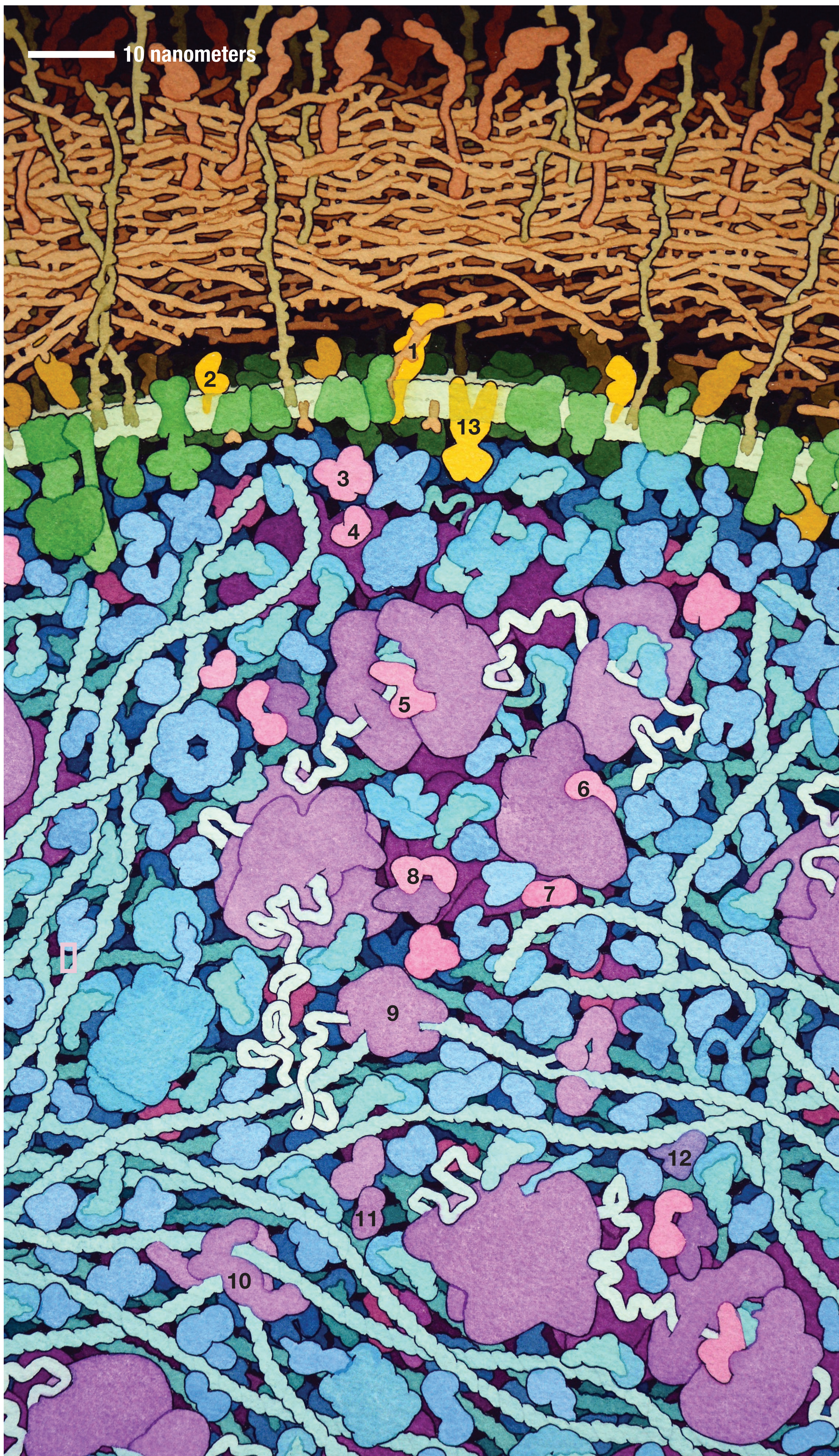
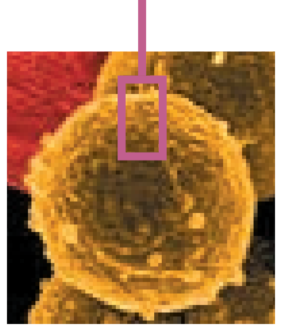
Superbugs! How bacteria evolve resistance to antibiotics

ANTIBIOTICS are one of the miracles of modern medicine, allowing us to fight infections by pathogenic bacteria. Antibiotics attack essential molecular machines in bacteria, stopping or slowing their action, ultimately slowing growth or killing the cell.

