OPEN ACCESS Freely available online

Biochemistry & Pharmacology: Open Access

Commentary

Drug Mechanisms: Cellular and Molecular Insights into Therapeutic Effects

Hayou Li*

Department of Pharmacology, Seoul National University, Seoul, South Korea

ABOUT TO STUDY

The study of drug effects at the molecular and cellular levels is crucial for understanding how drugs exert their therapeutic and side effects. By examining these effects, researchers can gain insights into the mechanisms of action, improve drug design, and predict potential side effects. This field, often referred to as pharmacodynamics, explores the interaction between drugs and biological systems at the most fundamental levels.

Molecular mechanisms of drug action

At the molecular level, drugs typically exert their effects by interacting with specific molecular targets in the body. These targets can be proteins, nucleic acids, lipids, or small molecules that play pivotal roles in cellular functions. The most common molecular targets are receptors, enzymes, ion channels, and transporters.

Receptors: Many drugs work by binding to receptors, which are typically proteins located on the surface or inside cells. These receptors are involved in signal transduction, where the binding of a drug (or its natural ligand) to a receptor triggers a cascade of intracellular events. For example, many G-Protein-Coupled Receptors (GPCRs) and tyrosine kinase receptors are involved in regulating key cellular processes such as growth, immune responses, and neurotransmission. Drugs like beta-blockers target adrenergic receptors to reduce heart rate and blood pressure.

Enzymes: Some drugs act by inhibiting or stimulating enzymes, which are proteins that catalyze biochemical reactions in the body. Enzyme inhibitors are commonly used in the treatment of diseases like cancer, bacterial infections, and cardiovascular disorders. For example, acetylcholinesterase inhibitors are used in the treatment of Alzheimer's disease, as they increase acetylcholine levels, compensating for the loss of this neurotransmitter in patients with neurodegeneration.

Ion channels: Ion channels are proteins that allow the passage of ions (such as sodium, calcium, and potassium) across cell membranes, and their activity is vital for processes like nerve transmission, muscle contraction, and heart rhythm. Drugs that target ion channels, like calcium channel blockers, can affect muscle function and are used to treat conditions such as hypertension and arrhythmias.

Transporters: Drugs can also interact with transporters, which are proteins responsible for moving molecules across cell membranes. Inhibiting or stimulating these transporters can affect the concentration of specific molecules within cells. For example, Selective Serotonin Reuptake Inhibitors (SSRIs) inhibit the serotonin transporter, leading to increased serotonin levels in the brain and improved mood in patients with depression.

Cellular effects of drug action

At the cellular level, the effects of drugs are a direct result of the molecular interactions described above. When a drug binds to its target, it initiates a series of cellular responses that can include changes in gene expression, protein activity, and cellular signaling. These cellular effects can be beneficial, such as promoting cell survival, reducing inflammation, or inhibiting tumor growth. However, they can also lead to adverse effects, such as cell death, tissue damage, or cancer development.

Gene expression: Many drugs can alter gene expression by binding to nuclear receptors or other intracellular proteins that regulate transcription. For example, steroid hormones like cortisol and estrogen bind to their respective nuclear receptors and regulate the expression of genes involved in immune response, metabolism, and reproductive function. Similarly, antibiotics like tetracycline can affect the transcription of bacterial genes, inhibiting bacterial growth and replication.

Signal transduction: Drug binding to receptors or enzymes often activates complex signal transduction pathways inside the cell. These pathways can lead to the activation or inhibition of various cellular processes. For example, the binding of insulin to its receptor on target cells activates a signaling pathway that promotes glucose uptake into cells, thereby lowering blood sugar levels. Disruptions in cellular signaling pathways are also linked to diseases such as cancer, where mutations can result in uncontrollable cell division.

Cellular growth and death: Drugs can influence cellular growth and death by modulating processes like apoptosis (programmed

Correspondence to: Hayou Li, Department of Pharmacology, Seoul National University, Seoul, South Korea; E-mail: hyoli@gmail.com

Received: 31-Dec-2024, Manuscript No. BCPC-25-36686; **Editor assigned:** 03-Dec-2024, PreQC No. BCPC-25-36686 (PQ); **Reviewed:** 17-Jan-2025, QC No. BCPC-25-36686; **Revised:** 08-Sep-2025, Manuscript No. BCPC-25-36686 (R); **Published:** 15-Sep-2025, DOI: 10.35248/2167-0501.25.14.383

Citation: Li H (2025) Drug Mechanisms: Cellular and Molecular Insights into Therapeutic Effects. Biochem Pharmacol. 14:383.

Copyright: © 2025 Li H. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution and reproduction in any medium, provided the original author and source are credited.

cell death) and autophagy (the cell's process of degrading and recycling components). Cancer therapies, for instance, often work by inducing apoptosis in tumor cells, either by directly targeting cancerous cell pathways or by sensitizing cells to death signals. Conversely, drugs like cytotoxic agents can kill healthy cells, leading to side effects such as hair loss and immune suppression.

Membrane potential and ion homeostasis: Drugs that affect ion channels or transporters can have a significant impact on the membrane potential and ion balance of cells. For instance, drugs like lithium, used in the treatment of bipolar disorder, can alter sodium and potassium ion fluxes, affecting cellular excitability and neurotransmission in the brain. Disruption of ion homeostasis can also contribute to the side effects of drugs like diuretics, which can lead to electrolyte imbalances.