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Innate Immunity

A Level
P P P

Innate immunity, also called non-specific immunity, is a form of immunity that most animals have. It consists of two "lines of defence": the first being barriers that prevent pathogens from entering the body's tissues, and the second being a general immune response that is triggered if the first line of defence is breached.

Part A First line of defence: barriers

The "first line of defence" from pathogens involves preventing the pathogens from entering the body's tissues. This is done by various physical and chemical barriers.

Match the barrier to the mechanism in the table below.

Barrier	Mechanism
	Acts as a physical barrier to prevent pathogens from entering the body from outside. Also secretes sebum: an acidic, oily substance that inhibits bacterial growth.
	Line the inside walls of various organs. Secrete mucus: a sticky substance that traps pathogens.
	Flushes potential pathogens out of the eyes.
	Traps and breaks down potential pathogens in the mouth.
	Extremely low pH (between 1 and 2 in humans) solution which kills most pathogens.

Items:

mucous membranes **stomach acid** **tears** **saliva** **skin**

Part B First line of defence: lysozyme

Lysozyme is an enzyme found in mucus, saliva, and tears. It breaks down the glycosidic bonds in peptidoglycan (also called murein): a polymer consisting of long polysaccharide chains linked together by short peptide chains.

Which type of pathogen will be destroyed by lysozyme?

- viruses
- protists
- bacteria
- fungi

Part C Second line of defence: inflammation

The "second line of defence" in innate immunity refers to what happens to pathogens that manage to break through the first line of defence i.e. enter the body's tissues. In the case of pathogens that break through the skin, this involves a response called "inflammation" (also referred to as an "inflammatory response"), which is characterised by the area of skin becoming red, hot, swollen, and painful.

Fill in the blanks below to explain how this response works.

Damage of a particular tissue activates ______ (a type of white blood cell) within that tissue. This causes these cells to release two types of chemicals: cytokines and histamines.

______ are chemicals that cause nearby blood vessels to ______, thus increasing blood flow to this region. This is what causes the ______ and heat. The increase in blood flow ensures that more white blood cells can reach the site of damage. The increase in temperature inhibits pathogen reproduction (as the temperature is raised above the optimum temperature for most pathogens). These chemicals also make the blood capillaries more leaky, allowing plasma (and the white blood cells within it) to move out of the capillaries and into the damaged tissue. The white blood cells can then destroy the pathogens inside the tissues. The leakage of plasma into the tissues is what causes the ______.

______ are chemicals that attract ______ (a type of white blood cell) to the site of damage. These are cells that engulf and destroy pathogens. There are two main classes of this cell type: macrophages and neutrophils.

Items:

redness **Histamines** **dilate** **mast cells** **Cytokines** **phagocytes** **swelling** **constrict**

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Home Gameboard Biology Physiology Disease & Immunity Pathogen Phagocytosis

Pathogen Phagocytosis

A Level
P P P

An important part of the innate immune response is the phagocytosis of pathogens by white blood cells called phagocytes. There are two main types of phagocytes involved in the innate immune response: macrophages and neutrophils.

Part A Phagocytosis process

Drag the items below into the correct order on the right to show how pathogens are phagocytosed as part of the innate immune response.

Available items

- the phagocyte membrane forms an infolding
- phagocytes bind to pathogens and recognise them as non-self
- the pathogen is engulfed in a vesicle called a phagosome
- enzymes from the lysosome digest the pathogen
- phagocytes are attracted to the area containing pathogens by chemicals produced by mast cells and/or by the pathogens themselves
- a lysosome fuses with the phagosome to form a phagolysosome

Part B Non-self recognition

It is important that macrophages and neutrophils only phagocytose pathogens and not the body's own cells. To ensure this, these cells have membrane receptors for types of molecules that are commonly found on the surface of bacterial cells but not on the surface of the organism's own cells. Phagocytosis only occurs if these receptors bind to these molecules.

Which of the following types of molecules would you expect macrophages and neutrophils to have membrane receptors for? Select all that apply.

- [ ] proteins
- [ ] peptidoglycan/murein
- [ ] sterols
- [ ] carbohydrates
- [ ] lipopolysaccharides
- [ ] phospholipids

Part C Neutrophils vs macrophages

Neutrophils, as well as destroying pathogens by phagocytosis, also release antimicrobial enzymes from their vesicles into the surrounding tissue by the process of ______ (sometimes called "degranulation" in the case of immune cells).

