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PHARMACOLOGY

The four main mechanisms by which antimicrobes exhibit resistance are:

1. Drug inactivation or modification: for example, enzymatic deactivation of *[penicillin](https://en.wikipedia.org/wiki/Penicillin" \o "Penicillin)*[G](https://en.wikipedia.org/wiki/Penicillin" \o "Penicillin) in some penicillin-resistant bacteria through the production of [β-lactamases](https://en.wikipedia.org/wiki/Beta-lactamases" \o "Beta-lactamases). Most commonly, the protective enzymes produced by the bacterial cell will add an acetyl or phosphate group to a specific site on the antibiotic, which will reduce its ability to bind to the bacterial ribosomes and disrupt protein synthesis. Alteration of target- or binding site: for example, alteration of [PBP](https://en.wikipedia.org/wiki/Penicillin_binding_protein" \o "Penicillin binding protein)—the binding target site of penicillins—in [MRSA](https://en.wikipedia.org/wiki/Methicillin-resistant_Staphylococcus_aureus" \o "Methicillin-resistant Staphylococcus aureus) and other penicillin-resistant bacteria. Another protective mechanism found among bacterial species is ribosomal protection proteins. These proteins protect the bacterial cell from antibiotics that target the cell's ribosomes to inhibit protein synthesis. The mechanism involves the binding of the ribosomal protection proteins to the ribosomes of the bacterial cell, which in turn changes its conformatioval shape. This allows the ribosomes to continue synthesizing proteins essential to the cell while preventing antibiotics from binding to the ribosome to inhibit protein synthesis.
2. Alteration of metabolic pathway: for example, some [sulfonamide](https://en.wikipedia.org/wiki/Sulfa_drugs" \o "Sulfa drugs)-resistant bacteria do not require [para-aminobenzoic acid](https://en.wikipedia.org/wiki/Para-aminobenzoic_acid" \o "Para-aminobenzoic acid) (PABA), an important precursor for the synthesis of [folic acid](https://en.wikipedia.org/wiki/Folic_acid" \o "Folic acid) and [nucleic acids](https://en.wikipedia.org/wiki/Nucleic_acid" \o "Nucleic acid) in bacteria inhibited by sulfonamides, instead, like mammalian cells, they turn to using preformed folic acid. Reduced drug accumulation: by decreasing drug [permeability](https://en.wikipedia.org/wiki/Semipermeable_membrane" \o "Semipermeable membrane) or increasing active [efflux](https://en.wikipedia.org/wiki/Efflux_(microbiology)" \o "Efflux (microbiology)) (pumping out) of the drugs across the cell surface. These pumps within the cellular membrane of certain bacterial species are used to pump antibiotics out of the cell before they are able to do any damage. They are often activated by a specific substrate associated with an antibiotic. as in [fluoroquinolone](https://en.wikipedia.org/wiki/Fluoroquinolone" \o "Fluoroquinolone) resistance.