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.

**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.

1. **1maw**
   - PB2a 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.

3. **1e4e**
   - VanA builds the new type of building block that does not bind vancomycin.

4. **1r44**
   - VanX breaks down any of the original building blocks.

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

**MACROLIDES** and **AMINOLGOSIDES** attack ribosomes, blocking manufacture of new proteins.

5. **3j9y**
   - TetM protein displaces the macrolide erythromycin, restoring the ribosome to its normal function.

6. **4ox9**
   - rRNA Methyltransferases modify ribosomal RNA, providing resistance against aminoglycosides like streptomycin.

7. **1bo4**
   - Aminoglycoside acetyltransferases modify antibiotics, making them unable to bind to ribosomes.

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

8. **2mzw**
   - FusB protein binds to EF-G and protects it from fusidic acid.

**RIFAMPICIN, QUINOLINES** and **ANTIFOLATES** attack essential enzymes in bacteria.

9. **5uhc**
   - RNA Polymerase Target of rifampicin

10. **3k9f**
    - Topoisomerase Target of quinolines

11. **2onj**
    - Dihydrofolate Reductase Target of antifolates

**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 PB2a.

**MULTIDRUG RESISTANT TRANSPORTERS** are expressed by bacteria when toxins are detected.

13. **2qoj**
    - Sav1866 uses a scissor-like motion to transport antibiotics across the cell membrane.

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

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

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

**TARGETS** of these antibiotics include essential enzymes and proteins involved in the bacterial life cycle.

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.