Chapter

13 Immunity

At the end of this chapter the students will be able to:

- Describe the structural features of human skin that make it impenetrable barrier against invasion by microbes.
- Explain how oil and sweat glands within the epidermis inhibit the growth and also kill microorganisms.
- Recognize the role of the acids and enzymes of the digestive tract in killing the bacteria present in food.
- State the role of the ciliated epithelium of nasal cavity and of the mucous of the bronchi and bronchioles in trapping air borne microorganisms.
- Describe the role of macrophages and neutrophils in killing bacteria.
- Explain how the Natural Killer (NK) cells kill the cells that are infected by microbes.
- State how the proteins of the complement system kill bacteria and how the interferons inhibit the ability of viruses to infect cells.
- State the events of the inflammatory response as one of the most generalized nonspecific defenses.
- Outline the release of pyrogens by microbes and their effect on hypothalamus to boost the body's temperature.
- List the ways the fever kills microbes.
- Categorize the immune system that provides specific defense and acts as the most powerful means of resisting infection.
- Identify monocytes, T-cells and B-cells as the components of the immune system.
- State the inborn and acquired immunity as the two basic types of immunity.
- Differentiate the two types of acquired immunity (active and passive immunity).
- Identify the process of vaccination as a means to develop active acquired immunity.
- Describe the roles T-cells in cell-mediated immunity.
- Describe the role of B-cells in antibody-mediated immunity.
- Draw the structural model of an antibody molecule.
- Explain the role of memory cells in long-term immunity.
- Define allergies and correlate the symptoms of allergies with the release of histamines.
- Describe the autoimmune diseases.

Introduction

The immune response is how your body recognizes and defends itself against bacteria, viruses, and substances that appear foreign and harmful. Immunology is one of the branch of Biology which is the study of our protection from foreign macromolecules or invading organisms and our responses to them. These invaders include viruses, bacteria, protozoa or even larger parasites. In addition, we develop immune responses against our own proteins (and other molecules) in autoimmunity and against our own aberrant cells in tumor immunity. Organisms must find a means of defense against antigens otherwise bacteria, fungi and viruses would replicate out of control and results in the destruction of the body. Therefore organisms employ many types of defense to stop this happening. Means of defense can be categorized into first second and third lines of defense. In this chapter you will see the overall setup which is running the immune system in our body and how our body triggers responses and employs methods which ensures our healthy survival.

13.1 First line of Defense

In humans, the skin is the largest organ of the integumentary system. Skin is regarded as one of the first line of defense because it provides an almost impenetrable biological barrier protecting the internal environment. It protects the body (especially the underlying tissues) against pathogens and excessive water loss. It is also involved in providing insulation, temperature regulation and sensation.

13.1.1 Physical Components of the Skin's Defense

Our body's first line of defense is nonspecific and includes structures, chemicals, and processes that work to prevent pathogens entering the body. These first line defenders include the skin and mucous membranes of the respiratory, digestive, urinary, and reproductive systems. Skin is comprised of two main layers.

- Epidermis
- Dermis

a. The Epidermis

The epidermis is composed of multiple layers of tightly packed cells, which few pathogens can penetrate on their own. In addition to this structural barrier, the natural shedding of dead skin cells removes many attached microorganisms. Then there are other cells called epidermal dendritic cells that actively patrol the skin to phagocytize (engulf and digest) pathogens.

b. The Dermis

The dermis is situated beneath the epidermis and contains protein fibers called collagen. Collagen is a tough fibrous protein which gives skin the strength and

pliability to resist abrasions that could introduce microorganisms.

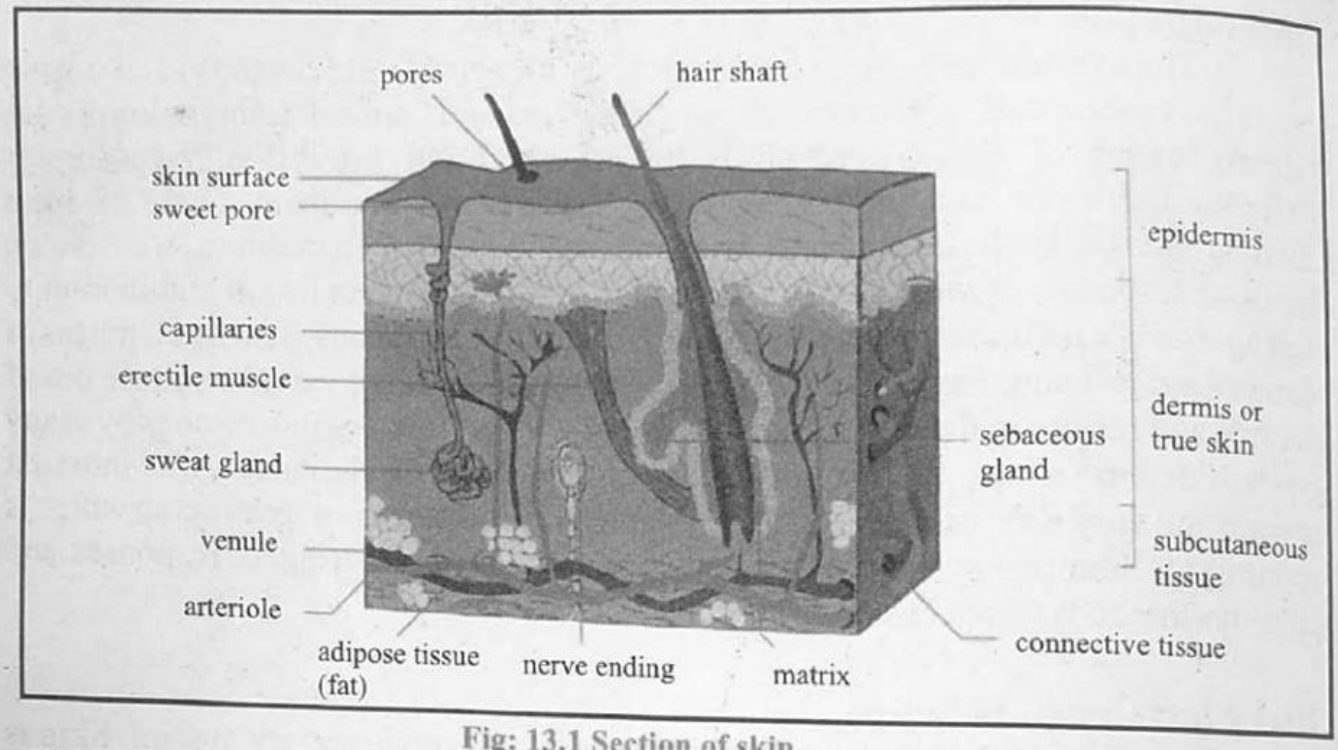


Fig: 13.1 Section of skin

13.1.2 Components of the Skin's Defense

a. Perspiration

Secreted by the skin's sweat glands, perspiration contains salt and enzymes. Few microbes can live in a highly saline environment, like that of the skin's surface. The lysozymes in sweat are a type of enzyme that can destroy the cell walls of bacteria.

b. Sebum

Sebum is secreted by skins sebaceous (oil) glands. The oil helps keep skin pliable and less likely to break or tear and also lowers the pH of the skin to a more acidic level that inhibits the growth of many types of bacteria.

13.1.3 Defense against Infection in Digestive Tract

Proper levels of HCI in the stomach are our first line of defense against bacterial and viral infections. All day long we unavoidably ingest all kinds of bacteria and viruses through the mouth, nose and food we eat. These germs just cannot survive the trip into the stomach because of acidic environment. The healthy stomach essentially remains sterile.

Normally good bacteria, that live lower down in your digestive tract, can also move up into the stomach if it becomes more alkaline. Proper acid levels in the stomach prevent this over-growth from occurring.

