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VCE Biology ¾
Lymphatics & Adaptive Immunity (Humoral) [3.3]
Workbook Solutions

Outline:

Study Design Key Knowledge:

Study Design: Responding to Antigens

The role of the lymphatic system in the immune response as a transport network and the role of lymph nodes as sites for antigen recognition by B lymphocytes.

The characteristics and roles of the components of the adaptive immune response against extracellular threats, including the actions of B lymphocytes and their antibodies.

https://www.vcaa.vic.edu.au/Documents/vce/biology/2016BiologySD.pdf#page=23

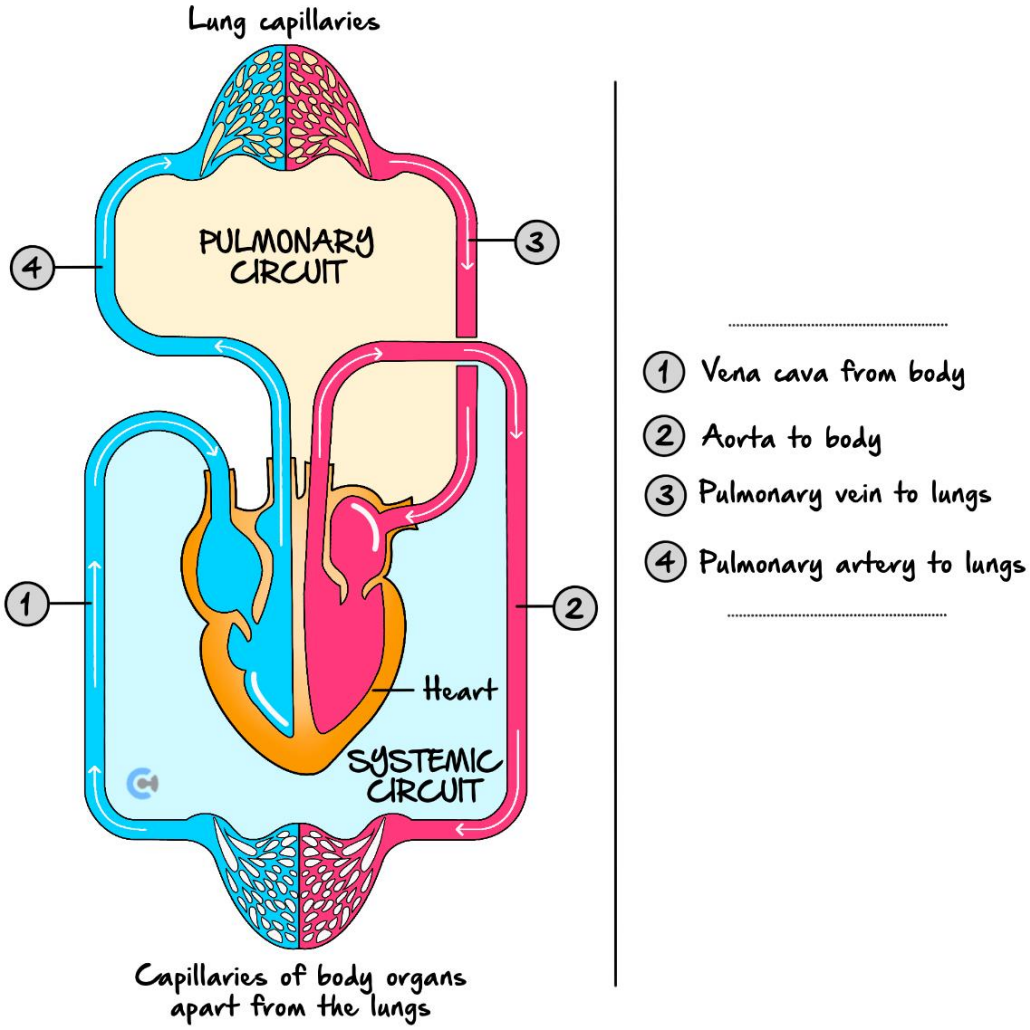
Learning Objectives:

- **BI34 [3.3.1]** - Identify the Structure of the Lymphatic System, including Primary & Secondary Lymphatic Tissue
- **BI34 [3.3.2]** - Identify the Role of the Lymphatic System in Fighting Infections
- **BI34 [3.3.3]** - Explain Antigen Presentation as a means to initiate the Adaptive Immune Response
- **BI34 [3.3.4]** - Identify the Characteristics of the Adaptive Response which Differentiate it from the Innate Response
- **BI34 [3.3.5]** - Identify & Explain the Humoral Response as a Response to Extracellular Pathogens, including the Role of B and T Helper Lymphocytes
- **BI34 [3.3.6]** - Explain the Significance of Memory Cells to generate Immunological Memory, & How that prevents Future Infections
- **BI34 [3.3.7]** - Differentiate between Extracellular & Intracellular Threats
- **BI34 [3.3.8]** - Explain how Antibodies are used to Fight against Infections, and Draw their Structure

Section A: Understanding the Lymphatic System

Context: The Circulatory System

- Before we can start to understand the lymphatic system, we need to understand how fluids can move through the body.
- The circulatory system describes how blood and the nutrients carried by it can move around the body!
- What is responsible for pumping blood around the body? What tubes does blood use to go TOWARDS tissue? How does it come back?



Head Tutor's Note: Annotate the diagram to really illustrate what blood does and emphasise that blood flow is a CLOSED system!

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Sub-Section: Overview of the Lymphatic System

Introduction to Lymphatics

- _____ Network of vessels that carry lymph _____ - acting as a transport system for immune cells, particularly antigen-presenting cells, whilst also serving other general functions.
  - Important roles in the _____ circulatory _____ and _____ immune _____ systems.
- Its main functions include:
  - Transportation of _____ antigen-presenting cells _____ to secondary lymphoid tissues for _____ antigen presentation _____.
  - Production of leukocytes, including _____ lymphocytes _____ in primary lymphoid tissues.
  - Removal and filtration of fluid from tissues around the body.
  - Absorption of fatty acids from the digestive system.
- Very complicated in terms of its function, but we will only be focusing on the immune side!

How does fluid that leaves the circulatory system come back?

Discussion: How does returning this fluid allow the body to maintain a fluid balance?

- What would happen if there was no mechanism for this to return?

We would get swelling! No way for us to recycle our fluid!

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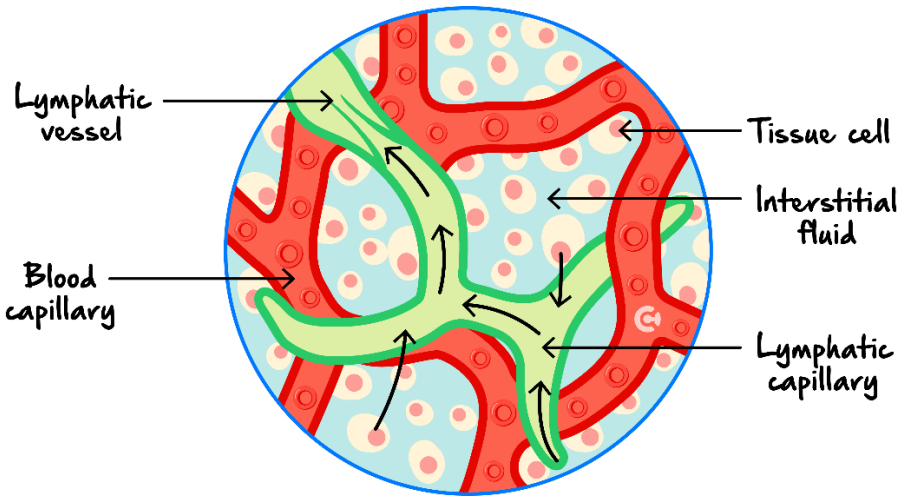
Analogy

- Your **blood vessels** act like the city's plumbing system, delivering water (blood) to homes (tissues). But not all the water stays inside the pipes, some leaks out into the streets (the spaces between cells).
- Without a drainage system, these streets would flood.
- That's where the **lymphatic system** comes in: it's the **stormwater drain**, collecting leaked fluid and returning it to the main water supply near the heart.
- This keeps the city (your body) from flooding (swelling), and lets circulation work smoothly.

