Animal Health Research Journal Vol. 9, No. 2, December 2024 pp. 64-68

ISSN: 2356-7767

# Bacterial resistance to antibiotics: Why it occurs and different ways to solve it

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**Review Article**
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Received in 4/11/2024
Accepted in 22/12/2024

**Abstract**
The challenge of antimicrobial resistance (AMR) is indeed a pressing global health concern. The World Health Organization (WHO) has outlined 40 research priorities to address this issue, emphasizing the need for innovative and effective strategies to combat drug-resistant pathogens. These priorities include understanding the epidemiology and burden of AMR, developing new diagnostic tests, and improving treatment regimens. Additionally, the emergence of AMR has significant economic implications, with potential healthcare costs. This underscores the urgency of addressing AMR through comprehensive research, policy-making, and the implementation of effective interventions, particularly in resource-limited settings.

***Keywords:*** *Bacterial resistance, antibiotics, antimicrobial resistance.*

## Introduction
Antibiotics are used to treat bacterial infections by either killing or inhibiting their growth. Antimicrobial agents are classically grouped into two main categories based on their in-vitro effect on bacteria either bactericidal or bacteriostatic. Antimicrobial agents are divided into two main groups according to their mode of action, either bactericidal or bacteriostatic. Bactericidal antibiotics kill bacteria and bacteriostatic antibiotics inhibit its growth. Each class of antibiotics targets specific bacterial processes, making them effective against different types of bacterial infections. It's important to use antibiotics as prescribed to avoid resistance and ensure their effectiveness **Pankey and Sabath, (2004).**

**Types of Antibiotics** Nemeth ***et al.,*** **(2015):**
**1. Bacteriostatic antibiotics:**
Bacteriostatic antibiotics inhibit the growth and reproduction of bacteria, giving the immune system time to eliminate the infection. Examples include tigecycline, which is a glycylcycline, and doxycycline, a member of the tetracyclines. Clindamycin and erythromycin fall under lincosamides and macrolides, respectively, both of which are effective against a variety of infections. Linezolid and sulfamethoxazole represent oxazolidinones and sulfonamides, known for their broad-spectrum activity.

**2.Bactericidal antibiotics:**
On the other hand, bactericidal antibiotics kill bacteria directly. This category includes aminoglycosides like gentamicin, which are particularly effective against aerobic gram-negative bacteria. The beta-lactams, such as penicillins, cephalosporins, and carbapenems, with drugs like amoxicillin, are widely used due to their efficacy and safety profile. Fluoroquinolones, glycopeptides, cyclic lipopeptides, and nitroimidazoles, with drugs like levofloxacin, vancomycin, daptomycin, and metronidazole, respectively, offer targeted action against specific bacteria, making them valuable in treating various infections.

**Bacterial resistance to antibiotics:**
The phenomenon of antimicrobial resistance is a formidable challenge in modern medicine, caused by the widespread use of antibiotics in healthcare and agriculture. This resistance arises as bacteria evolve mechanisms to evade the lethal action of these drugs, ensuring their survival. The Minimum Inhibitory Concentration (MIC) is a critical parameter that quantifies the extent of this resistance, indicating the lowest concentration of an antibiotic that can prevent bacterial growth **Brauner *et al.,* (2016)**. When the MIC exceeds established thresholds, it signals a resistant infection, necessitating alternative therapeutic strategies. Bacterial resistance can be intrinsic, where the bacterium naturally lacks the target of the antibiotic, or acquired, through genetic mutations or the acquisition of resistance genes, which can drastically reduce the effectiveness of antibiotics **Chen *et al.*, (2009).**

The battle between bacterial adaptation and antibiotic efficacy is complex, involving various resistance mechanisms. These include limiting the drug's entry into the bacterial cell, altering the drug's target site, enzymatically deactivating the drug, and actively pumping the drug out of the cell. Gram-negative bacteria, with their unique outer membrane and sophisticated efflux pumps, can employ all these mechanisms. In contrast, gram-positive bacteria, lacking certain structural components such as the Lipopolysaccharide (LPS) outer membrane, are less likely to restrict drug uptake but may still utilize other resistance strategies **Chancey *et al.,* (2012); Mahon *et al.,* (2014).**
Antibiotic resistance is a significant public health concern, but by using antibiotics responsibly, we can help mitigate its impact. Avoiding antibiotic resistance is crucial for maintaining the effectiveness of these vital medications. This goal can be achieved by following some strategies (figure 1):


**Figure (1).** How to avoid antibiotic resistance

1. Use antibiotics only when necessary.
2. Complete the full course.
3. Avoid infections.
4. Monitor and track resistance
5. Raising awareness about antibiotic resistance**.**
6. Support research: by investing in research and development of new antibiotics and alternative treatments: explore alternative treatments and preventive measures, such as probiotics and vaccines (Centers for Disease Control and Prevention, 2024; Richardson, 2017).

Antibiotic resistance has profound implications for global health**.** Resistant infections are harder to treat, leading to increasing the risk of complications or higher mortality rates **World Health Organization, (2023); Centers for Disease Control and Prevention, (2024); Richardson, (2017).**

There are several alternative treatments to antibiotics that are being explored to combat infections and reduce the reliance on traditional antibiotics such as:

**Bacteriophage therapy**: it uses viruses that specifically infect and kill bacteria **without harming beneficial microbes Abedon *et al.,* (2011)**.

**Probiotics**: which consists of **l**ive useful bacteria that can help regain the natural balance of the gut microbiota. They can prevent and treat infections by outcompeting harmful bacteria **Gaggia *et al.,* (2010).**

**Immunotherapy**: it enhances the body's immune response to fight infections. It includes treatments like monoclonal antibodies and vaccines that can target specific pathogens **Molineux, (2004).**

**Antimicrobial Peptides (AMPs)**: it consists of short proteins that can kill bacteria by disrupting their cell membranes**. They have a broad spectrum of activity and are less likely to induce resistance Huan *et al.,* (2020).**

**Natural Antimicrobials** as garlic and onion have been shown to possess antibacterial properties and can be used as complementary treatments **Quinto *et al.*, (2019).**

**Quorum Sensing Inhibitors are** compounds that disrupt bacterial communication (quorum sensing), which is essential for biofilm formation and virulence. They can prevent bacteria from coordinating attacks and forming protective biofilms **Vashistha *et al.,* (2023).**

**Fecal Microbiota Transplantation: which is t**ransplanting stool from a healthy donor to a patient to restore healthy gut bacteria. This method is effective in reating recurrent *Clostridium difficile* infections **Wang *et al.,* (2019).**

These alternatives are still under research and development, but they hold promise for reducing the reliance on traditional antibiotics and combating antibiotic resistance.

By taking these steps, we can help preserve the effectiveness of antibiotics and protect public health.

## Conclusion

The adaptability of bacteria to withstand toxic substances and their ability to defend against antimicrobial agents is a testament to their evolutionary success. However, this resilience poses significant challenges in treating bacterial infections, especially with the rise of antimicrobial resistance (AMR). The WHO has acknowledged AMR as a critical threat to global health, prompting a call for innovative research and the development of new strategies to combat these pathogens.

Natural substances are being explored for their potential in this fight, with garlic and onion showing promise due to their antibacterial properties. These natural compounds contain active ingredients that have been effective against multi-drug resistant bacteria and could serve as a blueprint for future antibiotics.

As the search for solutions continues, it is clear that a multifaceted approach, including the exploration of nature's pharmacopeia, will be essential in addressing the complex issue of AMR. Combating AMR will require not only scientific innovation but also global collaboration and a commitment to sustainable practices that prevent the emergence and spread of resistance.

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