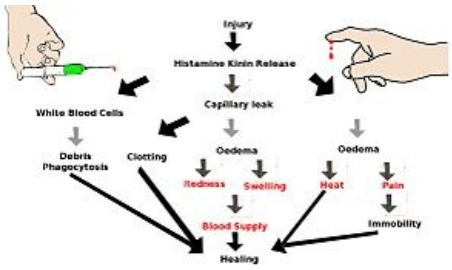
Principles of defense against viral infections

Introduction

Viral infections are diseases caused by viruses. Viruses can infect both animals and plants, as well as bacteria. The most well-known viral diseases include *Covid-19*, influenza, AIDS, measles, smallpox, tick-borne encephalitis, and others. The human body defends itself against viral diseases by both non-specific and specific defense mechanisms. Non-specific immunity mechanisms serve to defend the body against potentially harmful agents, regardless of their more precise identification. Mechanisms of specific immunity represent a highly selective reaction focused on a specific agent after its precise identification, their properties are the strengthening and acceleration of the response upon repeated encounter with a certain antigen.

Non-specific immunity

Non-specific immunity involves a wide range of mechanisms – the skin and mucous membrane barrier, secretions produced by epithelial cells, the inflammatory response, interferons, killer lymphocytes, and the complement system.



Inflammatory response

Inflammation

Inflammation is a complex response of the body to tissue damage that occurs after the penetration of infectious microorganisms. The main processes of the inflammatory response are phagocytosis of foreign materials by macrophages, vasodilation and increased capillary permeability, and leukocyte migration to the site of inflammation. Cytokines (mediators of inflammation) are produced at the site of infection and are activated by kinins. The first leukocytes that travel to the tissue affected by inflammation are the neutrophilic granulocytes, and with a few hours delay also monocytes, which rapidly transform into macrophages. All of these phagocytic cells arrive at their destination by a carefully regulated procedure that includes marginalization, diapedesis, and chemotaxis. Margination is the movement and attachment of leukocytes to the vessel wall. Diapedesis represents their penetration through the vessel wall, chemotaxis means the movement of leukocytes in the tissue towards the affected site.

Phagocytosis

Phagocytosis is the ability of cells to absorb various particles. The major cells involved in phagocytosis are polymorphonuclear leukocytes, monocytes, and macrophages. Phagocytosis consists of four steps – the capture of foreign material, its internalization, degradation, and exocytosis. Leukocytes recognize foreign material due to its irregular surface and opsonins, which are proteins, that bind to this material and accelerate its identification (opsonization). Internalization takes place in the process of endocytosis, then the foreign material is degraded due to digestive enzymes, and subsequently, aminoacids and other digestive products are eliminated from the cell by exocytosis.

Interferons

Interferons are non-specific immune proteins that inhibit the replication of viruses that have a paracrine effect (i.e., on cells in their vicinity). By binding to the membrane of surrounding cells, they increase their resistance to viral infection, further suppress cell proliferation, modulate antibody production and cellular immunity, stimulate increased histocompatibility antigen expression, activate NK cells and macrophages, and potentiate the cytotoxic activity of T_C cells.

NK cells

NK cells or natural killers have a non-specific cytotoxic effect on morphologically intact cells. Their antiviral effect lies in the premature interruption of the replication cycle.

Complement

Complement is a set of serum proteins that have the nature of proenzymes and are cascaded after binding of C1 to the antigen-antibody complex, resulting in lysis of microorganisms. These proteins occur in an inactive form in the blood plasma and are activated by contact with some sugars on the surface of the microbial wall.

Specific immunity

Non-specific immune response agents are very effective, but may not always completely eliminate the foreign material. Therefore, it is important that the body also has mechanisms of specific immunity, which, although their onset is a little bit slower, are highly effective. Both B-, and T-lymphocytes are involved in specific immune

responses.

B-lymphocytes

B-lymphocytes transform into plasma cells, which secrete specific antibodies, which then circulate in the blood and lymph, so this component of the specific immune response is called humoral immunity.

Plasma cell

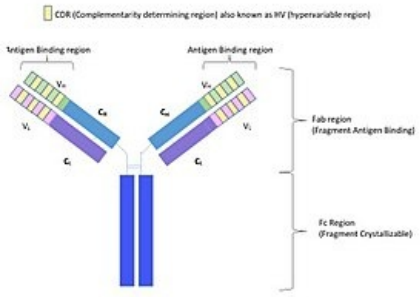
T-lymphocytes

T-lymphocytes transform into cytotoxic T-cells, which bind directly to abnormal cells in the body and subsequently destroy them, therefore this component of the specific immune response is called cellular immunity.

