Brief Description of the Human Immune System

Kexi Xiang

Chengdu Foreign Languages School, Sichuan, China

Abstract. Due to the invention of mRNA vaccines and tumor immunotherapy, immunology has become the hot spot in recent years. It is believed that the immune system in the human body can protect us from pathogens and tumors by self-nonself discrimination. Here, we briefly review the composition of the immune system, including immune organs, cells, and molecules. After that, we conclude the fundamental biological process of how a body generates humoral and cellular immune responses after recognizing antigens, hoping to gain a deeper understanding of the human body's immune system.

Keywords: Immune System; Composition; Immune Response.

1. Introduction

Historically, human beings have been plagued by various infectious diseases for a long time. Severe contagious diseases such as yellow fever, plague, cholera, smallpox, and influenza spread rapidly in large areas and have a high mortality rate, directly threatening human survival. Over 200 years ago, British physician Edward Jenner successfully developed a live vaccine against smallpox from vaccinia. Since then, vaccination against smallpox has been introduced globally to control the epidemic gradually. After more than a hundred years of human efforts, the last patient with smallpox was cured in Somalia in 1976. The World Health Organization (WHO) officially announced the elimination of smallpox in the world in 1980. This is a successful example of using immune intervention to control severe infectious diseases. It is one of the brilliant achievements of modern medicine, and immunology was born.

With the penetration of cell biology, molecular biology, genetics, and other disciplines, modern immunology has gone beyond the scope of simple anti-infection. One of the manifestations is that immunity is defined as identifying and removing antigenic foreign bodies. Immunology has become a science for the body to identify and remove non-self components.

In this review, we mainly introduce the composition of the immune system, the functions of the innate immune system and the adaptive immune system, and discussing some = applications of immunology, hoping to gain a better understanding of the immune system of the human body.

2. Composition of the Immune System

The immune system includes immune organs, immune cells, and immune molecules.

2.1 Immune Organs

Immune organs include central immune organs, including the thymus and bone marrow, which are the places where immune cells such as lymphocytes occur and differentiate. Hematopoietic stem cells develop into mature B cells in the bone marrow, and some hematopoietic stem cells migrate to the thymus and develop into mature T cells. Peripheral immune organs and tissues, including the spleen, lymph nodes, and mucosa-associated lymphoid tissues, are places where lymphocytes settle, and immune responses occur. They mainly perform three functions: capturing antigens from the site of infection, presenting antigens to lymphocytes to initiate an adaptive immune response, providing necessary signals for the survival of antigen-specific lymphocytes, and maintaining immune memory after antigen clearance.

2.2 Immune Cells

Immune cells include innate immune cells and adaptive immune cells (lymphocytes).

The cells involved in the innate immune response include monocytes/macrophages, DC, NK cells, granulocytes, and mast cells, which are distributed in different tissues and organs of the body and can quickly respond to invading pathogens and produce non-specific anti-infective immune effects; it can also be involved in clearing the body's damaged components, aging and malignantly transformed cells. Moreover, some innate immune cells can also stimulate adaptive immune response through antigen presentation, becoming a bridge between natural defense and specific immunity.

Adaptive immune cells, including T and B cells, are multipotent hematopoietic stem cells derived from bone marrow. In pluripotent hematopoietic stem cells, lymphatic stem cells differentiate into precursor T cells and precursor B cells. Precursor T cells enter the thymus and develop into mature T cells, which settle and proliferate in the thymus-dependent region of peripheral immune organs through blood circulation or enter tissues through blood or lymph circulation to participate in cellular immune response or immune regulation. Precursor B cells differentiate into mature B cells in the bone marrow and join in the humoral immune response.

2.3 Immune Molecules

Immune molecules include cytokines and their receptors; complements and their regulatory molecules; differentiation antigens; adhesion molecules; TCR, BCR, antibody molecules, etc.

Among them, cytokines are a class of multifunctional polypeptide molecules produced by immune cells and related cells, including interleukins, interferons, tumor necrosis factors, colony-stimulating factors, growth factors, and chemokines. Cytokines can play a variety of biological functions such as immune regulation, antiviral, mediating inflammatory response, and hematopoiesis. Cytokines function by binding to cytokine receptors on cells.