13.1.4 Cilia and Mucus

The most important function of the nose and nasal cavity is to process each breath before it enters the lungs. This filtering process is important for several reasons. Considering the amount of air that passes through the respiratory system each day, it is important that the nose:

- Filter out dangerous particles (bacteria, viruses, dust, pollen etc.) that could otherwise enter into the lungs, causing damage. Tiny hairs (*cilia*) and a mucous membrane line the inside of the nose to trap particles before they enter the body. The cilia are capable of small movements and can direct the flow of *mucus* (a substance secereted by mucous membranes), removing it from the nasal cavity. Sneezing forces air through the nasal cavity and is also effective at removing particles and mucus.

- Warm each breath to prevent cold air from damaging sensitive lung tissue. The large amount of surface area and many blood vessels in the nasal cavity help warm each breath quickly as heat transfers from the blood to the passing air.

- Add moisture to each breath to prevent the airways and lungs from becoming dry and damaged. As air passes through the nasal cavity, moisture is transferred from the mucus secreted by the lining of the nasal cavity into the air.

Because the nose and nasal cavity are so effective at filtering, warming and moisturizing each breath, it is generally better to breathe through the nose than the mouth. Though the mouth can allow a person to inhale more quickly, over time, mouth breathing can dry out the delicate tissue in the airways and lungs. Furthermore, oxygen may be easier for the lungs to extract from air that has been filtered, warmed and humidified through the nose and nasal cavities.

In normal lungs, the oxygen from the air is drawn through the nose and mouth, travels down the trachea into the right and left bronchus and bronchioles and then finally into millions of alveoli (air sacs). From the alveoli the oxygen is

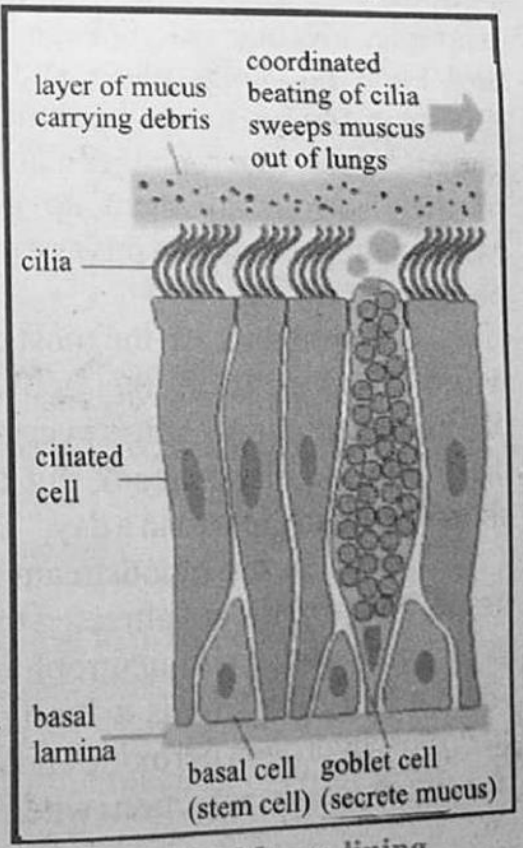
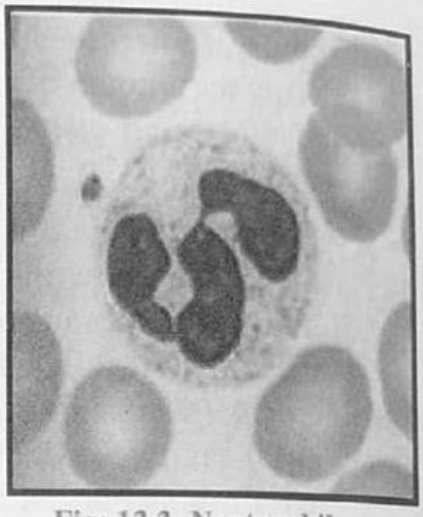


Fig: 13.2 Mucus lining

absorbed into the blood stream and is carried to all parts of the body.

To help the breathing process, the lungs have their own natural clearance methods. Your airways produce a thin coat of mucous that catches the dust and bacteria that you breathe in daily. This thin mucous is swept up towards the windpipe by tiny beating hairs called cilia, where it can be coughed up or swallowed.



Fig; 13.3 Neutrophil

13.2 Second Line of Defense

Once pathogens are able to neutralize the responses from the first line of defense i.e skin and mucous membranee and are able to penetrate inside the body they are encounter by the second line of defense which is nonspecific because it handles a variety of microbes.

Nonspecific defense includes macrophages, neutrophils, natural killers cells, the complement system etc.

13.2.1 Role of Macrophages and Neutrophils

Monocytes and neutrophils are types of white blood cells. As we know that WBCs are involved in providing immunity to the body. Monocytes are released by the bone marrow, These float in the bloodstream from where they enter tissues and turn into macrophages. Of all blood cells, macrophages are the biggest. Most boundary tissue has its own macrophages. For example, alveolar macrophages live in the lungs and keep the lungs clean and disease free by ingesting foreign things like smoke, dust bacteria and microbes. Macrophages also swim freely. One of their jobs is to clean up dead neutrophils. Macropghages clean up pus as a part of the healing process.

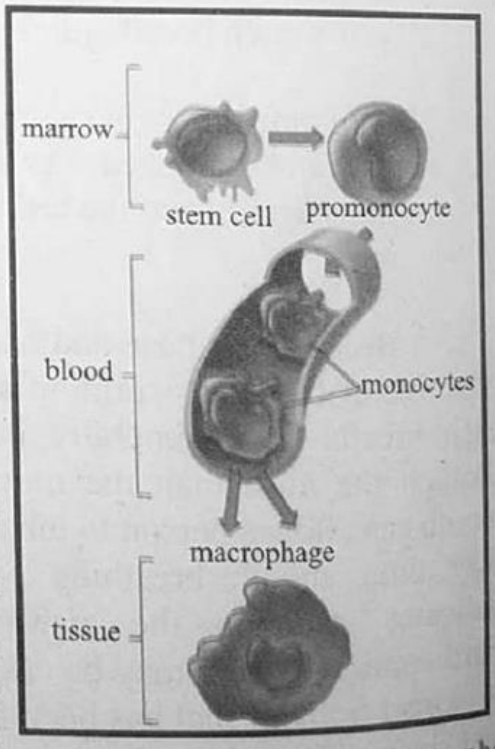


Fig: 13.4 Formation of macrophage.

Neutrophils are the most common form of white blood cells in the body. Bone marrow produces trillions of WBCs every day and releases them into the bloodstream, but their life span is short - generally less than a day.

Once in the bloodstream neutrophils can move through capillary walls into tissue. Neutorphils are attracted to foreign material, inflammation and bacteria. If you get a splinter or a cut, neutrophils will be attracted by a process called chemotaxis. Once a neutrophil finds a foreign particle or a bacteria it will engulf it, releasing enzymes, hydrogen peroxide and other chemicals from its granules to kill the bacteria. In a site of serious infection (where lots of bacteria have reproduced in the area), pus

will form. Pus is simply dead neutrophils and other cellular debris.

13.2.2 Role of Natural Killers (NK) Cells

Natural killer cells are a type of lymphocyte (a white blood cell) and a component of innate immune system. NK cells play a major role in the host-rejection of both tumours and virally infected cells. NK cells are cytotoxic; small granules in their cytoplasm contain special proteins such as perforin and proteases known as granzymes.

Upon release in close proximity to a cell selected for killing, perforin forms pores in the cell membrane of the target cell through which the granzymes and associated molecules can enter, inducing apoptosis.

The distinction between apoptosis and cell lysis is important in immunology - lysing a virus-infected cell would only release the virions, whereas apoptosis leads to destruction of the virus inside. NK cells are activated in response to interferons or macrophage-derived cytokines.