RESISTANCE to antibiotics is posing a new danger to our health care. Infections by resistant bacteria are difficult to treat as they evolved proteins that destroy or modify antibiotics, or evade the drugs.

EVOLUTION of resistance is very fast in bacteria as they multiply rapidly to generate large populations. Antibiotics can kill susceptible strains, leaving resistant ones to proliferate.





Scanning electron micrograph of methicillin-resistant *Staphylococcus aureus* by NIAID used under CC BY 2.0

Superbugs such as MRSA (METHICILLIN-RESISTANT *STAPHYLOCOCCUS AUREUS*), shown in full on the EM-scan on the left and in detail in the illustration above, have found ways to evade almost all current antibiotics. Medical researchers are now using protein structures to search for new ways to fight them.

Use the PDB IDs (*e.g.*, 4ox9) to explore the resistance proteins shown in this poster in 3D and access more educational materials about antimicrobial resistance:

RCSB PDB PROTEIN DATA BANK
RCSB.ORG
A Living Digital Data Resource that Enables Scientific Breakthroughs

RCSB PDB-101
PDB101.RCSB.ORG
Molecular Explorations through Biology and Medicine

CELL WALL: essential protective layer composed of a crosslinked network of peptidoglycan chains

BETA-LACTAM ANTIBIOTICS

such as penicillin and methicillin, contain an extremely reactive beta-lactam ring that attacks PBPs (penicillin-binding proteins) that build the cell wall.

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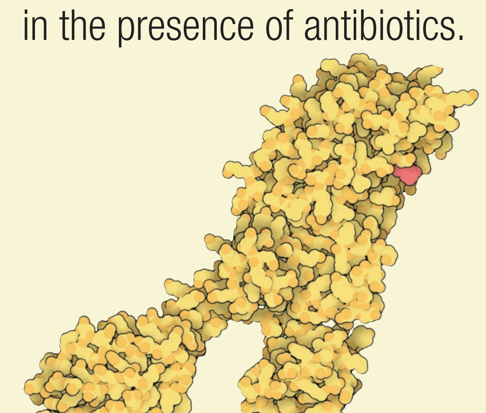
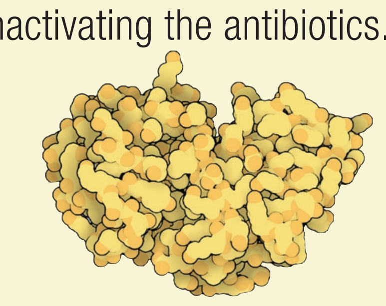
PBP2a is a mutated form of PBP. It binds weakly to beta-lactam antibiotics (red), so it can cross-link the peptidoglycan chains in the presence of antibiotics.



2 1pio

Beta-lactamases break the reactive beta-lactam ring, inactivating the antibiotics.



VANCOMYCIN

sequesters the building blocks of the cell wall so that they can no longer be crosslinked to form a tough protective layer.

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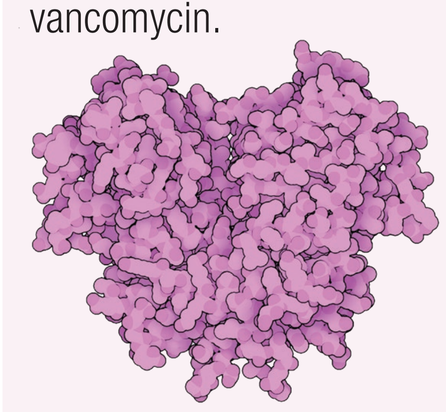
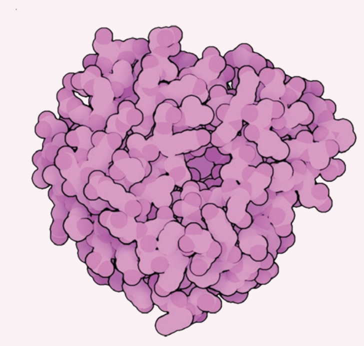
VanA builds the new type of building block that does not bind vancomycin.



4 1r44

VanX breaks down any of the original building blocks.



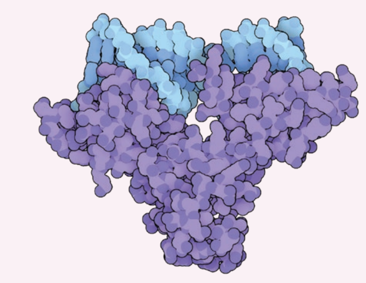
CELL MEMBRANE: filled with protein pumps and enzymes that build the cell wall

DETECTING AND AVERTING DANGER

Cells use REPRESSOR PROTEINS to regulate the genes involved in resistance, so that the proteins are made only when needed.