What is lymph?

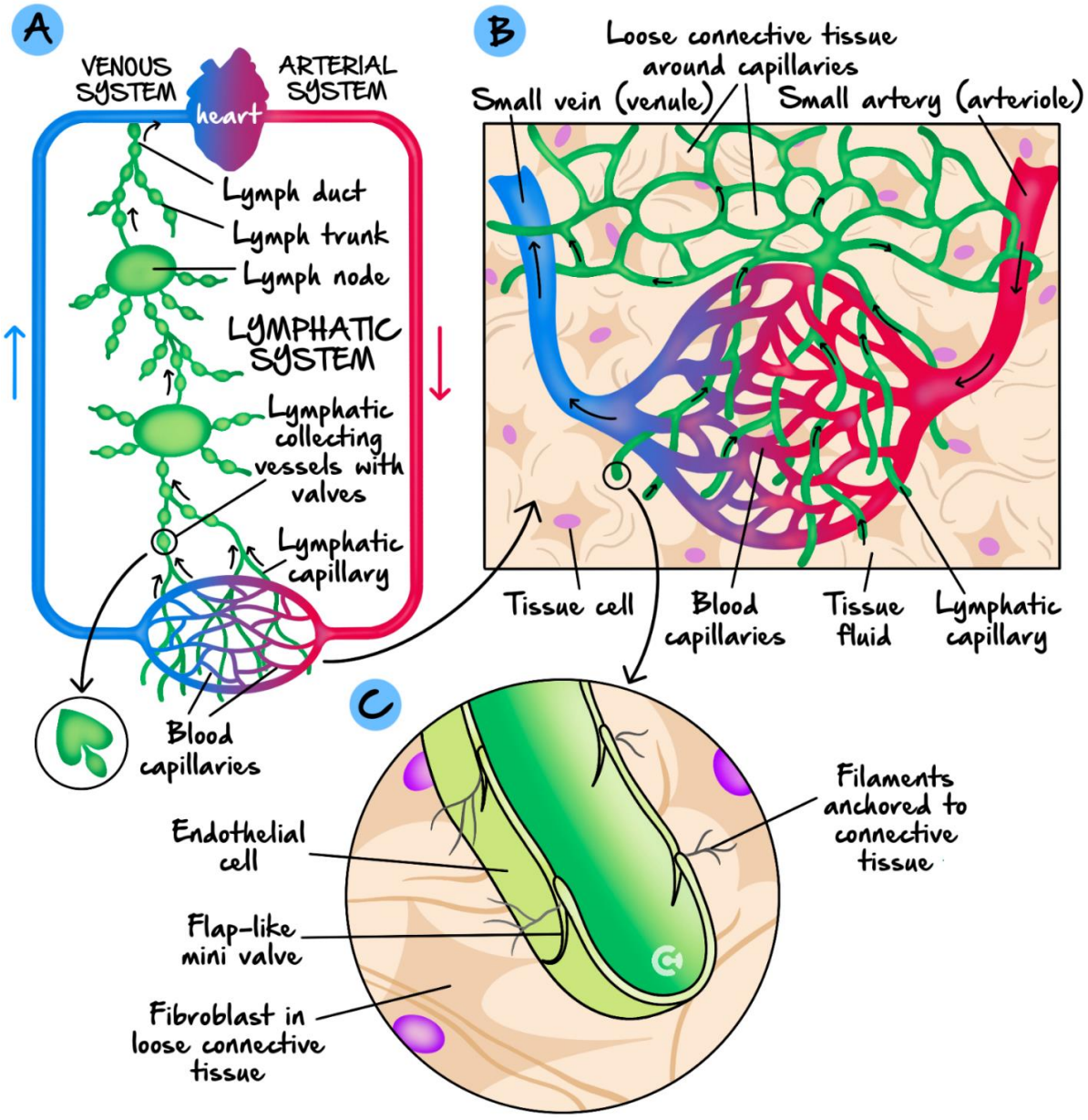
- Clear fluid that is drained from the interstitial space!



Sub-Section: Structure of the Lymphatic System

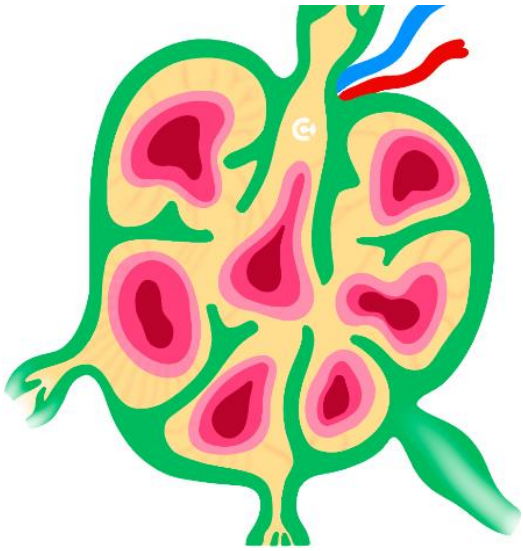
Structure of the Lymphatic System

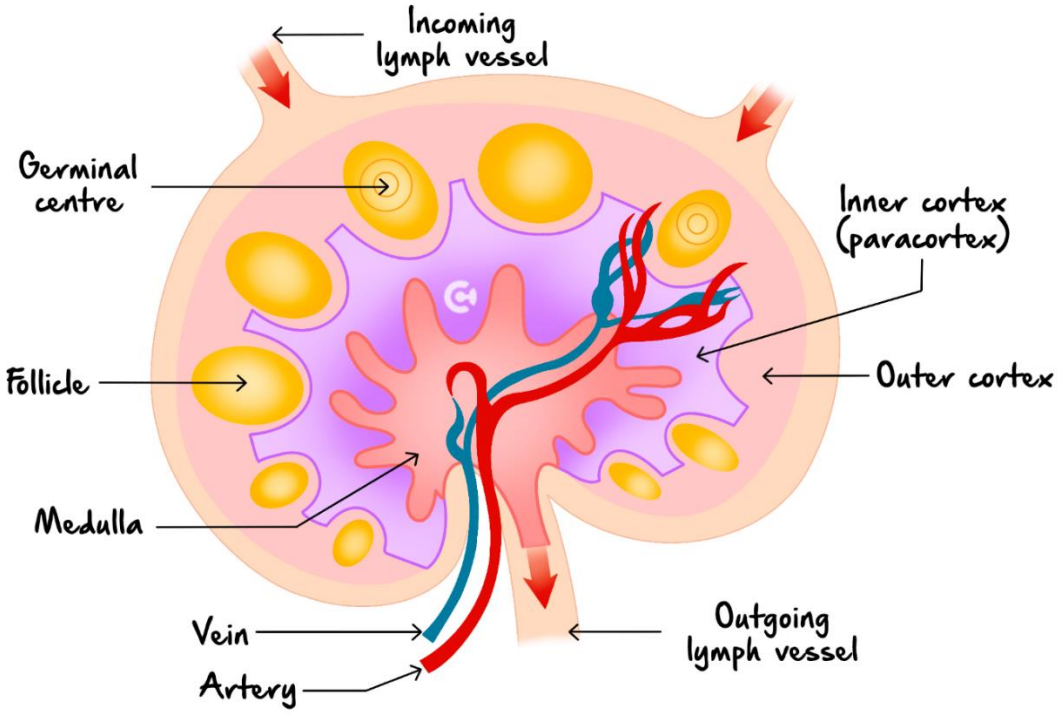
- There are lymphatic vessels that essentially drain lymph from interstitial tissues, where it re-enters circulation via veins near the heart.
  - Lymphatic capillaries will drain lymph from the tissue, these are separate to blood vessels.