13.2.3 Complement System and interferons

If pathogenic bacteria get through all the immune system's initial defenses, the arsenal of the complement system is initiated. The complement system includes proteins and white blood cells, which carry antibodies. The antibodies are microscopic killing cells that seek out anything they don't recognize as being part of the body.The proteins circulate in an inactive form, but in response to the recognition of molecular components of microorganism, they become sequentially activated, working in a cascade where in the binding of one protein promotes the binding of the next protein in the cascade. The white blood cells and the proteins work together to coat any invading bacteria with antigen, which often makes the bacteria incapable of reproducing or binds the bacterium to a toxic chemical to make it break apart. The white blood cells and the proteins work together to coat any invading bacteria with antigen, which often makes the bacteria incapable of reproducing or binds the bacterium to a toxic chemical to make it break apart.

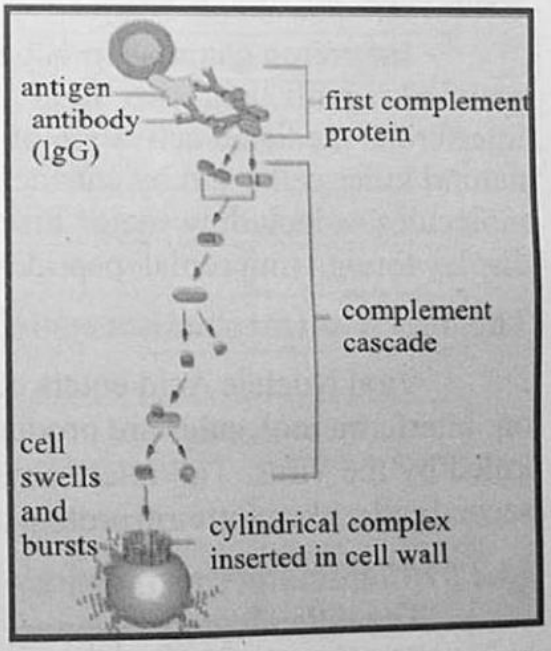


Fig: 13.5 Mechanism of complement system.

The cells in the blood that detect pathogenic bacteria and signal the complement system to get to work are macrophages. The bacteria are passed on to T cells and B cells that are able to recognize and remember how to manufacture the

specific antibody to break apart the bacteria.

13.2.4 Interferon

Body frequently encounter situations of viruses attacks. Although viruses are efficient source of some of the lethal infections but at the same time Allah has gifted us with set of proteins which provide an effective shield against viral attacks.

The interferons are a group of natural proteins that are produced by human cells in response to viral infection and other stimuli. They have the ability to interfere with viruses that are replicating. There are three main types of interferon:Interferons beta and alpha—produced mainly by white blood cells and certain connective tissue cells called fibroblasts.

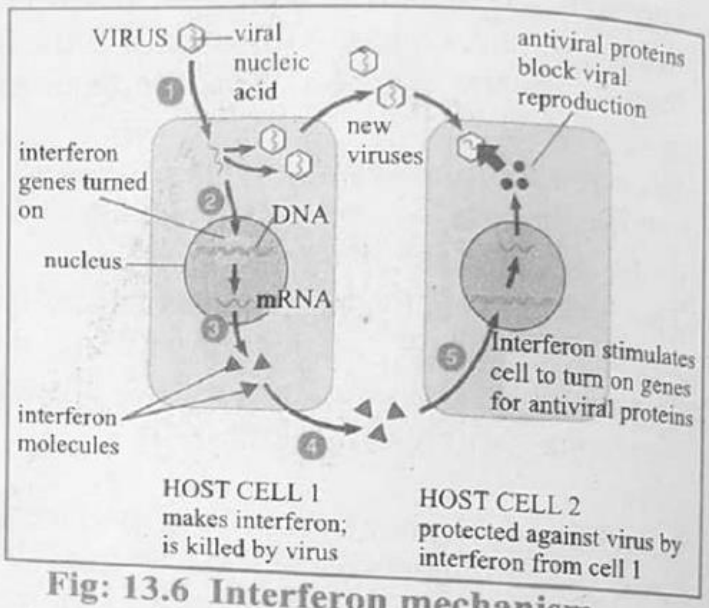


Fig: 13.6 Interferon mechanism against viruses.

Interferon gamma—produced primarily by activated T cells. Interferons are antiviral agents and can fight tumors. These activities are co-ordinated by interferons-mediated activation of certain immune cells, such as macrophages and natural killer cells, and by enhancing cell surface expression of important immune molecules -- including major histocompatibility complex classes I and II, which display foreign (microbial) peptides for activation of T cells.

The Interferon mechanism against viruses

Viral Nucleic Acid enters cell. Interferon genes of the cell's DNA are turned on. Interferon molecules are produced and released by the cell. The first host cell is killed by the virus. The interferons are recieved by another cell. In response, the second cell makes antiviral proteins, which block viral reproduction.

13.2.5 Inflammatory response as one of the non specific defenses

The inflammatory response (inflammation) occurs when tissues are injured by bacteria, trauma, toxins, heat, or any other cause. These damaged tissue releases chemicals including histamine, bradykinin, and serotonin. These chemicals cause blood vessels to leak fluid into the tissues, causing swelling. This helps isolate the foreign substance from further contact with body tissues. The chemicals also attract white blood cells called phagocytes that "eat" microorganisms and dead or damaged cells. This process is called phagocytosis. Phagocytes eventually die. Pus is formed from a collection of dead tissue, dead bacteria, and live and dead phagocytes. The main symptoms of the inflammatory response are as follows.

- The tissues in the area are **red** and **warm**, as a result of the large amount of blood reaching the site.
- The tissues in the area are **swollen**, again due to the increased amount of blood and proteins that are present.
- The area is **painful**, due the expansion of tissues, causing mechanical pressure on nerve cells, and also due to the presence of pain mediators.

Once the inflammatory process has begun, it continues until the infection that caused it has been eradicated.

13.2.6 Pyrexia and Pyrogens

In case microbes proceeds in establishing a major infection the body often produces fever, which slows down microbial production and enhances the body's own fighting abilities.

Pyrexia (fever) means the elevation of body temperature above the normal range. It may be caused by abnormalities in the brain itself or by toxic substances that affect the temperature regulating centers. Such causes include bacterial or viral infections. Normally, the temperature of the body is regulated almost entirely by nervous feedback mechanisms, and almost all of these operate through a temperature regulating center located in the hypothalamus at the base of the brain. Nerve receptors in the skin and spinal cord provide feedback that drives the body to either conserve heat, produce increased quantities of heat (shivering), or increase heat loss (sweating or panting). Changes in the heat regulating process are constantly undergoing modifications that go unnoticed. In other words, heat regulation is not a static process but an ever-moving one that is important to normal body function.

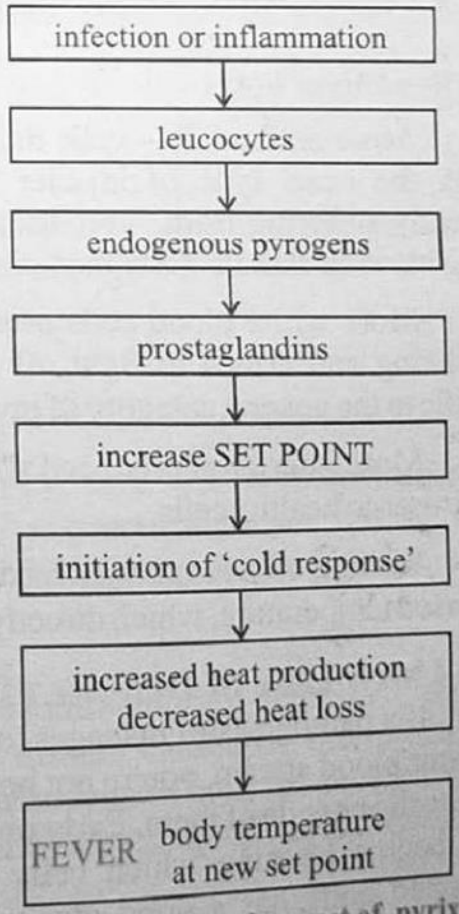


Fig: 13.7 Stages in the onset of pyrixia.

