes 65, 79, 82, 83, 115, 123
 Bacterial pathogenicity 163
 Bactericidal 15, 88
 Bacteriophages 45, 79, 90, 91, 92, 110, 114, 130, 183
 Bacteriostatic 88
 Berberine 7, 9, 11, 18, 19, 21, 25
 Bioavailability 24
 Biocompatibility 61, 62
 Biofilm formation 7, 8, 10, 14, 15, 17, 18, 19, 104, 111, 163
 Biomarkers 84, 96
 Biosensors 82, 83, 84, 85, 104

C

Campylobacter jejuni 126, 129
 Cancer therapy 43, 44, 60, 165, 167
 Carbapenem-resistant Enterobacteriaceae (CRE) 76, 77, 164
 Carvacrol 7, 9, 13, 14, 15, 19, 23
 Cas9 nucleases 56, 129
 Cas12a 52, 129
 Cationic nanoparticle 62
 Chromatography 6
 Ciprofloxacin 16, 17, 19, 20, 25
 Clinical decision support systems (CDSS) 139, 148, 149, 151, 153, 155
 Clinical trials 13, 21, 22, 23, 26, 42, 91, 105, 106, 107, 175
 Clostridioides difficile 77
 CRISPR-Cas systems 52, 53, 54, 73, 92, 93, 123, 124, 125, 126, 127, 130, 131
 Curcumin 7, 11, 14, 19
 Cytokines 39, 40, 41
 Cytosine base editors (CBEs) 57, 123

D

Data analysis 86, 157
Datasets 115, 136, 146, 149, 154, 155
Diagnostic technologies 81, 83, 104
DNA 11, 53, 55, 57, 58, 59, 63, 99, 123, 128, 129
Double-strand break (DSBs) 52, 53, 55, 56, 57, 63, 123, 127, 128
Drug resistance 22, 61, 113, 125, 126, 130, 162
Dysbiosis 43

E

Electronic health records (EHRs) 140, 144, 146, 147, 149, 150, 151, 155
Efflux pump inhibitors (EPIs) 126
Efflux pumps (EP) 2, 8, 10, 18, 111
Electrochemical gradients 156
Endonucleases 124
Epigallocatechin gallate (EGCG) 8, 10, 11, 16, 17
Escherichia coli 7, 8, 10, 14, 17, 53, 75, 126, 163, 168

F

Fecal microbiota transplantation (FMT) 43, 46
Flavonoids 1, 6, 7, 9, 13, 19, 20, 23
Fluconazole 61

G

Genome editing 52, 55, 123, 124, 127, 129
Genomic modification 53
Global antimicrobial resistance and use surveillance system (GLASS) 168

H

Helicobacter pylori 7, 8, 14, 20
High-performance liquid chromatography (HPLC) 21
Horizontal gene transfer (HGT) 76, 111, 125, 130
Host defense peptides (HDPs) 39, 42, 126

I

Immunomodulation 39, 40, 41, 45
Immunotherapy 111, 130
Inpatient prospective payment system (IPPS) 107

K

Klebsiella pneumoniae 8, 9, 16, 20, 42, 53, 75, 168

L

Lab-on-a-chip (LOC) 83, 84
Listeria monocytogenes 8, 14, 15, 19

M

Mesenchymal stem cells (MSCs) 45
Methicillin-resistant Staphylococcus aureus (MRSA) 15, 17, 20, 62, 74, 76, 77, 114, 130, 164, 168, 178, 184
Mycobacterium tuberculosis 76, 77, 163

N

Nanotechnology 24, 26, 58, 73, 80, 82, 93, 94, 95, 113, 115
Natural language processing (NLP) 136, 139, 147, 148, 149, 155, 157
Next-generation sequencing (NGS) 73, 79, 81, 82, 113, 116

O

Origanum vulgare 9

P

Pattern recognition receptor (PRRs) 46
Peptide nucleic acids (PNAs) 58
Pharmacogenomics 80, 96, 97, 98
Pharmacokinetics 95, 97, 98
Protospacer adjacent motif (PAM) 54, 57, 128, 129
Pseudomonas aeruginosa 7, 8, 9, 10, 14, 15, 16, 17, 19, 20, 53

