THE STRUCTURE AND FUNCTION OF ORGANISMS

To carry on with the business of life, higher organisms must all contend with the same basic challenges: obtaining nutrients, distributing them throughout their bodies, voiding wastes, responding to their environments, and reproducing. To accomplish these basic tasks, nature has come up with solutions. However, for all their differences, most animals have remarkably similar ways of dealing with these challenges.

While the AP Biology Exam does not include memorization questions about body systems, you'll likely see thematic questions which cover structure and function relationships, communication between cells and tissues, and interaction and interconnectedness of organismal biology. Although the AP Biology Course and Exam used to require memorization of each of the body systems, the curriculum (and, therefore, the exam) now requires only specific knowledge about the immune system, the nervous system, the endocrine system, and reproductive development because these systems best illustrate the communication and interaction between different cells within the organism as a whole. Questions discussing other systems will do so in the context of these themes. Therefore, this chapter covers these four key systems in detail, while giving you a solid foundation in the themes that you may see reflected in questions on the exam.

The systems we'll look at include the following:

- immune system
- nervous system
- endocrine system
- reproductive system, or morphogenesis

THE IMMUNE SYSTEM

The immune system is the body's defense system. It is a carefully and closely coordinated system of specialized cells, each of which plays a specific role in the war against bodily invaders. Foreign molecules—be they viral, bacterial, or chemical—that can trigger an immune response are called **antigens**.

The Innate Immune System

The body's first line of defense against foreign substances is the skin and mucous lining of the respiratory and digestive tracts. If these defenses are not sufficient, other nonspecific defense mechanisms are activated. These include **phagocytes** (which engulf antigens), **complement proteins** (which lyse the cell wall of the antigen), **interferons** (which inhibit viral replication and activate surrounding cells that have antiviral actions), and **inflammatory response** (a series of events in response to antigen invasion or physical injury). Activation of these defenses requires immune cells to recognize the foreign substance (usually via receptor binding) and activate intracellular signaling pathways. This is another example of how important cell communication is to survival. These first line defenses are called the innate immune system, and many organisms have this level of defense. The specifics vary with organism structure, but there are several common themes. For example, a thick outer surface is generally protective, be it the skin of a human, the cell wall of a bacteria, or the cuticle of a plant. In all organisms, cell communication pathways are essential to recognize "self" cells, recognize foreign substances, and initiate immune responses when under attack by a **pathogen** (a disease-causing agent) or chemical.

Types of Immune Cells

Lymphocytes are the primary cells of the immune system. They are found mostly in the blood and lymph nodes, and are a type of white blood cell (or leukocyte). There are two types of lymphocytes: B-cells and T-cells. When an individual becomes infected by a pathogen, B- and T- lymphocytes get activated.

B-lymphocytes mature in bone marrow and are involved in the **humoral response**, which defends the body against pathogens present in extracellular fluids, such as lymphatic fluid or blood. When B-lymphocytes encounter pathogens, they are activated and produce clones. Some B-cells become **memory B-cells** that remain in circulation, allowing the body to mount a quicker response if a second exposure to the same pathogen should occur. Other B-cells become **plasma cells** that produce **antibodies**, which are specific proteins that bind to antigens on the surface of pathogens that originally activated them. Antibodies are typically made only when the appearance of antigens in the body stimulates a defense mechanism. Antibodies have several functions; they usually trigger antigen inactivation or destruction.

T-lymphocytes, maturing in the thymus, are involved in **cell-mediated immunity**; this branch of the immune system is responsible for monitoring "self" cells to make sure they are still healthy. The plasma membrane of cells has **major histocompatibility complex (MHC) markers** that distinguish between self and foreign cells, and allow T-cells to get a glimpse of what is happening inside each cell. When T-cells encounter cells infected by pathogens or cells that have transformed into a cancerous state, they recognize the foreign antigen-MHC markers on the cell surface. In the case of cancer cells, the foreign antigen can be a cancer-associated protein that the cell shouldn't normally be making. Once activated, T-cells multiply and give rise to clones. Some T-cells become **memory T-cells**, which are long-lived cells that recognize pathogens they have encountered before (similar to memory B-cells, above). Others become **cytotoxic T-cells**, which recognize and kill infected cells. These cells are also called killer T-cells. Finally, **helper T-cells** activate B-lymphocytes and other T-cells in responding to the infected cells. This interaction between different branches of the immune system requires B-cells and T-cells to recognize each other and coordinate an immune attack—another process tightly controlled by cell signaling and communication pathways.

A **lymph node** is a mass of tissue found along a lymph vessel. A lymph node contains a large number of lymphocytes. Because lymphocytes are important in fighting infection, they multiply rapidly when they come in contact with an antigen. As a consequence, lymph nodes swell when they're fighting an infection. That's why when you have a sore throat, one of the first things a doctor does is touch the sides of your throat to see if your lymph nodes are swollen, a probable sign of infection.

One thing to remember about immune cells and blood cells: All blood cells, white and red, are produced in the bone marrow. To summarize

- Red blood cells (or erythrocytes) play no role in the immune system, and help transport oxygen throughout the body. They are full of hemoglobin.
- There are many types of white blood cells (or leukocytes), including phagocytes and lymphocytes.
- T-lymphocytes actually fight infection and help the B-lymphocytes proliferate.
- B-lymphocytes produce antibodies.

