MDCAT Biology Unit 12: Immunity, study guide with practice MCQs

What MDCAT asks

This unit covers the non-specific defences you are born with (innate immunity), the specific, memory-forming response of B and T lymphocytes (adaptive immunity), the four ways immunity is acquired, how vaccines work, and what happens when the immune system over-reacts (allergy) or attacks the body (autoimmunity). The two subtopics carry equal weight and together account for about 2 to 3 of the 81 Biology questions, mostly one-step recall or classification: which line of defence, which cell does what, which type of immunity a case describes, primary versus secondary response.

B12.1 Innate and adaptive immunity

B12.1.1 The first and second lines of defence, phagocytosis and inflammation

Immunity is the ability of the body to resist infection. The defences form three lines. The first two are **innate** (non-specific): present from birth, needing no previous contact with the microbe, the same against every invader. The third is **adaptive** (specific): directed against one antigen and leaving behind memory.

First line of defence: keeping microbes out. Physical and chemical barriers at the body surface.

- **Skin**: the dry, keratinised epidermis is a physical barrier; sebum and acidic sweat discourage microbial growth.
- **Mucous membranes**: mucus in the airways traps microbes; cilia sweep it up to the throat to be swallowed.
- **Stomach acid** (pH about 2) kills most swallowed microbes.
- **Lysozyme**, an enzyme in tears, saliva and nasal secretions, breaks down bacterial cell walls.
- **Normal flora**: harmless bacteria on the skin and in the gut compete with pathogens.

Second line of defence: acting inside the body. If a microbe crosses the first line, non-specific cells and chemicals attack it.

- **Phagocytes**: white blood cells that engulf and digest microbes. **Neutrophils** are the most numerous white cells, short-lived, and the first to arrive. **Macrophages** develop from monocytes, are larger and longer-lived, and settle in tissues such as the lungs, liver and lymph nodes.
- **Inflammation**: the local response to tissue damage or infection (below).
- **Fever**: a raised body temperature slows the growth of many microbes and speeds up the body's own defences.
- **Interferons**: proteins released by virus-infected cells; they do not save that cell but make neighbouring cells resistant to the virus.
- **Natural killer (NK) cells** destroy virus-infected and tumour cells non-specifically; **complement** proteins in the blood lyse microbes.

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Phagocytosis follows a fixed sequence that MDCAT likes to test as an ordering question:

1. **Chemotaxis**: the phagocyte is attracted by chemicals from damaged tissue and microbes.
2. **Attachment**: the phagocyte binds to the microbe (easier if it is coated with antibodies or complement).
3. **Engulfing**: pseudopodia surround the microbe and enclose it in a vacuole, the **phagosome**.
4. **Fusion**: lysosomes fuse with the phagosome.
5. **Digestion**: lysosomal enzymes destroy the microbe and the waste leaves by exocytosis. Macrophages then display pieces of the microbe (its antigens) on their surface, which links the innate response to the adaptive one.

Inflammation is the reaction of a tissue to injury or infection. Damaged cells and **mast cells** release **histamine**, which makes the local arterioles dilate (more blood flows in) and the capillary walls more permeable (plasma leaks into the tissue). The result is the four classic signs: **redness** and **heat** from the extra blood, **swelling** from leaked fluid, and **pain** from pressure on nerve endings and from the chemicals released. The extra blood brings phagocytes and clotting factors, and the leaked plasma dilutes toxins. **Pus** is the dead phagocytes, dead microbes and tissue fluid left at the site.

Line of defence	Innate or adaptive?	Specific?	Memory?	Examples
First	Innate	No	No	Skin, mucus and cilia, stomach acid, lysozyme, normal flora
Second	Innate	No	No	Phagocytes, inflammation, fever, interferon, NK cells, complement
Third	Adaptive	Yes, one antigen	Yes	B lymphocytes (antibodies), T lymphocytes (cell-mediated)

B12.1.2 The roles of B and T lymphocytes and the structure of an antibody

An **antigen** is any molecule, usually a protein or polysaccharide on the surface of a microbe, that the immune system recognises as foreign and that provokes a response. The adaptive response is carried out by **lymphocytes**, all made in the bone marrow and named after where they mature:

- **B lymphocytes (B cells)** mature in the **bone marrow**. They give **humoral** (antibody-mediated) immunity against bacteria, toxins and viruses free in the blood and tissue fluid.
- **T lymphocytes (T cells)** mature in the **thymus**. They give **cell-mediated** immunity against the body's own cells when infected by viruses or cancerous, and against transplanted tissue.

