ANSWER KEY (GENERAL IMMUNOLOGY)

The answers below may include more detail than would be provided by most students. They are meant to give additional information that you may want to discuss with students.

PART 1: INTRODUCTION TO IMMUNE SYSTEM ANATOMY

1. The body has physical and chemical barriers to prevent pathogens from entering and infecting tissues.
   a. Having a runny nose (and blowing your nose) protects your body from pathogens. How do you think that works?
   Cells that line the inside of the nose are covered in sticky mucus, which traps pathogens. When you have a runny nose, these cells are making more mucus. Blowing your nose helps to eliminate the mucus and the pathogens trapped in it.

   b. Why do cells that line the respiratory tract (including the nose and lungs) have hairs?
   The hairs sweep mucus and pathogens out of the body.

2. The table below is an example "report" from a blood test. It shows the numbers of five different cell types in a person's blood. It also shows the expected ranges of numbers if the person is currently healthy. (These values are just examples — other people's might be different.)

Type of cell	**Number of cells** (per microliter of blood)	**Expected number of cells** (per microliter of blood)
Neutrophils	4,165	1,560–6,450
Lymphocytes (T cells, B cells, NK cells)	1,050	950–3,070
Eosinophils	142	30–480
Monocytes	519	260–810
Basophils	24	10–80

   a. Where in the body are these types of cells produced?
   They are produced in the bone marrow.

   b. Are this person's numbers of immune cells within their expected ranges? If not, which cell types are *not* within their expected ranges?
   All the numbers of cells (per microliter of blood) are within their expected ranges.

3. Below is a similar report for an adult with **leukemia**, a cancer of immune cells. Cancer is caused by uncontrolled cell division.

Type of cell	**Number of cells** (per microliter of blood)	**Expected number of cells** (per microliter of blood)
Neutrophils	2,580	1,560–6,450
Lymphocytes (T cells, B cells, NK cells)	124	950–3,070
Eosinophils	30	30–480
Monocytes	2,280	260–810
Basophils	60	10–80

a. Which parts of this report might show that this person has leukemia? Be specific.
The number of monocytes (2,280 cells/microliter) is much higher than expected (260–810 cells/microliter). These results could indicate uncontrolled division of immune cells, which is indicative of leukemia.

Students may wonder why the number of lymphocytes is lower than expected. This can happen if the monocytes crowd out other blood cells. Different types of leukemias have different symptoms and numbers of cells.

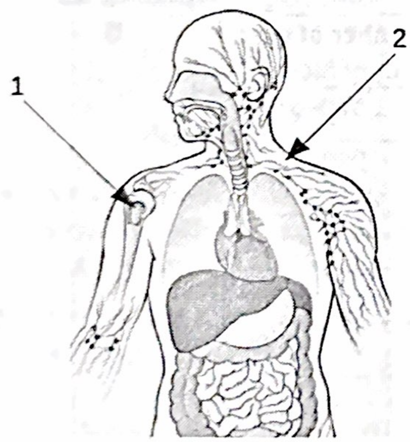
b. One treatment for leukemia is a **bone marrow transplant**. First, doctors use various methods to kill the cancer cells in the person's body. They can then replace these cells with stem cells from the bone marrow of a person without leukemia. Why might a bone marrow transplant help a person with leukemia?
Immune cells develop from blood stem cells in the bone marrow. When a person has leukemia, it could be because their blood stem cells or the resulting immune cells are dividing uncontrollably. A bone marrow transplant replaces these stem cells with new stem cells, which should divide at more controlled rates and produce the appropriate numbers of immune cells.

4. In very rare cases, a baby may be born without a thymus. How might this affect their immune system?
T cells develop in the thymus, so a baby without a thymus might not be able to produce fully developed T cells. Without T cells, the baby could be more likely to get infections. (Students may also suggest that other parts of the baby's immune system could help compensate for their lack of T cells.)

5. When a person is sick, a doctor may check the lymph nodes under their jaw and on each side of their neck. Swollen lymph nodes can be a sign that the body is responding to an infection. Why do you think this is?
Lymph nodes are organs with a variety of immune cells. When you are infected by a pathogen, the lymph nodes may swell due to increased immune cell activity. (Students will learn more about inflammation in the "Immune Response" tab.)

