

Anti-Microbial Resistance – A Comprehensive Review

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ABSTRACT

Antimicrobial Resistance (AMR) is a major health threat caused by overuse of antibiotics in humans, animals, and agriculture. Resistant microbes survive through mutations and biofilms, making infections hard to treat and increasing deaths and costs. AI and a One Health approach with surveillance, stewardship, and public awareness are key to controlling AMR by 2050. AMR is mainly caused by the misuse and overuse of antibiotics in humans, animals, and agriculture. Preventing AMR requires infection control, antimicrobial stewardship, surveillance, development of new therapies, and global cooperation. Artificial intelligence is also helping improve diagnosis, surveillance, and the discovery of new antibiotics. Antimicrobial resistance (AMR) occurs when germs like bacteria, viruses, fungi, and parasites change and stop responding to medicines. This makes infections harder to treat, raises the risk of severe illness, and causes millions of deaths worldwide.

KEY WORDS

Pseudomonas aeruginosa; alternative therapeutics; antibiotic resistance; new antibiotics; resistance mechanisms.

INTRODUCTION

Antimicrobial peptides (AMPs) are small, naturally occurring molecules that are an important part of the innate immune system in almost all living organisms [1]. They exhibit broad-spectrum activity against bacteria, fungi, viruses, and parasites, including many antibiotic-resistant strains [2]. Due to their unique mechanism of action and low potential for developing resistance, AMPs are considered promising alternatives to conventional antibiotics [3]. have gained significant attention for therapeutic applications [4] There is evidence for increased resistance against the antimicrobials used to treat keratitis [5]. This review aims to provide global and regional prevalence estimates of antimicrobial resistance in corneal isolates and the range of minimum inhibitory concentrations (MIC) with their associated resistance breakpoints [6].



Figure 1: Antibiotic resistance

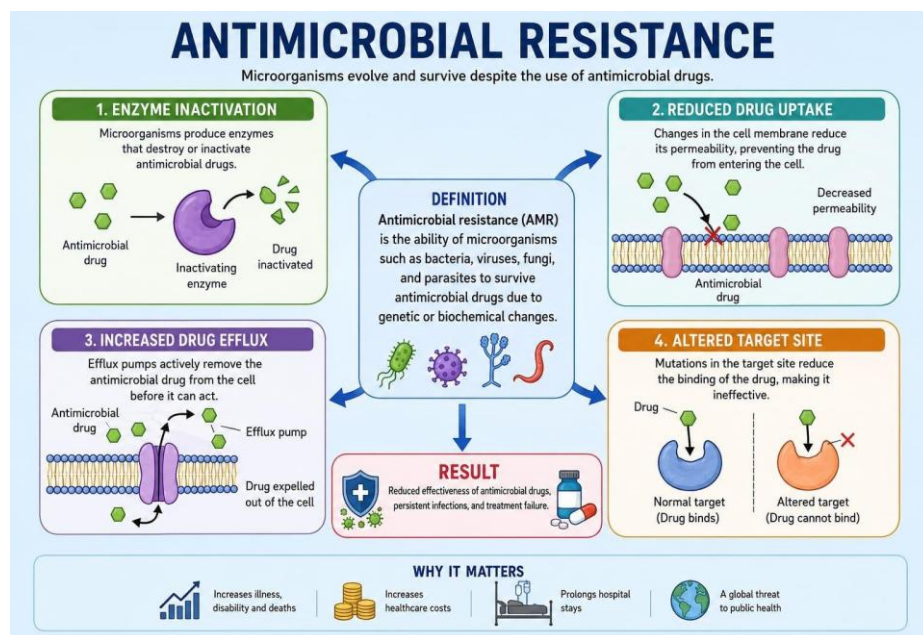


Figure 2: Occurrence Antimicrobial Resistance occurs

DEFINITION AND OVERVIEW OF ANTIMICROBIAL RESISTANCE

Antimicrobial resistance (AMR) happens when germs like bacteria, viruses, fungi, and parasites change and stop responding to the medicines designed to kill them. As a result, standard medical treatments become ineffective, making routine infections harder to cure and increasing the risk of severe illness or death [7].