How B cells work. Each B cell carries receptors that fit one antigen only. When it meets its antigen and receives a signal from a helper T cell, it is activated and divides repeatedly (clonal selection). The clone forms **plasma cells**, short-lived cells packed with rough endoplasmic reticulum that secrete antibodies, and **memory B cells**, which stay in the body for years and respond rapidly if the same antigen returns.

How T cells work. T cells do not secrete antibodies. They recognise an antigen only when it is displayed on another body cell, such as a macrophage that has digested a microbe.

- **Helper T cells**: the organisers. They release chemical signals (cytokines) that activate B cells, killer T cells and macrophages. HIV destroys helper T cells, which is why AIDS patients lose

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both humoral and cell-mediated immunity.

- **Killer (cytotoxic) T cells**: bind to infected or cancerous body cells and kill them by contact, releasing perforin, which punches holes in the target membrane.
- **Memory T cells** remain after the infection; **suppressor T cells** switch the response off once the antigen is cleared.

Structure of an antibody. Antibodies, or **immunoglobulins** (Ig), are glycoproteins made by plasma cells. Each molecule is **Y-shaped** and has:

- **Four polypeptide chains**: two identical long **heavy chains** and two identical short **light chains**, held together by **disulphide bonds**.
- **Variable regions** at the tips of the two arms. The amino-acid sequence here differs from one antibody to another and forms the two identical **antigen-binding sites**, so one antibody binds two antigen molecules.
- A **constant region** (the stem and the rest of the arms), the same in all antibodies of one class; it decides what happens after binding, for example whether phagocytes or complement are recruited.

Antibodies act by **neutralising** toxins and viruses, **agglutinating** (clumping) microbes for phagocytes, coating microbes for easier phagocytosis (**opsonisation**), and activating **complement**.

Feature	B lymphocytes	T lymphocytes
Made in	Bone marrow	Bone marrow
Mature in	Bone marrow	Thymus
Type of immunity	Humoral (antibody-mediated)	Cell-mediated
Recognise antigen	Free in blood or lymph	Only when displayed on a body cell
Effector cells	Plasma cells (secrete antibodies)	Helper, killer, suppressor T cells
Main targets	Bacteria, toxins, free viruses	Virus-infected cells, cancer cells, transplants
Memory cells	Memory B cells	Memory T cells

MDCAT trap: who engulfs, who secretes, who kills?

Examiners swap the jobs of the white cells and hope you do not notice. Keep three verbs with three cells: **phagocytes engulf** (neutrophils and macrophages), **plasma cells secrete** (antibodies, after a B cell is activated), and **killer T cells kill** (infected body cells, by contact). No lymphocyte engulfs a microbe and no T cell secretes antibodies. Two more pairs: helper T cells *activate* other cells, they do not kill; macrophages, after engulfing, *present* antigen, the step that wakes the helper T cells. An option that says "lymphocytes engulf the bacterium" is wrong however convincing the rest looks.

Worked example

A child scrapes her knee. Within hours the wound is red, warm, swollen and sore, and pus forms by the next day. Which line of defence has been breached, which line is producing the signs, and

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what is the pus?

1. The scrape breaks the skin, so the **first line** has been breached and bacteria have entered the tissue.
2. Redness, heat, swelling and pain are the four signs of **inflammation**, a **second-line** (innate) response: mast cells release histamine, arterioles dilate and capillaries leak plasma.
3. The extra blood brings **neutrophils** first and then **macrophages**, which engulf the bacteria.
4. **Pus** is the dead phagocytes, dead bacteria and tissue fluid left behind.

Answer: first line breached; second line (inflammation and phagocytosis) at work; pus is dead phagocytes and microbes. No antibodies are needed to explain the first day.

B12.2 Types of immunity and vaccination

B12.2.1 Active and passive, natural and artificial immunity, and vaccination

Adaptive immunity can be acquired in four ways. To classify any case, ask two questions.

