4. Nobel Prize in Physiology or Medicine 2025

The Nobel Prize in medicine or physiology was announced for three scientists, for their discoveries on peripheral immune tolerance. The three scientists Mary Brunkow, Fred Ramsdell and Shimon Sakaguchi shared the Nobel Prize in Physiology or Medicine.

Introduction to the Human Immune System

The immune system is the body's primary defense mechanism against pathogens including bacteria, viruses, fungi, and parasites. It is a complex network of organs, cells, and molecules that work together to recognize, neutralize, and eliminate harmful substances while distinguishing them from the body's own healthy cells. A well-functioning immune system is essential not only for fighting infections but also for detecting and eliminating aberrant cells, such as cancerous or mutated cells.

Major Components of the Immune System

(A) Organs

Bone Marrow - Primary site of hematopoiesis; produces all blood cells including lymphocytes.

Thymus - Site of T-cell maturation; ensures T-cells can distinguish between self and non-self.

Spleen - Filters blood, removes old or damaged red blood cells, and provides a site for immune cell interaction.

Lymph Nodes - Small, bean-shaped structures that filter lymph, trap pathogens, and provide sites for lymphocyte activation.

Tonsils and Mucosal-associated lymphoid tissue (MALT) - Guard entrances to the body (mouth, nose, gut).

(B) Cells

Leukocytes (White Blood Cells) - Key players in recognizing and neutralizing pathogens.

1. **Lymphocytes -** B-cells and T-cells.
2. **Macrophages -** Engulf pathogens and present antigens to lymphocytes.
3. **Neutrophils -** First responders to infections; phagocytose bacteria.
4. **Dendritic cells -** Antigen-presenting cells that activate T-cells.

(C) Molecules

Antibodies (Immunoglobulins) - Bind specifically to antigens, neutralizing pathogens or marking them for destruction.

Cytokines - Signaling molecules that regulate immune responses, including inflammation and cell proliferation.

Complement Proteins - Circulate in the blood, enhancing pathogen destruction through lysis or opsonization.

B and T Cells - Key Lymphocytes

(A) T-Cells - Origin - Produced in bone marrow, mature in thymus, and migrate to lymph nodes, spleen, and bloodstream.

Types of T-cells -

1. **Cytotoxic T-cells ($CD8^+$) -** Destroy infected cells and tumor cells.
2. **Helper T-cells ($CD4^+$) -** Secrete cytokines to orchestrate immune responses and activate B-cells, macrophages, and cytotoxic T-cells.
3. **Regulatory T-cells (Tregs) -** Suppress overactive immune responses, maintaining self-tolerance and preventing autoimmune diseases.

(B) B-Cells - Produce antibodies in response to antigens, marking pathogens for destruction.

Types of B-cells -

Plasma Cells - Secrete large amounts of antibodies to fight current infections.

Memory B-Cells - Provide long-term immunity by "remembering" past infections for rapid future response.

Discovery of Regulatory T-Cells - Scientists recognized the existence of immune system "security

guards" — regulatory T-cells that prevent immune cells from attacking the body's own tissues. This discovery was pivotal in understanding peripheral tolerance, the process by which the immune system avoids harming self-tissues while remaining responsive to pathogens.

Significance and Implications

(A) Immunology and Disease

1. **Autoimmune Diseases -** Dysregulation of Tregs can lead to autoimmune conditions like lupus, rheumatoid arthritis, and type 1 diabetes.
2. **Cancer -** Some tumors recruit Tregs to evade immune attack, creating a protective microenvironment.
3. **Transplantation -** Tregs help in preventing organ rejection by suppressing immune responses against transplanted tissues.
4. **Chronic Inflammation -** Understanding Tregs provides strategies to control excessive inflammation, reducing tissue damage.

(B) Medical and Therapeutic Applications - Targeting Tregs is a promising avenue in immunotherapy for cancer, aiming to boost anti-tumor immune responses. Modulating Treg activity can help treat autoimmune diseases by restoring immune tolerance. Vaccines and biologics can leverage knowledge of Tregs to fine-tune immune responses.

(C) Paradigm Shift - The discovery underscored that the immune system is not solely attack-oriented but also self-regulating, balancing defense and tolerance. Opened a new field of research in peripheral immune tolerance, reshaping treatment strategies for cancer, autoimmunity, transplantation, and chronic inflammatory conditions.

Conclusion

The human immune system is a highly sophisticated network that balances aggression against pathogens with restraint against self-cells. Regulatory T-cells are central to this balance, preventing autoimmune diseases while influencing cancer progression. Understanding B-cells, T-cells, and their regulatory mechanisms has been transformative for medicine, enabling therapies that harness or modulate immunity. The discovery of Tregs has paved the way for personalized immunotherapies, contributing significantly to the fight against autoimmune disorders, cancer, and transplant rejection.

About Nobel Prize

Since 1901, the Nobel Prize has been awarded in the fields of physics, chemistry, physiology or medicine, literature and peace, while a memorial prize in economic sciences was added in 1968.

1. In 1895 Alfred Nobel gave the largest share of his fortune to a series of the Nobel Prizes.

From Stockholm, the Royal Swedish Academy of Sciences confers the prizes for physics, chemistry, and economics, the Karolinska Institute confers the prize for physiology or medicine, and the Swedish Academy confers the prize for literature. The Norwegian Nobel Committee based in Oslo confers the prize for peace. The Nobel Peace Prize is awarded in Oslo (Norway), while all other prizes are awarded in Stockholm (Sweden). The Nobel Foundation is the legal owner and functional administrator of the funds and serves as the joint administrative body of the prize-awarding institutions. It is not concerned with the prize deliberations or decisions, which rest exclusively with the four institutions.

Process of Selection -

1. Nominations are invited from qualified individuals (scientists, professors, former laureates, etc.).
2. Selection Committees review and recommend the winners.
3. The final decision is made by the respective Nobel institutions.

Source - https - //www.thehindu.com/sci-tech/science/medicine-nobel-2025-awarded-to-trio-for-t-cells-discovery/article70130490.ece