12 2d45

The **MecI repressor** regulates the gene that encodes PBP2a.



MULTIDRUG RESISTANT TRANSPORTERS

are expressed by bacteria when toxins are detected.

13 2onj

Sav1866 uses a scissor-like motion to transport antibiotics across the cell membrane.

CYTOPLASM: filled with DNA, ribosomes, enzymes, and other proteins key to bacerial life cycle

MACROLIDES and AMINOGLYCOSIDES

attack ribosomes, blocking manufacture of new proteins.

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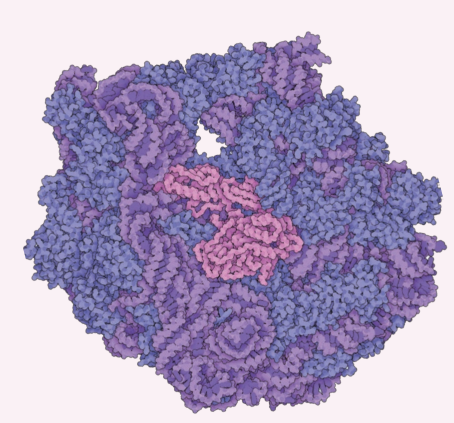
TetM protein displaces the macrolide erythromycin, restoring the ribosome to its normal function.



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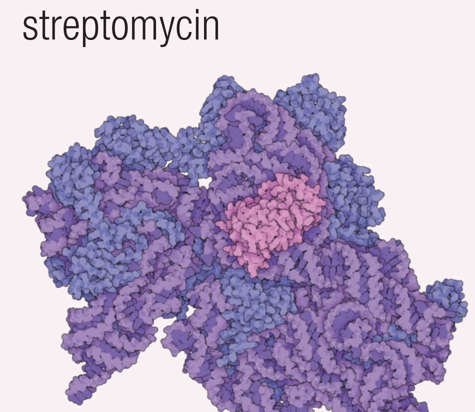
rRNA Methyltransferases modify ribosomal RNA, providing resistance against aminoglycosides like streptomycin



FUSIDIC ACID

glues elongation factor G (EF-G) to ribosomes, stalling protein synthesis.

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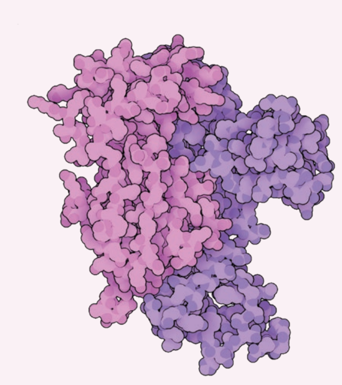
FusB protein binds to EF-G and protects it from fusidic acid.



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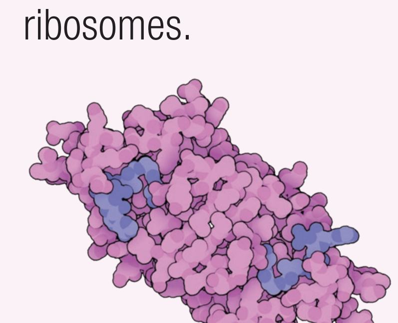
Aminoglycoside acetyltransferases modify antibiotics, making them unable to bind to ribosomes.



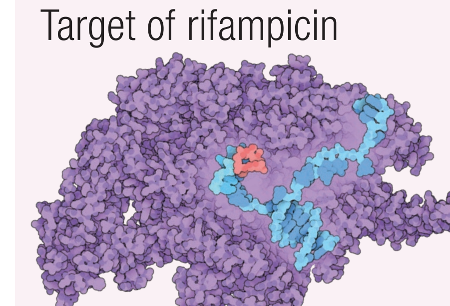
RIFAMPICIN, QUINOLINES and ANTIFOLATES

attack essential enzymes in bacteria.

Resistance occurs through mutations that block the antibiotic binding but allow the enzyme to function.

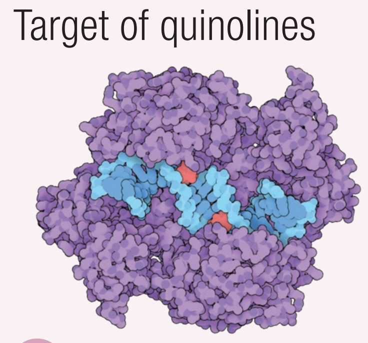
9 5uhc

RNA Polymerase
Target of rifampicin



10 3k9f

Topoisomerase
Target of quinolines



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Dihydrofolate Reductase
Target of antifolates