Figure 3: overview of Antimicrobial Resistance

HISTORY AND EVOLUTION OF ANTIMICROBIAL RESISTANCE

Antimicrobial resistance (AMR) emerged soon after the introduction of antibiotics, with resistant bacteria reported in the 1940s. The misuse and overuse of antibiotics accelerated the spread of resistant microorganisms. Today, AMR is a major global public health threat, reducing the effectiveness of life-saving antimicrobial drugs [8].

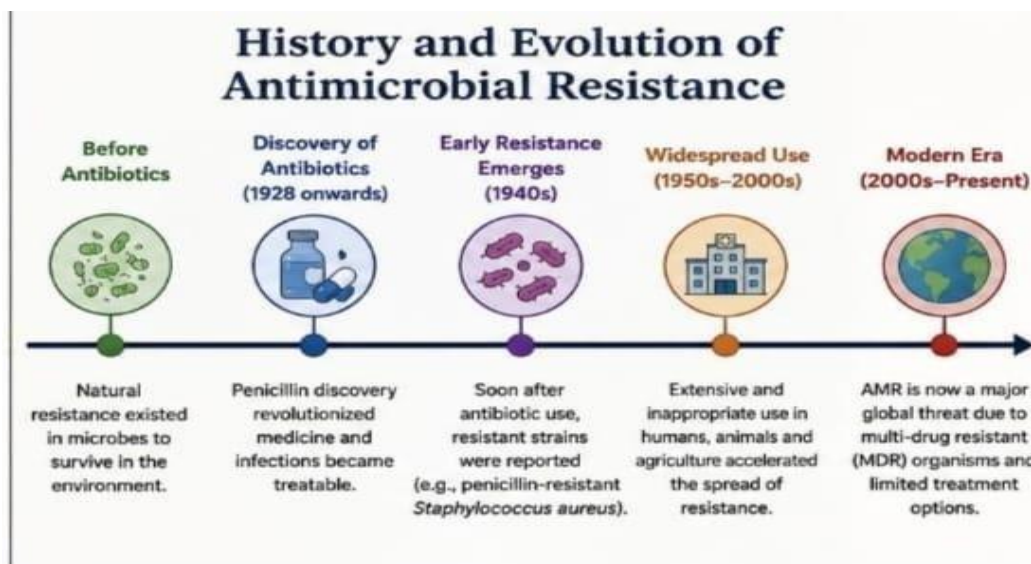


Figure 4: History of Antimicrobial Resistance

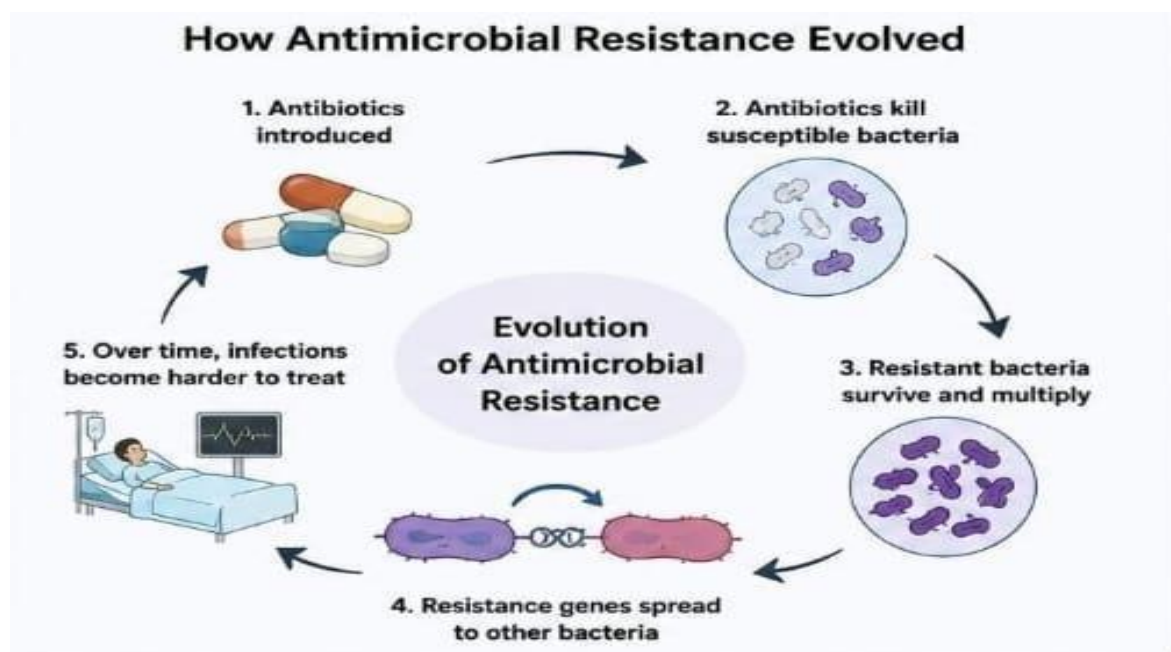


Figure 5: Evolution of Antimicrobial Resistance

TYPES OF ANTIMICROBIAL RESISTANCE

- Intrinsic Resistance: Natural resistance present in bacteria without prior antibiotic exposure.