  - Lymph vessels all contain one-way valves.
  - Muscle contractions help push the lymph towards the heart.

- As the lymph is collected, it passes through lymph nodes where the main filtration of this fluid occurs, considered to be _____ secondary lymphoid tissue. _____.
  - Large numbers of immune cells will be gathered there, ready to detect and eliminate pathogens, and immune cells drained from the tissue will be able to present antigens to them as well to initiate an adaptive immune response!





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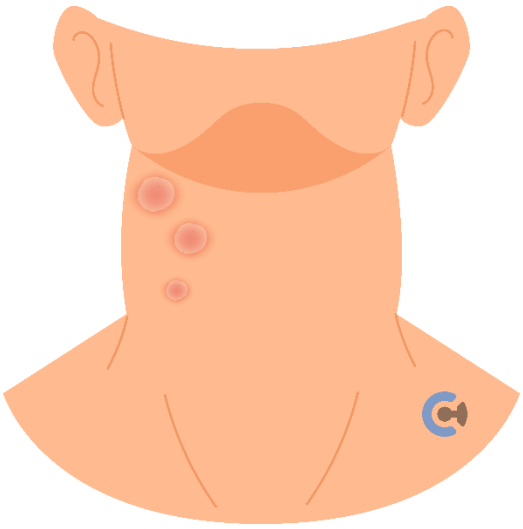
NOTE: The Victorian Curriculum and Assessment Authority (VCAA) traditionally doesn't delve into the granular workings of the lymphatic system. Instead, the focus is laid on its immunological roles, such as being a conduit for antigen-presenting cells and a cradle for the adaptive immune response. This added detail serves as a foundation for understanding the expected knowledge.

Discussion: Why do lymph nodes swell?



Discussion: What is the difference between primary and secondary lymphoid tissue?

Feature	Primary Lymphoid Tissue	Secondary Lymphoid Tissue

Feature	Primary Lymphoid Tissue	Secondary Lymphoid Tissue
Main function	Maturation of lymphocytes	Activation of mature lymphocytes
Key examples	Bone marrow, thymus	Lymph nodes, spleen
Involved in antigen recognition?	❌	✅

Discussion: Why is this lymph filtration at the nodes useful?

- Ensures that we don't cause the disease to spread everywhere via venous system return.

Key Takeaways

- Understanding the Lymphatic System:
  - The lymphatic system is a secondary circulatory system that transports lymph – a clear fluid containing immune cells and waste products.
    - Lymph originates from plasma that leaks out of blood vessels and bathes tissues (interstitial fluid).
    - It is collected by lymphatic capillaries and returned to circulation near the heart.
  - Maintains tissue fluid balance by draining excess fluid and preventing accumulation.
    - Without drainage, fluid builds up causing swelling (oedema).
  - Lymphatic vessels contain one-way valves and rely on skeletal muscle contractions to move lymph toward the heart.
  - Plays a major role in immune surveillance and defence.
    - Transports antigen-presenting cells (APCs) like dendritic cells to lymph nodes.
    - Delivers pathogens or antigens from tissues to immune hubs.
  - Primary lymphoid tissues (bone marrow, thymus) are where lymphocytes are formed and matured.
  - Secondary lymphoid tissues (lymph nodes, spleen) are sites where mature lymphocytes encounter antigens.
    - Lymph nodes filter lymph and concentrate immune cells for rapid detection of pathogens.
  - Lymph nodes swell when many immune cells are activated and proliferating during an infection.

Section B: Introduction to Adaptive Immunity

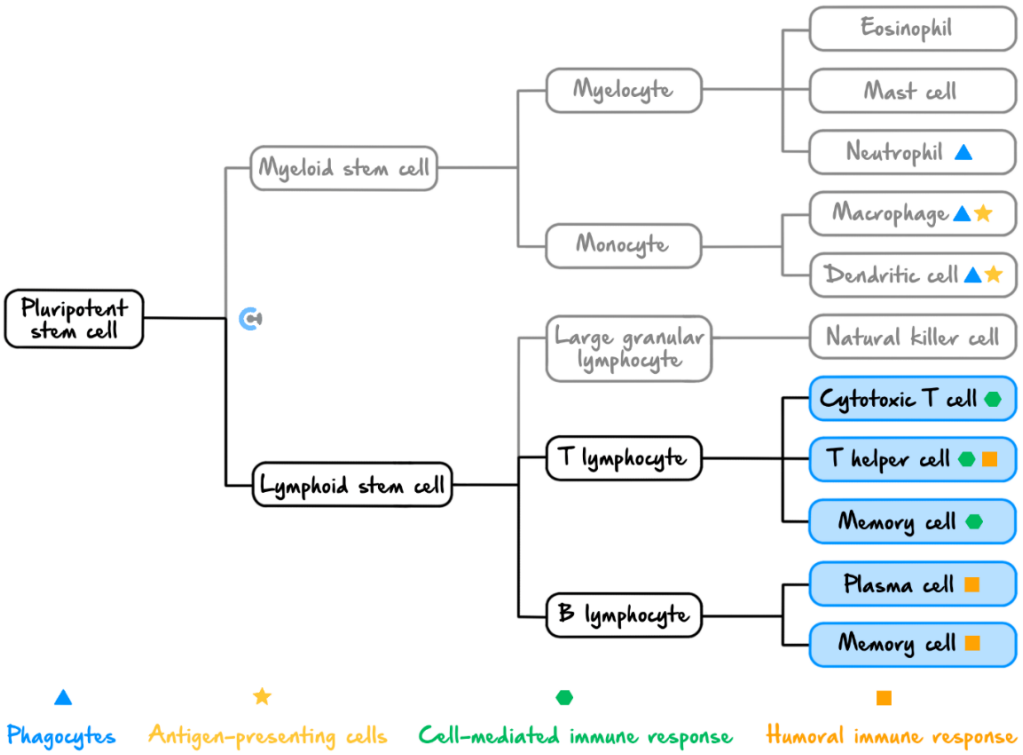
Sub-Section: Characteristics of the 3rd Line of Defence

What differentiates the 2nd and 3rd lines of defence?

The Third Line of Defence

- **Adaptive immunity** is the branch of your immune system that mounts a **specific, targeted response** to invaders, and remembers them for faster defence in the future.
- There are two key features that separate the third line of defence from the second line of defence:
  - _____ Specificity _____
  - _____ Immunological memory _____
- The adaptive immune response primarily engages the use of lymphocytes to facilitate it. These lymphocytes have receptors _____ specific to a certain antigen _____ which allows them to be selected and then cloned.