Macrophages, as well as destroying pathogens by phagocytosis as part of the ______ immune response, also play an important role in triggering the ______ immune response. After digestive enzymes have broken down a pathogen into smaller molecules, major histocompatibility complex (MHC) II molecules inside the cell will bind to these pathogen molecules, and then move to (and integrate within) the macrophage cell membrane, "presenting" the pathogen molecules on the outside of the membrane. If a matching membrane receptor of a ______ cell binds to this pathogen molecule, an active/specific immune response is triggered. Macrophages are therefore referred to (along with a few other cell types) as professional ______, as the pathogen molecules that they present to other immune cells can act as ______.

Items:

innate/non-specific **memory B** **natural killer (NK) cells** **endocytosis** **antigen-presenting cells (APCs)** **helper T** **antibodies** **exocytosis** **adaptive/specific** **antigens**

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Gameboard:

STEM SMART Biology Week 41 - The Immune System

Adaptive Immunity

A Level

Adaptive immunity, also called specific immunity or acquired immunity, is a form of immunity that is unique to vertebrates. Unlike innate immunity, which involves general defence mechanisms against whole types of organisms (e.g. bacteria), adaptive immunity involves a specific response for each particular species/strain of pathogen.

Part A Cell-mediated immunity

Cell-mediated immunity refers to the destruction of pathogens that are ______ the body's cells. This response is carried out by a group of lymphocytes called ______.

After a professional antigen-presenting cell (APC) has phagocytosed a pathogen, it migrates through the lymphatic system to the nearest lymph node. ______ in the lymph node with a matching membrane receptor to the antigen will bind to the APC and become activated. This activation will cause these cells to release ______: molecules that will stimulate other activated lymphocytes to divide and differentiate. The cell itself will also divide and some cells will differentiate into memory cells: long-lived cells that enable a more rapid response in the case of a future infection by the same pathogen.

______ with a matching membrane receptor to the pathogen's molecules will bind to infected cells (because infected cells display pathogen's molecules on their cell membranes) and become activated. These activated immune cells will then destroy the infected cells by releasing perforin: a protein that destroys the cell membrane and thus causes cell death. Upon stimulation (see above), these cells will divide and some will differentiate into memory cells.

Items:

effector B cells (plasma cells) **Cytotoxic T cells (killer T cells)** **T cells** **outside of** **interleukins** **B cells** **inside** **memory B cells** **Helper T cells** **antibodies**

Part B Humoral immunity

Humoral immunity refers to the destruction of pathogens that are ______ the body's cells. This response is carried out by a group of lymphocytes called ______.

These cells have membrane receptors (also called membrane-bound ______), and every cell has a different type. When one of these cells binds to an antigen that matches its receptor, the cell becomes activated. It will then divide and the daughter cells will differentiate into two main types of cells.

The first type are the ______, which will produce and secrete large numbers of ______. These molecules, when bound to the pathogen, have various functions. They prevent the pathogen from entering the body's cells, and they may also act as anti-toxins by binding to toxins produced by the pathogen, thus making them harmless. They can also act as ______: causing the pathogens to clump together in one place (thus preventing them from spreading). Finally, they act as ______: molecules that phagocytes will recognise and bind to, thus ensuring that the pathogens are destroyed by phagocytosis.

The second type are the memory cells: long-lived cells that enable a more rapid response in the case of a future infection by the same pathogen.

Items:

outside **plasma cells (effector cells)** **agglutinins** **cytotoxic T cells (killer T cells)** **opsonins** **helper T cells**

antibodies **interleukins** **inside** **B cells** **T cells**

Part C Cell-mediated vs humoral immunity

Match the type of adaptive immunity to the description in the table below.

Description	Type of adaptive immunity
carried out by B lymphocytes	
carried out by T lymphocytes	
involves antibodies binding to pathogens outside of cells (e.g. in blood plasma)	
involves immune cells killing infected cells (thus destroying pathogens inside those cells)	

Items:

cell-mediated **humoral**

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Gameboard:

STEM SMART Biology Week 41 - The Immune System

Immune Cell Types

A Level

P P P

The immune system involves many different types of leukocytes (white blood cells), and each type has its own specific function.

Part A Cell functions

Match the cell type to the function in the table below.