- Acquired Resistance: Resistance developed through gene mutation or transfer after antibiotic exposure.
- Adaptive Resistance: Temporary resistance that occurs in response to environmental stress or antibiotics [9].

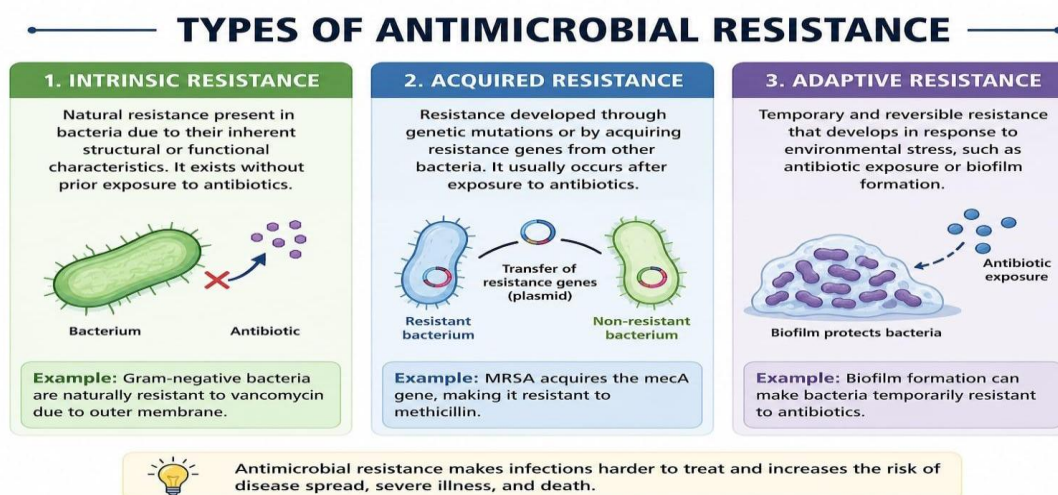


Figure 6: Types of Antimicrobial resistance

MECHANISM OF ACTION

The use of antimicrobial agents in food animals creates selection pressure, allowing resistant bacteria to survive while susceptible bacteria are eliminated. These resistant bacteria or their resistance genes can spread to humans through contaminated food, direct animal contact, or the environment, leading to antimicrobial-resistant infections [10].