AIDS

AIDS, or "acquired immunodeficiency syndrome," is a devastating disease that interferes with the body's immune system. AIDS is caused by the specific infection of helper T-cells by human immunodeficiency virus (HIV). The virus essentially wipes out helper T-cells, preventing the body from defending itself. Those afflicted with AIDS do not die of AIDS itself but rather of infections that they can no longer fight off, due to their compromised immune systems.

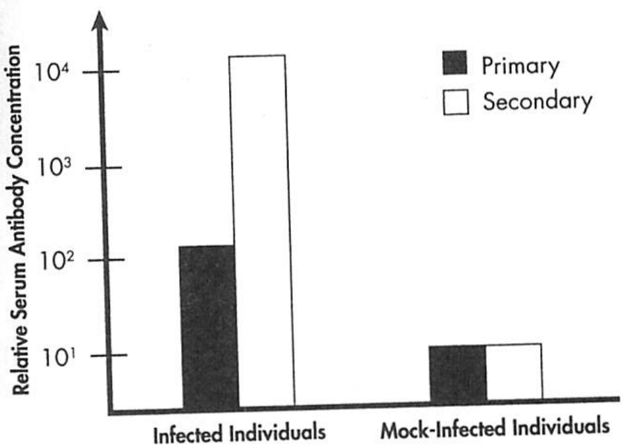
Immune Systems Drill

Answers and explanations can be found in Chapter 16.

1. Lymph nodes are often evaluated when a patient is believed to have an active infection or cancer. Why?

   (A) Active infections or cancer often generate large quantities of fluids as cells rupture, the lymph nodes often swell as a result of the buildup of these fluids.
   (B) During an active infection, lymphocytes expand rapidly in lymph nodes causing swelling of the structures.
   (C) Lymph nodes are the most common tissue site of active infections or cancer.
   (D) Cancer often metastasizes to lymph nodes causing them to expand as new cancerous cells multiply.

Questions 2-4 refer to the following chart and paragraph.



A scientist wishes to test the efficacy and immunogenicity of a newly developed live-attenuated virus vaccine strain. To test for immunogenicity, the scientist acquires 100 healthy volunteers and challenges them with either the vaccine strain or a placebo strain (consisting of isotonic saline solution). 12 days following the initial primary challenge, the serum antibody concentration is determined by an ELISA analysis. A follow-up challenge to test for existing memory was performed on day 60 using the same 100 individuals. Serum antibody titers were determined for the secondary challenge on day 72. These data are shown in the chart above.

2. The placebo strain was included in the experimental design in order to

   (A) evaluate the immune response to isotonic saline solution
   (B) determine primary and secondary immune responses to the virus
   (C) compare antibody titers of infected and mock-infected individuals as a control
   (D) practice before challenging the same individuals with the vaccine strain

3. What type of immune cells is responsible for generating the antibodies generated in this experiment?

   (A) Erythrocytes
   (B) B-cells
   (C) T-cells
   (D) Phagocytes

4. How can the scientist increase the statistical significance of these data?

   (A) They could repeat the experiment with a greater sample size.
   (B) They could use more control variables.
   (C) They could perform a third challenge on the same 100 individuals.
   (D) They could use a different statistical test, which provides the necessary statistical significance.

5. Myasthenia gravis is an autoimmune disorder in which patients experience fatigue, sluggishness, and weakness. Rogue autoantibodies in the bloodstream target the body's own acetylcholine receptors at the neuromuscular junctions, causing the patients' muscles to exhibit delayed responses. Which treatment would have the most immediate positive effect for patients of this disorder?

   (A) Broad-spectrum immunosuppression drugs to reduce the effectiveness of the immune system
   (B) Removal of the thymus because it is responsible for maturation of macrophages
   (C) Blood transfusion to remove or dilute the acetylcholine autoantibodies
   (D) Additional acetylcholine

6. Drugs that use the immune system to attack cancer cells have shown great promise in treating specific cancers like Hodgkin's lymphoma. With this type of drug, the doctors hope to permit the patient's own immune system to attack the abnormal cancer cells, resulting in shrinking tumors and remission in patients. Which type of cell are they likely mobilizing against the cancer?

   (A) Memory B-cells
   (B) Lymphocytes
   (C) Phagocytes
   (D) Natural T-killer cells

7. Innate immune system defenses in animals include skin, mucous membranes, and defensive enzymes present in saliva, tears, stomach acid, and skin. Analogous structures in plants could include

   (A) long stems
   (B) thorns and spines
   (C) attractive scents
   (D) stomata

8. When lymphocytes first encounter a pathogen, receptors on their surface first bind to the outside of the pathogen. Next, this activated lymphocyte multiplies and becomes numerous, allowing it to bind to many more pathogens of the same type that exist in the bloodstream. What are other results from this initial recognition of the pathogen?

   (A) Antibodies specific to the pathogen are secreted by B-cells.
   (B) The pathogen is destroyed by helper T-cells.
   (C) Only plasma B-cells remain.
   (D) The pathogen is permitted to infect more cells prior to its destruction.

9. After a macrophage engulfs a pathogen through phagocytosis, it destroys the pathogen and then the macrophage matures to become

   (A) T-cells that secrete specific antibodies for the pathogen
   (B) MHC antigen-presenting cells
   (C) activated plasma cells
   (D) memory B-cells