Question 1: who made the antibodies?

- **Active immunity**: the person's **own** lymphocytes meet the antigen and make antibodies. It takes days to develop, but memory cells form, so it is **long-lasting** (years, often for life).
- **Passive immunity**: **ready-made antibodies** from another person or animal are received. Protection is **immediate**, but no memory cells form and the borrowed antibodies are broken down, so it lasts only **weeks to months**.

Question 2: did it happen by itself (natural) or through a medical procedure (artificial)?

	Natural	**Artificial**
Active (own antibodies, memory, long-lasting)	Recovering from an infection, e.g. measles, chickenpox	Vaccination (antigen by injection or by mouth)
Passive (borrowed antibodies, no memory, short-lived)	Antibodies across the placenta; antibodies in breast milk, especially colostrum	Injection of antiserum or antitoxin, e.g. anti-tetanus serum, anti-rabies immunoglobulin, anti-venom

Vaccination. A **vaccine** is a preparation containing a harmless form of an antigen. Given by injection or by mouth, it stimulates a **primary response**: the person's own B and T cells are activated and **memory cells** are left behind. If the real pathogen enters later, the memory cells mount a secondary response so fast that the person does not fall ill. Vaccination therefore gives **artificial active** immunity. Kinds of vaccine:

- **Live attenuated**: a living microbe weakened so that it multiplies without causing disease, e.g. measles, BCG, oral polio vaccine.
- **Killed (inactivated)**: the microbe is killed by heat or chemicals; boosters are often needed, e.g. injectable polio and rabies vaccines.
- **Toxoid**: a bacterial toxin treated so that it is harmless but still antigenic, e.g. tetanus and diphtheria.

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- **Subunit**: one purified antigen, often made by genetic engineering, e.g. hepatitis B surface antigen.

A **booster dose** is a later dose of the same vaccine; it acts as a second exposure and raises the number of memory cells and the antibody level. **Edward Jenner** introduced the first vaccine in 1796, using cowpox material against smallpox (*vacca* is Latin for cow); smallpox was declared eradicated in 1980.

B12.2.2 Primary and secondary responses, allergies and autoimmunity

Primary response. When an antigen is met for the first time, only a few B and T cells recognise it, and they must be activated and multiplied before plasma cells appear. There is a **lag period** of several days, antibody rises slowly to a **low peak** in one to two weeks, then falls. Symptoms usually appear during the lag. Memory cells remain.

Secondary response. On a second meeting with the same antigen, the memory cells respond at once. The lag is short (one to three days), the antibody level rises **much higher** and stays raised for **longer**, and the pathogen is usually destroyed before symptoms appear. This is the basis of long-term immunity after infection and of vaccination. It is specific: memory cells for measles do nothing against mumps, and a changed antigen, as with influenza each year, forces a fresh primary response.

Feature	Primary response	Secondary response
Antigen exposure	First	Second or later
Cells that start it	Naive B and T cells	Memory B and T cells
Lag period	Long (several days)	Short (one to three days)
Antibody level	Low peak	Much higher peak
Duration of raised antibody	Short	Long
Main antibody class	IgM first, then IgG	Mostly IgG
Symptoms	Usually present	Usually none

Allergy (hypersensitivity). An allergy is an **exaggerated immune response to a harmless substance**, the **allergen**: pollen, dust, animal hair, foods such as peanuts, insect venom or drugs such as penicillin. On first exposure the person is **sensitised**: plasma cells make **IgE** antibodies, which attach to mast cells. On later exposure the allergen binds to this IgE and the mast cells release **histamine**, causing rapid inflammation: hay fever, asthma, itching and rash, or swelling. A severe body-wide reaction, **anaphylactic shock**, drops the blood pressure and narrows the airways and is treated with adrenaline. **Antihistamines** block histamine.

Autoimmunity. Normally the immune system is **self-tolerant**: lymphocytes that would react against the body's own molecules are destroyed or switched off during development. In an **autoimmune disease** this tolerance fails and antibodies or T cells attack the body's own tissues. Examples:

- **Type 1 diabetes mellitus**: the insulin-producing beta cells of the islets of Langerhans are destroyed.
- **Rheumatoid arthritis**: the membranes lining the joints are attacked, causing painful swelling

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and deformity.