Highlighted are the cellular components of the adaptive immune system



- The adaptive immune response can essentially be split up into two components – the _____ humoral response _____ targeted to _____ extracellular _____ threats, and the _____ cell-mediated response _____ targeted to _____ intracellular threats.
- This is facilitated by B cells and T cells, with T helper cells being involved in both responses.

Active Recall: What is the importance of having a specific response with memory?

_____

_____

What is the difference between intracellular and extracellular pathogens?

Discussion: Extracellular vs Intracellular Pathogens

- Think about the prefixes – 'extra' and 'intra'.
- What pathogens might be examples of each of these?
- How should we protect against them?

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Analogy: The Defence of China feat. Mulan and Mongolians

- Credit to Wayne Tze Wei Tan for this analogy!
- Pathogen: Mongolians (No racism).

- 1st line of defence: The wall, serving as a physical barrier to Mongolian invasion.

- 2nd line of defence: The soldiers on the wall, ready to attack anything that they see climb over.

- Antigen presentation: Helpless soldier calls for backup, alerting the rest of China about the threat.

- 3rd line of defence: Training up Mulan so she can beat the Mongolians up.

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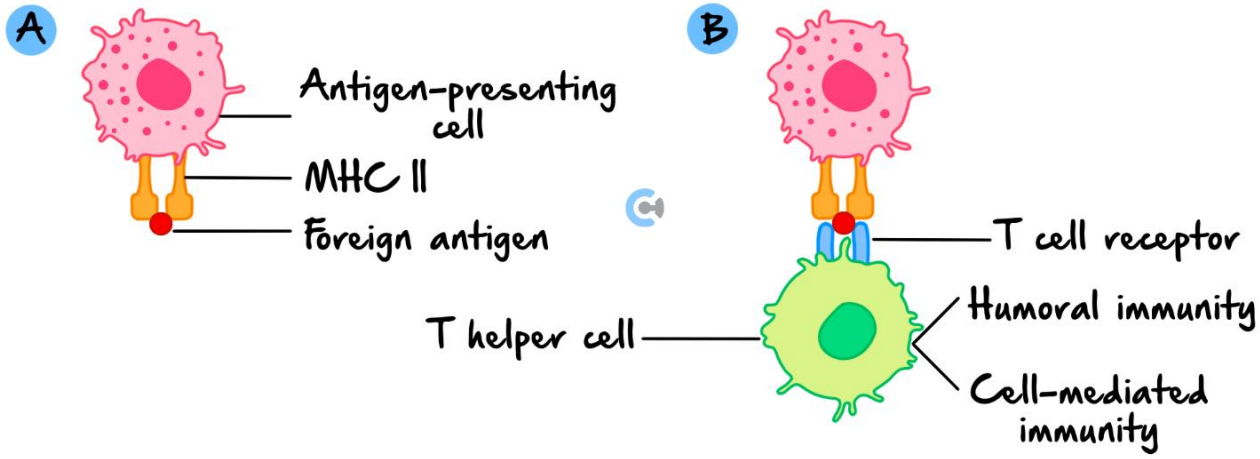
Sub-Section: Antigen Presentation

How does the 3rd line know when to act?

How can it be specific to antigens?

Antigen Presentation

- **Antigen presentation** is the process where ___antigen-presenting cells___ (**APCs**) display fragments of a foreign pathogen on their **MHC** ___class II___ **molecules**.
- This allows **specific helper T lymphocytes** to recognise the antigen and activate the **adaptive (third line) immune response**.



A An antigen-presenting cell displaying a foreign antigen via MHC II.

B An antigen-presenting cell presenting an antigen to a complementary T cell receptor on a T helper cell, consequently activating it.

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Analogy: Cinderella's Glass Slipper

- Finding the matching receptor is a lot like Cinderella finding her matching slipper!
- Has to be a complementary fit between antigen and receptor to generate a SPECIFIC response!

Only the lymphocyte with the exact matching receptor can bind to the antigen. Just like only Cinderella's foot fits the slipper, only the 'right' cell fits the antigen–and gets selected.

Introduction to Adaptive Immunity

- The adaptive immune system is the body's third line of defence, acting with precision and long-term memory.
- Two hallmark features distinguish it from the innate immune system:
  - Specificity: Each immune cell targets a unique antigen.
  - Memory: Once exposed, the immune system "remembers" the antigen and responds faster next time.
- Adaptive immunity includes two major responses:
  - Humoral immunity: B cells produce antibodies targeting extracellular pathogens (e.g., bacteria, viruses in blood).
  - Cell-mediated immunity: T cells eliminate intracellular pathogens (e.g., viruses inside host cells).
- Activation depends on specific binding between antigens and lymphocyte receptors.
  - Lymphocytes with receptors matching the presented antigen are selected and activated.

- Helper T cells (Th cells) are central to coordination.
  - They activate both B cells and cytotoxic T cells by releasing cytokines.
- Antigen presentation is key to triggering adaptive immunity.
  - Antigen-presenting cells display antigens on MHC-II molecules to alert helper T cells.
- Only lymphocytes with matching receptors become activated – ensuring precision and preventing overreaction.
  - Like a "lock-and-key" or "Cinderella's slipper" – only the correct fit initiates a response.

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Section C: Humoral Immunity

Overview: Humoral Glossary

Term	Definition
Native B Cell	A 'B cell' that has never encountered its matching antigen before.
Clonal Selection	The process of selecting a lymphocyte with a receptor complementary to the antigen.
Clonal Expansion	The rapid multiplication of selected lymphocytes.
Plasma Cell	An effector B cell that secretes large amounts of antibody.
Memory B Cell	A long-lived B cell that remembers the antigen for faster future response.
Cytokines	Chemical messengers secreted by helper T cells that activate other immune cells.

Head Tutor's Note: Do NOT teach this box but direct students to it instead.

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Sub-Section: Activating Humoral Immunity

How can we deal with extracellular pathogens?