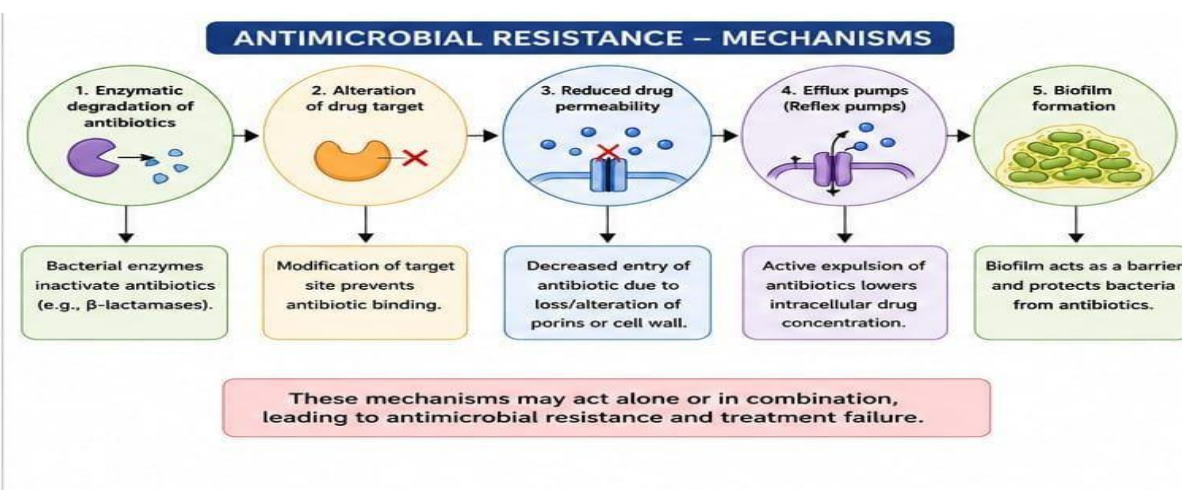


Figure 7: Mechanism of Antimicrobial Resistance

Causes and Risk Factors

- Overuse and misuse of antibiotics are the main causes of AMR.
- Poor infection control and self-medication increase resistance.
- AMR makes infections difficult to treat.
- It leads to longer hospital stays and higher healthcare costs.
- It increases the risk of severe illness and death [11].

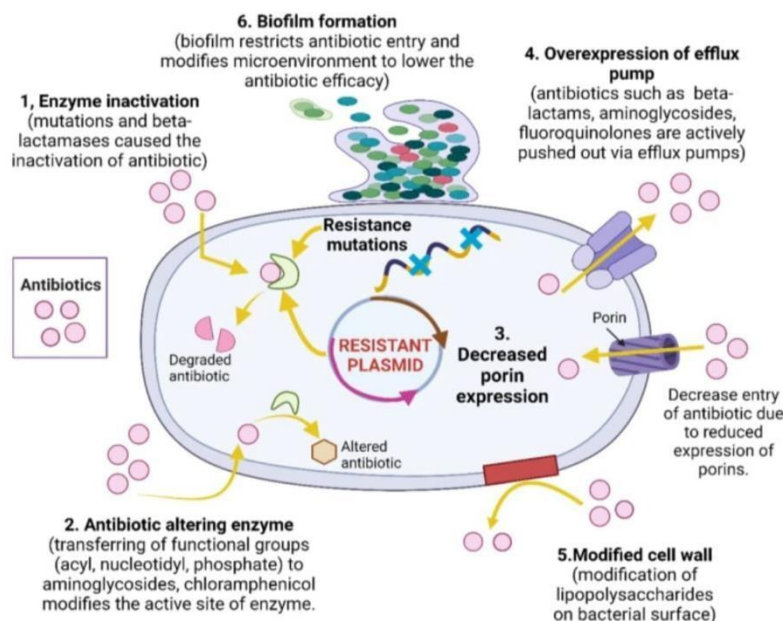


Figure 8: Causes of Antimicrobial Resistance

MAJOR RESISTANT PATHOGENS

- VRE – Resistant to vancomycin.
- ESBL-producing bacteria – Resist many β -lactam antibiotics.
- CRE – Resistant to carbapenem antibiotics.
- MDR *Pseudomonas aeruginosa* – Resistant to multiple drugs.
- *Clostridioides difficile* – Causes antibiotic-associated infections [12].