Both B- and T-lymphocytes respond to foreign molecules (antigens). Each antigen has a unique structure, of which the most important sections, from the point of view of the functioning of the immune system, are called antigenic determinants (epitopes). The ability of lymphocytes to recognize various antigenic determinants is due to the presence of antigenic receptors on their membrane. These receptors always bind only a specific antigen, the antigenic determinant of which corresponds to the structure of the antigen receptor. At the first encounter with a particular antigen, a primary immune response occurs. It proliferates and differentiates lymphocytes with a specific antigen receptor for the given antigen, leading to the formation of effector cells (plasma cells are formed from B-lymphocytes and cytotoxic cells are formed from T-lymphocytes) – this is called innate immunity. However, the whole process takes about 2 weeks, which is enough to eliminate the antigen, but usually, the disease is not prevented, because both bacteria and viruses multiply faster. Upon repeated encounters with the same antigen, memory cells can proliferate and differentiate into effector cells in just 2–7 days. Thanks to this, during this secondary immune response, the germs do not have time to multiply and the organism does not get sick – we are talking about the so-called acquired immunity.

Humoral immunity

Plasma cells, which are formed by the transformation of antigen-activated B-lymphocytes, produce specific antibodies. Antibodies are proteinaceous molecules of typical shape. They consist of four chains – two heavy and two light. Each antibody molecule consists of a constant and a variable region. The constant region consists of both heavy and light chains and is responsible for the shape of the molecule, similar to the letter Y, but mainly for the mechanism of action of the antibody. There are a total of 5 different classes of constant regions and accordingly, we also have 5 classes of antibodies (IgM, IgD, IgG, IgE, IgA). The variable section is at the end portions of both arms Y and is also formed by heavy and light chains. This region varies according to the antigen against which the antibody is directed, so it is responsible for its specific effect. Antibodies are involved in antigen elimination in a variety of ways (neutralization, opsonization, complement activation, and killer cell activation). Neutralization is the prevention of the pathogenic action of an antigen by the binding of an antibody to it. The most common mechanism of neutralization is antigen agglutination. Opsonization facilitates phagocytosis, a process in which cells or particles destined for phagocytosis are labeled.



Immunoglobulin structure

Cellular immunity

This type of immunity is mediated by T-lymphocytes, which, unlike B-lymphocytes, need direct contact with an infected or otherwise abnormal cell in order to function. We have three main types of lymphocytes in our body. *Helper T-lymphocytes*, which have regulatory functions and are the most numerous, carry CD4 on their surface, reacting only in the presence of HLA class II molecules. Their activation results in the production of cytokines, which then affect the activity of B-lymphocytes, cytotoxic and suppressor T-cells, and increase the activity of macrophages and killer cells, thereby regulating the non-specific immune response. *Cytotoxic (killer) T-lymphocytes* carry CD8 on their surface and respond only in the presence of HLA class I molecules. They are directly responsible for cellular immunity, they immediately kill cells infected with intracellular pathogens (e.g., viruses) and abnormal cells (e.g., tumor cells). *Suppressor T-lymphocytes* have regulatory functions, they are able to suppress the functions of B-lymphocytes, cytotoxic, and helper T-cells.

In a viral infection, antibodies are produced against a variety of viral antigens (superficial, internal, and non-structural) as well as against antigens that appear during the multiplication of the virus on the surface of the infected cell. The antibody against surface antigens binds to the virion (the basic virus particles capable of infecting the host cell, which are composed of nucleic acid and protein), which neutralizes the infectivity of the virus. The bound antibody prevents the virion from adhering to the receptors or interferes with its penetration into the cell. Antibodies to viral antigens on the surface of an infected cell allow immune lysis of infected cells by both complement and killer lymphocytes. Destroying an infected cell before a new generation of the virus is released will protect other cells from infection.

Links

Related articles

- B-lymphocytes
- T-lymphocytes
- Immune system
- Inflammation
- Interferons
- Phagocytosis
- Opsonization
- Non-specific immunity
- Specific immunity
- NK cells
- Complement

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Portal: Microbiology Portal: Immunology