Substances that may cause the "set point" of the hypothalamic thermostat to rise are called pyrogens. Many proteins, breakdown products of proteins, and certain other substances, such as lipopolysaccharide toxins (LPS or endotoxin) secreted by bacteria, can act as pyrogens. It is pyrogens secreted by toxic bacteria or pyrogens released from degenerating tissues of the body

T lymphocytes or T cells, along with macrophages, oversee the Cell mediated response, while the B lymphocytes or B cells take charge of the humoral response.

Monocytes develop from stem cells in the bone marrow. They then go into blood, where they circulate for a while and then migrate into tissues. In the tissue they further mature into macrophages. Monocytes and macrophages play important roles in the immune defence and inflammation.

Lymphocytes are one of the five kinds of white blood cells or leukocytes), circulating in the blood. Although mature lymphocytes all look pretty much alike, they are extraordinarily diverse in their functions. The most abundant lymphocytes are:

- B- lymphocytes (B cells)
- T -lymphocytes (T cells).

B cells are produced in the bone marrow. The precursors of T cells are also produced in the bone marrow but leave the bone marrow and mature in the thymus. Each B cell and T cell is specific for a particular antigen.

For Your Information

All complement pathways carry out 6 beneficial innate defense functions. They:

1. Trigger inflammation.
2. Chemotactically attract phagocytes to the infection site.
3. Promote the attachment of antigens to phagocytes (enhanced attachment or opsonization).
4. Cause lysis of gram-negative bacteria and human cells displaying foreign epitopes.
5. Plays a role in the activation of naive B-lymphocytes.
6. Remove harmful immune complexes from the body.

13.4 Basic Types of Immunity

There are two main types of immunity :

1. Innate or Inborn or Natural immunity

The innate immunity system is what we are born with and it is nonspecific; all antigens are attacked pretty much equally. It is genetically based and we pass it on to our off springs. It is present from the birth and is inherited from the mother to offspring through the placenta.

2. Acquired or Adaptive immunity.

It is not present from the birth but is acquired during one's own life. It is developed by the organism in response to a disease caused by the infection of microbes or vaccine. In this, the protective lymphocytes of body produce antibodies which not only inactivate the antigens and relieve from an infectious disease but also provide immunity against further attack.

It is so as some antibody producing cells persist as "memory cells" for long period and produce antibodies immediately after second infection to counter it. The

acquired immunity so developed may be temporary (e.g., influenza) or permanent (e.g., measles, mumps, polio, smallpox) for life long.

13.4.1 Types of acquired immunity

(a) Active or Natural immunity

It is a long lasting immunity developed by antibodies produced by an individual's own cells. It is developed in three ways :

a. By having the disease e.g., chickenpox, mumps, measles etc.

b. By having a subclinical infection e.g. live 'Sabin' vaccine (against polio).

c. By having killed micro-organisms or detoxified toxins e.g., killed 'Salk' vaccine (against polio), tetanus toxoid (against tetanus).

(b) Passive or Artificial immunity

Passive immunity is "borrowed" from another source and it lasts for a short time. For example, antibodies in a mother's breast milk provide a baby with temporary immunity to diseases the mother has been exposed to. This can protect the baby against infection during the early years of childhood.

Everyone's immune system is different. Some people never seem to get infections, whereas others seem to be sick all the time. As people get older, they usually become immune to more germs as the immune system comes into contact with more and more of them. That's why adults and teens tend to get fewer colds than kids — their bodies have learned to recognize and immediately attack many of the viruses that cause colds.

13.4.2 Vaccination a mean to develop active acquired immunity

Immunization is the process where body is made immune or resistant to an infectious disease, typically by the administration of a vaccine. Vaccine stimulates the body's own immune system to protect the person against subsequent infection or disease. The word vaccination or vaccine had been evolved from vacca which means cow pus, which contains virus for cowpox. The cowpox and smallpox virus is very similar in structure. If the human body is exposed to the cowpox virus through vaccine, the body acquired immunization against smallpox. We can define vaccine as a immuno -biological substance which produce specific protection against a given disease. It stimulates the production of protective antibody and other immune mechanism.

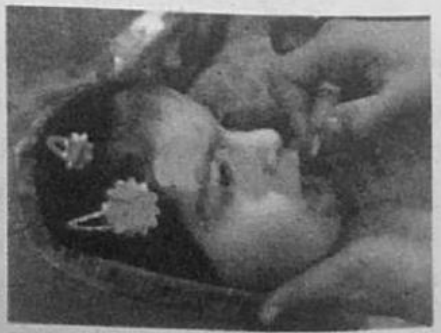


Fig:13.9 Polio vaccine is given against polio virus.

Vaccines may be prepared from live modified organisms, inactivated or killed organisms, extracted cellular fractions toxoids or combination of these. Prevention of disease is the need of the day.

The morbidity caused by the disease and rising costs of treating them requires us to focus more on their prevention. Immunization is among the most successful components of preventive medicine. It is effective public health intervention that has had the greatest impact on health of the people. Every year millions of children around the globe are saved from illness or death

because of vaccines.

13.5 Specific defense mechanisms

Specific defense mechanisms are effective against specific pathogens. There are two main types of specific defense mechanisms involved in the immune system.

a. Cell mediated immune response

b. The antibody mediated immune response

a. Cell mediated immune response

The cell-mediated immune system consists of T-cells which originate in the bone marrow, but moves to the thymus where their development is completed. T-cells are highly-specialized cells in the blood and lymph. They fight bacteria, viruses, fungi, protozoans, cancer, etc. within host cells and react against foreign matter such as organ transplants.

There are three kinds of T-cells. Cytotoxic T-cells directly kill invaders. Helper T-cells aid B cells and other T-cells to do their jobs. Suppressor T-cells suppress the activities of B- and other T-cells so they don't overreact. In the cellular immune response, cells of the immune system kill cells of the body that have been infected with a virus or that are cancerous. This response relies on cytotoxic T (Tc) cells, Tc cells contain molecules, called perforins, that they release onto target cells. The perforin makes holes in the target cells and thereby kills them. The cellular immune response occurs in two phases. In the first, called the activation phase, Tc cells that have the appropriate T-cell receptors are activated and triggered to divide repeatedly. In the second called the effectors phase, these activated Tc cells encounter target cells and kill them.