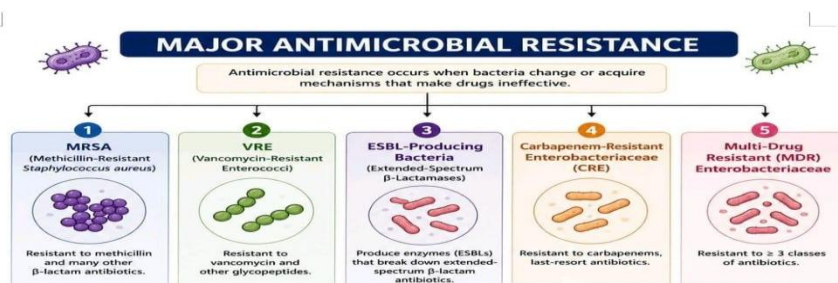


Figure 9: Major resistant pathogens

CLINICAL IMPACT OF AMR

- Increases illness and deaths.
- Prolongs hospital stays.
- Raises healthcare costs.
- Makes antibiotics less effective [13].

DIAGNOSIS AND DETECTION OF AMR

- Spontaneous reporting (Yellow Card)
- Active surveillance (Hospital monitoring, follow-up)
- Cohort studies
- Case-control studies

- Electronic health record (EHR)/Database monitoring [14]

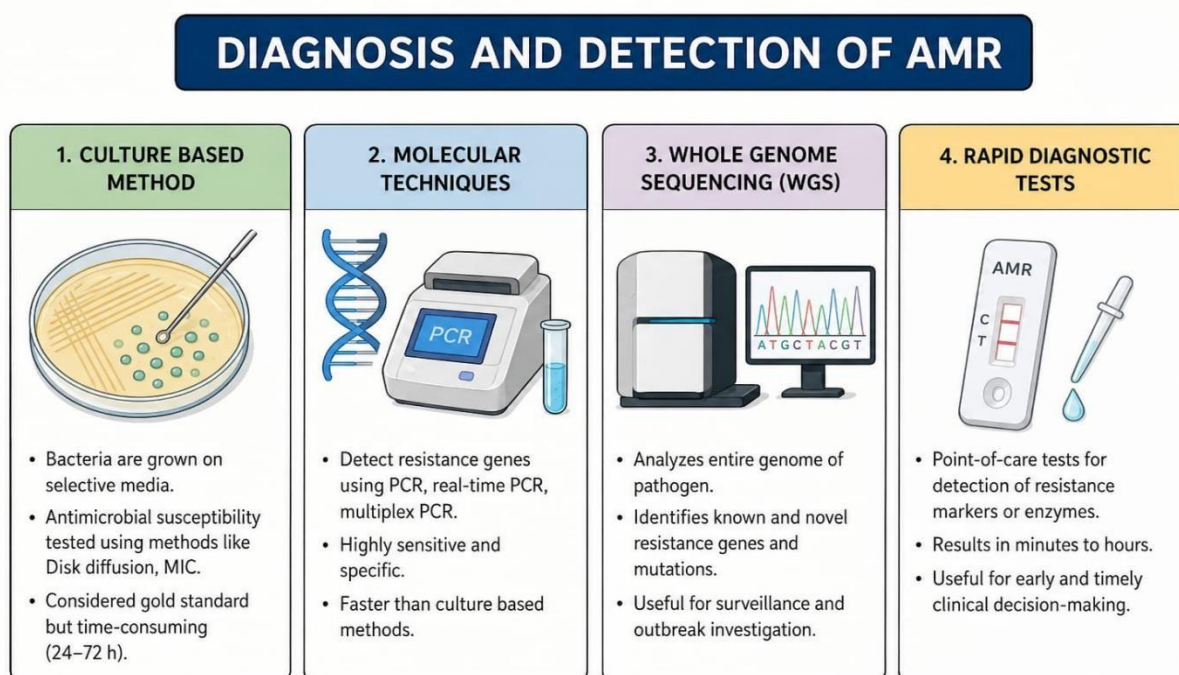


Figure 10: Diagnosis and Detection

CURRENT TREATMENT STRATEGIES

- Antimicrobial stewardship – Promotes the appropriate use of antibiotics.
- Targeted therapy – Uses culture and sensitivity tests to choose the right antibiotic.
- Combination therapy – Combines two or more antibiotics for resistant infections.
- New antibiotics – Uses newer or last-resort drugs for multidrug-resistant bacteria.
- Infection prevention – Vaccination, hygiene, and infection control help reduce AMR [15].