6. An athlete injured their spleen during a game. At the hospital, doctors removed the spleen and then recommended that the athlete get all their vaccines, including the flu vaccine. **Vaccines** are medicines that help protect the body from infections. Explain why getting vaccines would be particularly important for someone without a spleen.
The spleen is an organ that contains many immune cells (such as phagocytes, B cells, and T cells) that are important for destroying pathogens. If a person's spleen is removed, they might not have as many immune cells to respond to infections. Getting vaccines can help protect the person from some of these infections. (Students will learn more about vaccination in the "Immune Response" tab.)

7. Label **two** organs of the immune system on the figure below, and explain how they work together.
Student answers will vary; an example is shown below.



The two organs I chose are the bone marrow (1) and lymph nodes (2). The bone marrow produces immune cells, which include phagocytes, B cells, and T cells. Once these cells leave the bone marrow, they can eventually enter the lymph nodes, where they help destroy pathogens.

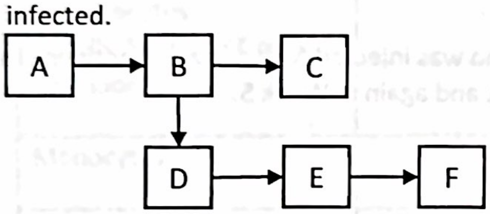
PART 2: IMMUNE RESPONSE

8. Determine whether each statement in the table below is true or false. Write your decision in the "True or False?" column.

Statement	True or False?
Innate immune cells can distinguish between specific types of viruses and bacteria.	***False***
Innate immune cells can activate other types of immune cells.	***True***
The innate immune response provides longer-lasting protection than the adaptive response.	***False***
The innate immune response includes phagocytes and proteins.	***True***

9. Cytokines are often referred to as "messengers." Provide **two** examples of "messages" that cytokines can deliver, and describe how cells or the body respond to each message.
Student answers will vary. Examples include the following:
   - ***Some cytokines signal the brain to raise the body's temperature, causing a fever.***
   - ***Some cytokines attract immune cells to the site of an infection.***
   - ***Some cytokines activate other cells to destroy pathogens, remove dead cells, or repair damaged tissues.***

10. Examine the diagram below. It represents some of the steps (A to F) that can occur when a person is infected.



Assign each letter in the diagram to a step in the table below. Some of the letters have already been filled in as examples.

Steps	Letter
Phagocytes with antigens on their surface activate T cells to start the adaptive immune response.	***E***
Pathogens get through the body's physical and chemical barriers.	***A***
Innate immune cells, which include phagocytes, respond to the pathogens.	***B***
Pieces of pathogens (antigens) attach to proteins on the surface of phagocytes.	D
The adaptive immune response destroys the pathogens, and the infection ends.	***F***
The innate immune response destroys the pathogens, and the infection ends.	C

11. In two or three sentences, describe how the innate and adaptive immune responses interact.
Student answers will vary. An example response is as follows:
Some cells from the innate immune response — such as dendritic cells and macrophages — engulf and destroy pathogens, then "display" antigens from these pathogens on their surfaces using MHC proteins. These antigen-MHC complexes bind to and activate T cells, which activate other cells in the adaptive immune response. The adaptive immune response can also strengthen the innate response by producing cytokines and antibodies, which promote inflammation, phagocytosis, etc.

12. Fill in the table below...

Immune response	
Innate immune response	**Adaptive** immune response
skin and mucous membranes	***cell-mediated immune response***
inflammation	***humoral immune response***
fever	

13. Hypogammaglobulinemia is a medical condition in which you have low levels of antibodies. People with hypogammaglobulinemia tend to get a lot of infections. Why do you think this is?
Antibodies can neutralize pathogens and mark them for destruction. If your body does not produce enough antibodies, the body might not be able to neutralize or destroy pathogens as effectively, resulting in more infections.

14. Explain the difference between an antibody and an antigen.
An antigen is a piece of biological material (protein, nucleic acid, carbohydrate, or lipid) that can trigger an immune response. An antibody is a specific protein produced by immune cells in response to a specific antigen. Antibodies bind to antigens.

15. What does it mean to say that the adaptive immune response has "memory"?
Some of the T and B cells that responded to a pathogen stay in the body. These cells, called memory cells, can respond quickly to a new infection with the same type of pathogen. The presence of these cells represents a "memory" of that specific pathogen.