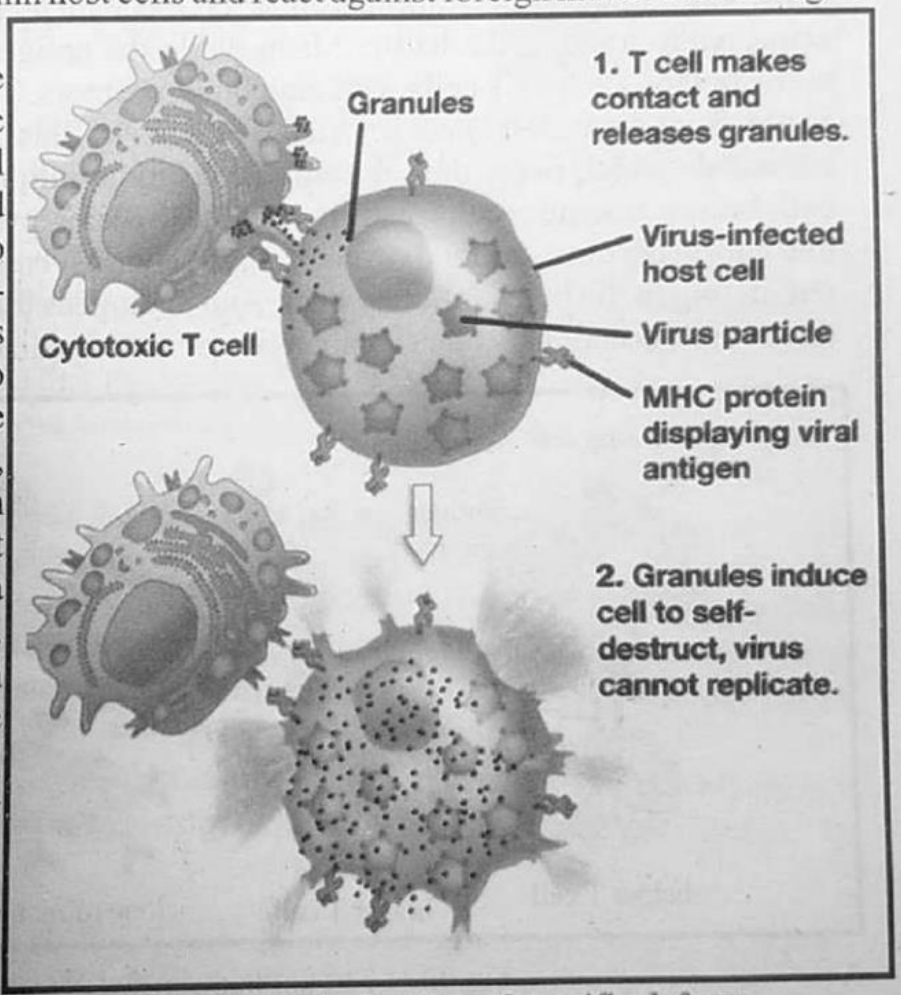


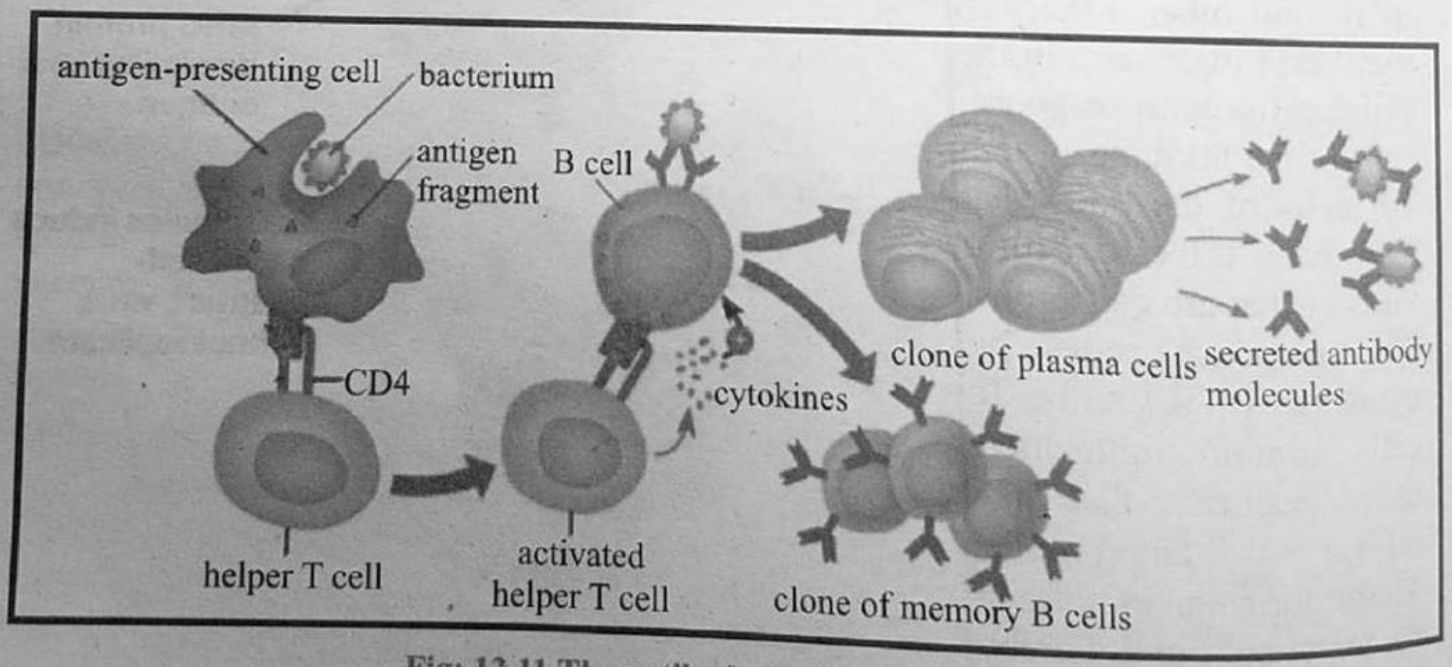
Fig: 13.10 Mechanism of specific defense.

\b. **The antibody mediated immune response**

The humoral immune system consists of B-cells which originate in the Bone marrow and stay there to develop. B-cells can produce antibodies, but need exposure to foreign antigens to do so. These antigens are cell surface oligosaccharides and proteins which the cell uses as "ID tags".

Antibodies are chemically proteins present in blood plasma and lymph. They help in fighting bacteria and viruses in body fluids. All daughter cells of a B-cell will be able to produce the same antibodies as the mother cell. Antibodies bind to certain parts of an antigen to mark it for destruction (by the T-cells).

The body humoral or antibody mediated immune response begins in the same manner as the cell mediated response. But here the macrophages are joined by B cells. The pathogens activate only those B cells with matching receptors. These cells stand ready to enter the battle. Mean while the antigens presenting macrophages activate those helper T cells with matching receptors. These T cells in turn lead the battle front with activated B cells. Triggers by this meeting the helper release chemicals which make the selected B cells to go into rapid reproduction. Some B cells become memory cells ready to respond to a later invasion by the same pathogens but most become antibody producing factories called Plasma cells. Freely circulating in the body antibody dock with pathogens this neutralizes them or marks them for destruction by other weapons in our immune arsenal.



Fig; 13.11 The antibody mediated immune response.

13.5.1 Structural Model of Antibodies

Antibodies are immune system-related proteins called immunoglobulins. Each antibody consists of four polypeptides– two heavy chains and two light chains joined to form a "Y" shaped molecule. The amino acid sequence in the tips of the "Y"

varies greatly among different antibodies.

This variable region, composed of 110-130 amino acids, give the antibody its specificity for binding antigen.

The variable region includes the ends of the light and heavy chains. The constant region determines the mechanism used to destroy antigen. Antibodies are divided into five major classes, IgM, IgG, IgA, IgD, and IgE, based on their constant region structure and immune function.

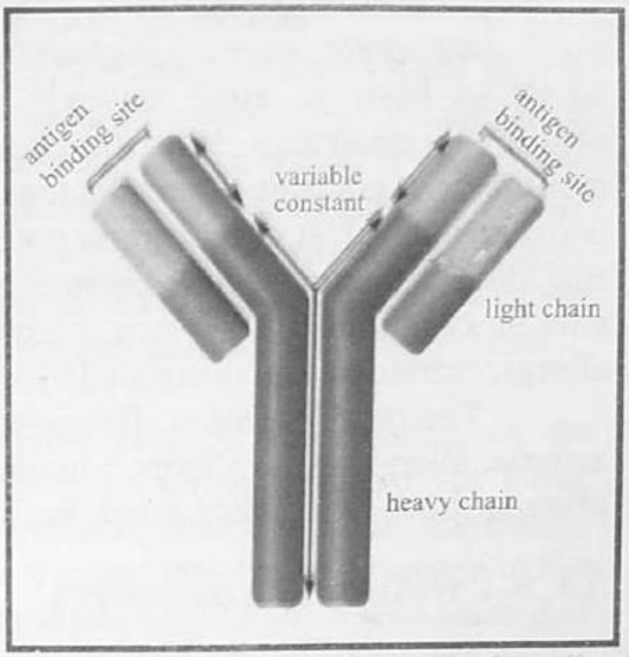


Fig:13.12 Structure of a typical antibody.