Q

Quorum sensing (QS) 8, 10, 14, 15, 16, 17,
111, 126

R

Reactive oxygen species (ROS) 11, 61, 62,
113

Rosmarinus officinalis 7, 23, 25

S

Salmonella typhimurium 7, 8, 19

Single-nucleotide polymorphism (SNP) 97

Staphylococcus aureus 7, 8, 9, 10, 11, 14, 18,
19, 20, 41, 42

Streptococcus pneumoniae 44, 53, 75, 163,
168

T

Terpenoids 1, 6, 7, 8, 9, 13, 19, 20, 25

Toll-like receptors (TLRs) 42, 46

Transcription activator-like effector nucleases
(TALENs) 63, 124

V

Vibrio cholerae 164

X

Xenotransplantation 58

Z

Zinc finger nucleases (ZFNs) 53, 55, 56, 63,
124



Mukesh Kumar Singh

Dr. Mukesh Kumar Singh is an Associate Professor at the School of Pharmaceutical Sciences, Faculty of Pharmacy, IFTM University, Moradabad, Uttar Pradesh, India. He holds an M.Pharm. in Pharmaceutical Biotechnology from SRM College of Pharmacy, SRM Institute of Science and Technology, and a Ph.D. in Pharmaceutical Sciences from CSVTU, Bhilai. With over 16 years of experience in pharmaceutical education and research, he has published 55+ research and review papers, 10 book chapters with leading publishers, and 10 patents. He has guided numerous doctoral and postgraduate students and is a member of the Association of Pharmaceutical Teachers of India. Dr. Singh also serves as an active reviewer for national and international journals.



Gurdeep Singh

Dr. Gurdeep Singh is a Professor at the School of Pharmaceutical Sciences, Lovely Professional University, Phagwara, Punjab, with over 16 years of academic and research experience. He holds a B.Pharm., M.Pharm. in Pharmaceutical Chemistry, and Ph.D. in Pharmaceutical Sciences from reputed Indian institutions. He has successfully guided over 30 M.Pharm. and 7 Ph.D. scholars and has published more than 65 research and review articles in national and international peer-reviewed journals. Dr. Singh holds five patents, is the author of Biostatistics and Research Methodology, and has contributed book chapters to publishers including Bentham, Elsevier, Wiley, and Springer. A recipient of the Young Scientist Award and Dynamic Professional Award, he is a life member of APTI and IPGA. His research interests focus on the design and synthesis of novel antidiabetic and anticancer agents.



Amrendra Pratap Yadav

Dr. Amrendra Pratap Yadav is a Professor at Meerut Institute of Technology, Meerut, Uttar Pradesh, India, with 16 years of experience in pharmaceutical education and research. He holds B.Pharm., M.Pharm., PGDCA, and Ph.D. degrees and qualified GPAT-2013. He is a life member of the Association of Pharmaceutical Teachers of India (APTI) and the Indian Pharmaceutical Association (IPA). His research interests include pharmaceutical biotechnology and the development of novel drug delivery systems. Dr. Yadav has published 16 research articles, contributed three book chapters, and holds two patents. He has presented his work at numerous national and international conferences. His contributions to academia have been recognized with the Best Teacher Award (2015) and the Inspirational Associate Professor Award (2021). He has successfully supervised two Ph.D. scholars.



Papiya Bigoniya

Dr. Papiya Bigoniya is a Certified Toxicologist and Fellow of the Academy of Toxicological Sciences (ATS, USA), with over 28 years of experience in academia, research, and regulatory consultancy. She holds a PhD in Pharmaceutical Sciences, along with advanced qualifications in Pharmacology, Cancer Biology, Public Health, and Pharmaceutical Management. Dr. Bigoniya has authored over 130 peer-reviewed publications, delivered more than 50 expert lectures, and received numerous national and international awards for her contributions to drug safety, toxicology, and pharmacovigilance. Her expertise in regulatory guidelines, including ICH and GCP, makes her a respected researcher, trainer, and consultant in pharmaceutical sciences.