NOVEL THERAPEUTIC APPROACHES FOR AMR

- Bacteriophage therapy: Uses viruses to kill antibiotic-resistant bacteria.
- Antimicrobial peptides (AMPs): Natural molecules that destroy bacterial cell membranes.
- CRISPR-Cas technology: Targets and removes antibiotic resistance genes.
- Nanotechnology: Improves antibiotic delivery and enhances drug effectiveness.
- Monoclonal antibodies: Boost the immune system to fight bacterial infections [16]

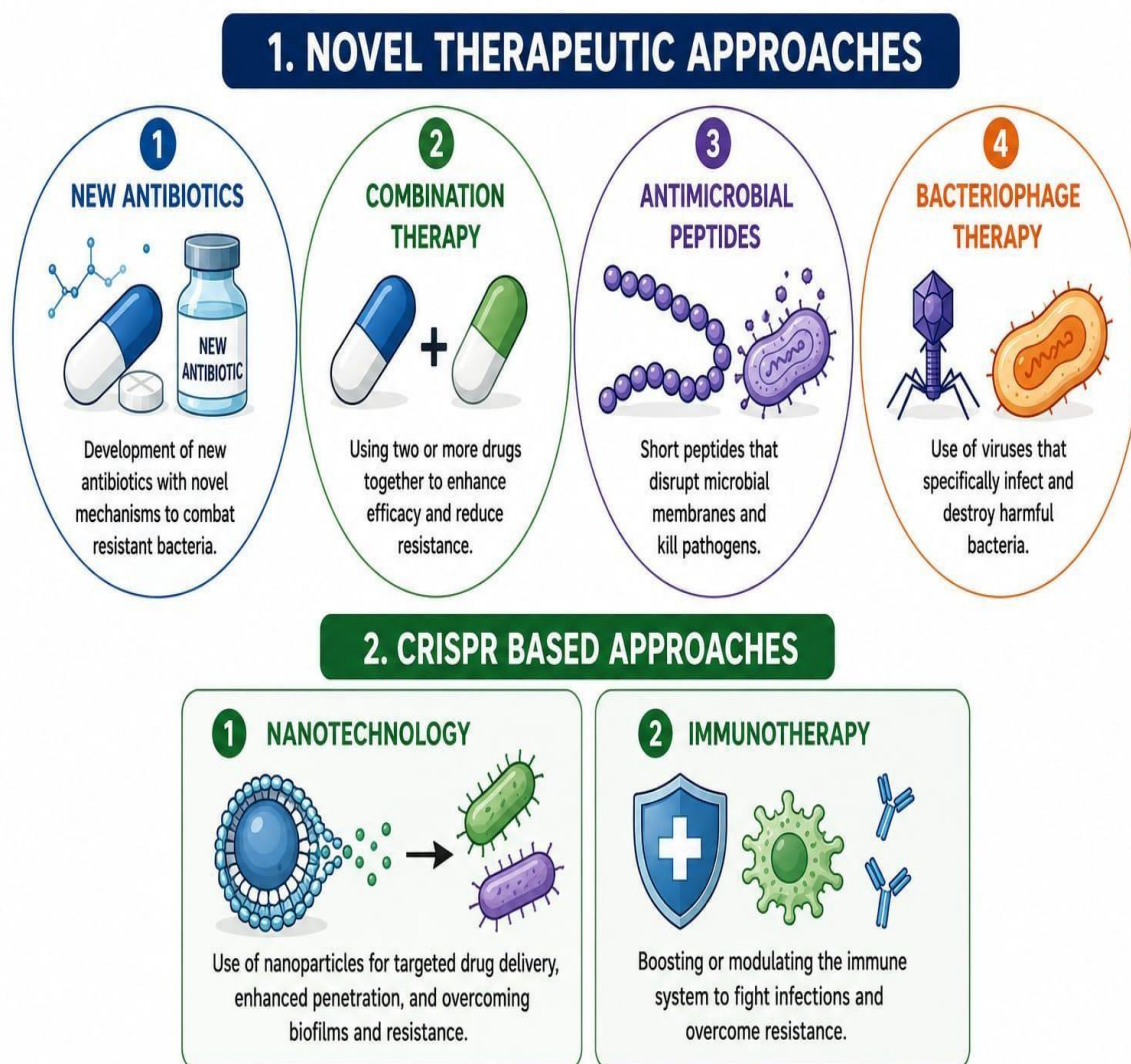


Figure 11: Novel therapeutic Approaches

ARTIFICIAL INTELLIGENCE (AI) AND PRECISION MEDICINE