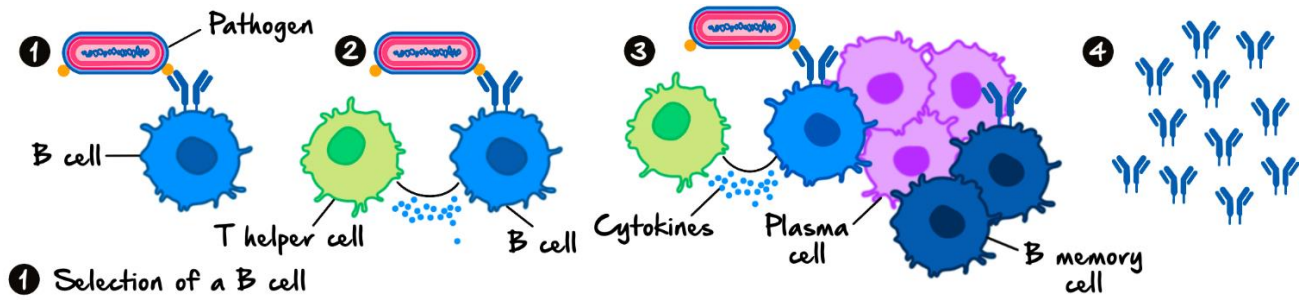
Overview

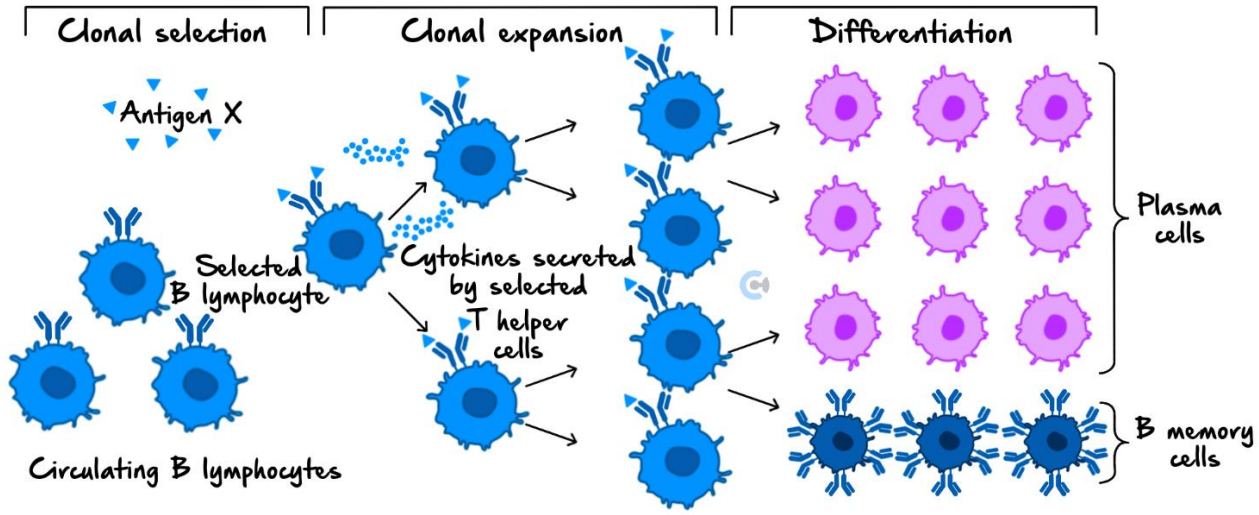
- Involves the destruction and neutralisation of extracellular antigens via the development and secretion of antibodies.
  - Facilitated by B lymphocytes and T helper lymphocytes – each cell has a receptor specific to the antigen.
  - We can describe it in a step-by-step process.

The Process of Humoral Immunity

Head Tutor's Note: Direct binding is PREFERRED.

- An antigen that is complementary in shape to the specific receptor present in a B cell will bind to it, and this is called _____ "selection" _____.
  - Antigens can be encountered in a number of ways. Can you think of some?
- Meanwhile, we have a T helper cell that has become activated by antigen presentation which will recognise this B cell and will secrete cytokines that will cause it to undergo _____ clonal expansion _____.
  - Cytokines also stimulate these B cells to differentiate – they can either differentiate into _____ B plasma cells _____ or _____ B memory cells _____.
  - They will serve to be our effector cells for the humoral immune response, with B plasma cells being the antibody production factories against that specific antigen.
  - B memory cells remain in tissue afterwards for a long period of time, to provide _____ immunological memory _____.





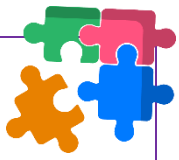
The processes of B cell clonal selection, expansion, and differentiation

Misconception

"B cells can work completely on their own–once they bind an antigen, they automatically start producing antibodies."

TRUTH: B cells need help from activated helper T cells to become fully functional.

- While a B cell can bind directly to a free-floating antigen (this is called **clonal selection**), it **can't undergo clonal expansion or differentiate into plasma/memory cells** without receiving cytokine signals from a **helper T cell**.
- These helper T cells are only activated if they recognise the same antigen on an **antigen-presenting cell** (**APC**) via **MHC-II**.
- This "double-check" system ensures **specificity and safety**–the body only launches a full immune response when both B and T cells confirm the same threat.



Analogy: Two Keys to Launch the Attack

- Activating a B cell is kind of like launching a nuclear missile (minus the destruction). You don't want it to happen by accident.
- Just like you need **two people** turning **two separate keys** at the same time to confirm a nuclear launch, the immune system uses **two separate confirmations** before producing antibodies:
  1. The **B cell** has to bind the antigen directly (clonal selection).
  2. The **helper T cell** must also recognise the same antigen on an antigen-presenting cell (APC) and send cytokines.
- Only when **both keys are turned** does the B cell get activated, multiply (clonal expansion), and produce plasma/memory cells.
- ✅ This double-check system ensures accuracy, prevents unnecessary immune responses, and guarantees the threat is real.

Discussion: Immunological Memory

IMMUNOLOGICAL MEMORY:

- Secondary immune response is always stronger than the primary response.
- In primary response (initial exposure to antigen), antibodies are produced by naive B cells. It takes longer for the body to produce antibodies and antibody levels drop as plasma B cells begin to die.
- In secondary response (re-exposure to antigen), antibodies are produced by memory B cells which differentiate into plasma B cells. Memory B cells are activated more rapidly and hence, antibodies are produced more quickly and in greater quantities.

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Can this pathway work in any other way?

Exploration: Receptor-Mediated Endocytosis

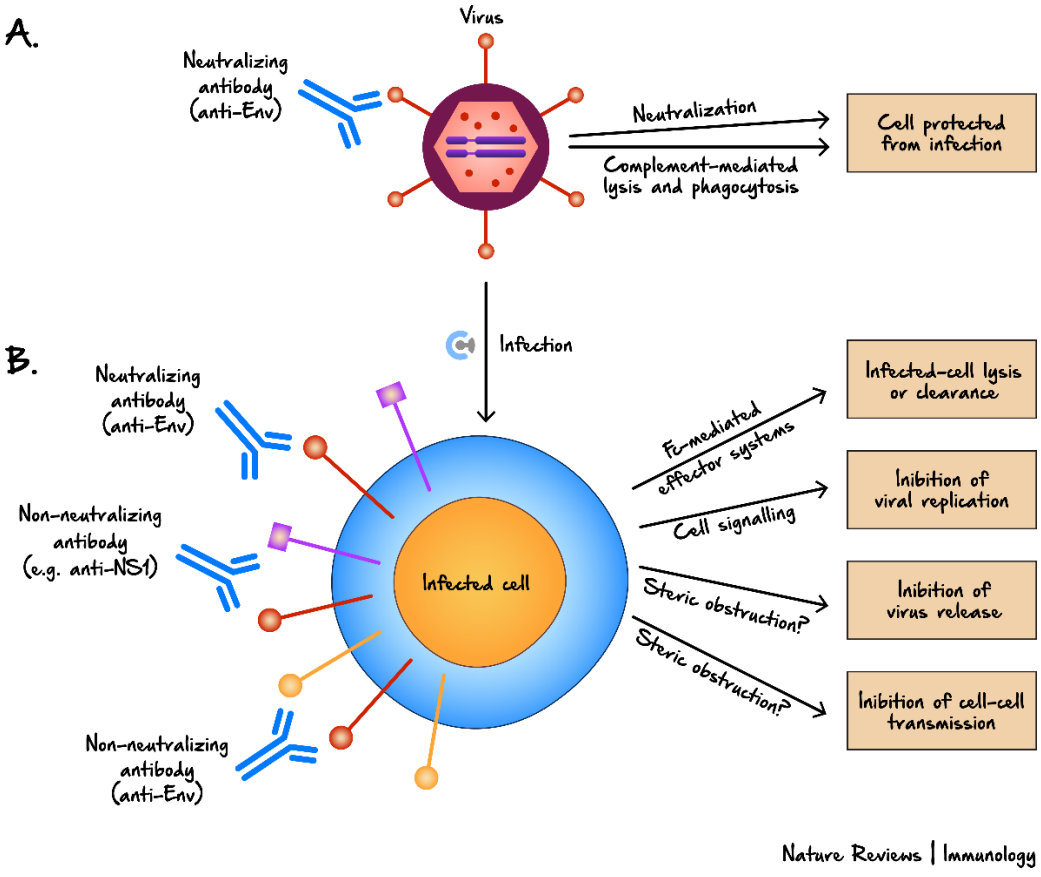
They can undergo receptor mediated phagocytosis and act as presentation cells for themselves.