13.6 Role of Memory Cells in Immunity

Neither the killer T-cells nor the B-cells just die off after they kill the pathogen. When their job is done, they leave behind memory cells. These memory cells are cells that stay behind and watch for the pathogen. If they find one, they start multiplying to kill it. Memory killer T-cells make killer T-cells and memory B-cells make B-cells. This process is so immediate and so explosive that the pathogen is killed off before it has a chance to infect you. Because of that, you are immune to that pathogen.

13.7 Allergies

Allergies are abnormal reactions to ordinarily harmless substances. The sensitizing substances, called allergens, may be inhaled, swallowed, or come into contact with the skin. Allergens that most frequently cause problems are: pollens, mold spores, house dust mites, animal danders, foods, insect bites or stings, plants, insect spores, latex, viruses, bacteria, medications and environmental conditions (such as cold temperatures).

Although allergies can develop at any age, the risk of developing allergies is genetic. It is related to ones family history of allergy. If neither parent is allergic, the

TIDBIT

One of the common allergies facing the city dwellers in Pakistan is pollen allergy. People with weak immune system fall easy victim to pollen allergy. Pollen allergy symptoms include sneezing and runny nose, itching and watering of eyes, coughing, difficulty in breathing, wheezing and eventually attacks of asthma. Main plants causing, this allergy, are mulberry in March-April while cannabis in June-July.

chance for allergies is about 15%. If one parent is allergic, the risk increases to 30% and if both are allergic, the risk is greater than 60%.

Allergens cause the production of immunoglobulin E (IgE), an antibody that all of us have in small amounts. Allergic persons, however, produce IgE in abnormally quantities. Normally, this antibody is important in protecting us from parasites, but not from other allergens. During the sensitization period in allergy, IgE is overproduced. It coats certain potentially explosive cells that contain chemicals including histamine. These chemicals, in turn, cause inflammation and the typical allergic symptoms. This is how the immune system becomes misguided and cause an allergic reaction when stimulated by an allergen.

The most common allergic conditions include hay fever (allergic rhinitis), asthma, allergic eyes (allergic conjunctivitis), allergic eczema, hives (urticaria), and allergic shock (also called anaphylaxis and anaphylactic shock).

13. 8 Autoimmune disorders

Autoimmune disorders are diseases that occur when the body produces an inappropriate immune response against its own tissues. Sometimes the immune system will cease to recognize one or more of the body's normal constituents as "self" and will produce autoantibodies – antibodies that attack its own cells, tissues, and/or organs. This causes inflammation and damage and leads to autoimmune disorders.

In a few types of autoimmune disease (such as rheumatic fever), a virus or infection with bacteria triggers an immune response and the antibodies or T-cells attack normal cells because some part of their structure resembles a part of the infecting microorganism. Symptoms of autoimmune disorders vary by the particular disorder but many include fatigue, dizziness, and low grade fever. Symptoms can also vary in severity over time.

Some of the autoimmune diseases include:

- **Lupus**, a chronic disease marked by muscle and joint pain and inflammation (the abnormal immune response also may involve attacks on the kidneys and other organs).
- **Juvenile rheumatoid arthritis**, a disease in which the body's immune system acts as though certain body parts (such as the joints of the knee, hand, and foot) are foreign tissue and attacks them.
- **Scleroderma**, a chronic autoimmune disease that can lead to inflammation and damage of the skin, joints, and internal organs.
- **Ankylosing spondylitis**, a disease that involves inflammation of the spine and joints, causing stiffness and pain.
- **Juvenile dermatomyositis**, a disorder marked by inflammation and damage of the skin and muscles.

13.9 Role of T-cells and B-cells in Transplant Rejection

Transplantation is the act of transferring cells, tissues, or organs from one site to another. The malfunction of an organ system can be corrected with transplantation of an organ (e.g kidney, liver, heart, lung, or pancreas) from a donor. However, the immune system remains the most formidable barrier to transplantation as a routine medical treatment. The immune system has developed elaborate and effective mechanisms to combat foreign agents. These mechanisms are also involved in the rejection of transplanted organs, which are recognized as foreign by the recipient's immune system.

Major Histocompatibility Complex (MHC) proteins are involved in the presentation of foreign antigens to T-cells, and receptors on the surface of the T-cell (TCR) are uniquely suited to recognition of proteins of this type. MHC are highly variable between individuals, and therefore the T-cells from the host recognize the foreign MHC with a very high frequency leading to powerful immune responses that cause rejection of transplanted tissue. Identical twins and cloned tissue are MHC matched, and are therefore not subject to T-cell mediated rejection.

KEY POINTS

The first line of defense is non-specific and is part of the innate immune system. The first line of defense consists of: 1) physical barriers 2) chemical barriers.

- The second line of defense is also part of the non-specific, innate immune system and includes non-specific immune cells, chemical mediators, fever; inflammation, phagocytosis.
- The third line of defense is part of the adaptive or acquired immune system. This line of defense provides specific, long-term protection against microbes. The third line of defense includes: 1) T-cells; 2) B-cells and 3) antibodies.
- Neutrophils are granular, non-specific immune cells that patrol the borders of the body and eliminate microbes by phagocytosis.
- Monocytes are agranular, non-specific immune cells that circulate in the blood and mature into macrophages when they migrate into tissues.
- Macrophages are agranular, non-specific immune cells that perform the following functions: 1) phagocytosis (professional eaters); 2) sound chemical alarm to alert other immune cells; and 3) present information about the foreign microbes (antigens) to the T cells, which are the generals of the immune army.
- Phagocytosis is a second line of defense process in which foreign materials (microbes) are engulfed and broken down by neutrophils or macrophages within a digestive compartment known as the lysosome.
- Inflammation is a non-specific response to tissue injury or infection that: 1) walls off damaged or infected tissue; 2) recruits immune cells to the site of injury or infection; and 3) clears away microbes or damaged cells so tissue repair can occur.
- Fever is an increase in body temperature induced by pyrogens and regulated by the hypothalamus, which decreases bacterial cell growth and increases immune cell activity.
- Interferons are anti-viral proteins released by virally-infected cells that help prevent the spread of infection to neighboring cells by degrading viral

KEY POINTS

DNA/RNA and blocking production of viral proteins.

Complement is a set of immune proteins that aid or "complement" immune function.. Complement proteins form the membrane attack complex, which forms holes on the surface of targeted microbes and leads to their lysis.

- Vaccine as a immuno -biological substance which produce specific protection against a given disease. It stimulates the production of protective antibody and other immune mechanism.
- There are two main types of specific defense mechanisms involved in the immune system.: Cell mediated immune response and the antibody mediated immune response.
- Antibodies are immune system-related proteins called immunoglobulins.
- Allergens cause the production of immunoglobulin E (IgE), an antibody that all of us have in small amounts. Allergic persons, however, produce IgE in abnormally large quantities
- When the body produces an inappropriate immune response against its own tissues it results in the autoimmune disorders.

EXERCISE

A. Select the best answers for the following questions.

1. Which of these is not true of both T cells and B cells?
   a. They are both lymphocytes.
   b. They both are responsible for immunity
   c. They both pass through the thymus.
   d. They both have receptor sites..