Complement is a group of heat-resistant and enzyme-active globulins in human serum. It has unique physical and chemical properties. After activation, it has significant biological effects such as cell dissolution, cell adhesion, opsonization, immune regulation, mediating inflammatory response, neutralizing virus, and immune complex dissolution and clearance. Complement activation has classical and alternative ways, and ultimately the formation of membrane attack complex, the target cell dissolution, and destruction.

The antibody is the product of the body's response to antigen, essentially immunoglobulin. The monomer molecule is composed of two heavy chains and light chains. Immunoglobulin has class, subclass, type, and subtype. The five immunoglobulins, IgG, IgM, IgA, IgE, and IgD, have their characteristics and immunological functions.

3. Immune Response

Immune response refers to the process in which immune cells recognize antigen molecules, produce complex immune chain reactions, and show specific biological effects after the body's immune system is stimulated by antigens. This process includes the treatment, processing, and presentation of antigens by antigen-presenting cells (APC), the recognition, activation, proliferation, and differentiation of antigens by antigen-specific lymphocytes, namely T and B lymphocytes, and finally, the production of immune effector molecules-antibodies and cytokines, as well as immune effector cells (cytotoxic T lymphocyte and delayed-type hypersensitivity T lymphocyte), and ultimately the elimination of antigen substances. Although the immune response is a continuous process, it can be divided into three stages: sensitization, reaction, and effect.

3.1 Sensitization Stage

The sensitization stage is when antigenic substances enter the body, antigen-presenting cells recognize, capture, process, and present them, and antigen-specific lymphocytes (T, B cells) recognize antigens.

Antigen-presenting cells (macrophages, dendritic cells, B lymphocytes, etc.) internalize antigenic substances through phagocytosis, pinocytosis, etc., or digest and degrade antigenic proteins in cells into antigenic peptides. The antigen peptide produced by the degradation of the antigen peptide is combined with the MHC molecule in the antigen-presenting cells to form an antigen peptide-MHC complex, which is then transported to the surface of the APCs cell membrane for display for immune cell recognition.

T cells recognize antigen peptides processed by APCs and bound to MHCI or MHCII molecules through TCR, and B cells recognize antigen substances through BCR.

3.2 Reaction Stage

The reaction stage is also called the proliferation and differentiation stage. This stage is where antigen-specific lymphocytes are activated after recognizing antigens, proliferate and differentiate, and produce effector lymphocytes and effector molecules.

After recognizing the antigen presented by APCs, T cells in the stationary phase express IL-1R on the cell surface and become inducible T cells, which are activated by IL-1 stimulation signals produced by macrophages, and then express IL-2R and become activated T cells, which then proliferate and differentiate into effector T cells, in which T_h cells secrete a series of cytokines to play a supporting role, and Tc cells exert cell killing function. During this process, some T cells stay in the intermediate stage of differentiation and no longer differentiate forward, called memory T cells.

Under the stimulation of the activation signal, B cells enter the G1 phase from the G0 phase. IL-4 can induce the volume of resting B cells to increase and synthesize DNA and protein. Activated B cells express a series of cytokine receptors. After binding to cytokines secreted by T cells, they proliferate and differentiate into mature plasma cells, synthesize and secrete antibodies. Some B cells become memory B cells during differentiation.

3.3 Effective Stage

This stage is a process in which activated effector cells, cytotoxic T lymphocyte (CTL), delayed-type hypersensitivity T lymphocyte (T_{DTH}), and effector molecules, antibodies, and cytokines exert cellular and humoral immunity. These effector cells and molecules work together to clear antigenic substances.

The cellular immune effect of the body is reflected by CTL and T_{DTH} cells and cytokines. CTL exists in vivo in the form of a non-activated precursor. Its TCR recognizes the antigen presented by APC. Under the action of interleukin produced by activated T_h cells, the non-activated precursor CTL is activated, proliferates and differentiates into cytotoxic T lymphocyte (CTL) with killing ability. CTL releases perforin and granzyme, leading to the dissolution of target cells. At the same time, CTL releases lymphotoxin, which can bind to receptors on the surface of target cells and induce suicide of target cells.