Head Tutor's Note: Explain that the VCAA FAQS clarify that B cells can be professional antigen presenting cells. Draw a diagram!

Can this be useful against intracellular pathogens too?

Exploration: Humoral Response against Intracellular Pathogens

They can act against those pathogens before they enter the cell! Run through viruses as an example.



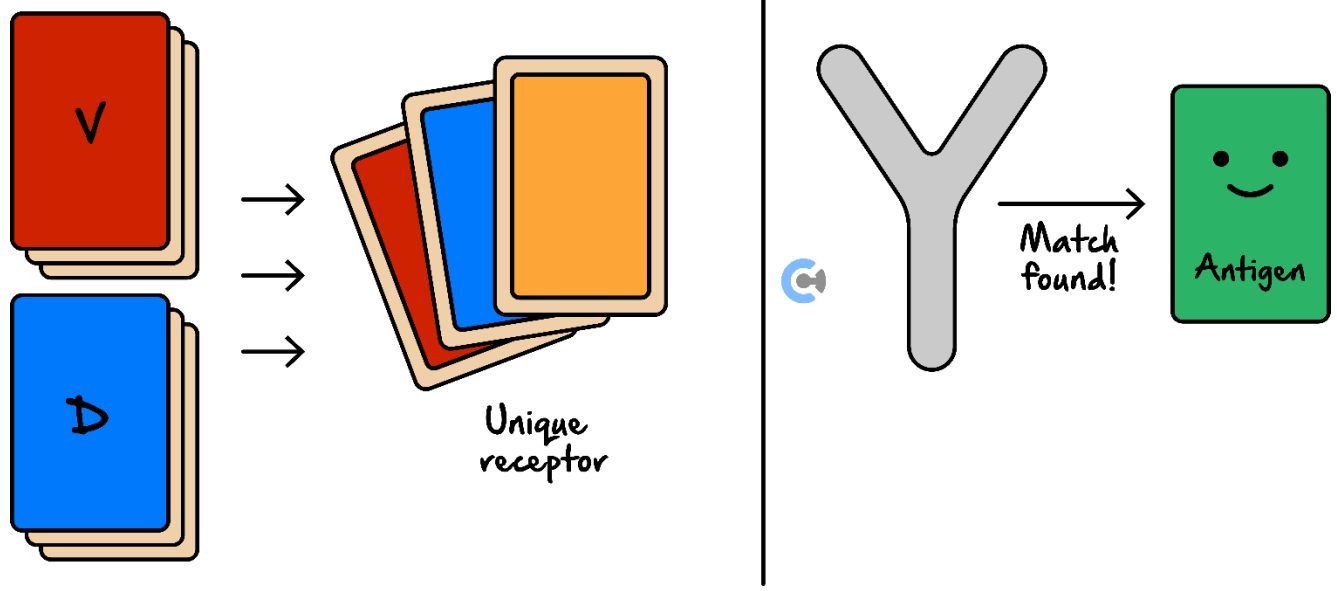
Is there a chance that we DON'T have the correct receptor?

Exploration: V (D) J recombination

The genes which code for the receptors, shuffle around randomly! This creates a BUNCH of combinations for receptors!

Analogy: Shuffling Cards to Make Unique Hands (V(D)J Recombination)

- Imagine you have three decks of cards:
  - One deck has **V cards**.
  - One has **D cards**.
  - One has **J cards**.
- To make a **unique hand**, you draw:
  - One card from each deck.
  - Then, combine them into a set.
- Even though the total number of cards is limited, the number of **possible combinations** is huge. That's exactly what your B cells do.
- 🧠 During development in the bone marrow, your B cells **randomly shuffle and select one V, one D, and one J gene segment**. These three segments are joined together to create a **unique receptor**, like a custom hand of cards.
- 🎯 This means your immune system has **millions of different B cells**, each with a receptor ready to match a specific "antigen card", even ones the body has never seen before.



NOTE: This idea is beyond the scope of VCE, and has been included to pre-emptively answer some of your understanding based questions!

How can we put this into a question-answering template?

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Sub-Section: Sample Response to Humoral Immunity

NOTE: There is a LOT of variation in the responses and the way schools teach it. VCAA doesn't really assess these minute details so, for the exam anything should work really!

Sample response: Humoral Immunity (The Contour Way)

- Antigen-presenting cells will engulf the pathogen and display antigens on MHC-II markers, travelling to the lymph nodes.
- At the lymph nodes, Naïve B cells can interact directly with an unbound, or raw, antigen via their receptors (CLONAL SELECTION). This can also occur through antigen presentation.
- A Th cell with complementary surface receptors to the antigen is also selected, releasing stimulatory cytokines to activate the selected B cell and induce proliferation (CLONAL EXPANSION).
- As they proliferate, cytokines will also trigger B cells to differentiate into plasma and memory B cells.
- Plasma cells produce and secrete specific antibodies to the antigen, whereas memory B cells are long-lived and remain in the tissue providing immunological memory (a faster and greater response to secondary exposure).

Annotations

Sample Response: VCAA (2021)

- A suitable answer was that the vaccine is taken up by, for example, macrophages and antigens presented on the surface of the cell. The antigen-presenting cell moves into the lymphatic system and is taken to the lymph node. Helper T cell stimulates naïve B cells. Each B cell divides to produce plasma cells, which produce specific antibodies. B memory and/or T memory cells are produced for long-term immunity.

- A suitable description of the sequence of events that occurs in the secondary lymphoid tissue includes any four of the following:

  - An antigen-presenting cell presents the antigen.
  - T helper cells are activated.
  - The T helper cell activates a B cell.
  - The B cell undergoes clonal expansion. Plasma cells are produced.
  - The plasma cells produce antibodies.

- Students were not required to name the specific secondary lymphoid tissue as part of their response. Standard abbreviations for cell types were accepted (e.g. Th cell for T helper cell).

- Students were able to provide an explanation of clonal expansion without writing the specific term.