2. Memory cells of the immune system are derived from:
   a. T lymphocytes
   b. B lymphocytes
   c. plasma cells
   d. Both a and b.

3. Which one of these is specifically responsible for antibody mediated immunity?
   a. T cells
   b. Epithelial cells
   c. Platelets
   d. Plasma cells

4. T cells:
   a. are responsible for cell mediated immunity.
   b. cause tumors in the body.
   c. stimulate and suppress red blood cells.
   d. helps in regeneration process.

5. Compound formed in an organism for inhibiting growth of another organism is:
   a. Antigen
   b. Antibody
   c. Antibiotic
   d. Antiallergic

6. Antigen binding site in an antibody is found between:
   a. two light chains.
   b. two heavy chains.
   c. one heavy and one light chain.
   d. two heavy and two light chain.

7. Humoral immunity is due to:
   a. T-lymphocytes
   b. L- lymphocytes
   c. P- lymphocytes
   d. B- lymphocytes

EXERCISE

Hypersensitivity to an allergen is due to:

a. Increase in temperature
b. Food habits
c. Age
d. Aberrent functioning of immune system

Surgical removal of thymus of a new born shall result in failure to produce:

a. Monocytes
b. B-Lymphocytes
c. T- lymphocytes
d. Basophiils

B. Write short answers to the following questions.

1. What are pyrogens? How they affect the hypothalamus?
2. List three benefits of fever.
3. How interferons inhibit the ability of viruses to infect cells?
4. What would happen if mucous of bronchi fails to do it job?
5. What are the agent of nonspecific defense and specific defense?
6. Define allergy and allergens. List down some common allergic conditions.
7. Differentiate between the two types of acquired immunity.

C. Write answers of the following questions in detail.

1. What are the main events of inflammatory response?
2. Describe the structural features of human skin which provide effective control against microbes.
3. How macrophages and neutrophils help in killing bacteria?
4. How cell mediated immunity is attained?
5. What do you mean by autoimmune diseases? Give some examples of autoimmune diseases.
6. Describe the role of T-cells and B-cells in transplant rejections.

Projects:

- Vaccination is a means to develop active acquired immunity. It is one of the precautionary measure recommended against different diseases. Write an informative article on vaccination programme being implemented by the Govt for new born infants. Identify the chemical nature of the vaccines being used in this programme.
- Make a model of a structure of a typical antibody.

GLOSSARY

A

abscisic acid (ABA)
A plant hormone that generally acts to inhibit growth, promote dormancy, and help the plant tolerate stressful conditions.

abscission
In plants, the dropping of leaves, flowers, fruits, or stems at the end of a growing season, as the result of formation of a two-layered zone of specialized cells (the abscission zone) and the action of a hormone (ethylene).

absorption
The movement of water and dissolved substances into a cell, tissue, or organism.

absorption spectrum
The range of a pigment's ability to absorb various wavelengths of light.

acetyl CoA
The entry compound for the Krebs cycle in cellular respiration; formed from a fragment of pyruvate attached to a coenzyme.

acoelomate
A solid-bodied animal lacking a cavity between the gut and outer body wall.

activation energy
The energy that must be possessed by atoms or molecules in order to react.

active site
The specific portion of an enzyme that attaches to the substrate by means of weak chemical bonds.

active transport
The movement of a substance across a biological membrane against its concentration or electrochemical gradient, with the help of energy input and specific transport proteins.

adenosine diphosphate (ADP)
A nucleotide consisting of adenine, ribose, and two phosphate groups; formed by the removal of one phosphate from an ATP molecule.

adenosine monophosphate (AMP)
A nucleotide consisting of adenine, ribose, and one phosphate group; can be formed by the removal of two phosphates from an ATP molecule; in its cyclic form, functions as a "second messenger" for a number of vertebrate hormones and neurotransmitters.

adenosine triphosphate (ATP)
An adenine-containing nucleoside triphosphate that releases free energy when its phosphate bonds are hydrolyzed. This energy is used to drive endergonic reactions in cells.

allergic reaction
An inflammatory response triggered by a weak antigen (an allergen) to which most individuals do not react; involves the release of large amounts of histamine from mast cells.

alternation of generations
A life cycle in which there is both a multicellular diploid form, the sporophyte, and a multicellular haploid form, the gametophyte; characteristic of plants.

amino group
A functional group that consists of a nitrogen atom bonded to two hydrogen atoms; can act as a base in solution, accepting a hydrogen ion and acquiring a charge of +1.

anaerobic
Lacking oxygen; referring to an organism, environment, or cellular process that lacks oxygen and may be poisoned by it.

antheridium *pl.* **antheridia**

In plants, the male gametangium, a moist chamber in which gametes develop.

anthocyanin
Natural water-soluble pigments of blue, purple or red which are dissolved in the cell-sap vacuole of plant cells.

antibiotic
A chemical that kills bacteria or inhibits their growth.

antibody
An antigen-binding immunoglobulin, produced by B cells, that functions as the effector in an immune response.

antigen
A foreign macromolecule that does not belong to the host organism and that elicits an immune response.

aorta
The major artery in blood-circulating systems; the aorta sends blood to the other body tissues.

apical dominance
Concentration of growth at the tip of a plant shoot, where a terminal bud partially inhibits axillary bud growth.

apical meristem
Embryonic plant tissue in the tips of roots and in the buds of shoots that supplies cells for the plant to grow in length.

apoplast
In plants, the nonliving continuum formed by the extracellular pathway provided by the continuous matrix of cell walls.

apoptosis
Programmed cell death brought about by signals that trigger the activation of a cascade of "suicide" proteins in the cells destined to die.

assimilation
The energy-requiring process by which plant cells convert nitrate ions (NO_3^-) taken up by the roots of plants into ammonium ions (NH_4^+), which can then be used in the synthesis of amino acids and other nitrogenous compounds.

atrioventricular valve
A valve in the heart between each atrium and ventricle that prevents a backflow of blood when the ventricles contract.

autoimmune disease
An immunological disorder in which the immune system turns against itself.

B

B cell
A type of lymphocyte that develops in the bone marrow and later produces antibodies, which mediate humoral immunity.

bark
All tissues external to the vascular cambium in a plant growing in thickness, consisting of phloem, phelloderm, cork cambium, and cork.

bile
A yellow secretion of the vertebrate liver, temporarily stored in the gallbladder and composed of organic salts that emulsify fats in the small intestine.

biochemical pathway
An ordered series of chemical reactions in a living cell, in which each step is catalyzed by a specific enzyme; different biochemical pathways serve different functions in the life of the cell.

bioenergetics

The study of how organisms manage their energy resources.

biosynthesis

Formation by living organisms of organic compounds from elements or simple compounds.

blood pressure

The hydrostatic force that blood exerts against the wall of a vessel.

bond energy

The quantity of energy that must be absorbed to break a particular kind of chemical bond; equal to the quantity of energy the bond releases when it forms.

bud

(1) In plants, an embryonic shoot, including rudimentary leaves, often protected by special bud scales. (2) In animals, an asexually produced outgrowth that develops into a new individual.

bulb

A modified bud with thickened leaves adapted for underground food storage.

C_4 pathway

The set of reactions by which some plants initially fix carbon in the four-carbon compound oxaloacetic acid; the carbon dioxide is later released in the interior of the leaf and enters the Calvin cycle.

C_4 plant

A plant that prefaces the Calvin cycle with reactions that incorporate CO_2 into four-carbon compounds, the end-product of which supplies CO_2 for the Calvin cycle.

callus

In plants, undifferentiated tissue; a term used in tissue culture, grafting, and wound healing.

