

MOLECULAR MECHANISMS OF INFLAMMATION AND ANTI-
INFLAMMATORY DRUGS

Xodjimurodov Davron Ikramaliyevich

Angren Medical University, Angren City,
Tashkent Region Teacher of the Faculty of Medicine

Dr.khodjimuratov@gmail.com

Raubjonov Xusanboy Mamatolibovich

Angren Medical University, Angren City,
Tashkent Region Teacher of the Faculty of Medicine

telefonprogramma44@gmail.com

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Relevance. Inflammation is a fundamental biological process essential for the protection of the human body against infection and injury. However, when this process becomes dysregulated or persistent, it contributes to the pathogenesis of a wide range of chronic diseases. Understanding the molecular mechanisms of inflammation is therefore crucial for developing effective therapeutic strategies.

At the molecular level, inflammation is regulated by complex signaling pathways involving cytokines (such as TNF- α , IL-1 β , and IL-6), eicosanoids (prostaglandins and leukotrienes), and transcription factors like nuclear factor kappa B (NF- κ B). These mediators coordinate immune cell activation, vascular changes, and tissue responses. Dysregulation of these pathways leads to excessive or prolonged inflammatory responses, which can result in tissue damage and disease progression.

Anti-inflammatory drugs are designed to modulate these molecular pathways and restore physiological balance. Non-steroidal anti-inflammatory drugs (NSAIDs) inhibit cyclooxygenase (COX) enzymes, reducing prostaglandin synthesis. Corticosteroids act at the genomic level by suppressing pro-inflammatory gene expression, while modern biologic agents target specific cytokines or receptors involved in inflammatory signaling.

Despite significant advances in pharmacology, current anti-inflammatory therapies are still associated with side effects and limited specificity. Therefore, there is a growing need to develop targeted drugs that act on precise molecular mechanisms. This makes the study of inflammation and its regulatory pathways highly relevant in modern biomedical research.

The Purpose of the Study. The purpose of this study is to analyze the molecular mechanisms involved in inflammation and to investigate the pharmacological actions of different classes of anti-inflammatory drugs. The study also aims to evaluate key inflammatory signaling pathways and identify potential molecular targets for more effective therapeutic interventions.

Research Materials and Methods. This study is based on a comprehensive review of current scientific literature in immunology, pharmacology, and molecular biology. Data from peer-reviewed articles, textbooks, and clinical studies were analyzed to understand inflammatory signaling pathways and drug mechanisms.

Key molecular pathways such as NF- κ B activation, cytokine signaling cascades, and arachidonic acid metabolism were examined. Comparative analysis of anti-inflammatory drug classes, including NSAIDs, corticosteroids, and biologic agents, was performed based on their mechanisms of action and clinical effects. Structural and biochemical data from previous studies were also reviewed to support the interpretation of molecular interactions.

Results and Discussion. The analysis shows that inflammation is primarily regulated by interconnected molecular pathways involving immune cells and signaling mediators. Activation of NF- κ B plays a central role in the expression of pro-inflammatory genes, leading to the production of cytokines and chemokines that amplify the inflammatory response.

NSAIDs effectively reduce inflammation by inhibiting COX-1 and COX-2 enzymes, thereby decreasing prostaglandin synthesis. However, their long-term use may lead to gastrointestinal and cardiovascular side effects. Corticosteroids demonstrate strong anti-inflammatory effects by suppressing multiple inflammatory genes, but they also cause systemic side effects due to their broad mechanism of action.

Biologic drugs, which target specific cytokines such as TNF- α or IL-6, offer a more selective approach and have shown promising results in treating autoimmune and chronic inflammatory diseases. Nevertheless, their high cost and potential immunosuppressive effects limit widespread use.

Overall, the results indicate that targeting specific molecular pathways provides a more effective and safer approach to controlling inflammation compared to traditional therapies. Advances in molecular biology and drug design are expected to further improve treatment strategies in the future.

Conclusion. Inflammation is a complex molecular process regulated by multiple signaling pathways and mediators. Understanding these mechanisms is essential for the development of effective anti-inflammatory therapies. Current pharmacological agents, including NSAIDs, corticosteroids, and biologics, act on different levels of the inflammatory cascade, each with specific advantages and limitations.

The study highlights the importance of molecular targeting in improving the efficacy and safety of anti-inflammatory drugs. Future research

should focus on developing highly selective therapeutic agents that minimize side effects while maximizing clinical benefits.

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