Cell type	Function
	triggers inflammation response by releasing histamines and cytokines
	destroys pathogens by phagocytosis and by exocytosis of antimicrobial compounds
	phagocytoses pathogens and presents their antigens to helper T cells to trigger a specific/adaptive immune response
	binds to specific antigen-MHC II complexes on the membranes of professional APCs and triggers a specific/adaptive immune response
	binds to specific antigen-MHC I complexes on the membranes of infected cells and destroys those cells
	short-lived cell type that rapidly secretes large numbers of a specific antibody into the bloodstream
	long-lived cell type responsible for secondary immune response to a specific pathogen

Items:

cytotoxic T cell (killer T cell) **effector B cell (plasma cell)** **helper T cell** **macrophage** **mast cell** **memory B cell** **neutrophil**

Part B Types of immunity

In the table below, show which type of immunity each cell type carries out.

Cell type	Type of immunity
cytotoxic T cell (killer T cell)	
effector B cell (plasma cell)	
macrophage	
mast cell	
memory B cell	
neutrophil	

Items:

innate (non-specific) **adaptive (specific): humoral** **adaptive (specific): cell-mediated**

Part C B cells and T cells

Leukocytes (white blood cells) can be categorised into different types. One of these groups is called lymphocytes. These are responsible for the specific (adaptive) immune response, and include B cells and T cells.

Which of the following statements about lymphocytes are correct? Select all that apply.

- [ ] Lymphocyte activation involves binding to an antigen and then proliferating and differentiating into memory cells and effector cells
- [ ] Lymphocyte **maturation** involves secreting antibodies (effector B cells/plasma cells) and killing infected cells (cytotoxic T cells)
- [ ] B cells and T cells are both **produced** in the bone marrow
- [ ] Lymphocyte **maturation** involves genetic rearrangement to produce a range of receptors/antibodies, and selection against receptors/antibodies that will bind to the body's own proteins/cells
- [ ] Lymphocyte activation involves the phagocytosis of pathogens by lymphocytes
- [ ] B cells are **produced** in the bone marrow whereas T cells are **produced** in the thymus
- [ ] B cells **mature** in the bone marrow whereas T cells **mature** in the thymus

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Gameboard:

STEM SMART Biology Week 41 - The Immune System

Antibody Structure and Function

A Level
P P P

An antibody is a large protein consisting of four polypeptide chains: two "heavy chains" and two "light chains". Each antibody is symmetrical (i.e. the two heavy chains are identical to each other and the two light chains are identical to each other). Each antibody has a constant region (which is the same across all antibodies) and a variable region (which is unique to the antibodies produced by that particular cell).

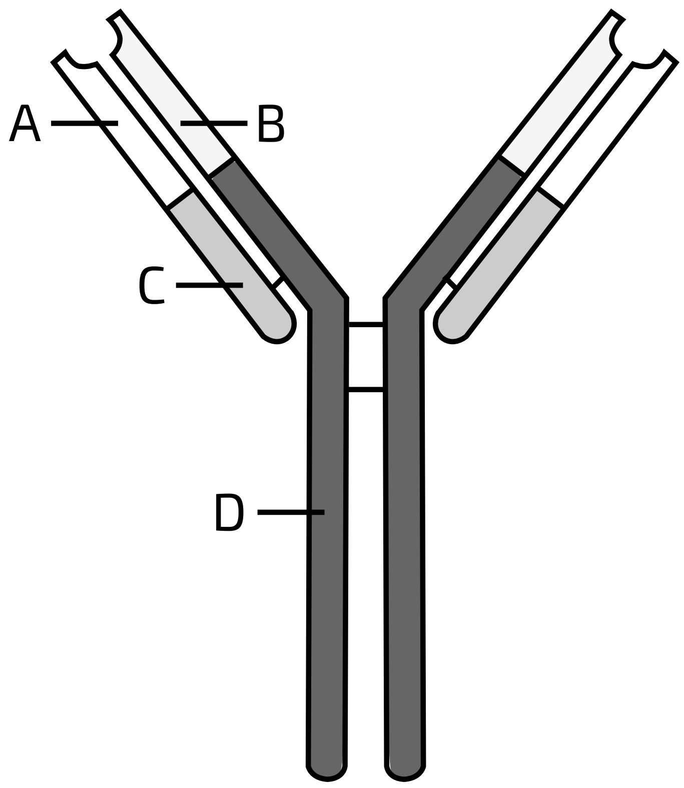

Figure 1: Antibody structure. Four parts of the left side of the antibody are labelled (A-D).