- **Multiple sclerosis**: the myelin sheaths of neurones in the central nervous system are destroyed.

Keep three faults apart: autoimmunity (attacks self), **immunodeficiency** such as AIDS (weakened), and allergy (over-reacts to a harmless foreign antigen).

MDCAT trap: an injection is not always a vaccine, and natural is not always active

Students see the word "injection" and write "vaccination, artificial active". Stop and ask what is in the syringe. If it contains **antigen** (a weakened or killed microbe, a toxoid or a purified protein), the person's own lymphocytes respond, memory cells form, and the immunity is **artificial active**. If it contains **antibodies** (antiserum, antitoxin, immunoglobulin, anti-venom), the lymphocytes do nothing, no memory cells form, and the immunity is **artificial passive**: it works within hours and is gone within weeks. Anti-tetanus serum after a deep wound and anti-rabies immunoglobulin after a dog bite are passive, even though both are injections. The same questions sort the natural cases: antibodies from the mother through the placenta or milk are passive; recovering from chickenpox is active. Final check: "immediate protection" means passive; "memory cells" means active.

Worked example

A man is bitten by a stray dog. At the hospital he is given anti-rabies immunoglobulin into the wound and, the same day, the first dose of rabies vaccine, with further doses over the following weeks. Why are both given, and what immunity does each provide?

1. Rabies takes days to weeks to reach the brain but is then fatal, so the patient needs protection **now** and **later**.
2. The **immunoglobulin** is ready-made antibody that neutralises virus in the wound at once. His lymphocytes are not involved and no memory cells form: **artificial passive** immunity, lasting a few weeks.
3. The **vaccine** is killed rabies virus (antigen). It provokes a primary response; his own plasma cells make antibodies after a lag of days, and memory cells form: **artificial active** immunity, long-lasting.
4. The later doses are boosters, each producing a larger secondary response, so antibody stays high while the borrowed antibodies disappear.

Answer: immunoglobulin gives immediate but short artificial passive immunity; the vaccine gives slower but lasting artificial active immunity; together they cover the gap.

Practice MCQs

1. Which of the following is part of the first line of defence?
   A. Interferon released by infected cells
   B. Histamine released by mast cells
   C. Lysozyme in tears and saliva
   D. Antibodies secreted by plasma cells
2. During phagocytosis, the correct order of events after a neutrophil attaches to a bacterium is:

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A. Lysosome fusion → engulfing into a phagosome → digestion → exocytosis
B. Engulfing into a phagosome → lysosome fusion → digestion → exocytosis
C. Digestion → engulfing into a phagosome → lysosome fusion → exocytosis
D. Engulfing into a phagosome → exocytosis → lysosome fusion → digestion

3. Which cell type is destroyed by HIV, and why does its loss weaken both humoral and cell-mediated immunity?
A. Killer T cells, because they secrete the antibodies that B cells need
B. Plasma cells, because they present antigen to T cells
C. Macrophages, because they are the only cells that form memory
D. Helper T cells, because they activate both B cells and killer T cells

4. An antibody molecule can bind to two antigen molecules at once because:
A. It has two identical variable regions, one at the tip of each arm
B. Its constant region changes shape to fit different antigens
C. Its two heavy chains are different from each other
D. Its disulphide bonds break on contact with antigen

5. A virus has infected some cells of the liver. The immune cells that directly destroy these infected liver cells are:
A. Plasma cells
B. Killer T cells
C. Helper T cells
D. Neutrophils

6. A newborn baby is protected against measles for a few months by antibodies that crossed the placenta. This immunity is:
A. Natural active
B. Artificial active
C. Natural passive
D. Artificial passive

7. An unvaccinated farmer with a deep, soil-contaminated wound is given an injection of anti-tetanus serum. Which statement is correct?
A. It stimulates his B cells to form memory cells against tetanus toxin
B. It gives immediate protection that will last for several years
C. It gives artificial active immunity because it was given by injection
D. It gives immediate protection but no memory cells, so it lasts only a few weeks