Artificial intelligence (AI) and precision medicine improve the management of antimicrobial resistance (AMR) by enabling rapid detection of resistant pathogens, predicting antibiotic resistance patterns, and helping clinicians choose the most effective, patient-specific antibiotic therapy. These approaches support antimicrobial stewardship and aid in the development of new antimicrobial drugs [17]

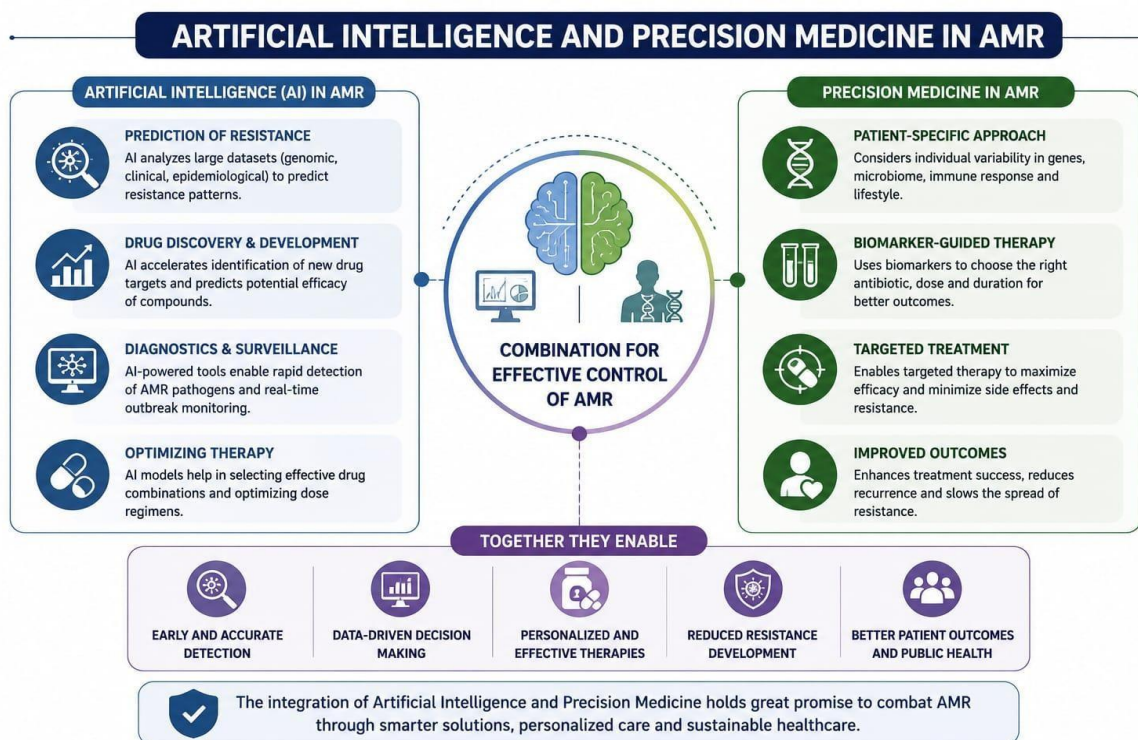


Figure 12: Artificial Intelligence in Antimicrobial Resistance

CHALLENGES AND LIMITATIONS.