When some subsets of T_h cells come into contact with specific antigens, they can secrete cytokines and induce a local inflammatory response, which is called delayed-type hypersensitivity. Delayed-type hypersensitivity T lymphocyte also exists as a non-activated precursor in vivo. It's surface antigen receptor specifically binds to the antigen of target cells and activates, proliferates, and differentiates into T_{DTH} cells with immune effect under various cytokines released by activated T_h cells. Its resistant product is through its release of a variety of soluble cytokines, causing local infiltration of the monocytes-based inflammatory response, namely delayed-type hypersensitivity.

The humoral immune response is achieved by B cells through antigen recognition, activation, proliferation, and finally, differentiation into plasma cells and secrete antibodies. Antibodies can eliminate antigens in vivo through various mechanisms: 1. neutralization, antibodies against bacterial toxins and viruses in vivo can neutralize the corresponding toxins and viruses. The antibody of a toxin can bind to the poison to change its molecular configuration, making it lose its toxic effect or forming an antigen-antibody complex to be swallowed by mononuclear/macrophages. Antibodies against the virus inhibit the ability of the virus to infect cells or make it lose infectivity to cells by binding to viral

surface antigens; 2. immune lysis: some Gram-negative bacteria and certain protozoa, after tying with antibody, can activate complement, resulting in bacteria or parasites dissolved; 3. opsonization: when bacteria bind to antibodies, they are more susceptible to phagocytosis by monocytes/macrophages if they reactivate complements to form bacteria-antibody-complement complexes. This is because monocytes/macrophages have Fc fragments of antibody molecules and C3b receptors on their surface, and the antigen-antibody-complement complexes formed in vivo are quickly captured by them; 4. local mucosal immunity : secretory IgA produced by plasma cells in lamina propria is the body's primary defense against pathogenic microorganisms from the respiratory tract, digestive tract and urogenital tract infection, which can prevent pathogenic organisms from adsorbing mucosal epithelial cells; 5. antibody-dependent cell-mediated cytotoxicity: some effector immune cells (such as NK cells) have receptors on the surface of the Fc fragment of the antibody molecule. When the antibody molecule binds to the corresponding target cells, the effector cells can use the Fc receptor to attach to the Fc fragment of the antibody molecule, thereby killing the target cells.

4. Discussion

The immune system works as an essential regulatory network in the body by identifying its own and non-self components, timely monitoring and removing foreign antigens and cancerous cells, thus maintaining a stable body environment and maintaining human health. This review briefly describes the composition of the immune system and the three stages of the immune response. It is worth noting that in the actual immune process in vivo, the above contents are not entirely separated, which also better illustrates that the immune system plays a delicate and vital function as a regulatory network.

Based on a deeper understanding of the immune system, humans have developed vaccines against various pathogens. When the human body is vaccinated, it will cause an immune response to produce antigen-specific antibodies, and produce memory T cells and memory B cells. When the human body contacts the same antigen again, memory cells rapidly proliferate and differentiate to produce effector T cells and effector B cells (plasma cells). Plasma cells produce high levels of antibodies, and then bind with antigen; the effector T cells contact with the target cells and lysate the target cells.

Besides the invention of vaccines, human beings have also developed tumor immunotherapy based on Chimeric antigen receptor T cell therapy (CAR-T) and PD-1. For example, chimeric antigen receptor T cell therapy uses bioengineered T cells with chimeric antigen receptors to treat cancer. This therapy uses chimeric antigen receptors to identify cancer cells, making the attack and elimination of cancer cells more effective. Scientists obtain T cells from humans, modify them, and then inject them into patients to attack tumors. Chimeric antigen receptor T cells can be modified from either the patient 's own blood cells (autologous) or blood cells from other healthy donors (allogeneic). When T cells are isolated in vitro, they are genetically engineered to express a special chimeric antigen receptor to target antigens on the surface of cancer cells.

With the development of immunology, human beings are gaining a deeper understanding of the immune system. In addition to the application in vaccine and tumor immunity, immunotherapy is also indispensable in other diseases. We believe that, in the future, people can use immunology to cure more diseases.

References

[1] Janis Kuby. Immunology. New York: Freeman W H. and Compang, 1997.

[2] Abul K, Abbas et al. Cellular and Molecular Immunology. 4th edition. Saumders W B. Company, 2000.

[3] Paul W E. Fundamental Immunology. Fourth edition. Philadelphia: Lippincott-Raven Publishers, 1999.

[4] Ratti I, Brostoff J, Male D. Immunology. Sixth edition. Ediburgh: Harcout Publishers Limited, 2001.