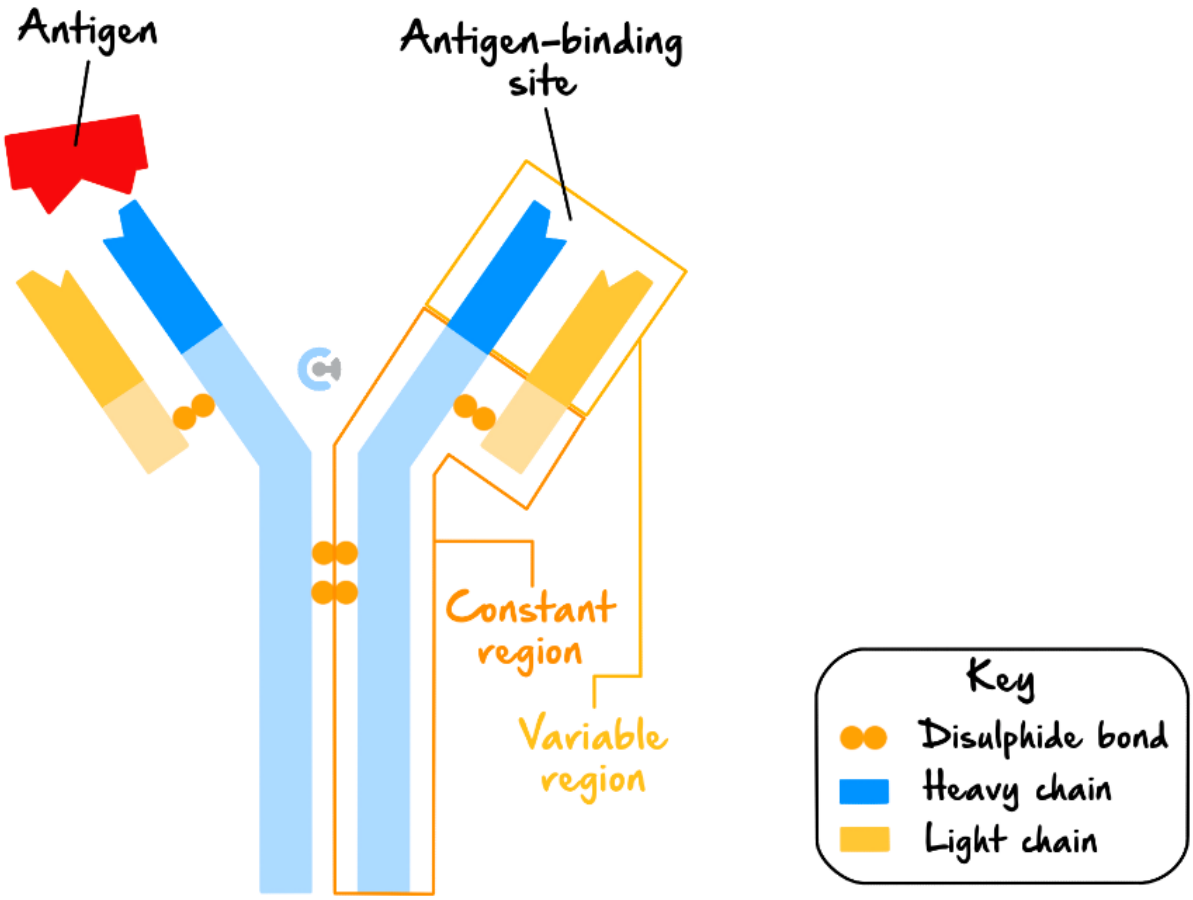
- Students who demonstrated a detailed understanding of the sequence of events wrote accurate answers of varying lengths.

Annotations

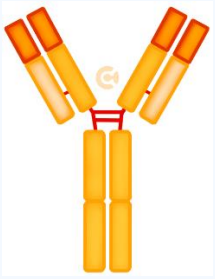
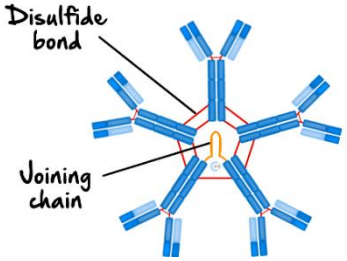
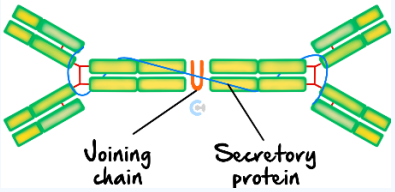
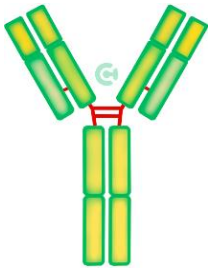
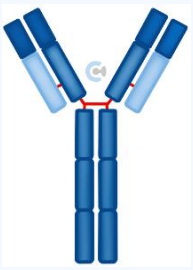
Sub-Section: Antibodies

Antibodies

- These are proteins that are secreted by B plasma cells to destroy or neutralise pathogens.

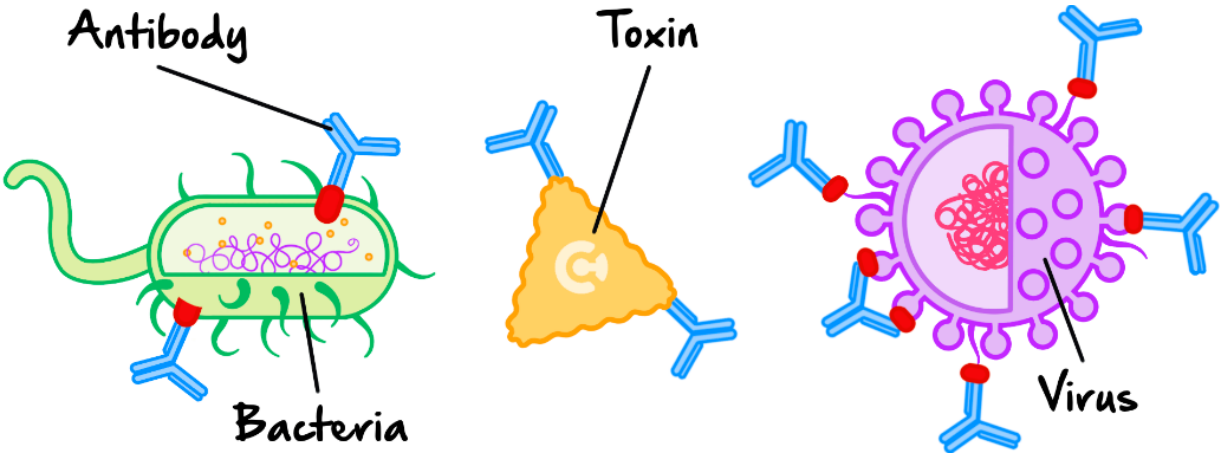


- There are a number of different types of antibodies, including IgG, IgE, IgA, IgD, and IgM.

Class	Half-life in serum	Presence	Functions	Structure
IgG	21 days	Blood, lymph and extracellular fluid; most circulating antibodies (> 80%); crosses placenta.	Agglutination, complement activation.	
IgM	10 days	Blood and lymph; produced early in infection response.	Agglutination, complement activation.	
IgA	6 days	Found in secretions such as tears, saliva, and milk.	Mucosal immunity.	
IgD	3 days	Blood and lymph; mostly present on B lymphocyte surfaces; small amount in circulation; binds to basophils and mast cells.	Functions not well-understood; possible role in regulating innate immune responses.	
IgE	2 days	Blood and lymph; attaches to mast cells.	Involved in allergic reactions.	

- They attack and destroy pathogens with a number of mechanisms:
  - Neutralisation –

They can bind to specific antigens which may serve to act as the main mechanism that pathogens use to attack cells.