Calvin cycle

The second of two major stages in photosynthesis (following the light reactions), involving atmospheric CO_2 fixation and reduction of the fixed carbon into carbohydrate.

carcinogen

A chemical agent that causes cancer.

cardiac muscle

A type of muscle that forms the contractile wall of the heart; its cells are joined by intercalated discs that relay each heartbeat.

catalyst

A substance that lowers the activation energy of a chemical reaction by forming a temporary association with the reacting molecules; as a result, the rate of the reaction is accelerated. Enzymes are catalysts.

cell cycle

An ordered sequence of events in the life of a dividing eukaryotic cell, composed of the M, G_1, S, and G_2 phases.

cell-mediated immunity

The type of immunity that functions in defense against fungi, protists, bacteria, and viruses inside host cells and against tissue transplants, with highly specialized cells that circulate in the blood and lymphoid tissue.

cell plate

A double membrane across the midline of a dividing plant cell, between which the new cell wall forms during cytokinesis.

centromere

The centralized region joining two sister chromatids.

centrosome

Material present in the cytoplasm of all eukaryotic cells and important during cell division; also called microtubule-organizing center.

chitin

A structural polysaccharide of an amino sugar found in many fungi and in the exoskeletons of all

ropods.

lesterol
eroid that forms an essential component of animal cell membranes and acts as a precursor molecule he synthesis of other biologically important steroids.

nzyme
organic molecule serving as a cofactor. Most vitamins function as coenzymes in important abolic reactions.

actor
y nonprotein molecule or ion that is required for the proper functioning of an enzyme. Cofactors can ermanently bound to the active site or may bind loosely with the substrate during catalysis.

esion
e binding together of like molecules, often by hydrogen bonds.

esion species concept
e idea that specific evolutionary adaptations and discrete complexes of genes define species.

k
econdary tissue that is a major constituent of bark in woody and some herbaceous plants; made up of ttened cells, dead at maturity; restricts gas and water exchange and protects the vascular tissues from ury.

rk cambium
cylinder of meristematic tissue in plants that produces cork cells to replace the epidermis during condary growth.

tokines
the vertebrate immune system, protein factors secreted by macrophages and helper T cells as gulators of neighboring cells.

tosol
he semifluid portion of the cytoplasm.

ay-neutral plant
A plant whose flowering is not affected by photoperiod.

lehydration reaction
A chemical reaction in which two molecules covalently bond to one another with the removal of a water nolecule.

diastole
The stage of the heart cycle in which the heart muscle is relaxed, allowing the chambers to fill with blood.

diastolic pressure
The pressure in an artery during the ventricular relaxation phase of the heart cycle.

dioecious
Referring to a plant species that has staminate and carpellate flowers on separate plants.

dispersion
The distribution of individuals within geographical population boundaries.

double fertilization
A mechanism of fertilization in angiosperms, in which two sperm cells unite with two cells in the embryo sac to form the zygote and endosperm.

double helix
The form of native DNA, referring to its two adjacent polynucleotide strands wound into a spiral shape.

E

electromagnetic spectrum: The entire spectrum of radiation; ranges in wavelength from less than a nanometer to more than a kilometer.

electron acceptor: Substance that accepts or receives electrons in an oxidation-reduction reaction, becoming reduced in the process.
electron carrier: A molecule that conveys electrons; one of several membrane proteins in electron transport chains in cells. Electron carriers shuttle electrons during the redox reactions that release energy used to make ATP.
electron transport chain: A sequence of electron-carrier molecules (membrane proteins) that shuttle electrons during the redox reactions that release energy used to make ATP.
endergonic reaction: A nonspontaneous chemical reaction in which free energy is absorbed from the surroundings.
energy of activation (E_A): The amount of energy that reactants must absorb before a chemical reaction will start.
exergonic reaction: A spontaneous chemical reaction in which there is a net release of free energy.
exocrine glands
Glands, such as sweat glands and digestive glands, that secrete their products into ducts that empty onto surfaces, such as the skin, or into cavities, such as the interior of the stomach.
exocytosis
The cellular secretion of macromolecules by the fusion of vesicles with the lasma membrane
F
facilitated diffusion: The spontaneous passage of molecules and ions, bound to specific carrier proteins, across a biological membrane down their concentration gradients.
fatty acid: A long carbon chain carboxylic acid. Fatty acids vary in length and in the number and location of double bonds; three fatty acids linked to a glycerol molecule form fat.
fibrin: The activated form of the blood-clotting protein fibrinogen, which aggregates into threads that form the fabric of the clot.
filtration: The first stage of kidney function; blood plasma is forced, under pressure, out of the glomerular capillaries into Bowman's capsule, through which it enters the renal tubule.
flaccid: Limp; walled cells are flaccid in isotonic surroundings, where there is no tendency for water to enter.
fossil: The remains of an organism, or direct evidence of its presence (such as tracks). May be an unaltered hard part (tooth or bone), a mold in a rock, petrification (wood or bone), unaltered or partially altered soft parts (a frozen mammoth).
G
gastric: Pertaining to the stomach.
gastrin: A digestive hormone, secreted by the stomach, that stimulates the secretion of gastric juice.
gastrovascular cavity
The central digestive compartment, usually with a single opening that functions as both mouth and anus.
glucagon
A peptide hormone secreted by pancreatic endocrine cells that raises blood glucose levels; an antagonistic hormone to insulin.
glycerol: A three-carbon molecule with three hydroxyl groups attached; a glycerol molecule
guard cell: A specialized epidermal plant cell that forms the boundaries of the stomata.
gH
helper T cell (T_H): A type of T cell that is required by some B cells to help them make antibodies or that helps other T cells respond to antigens or secrete lymphokines or interleukins.
histamine (hiss-tuh-meen) : A substance released by injured cells that causes blood vessels to dilate during an inflammatory response.
histone (hiss-tone): A small protein with a high proportion of positively charged amino acids that binds to the negatively charged DNA and plays a key role in its chromatin structure.

humoral immunity (**hyoo**-mur-al); The type of immunity that fights bacteria and viruses in body fluids with antibodies

Inflammation: A body strategy initiated by the release of chemicals following injury or infection which brings additional blood with its protective cells to the injured area.

Long-day plants: Plants that flower when the length of daylight exceeds some critical period.

Meristems: In plants, clusters of cells that retain their ability to divide, thereby producing new cells. One of the four basic tissues in plants.

Microfilaments: Thin protein fibers that are responsible for maintenance of cell shape, muscle contraction and cyclosis.

Microtubules: Thin, hollow tubes in cells; built from repeating protein units of tubulin. Microtubules are components of cilia, flagella, and the cytoskeleton.

parathyroid hormone (PTH). When blood calcium levels are low, PTH is secreted, causing calcium to be released from bone.

Pelagic zone: The open oceans, divided into threelayers:1) photo- or epipelagic,(sunlit), 2) mesopelagic (dim light), 3) aphotic or bathypelagic (always dark).

Placenta: In mammals (exclusive of marsupials and monotremes), the structure through which nutrients and wastes are exchanged between the mother and embryo fetus. Develops from both embryonic and uterine tissues.

Plasmid: A small circle of ON A in bacteria in addition to its own chromosome.

component of seed coats and nuts.

Sclerenchyma: Component of the ground tissue system of plants. They are thick walled cells of various shapes and sizes, providing support or protection. They continue to function after the cell dies.

Short -day plants: Plants that flower in late summer or fall when the length of daylight becomes shorter than some critical period.

Thigmotropism: Changes in plant growth stimulated by contact with another object, e.g., vines climbing on cement walls.

Transformation: A genetic transfer mechanism that produces new DNA in bacteria when DNA from a new organism is combined with the DNA of the host cell.

Translation: The cell process that converts a sequence of nucleotides in mRNA into a sequence of amino acids.

Vernalization: The promotion of flowering or germination after a plant is exposed to low temperatures.

Viviparous: Referring to an animal whose offspring are born rather than hatched through an egg.

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