8. Compared with the primary response, the secondary response to the same antigen shows:
A. A longer lag period and a lower antibody peak
B. A shorter lag period and a higher antibody peak
C. The same lag period but a lower antibody peak
D. A shorter lag period and the same antibody peak

9. A student who had measles as a child falls ill with mumps at twelve. The best explanation is:
A. Memory cells formed against measles were broken down within weeks
B. Measles infection gave passive immunity, which cannot protect against any virus
C. Memory cells are specific to one antigen, and the mumps antigens differ from those of measles
D. Mumps is caused by a bacterium, so cell-mediated immunity is not involved

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10. Which condition is correctly matched with its underlying cause?
    A. Hay fever: the immune system attacks the body's own nasal tissue
    B. Type 1 diabetes: an exaggerated IgE response to insulin in food
    C. AIDS: the immune system attacks the body's own helper T cells
    D. Rheumatoid arthritis: the immune system attacks the body's own joint tissue

1. C. Lysozyme in tears and saliva is a surface chemical barrier, so it is first-line. Interferon and histamine are second-line and antibodies are third-line.

2. B. The microbe is engulfed into a phagosome, lysosomes fuse with it, enzymes digest it, and the debris leaves by exocytosis. Digestion cannot happen before the lysosome has fused.

3. D. HIV destroys helper T cells, whose signals activate both B cells (humoral) and killer T cells (cell-mediated). Killer T cells do not secrete antibodies and plasma cells do not present antigen.

4. A. The two arms carry identical variable regions, each an antigen-binding site, so one antibody binds two antigens. The constant region is fixed and the two heavy chains are identical.

5. B. Killer (cytotoxic) T cells recognise antigen displayed on an infected body cell and destroy it by contact. Plasma cells secrete antibodies, helper T cells activate, neutrophils engulf free microbes.

6. C. The mother made the antibodies and they reached the baby by a natural route, so the baby made none of them: natural passive immunity, which fades within months.

7. D. Anti-tetanus serum is ready-made antibody against the toxin. It acts at once, but the farmer's lymphocytes are not stimulated, so no memory cells form and protection lasts weeks: artificial passive. Tetanus toxoid vaccine is needed for lasting protection.

8. B. Memory cells from the primary response let the secondary response start within one to three days and produce far more antibody for longer.

9. C. Adaptive memory is specific to the antigen that provoked it. Measles memory cells do not recognise mumps antigens, so mumps triggers a fresh primary response. Both diseases are viral.

10. D. Rheumatoid arthritis is an autoimmune attack on the joint linings. Hay fever is an allergy (pollen is not self), type 1 diabetes is autoimmune, not allergic, and AIDS is a viral immunodeficiency.

Before the test: 12 facts to recite

1. First line: skin, mucus and cilia, stomach acid, lysozyme, normal flora; keeps microbes out, non-specific.
2. Second line: phagocytes, inflammation, fever, interferon, NK cells, complement; innate, non-specific.
3. Phagocytosis: chemotaxis → attachment → engulfing into a phagosome → lysosome fusion → digestion → exocytosis.
4. Inflammation: mast cells release histamine → arterioles dilate and capillaries leak → redness, heat, swelling, pain.
5. Interferon is made by virus-infected cells and protects neighbouring cells, not the infected cell itself.

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6. B cells mature in the bone marrow, humoral immunity; T cells mature in the thymus, cell-mediated immunity.
7. Activated B cell → plasma cells (secrete antibodies) + memory B cells; helper T cells activate, killer T cells kill infected cells by contact.
8. Antibody: Y-shaped, two heavy and two light chains joined by disulphide bonds, two identical antigen-binding sites in the variable regions.
9. Active: own antibodies, memory cells, slow, long-lasting. Passive: borrowed antibodies, no memory, immediate, short-lived.
10. Natural active: recovery from infection. Artificial active: vaccination. Natural passive: placenta or colostrum. Artificial passive: antiserum or antitoxin.
11. Vaccines contain antigen (live attenuated, killed, toxoid, subunit) and leave memory cells; the secondary response is faster, larger and longer. Jenner, smallpox, 1796.
12. Allergy: exaggerated IgE and histamine response to a harmless allergen. Autoimmunity: attack on self, as in type 1 diabetes, rheumatoid arthritis, multiple sclerosis.

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