How Do **DRUGS** Work?  
**Examples from the PDB archive**

PROTEINS are tiny molecular machines that perform most of the tasks needed to keep cells alive. These machines are far too small to see, so you might imagine that it is impossible to affect their action. However, drugs can be used to turn proteins on or off. **DRUGS** are small molecules that bind to proteins and modify their actions. Some very powerful drugs, such as antibiotics or anticancer drugs, are used to completely disable a critical molecular machine. These drugs can kill a bacterial or cancer cell. Other molecules, such as aspirin, gently block less-critical proteins for a few hours. With the use of these drugs, we can make changes inside our own cells, such as the blocking of pain signals. Many structures of drugs that bind to proteins have been determined by scientists. These atomic structures allow us to see how drugs work, and perhaps how to modify them to improve their action. A few examples are shown here. Some of these drugs, like penicillin, were discovered in nature. Other drugs, such as HIV protease inhibition, were created by using the target protein structure to design new drug molecules. These structures of proteins and drugs, along with many others, can be explored at the RCSB Protein Data Bank (PDB).

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**Antibiotics & Antivirals**

Antibiotics and antiviral drugs are specific poisons. They need to kill pathogenic organisms like bacteria and viruses without poisoning the patient at the same time. Often, these drugs attack proteins that are only found in the targeted bacterium or virus and which are crucial for their survival or multiplication. For instance, **penicillin** attacks the enzyme that builds bacterial wall cells, and HIV protease inhibitors like **saquinavir** attack an enzyme that is needed for HIV maturation.

1. **D-alanyl-D-alanine carboxypeptidase** with penicillin (1pwc)  
2. **HIV protease** with saquinavir (1hxb)

**Anticancer Chemotherapy**

Cancer cells grow and multiply without control. Since these cells are still similar to normal cells, it is difficult to kill them selectively with drugs that can’t distinguish between the two. Many drugs currently used for cancer chemotherapy attack all growing cells, including cancer cells and normal cells. This causes the severe side effects of cancer chemotherapy, because the drugs attack rapidly-growing cells in hair follicles and the stomach. Two examples are shown here. Methotrexate attacks DNA in actively growing cells, often cleaving the DNA chain and killing the cell. Paclitaxel (Taxol) binds to **tubulin**, preventing the action of microtubules during cell division.

3. **tubulin with paclitaxel** (1jff)  
4. **tubulin with taxol** (1jff)

**Drug Metabolism**

You have probably noticed that when you take drugs, the effects gradually wear off in a few hours. Enzymes like cytochrome P450 continually break down drugs and get rid of them. This is important because it protects us from poisonous molecules in our diet and in the environment, but it means that we have to take multiple doses of drugs when being treated for a disease.

5. **Cytochrome P450 3A4 with atorvastatin** (2j0d)  
6. **Cytochrome P450 2A4 with omeprazole** (2nxd)

**Molecular Mimics**

Most drugs mimic the molecules that are normally processed by an enzyme or receptor protein. They bind tightly to the protein and block the site that usually performs the task. For instance, HIV protease normally binds to a protein chain, like the one shown at the left, and clips it into two pieces. Drugs used to treat HIV infection, like **saquinavir** shown here, are smaller than the protein chain but chemically very similar. The drug binds in a similar position as the peptide, completely blocking the active site so the enzyme is unable to cleave the peptide chain. **Diagram created with the Protein Modeler module of the Small Molecules page on the RCSB PDB site.**

**Suicide Inhibitors**

Some drugs are particularly effective because they form a chemical bond to the protein target (shown in turquoise), totally disabling it in the process. Penicillin (shown at the bottom with atomic colors) reacts with a serine amino acid in the bacterial enzyme, forming a new covalent bond to the enzyme. This completely blocks the active site, so the enzyme is unable to perform its role in cell wall synthesis. Another suicide inhibitor, **aspirin** (shown in red), attaches an acetyl group to its target which blocks an inflammation pathway.

**Pharmacological Inhibitors**

Pharmacological inhibitors are drugs used to completely disable a critical molecular machine. These drugs can kill a bacterial or cancer cell. Other drugs, such as aspirin, gently block less-critical proteins for a few hours. With the use of these drugs, we can make changes inside our own cells, such as the blocking of pain signals. Many structures of drugs that bind to proteins have been determined by scientists. These atomic structures allow us to see how drugs work, and perhaps how to modify them to improve their action. A few examples are shown here. Some of these drugs, like penicillin, were discovered in nature. Other drugs, such as HIV protease inhibition, were created by using the target protein structure to design new drug molecules. These structures of proteins and drugs, along with many others, can be explored at the RCSB Protein Data Bank (PDB).