Part A Heavy chains

Which letter(s) in **Figure 1** represent(s) a **heavy chain**?

- [ ] A
- [ ] B
- [ ] C
- [ ] D

Part B Light chains

Which letter(s) in **Figure 1** represent(s) a **light chain**?

- [ ] A
- [ ] B
- [ ] C
- [ ] D

Part C Constant region

Which letter(s) in **Figure 1** represent(s) the **constant region**?

- [ ] A
- [ ] B
- [ ] C
- [ ] D

Part D Variable region

Which letter(s) in **Figure 1** represent(s) the **variable region**?

- [ ] A
- [ ] B
- [ ] C
- [ ] D

Part E Cell type

What type of cell secretes antibodies?

Part F Functions

Which of the following are functions of antibodies? Select all that apply.

- [ ] increase permeability of blood capillary walls
- [ ] bind to pathogens and prevent them from entering the body's cells
- [ ] cause dilation of nearby blood vessels
- [ ] cause lysis of the membranes of cells infected with pathogens
- [ ] tag pathogens for phagocytosis by phagocytes
- [ ] stimulate other activated lymphocytes to divide and differentiate
- [ ] bind to toxins produced by pathogens, thus making them harmless
- [ ] clump pathogens together, thus preventing them from spreading

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STEM SMART Biology Week 41 - The Immune System

Human Antibody Diversity

A Level
C C C

An antibody is a protein composed of two identical heavy chains and two identical light chains. In humans, there is one gene that codes for antibody heavy chains, and two genes that code for antibody light chains. Each of these genes contain many coding segments, as shown in the table below. The heavy chain gene contains variable (V), diversity (D), and joining (J) segments, whereas the light chain genes only contain variable (V) and joining (J) segments.

Gene	Variable (V) segments	Diversity (D) segments	Joining (J) segments
Heavy chain	65	27	6
Light chain κ	40		5
Light chain λ	30		4

Within each gene, each coding segment produces a different protein sequence.

During B cell maturation in the bone marrow, these genes undergo a process called somatic recombination (also called V(D)J recombination) which involves randomly removing different gene segments until only 1 segment of each type remains. These remaining segments are recombined to form one continuous DNA sequence.

i.e.

- a heavy chain gene will only contain one V segment, one D segment, and one J segment after recombination
- a light chain gene will only contain one V segment and one J segment after recombination

Because this process is random, every mature B cell will have a unique DNA sequence for each of these three genes.

Each of these genes also contain a constant region which does not undergo somatic recombination. The recombined VDJ/VJ region will be translated to produce the variable region of the heavy chain/light chain protein, and the constant region will be translated to produce the constant region of the heavy chain/light chain protein.

In a mature B cell, an antibody is formed by combining two identical copies of the heavy chain protein with two identical copies of a light chain protein (**either** the light chain κ protein **or** the light chain λ protein).

The same process also occurs in T cells to produce a wide range of possible T cell receptors.

Part A Heavy chain possibilities

During maturation, how many possible heavy chain DNA sequences could be produced from the initial gene in a human B cell?

Part B Light chain κ possibilities

During maturation, how many possible light chain κ DNA sequences could be produced from the initial gene in a human B cell?

Part C Light chain λ possibilities

During maturation, how many possible light chain λ DNA sequences could be produced from the initial gene in a human B cell?

Part D Total antibody possibilities

How many different antibodies can a human produce (in terms of variable regions), based on this process of V(D)J recombination? Give your answer to 2 significant figures.

Assume that both copies (maternal and paternal) of each gene are identical.

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STEM SMART Biology Week 41 - The Immune System

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Home Gameboard Biology Physiology Disease & Immunity Influenza vaccination

Influenza vaccination

A Level

P P P

The figure below shows the concentration of antibodies in a patient's bloodstream following an influenza (flu) vaccination, and then a subsequent infection with the influenza virus.