- Slow diagnostic methods
- Global spread of resistant organisms
- Poor surveillance in low-resource settings
- Inappropriate antimicrobial use in agriculture
- Economic barriers • Weak antimicrobial stewardship [18]

FUTURE PERSPECTIVES

- AI-based diagnostics for faster and more accurate detection of resistant pathogens.
- Development of novel antibiotics to combat multidrug-resistant microorganisms.
- Precision medicine for personalized antimicrobial treatment based on patient and pathogen data.
- Advanced vaccines to reduce infections and decrease antibiotic use [19]

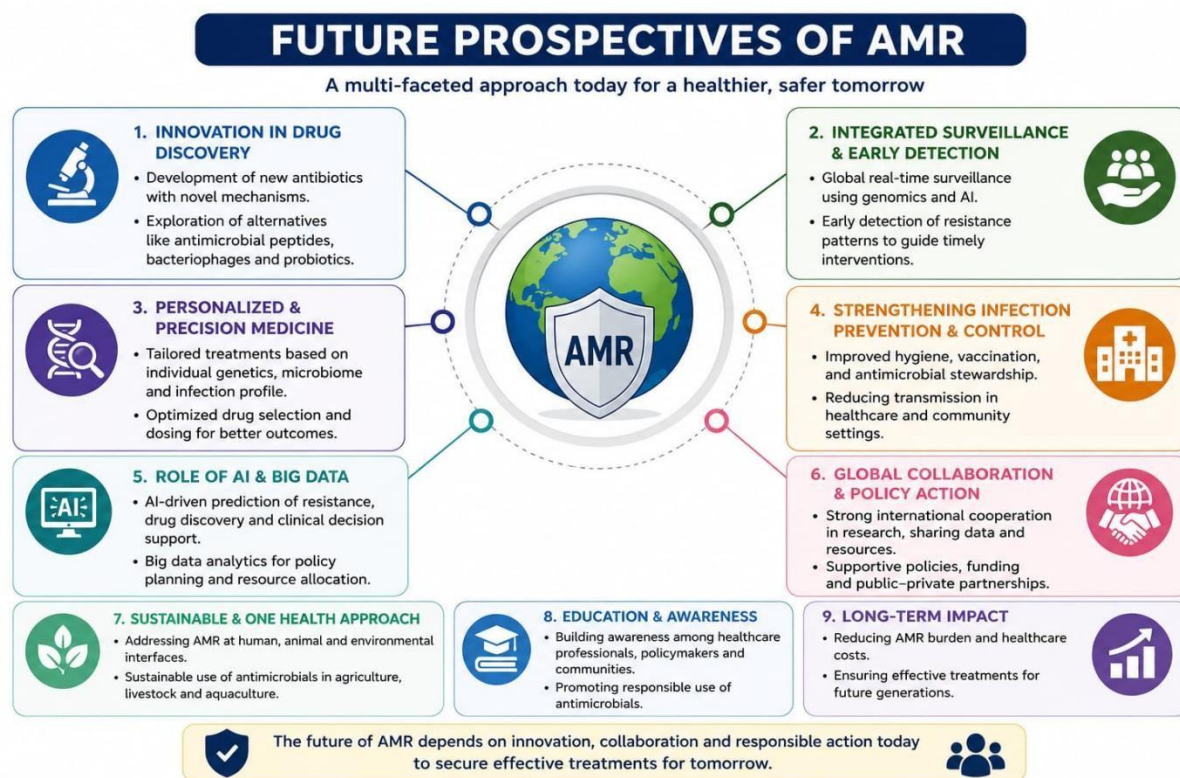


Figure 13: Future perspectives

CONCLUSION

Antimicrobial resistance (AMR) is a major global public health threat. It reduces the effectiveness of antibiotics and makes infections harder to treat. The rapid spread of multidrug-resistant pathogens increases illness, death, and healthcare costs. Early diagnosis and appropriate antimicrobial use are essential to control resistance. Advances in molecular diagnostics, artificial intelligence, and novel therapies offer promising solutions. Antimicrobial stewardship and continuous surveillance are critical for preventing AMR. Global cooperation and public awareness are also necessary to combat resistance. A combined effort in research, policy, and healthcare is essential to protect the effectiveness of antimicrobials for future generations [20].

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