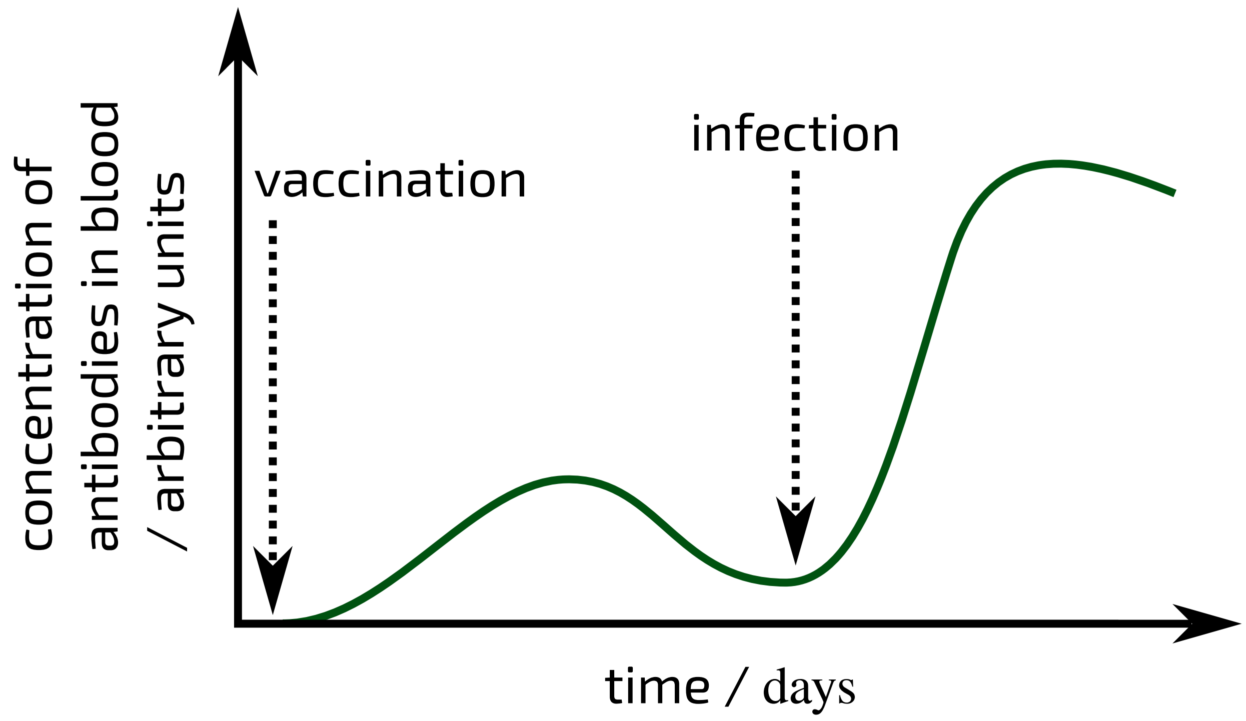

Figure 1: Concentration of antibodies in a patient's bloodstream following an influenza vaccination and subsequent influenza infection.

Part A Vaccination response

Which of the following statements about the response to **vaccination** in **Figure 1** are correct? Select all that apply.

- [ ] this is a primary immune response
- [ ] this is a secondary immune response
- [ ] the response is triggered by the binding of antigens to pre-existing memory B cells and memory T cells
- [ ] the response is triggered by the binding of antigens to naïve B cells and T cells
- [ ] the antibodies in the bloodstream are secreted by plasma cells (effector B cells)
- [ ] the antibodies in the bloodstream are secreted by memory B cells
- [ ] this is the humoral immune response
- [ ] this is the cell-mediated immune response

Part B Infection response

Which of the following statements about the response to **infection** in **Figure 1** are correct? Select all that apply.

- [ ] this is a primary immune response
- [ ] this is a secondary immune response
- [ ] the response is triggered by the binding of antigens to pre-existing memory B cells and memory T cells
- [ ] the response is triggered by the binding of antigens to naïve B cells and T cells
- [ ] the antibodies in the bloodstream are secreted by plasma cells (effector B cells)
- [ ] the antibodies in the bloodstream are secreted by memory B cells
- [ ] this is the humoral immune response
- [ ] this is the cell-mediated immune response

Part C Primary vs secondary responses

Why are secondary immune responses faster than primary immune responses? Select all that apply.

- [ ] there are more cells in the body with the correct membrane receptors/membrane-bound antibodies for the antigen
- [ ] the existing antibodies replicate themselves to produce more antibodies
- [ ] activation of immune cells (by binding to antigens) occurs more quickly
- [ ] the pathogen will always have evolved to become more deadly
- [ ] memory B cells divide and differentiate into plasma cells (effector B cells) more quickly than naïve B cells do
- [ ] memory B cells can produce and secrete antibodies into the bloodstream faster than naïve B cells

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Adapted with permission from OCR A Level Biology A, June 2017, Depth in Biology, Question 4b