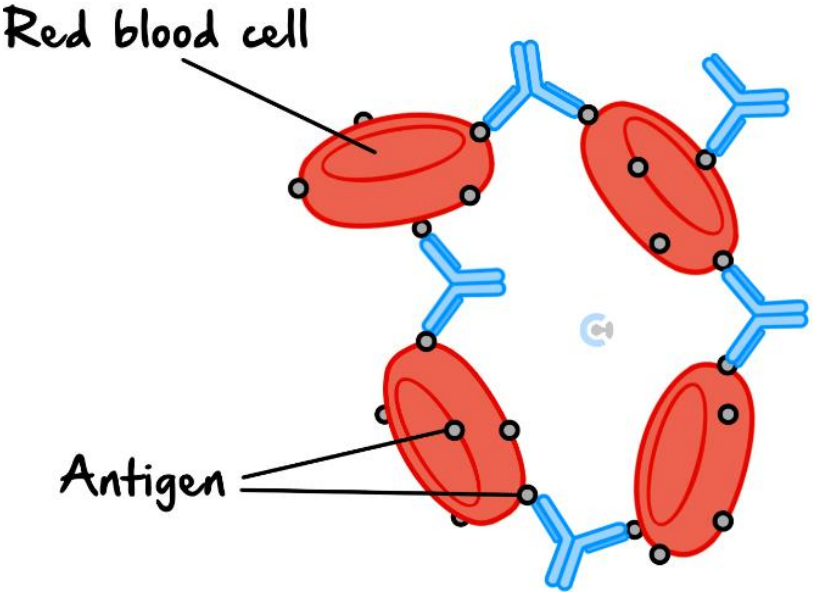


  - Agglutination –

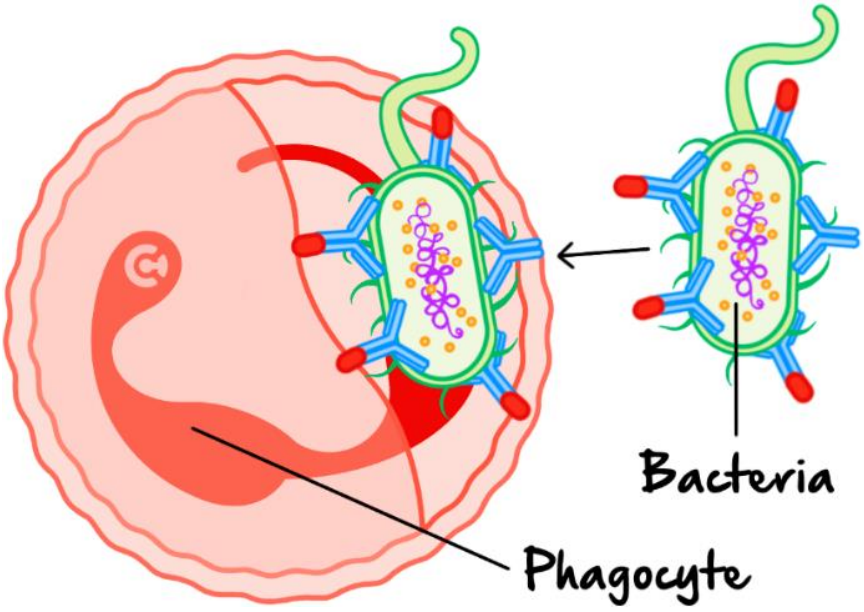
Binding together between multiple pathogens, allowing the formation of large complexes which make it easier for phagocytes to collect and digest.

  - Immobilisation –

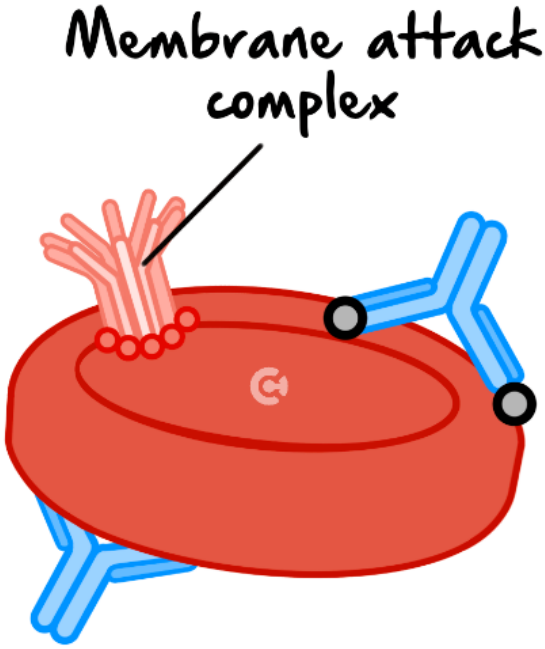
These large complexes can stop and inhibit the movement of the pathogen itself.



- Opsonisation – Directly binding to the pathogen that allows phagocytes to bind to them and then digest them.



- Complement activation – Can trigger the activation of a complement cascade resulting in the outcomes of complement activation.



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Sub-Section: Case Study

Exploration: Ali, the Knight has been Injured!

- ⚔️ **Ali the Knight is injured...**
- Ali is stabbed by a rusty sword, trying to courageously defend Baghdad against the Mongols. The pathogen enters through broken skin.
- **Stage 1: First Line of Defence**
  - ✏️ Q: What line of defence has been breached?
  - ✏️ Q: Which part of the innate immune system responds next?
- 💉 **Stage 2: Antigen Presentation**
  - A dendritic cell engulfs the pathogen and presents it on MHC II.
    - ✏️ Q: What is the name of this type of cell?
    - ✏️ Q: Where does this cell travel to present the antigen?

- **Stage 3: Clonal Selection & Activation**
  - In the lymph node, a helper T cell is activated, which then helps activate a B cell with a matching receptor.
    - Q: What process is occurring here (starts with C)?
    - Q: What does the helper T cell secrete to activate the B cell?
- **Stage 4: Clonal Expansion & Differentiation**
  - The B cell divides and forms two types of cells.
    - Q: What are the names of these two types?
    - Q: What does each type do?
- **Stage 5: Destruction of the Pathogen**
  - Plasma cells secrete antibodies that neutralise the pathogen and mark it for destruction.
    - Q: Name one antibody mechanism that helps destroy the pathogen.
- **Stage 6: Immunological Memory**
  - Months later, Ali is stabbed again–but this time, the immune response is faster.
    - Q: Which cell type is responsible for this faster secondary response?
    - Q: How is the second exposure different from the first?
- What will happen when Ali the Knight gets stabbed with a rusty sword again?

Space for Personal Notes

Key Takeaways

Humoral Immunity

- Humoral immunity protects against extracellular pathogens by producing antibodies.
- The process begins with clonal selection:
  - A 'B cell' binds to a free-floating antigen with a complementary receptor.
- The same antigen must be recognised by a helper T cell presented on an APC.
  - The helper T cell becomes activated and secretes cytokines.
- Cytokines trigger clonal expansion:
  - The activated B cell divides to produce many identical B cells.
- These B cells differentiate into:
  - Plasma cells: Antibody-producing factories that release large amounts of specific antibodies.
  - Memory B cells: Long-lived cells that provide rapid response on re-infection.
- This dual-signal system (antigen binding + helper T cell cytokines) acts as a "double-check" for immune accuracy.
- B cells can also perform receptor-mediated endocytosis and act as APCs.
  - This ability allows them to present antigen to helper T cells and receive cytokine support.
- Humoral immunity is most effective before pathogens enter cells.
  - Useful against viruses in the bloodstream or bacteria in body fluids.
- Antibody diversity is generated via V(D)J recombination in developing B cells.
  - This gene shuffling process creates millions of unique B cell receptors – enabling recognition of countless antigens.

Antibodies

- Antibodies are Y-shaped proteins secreted by plasma cells that bind specifically to antigens.
  - Each antibody matches a specific antigen like a lock and key.
- Five major classes of antibodies (immunoglobulins), each with distinct roles:
  - **IgG**: Most abundant; found in blood, lymph, and extracellular fluid; crosses placenta; supports agglutination and complement activation.
  - **IgM**: First antibody released during an infection; large and effective at agglutination and activating complement.
  - **IgA**: Found in secretions (tears, saliva, breast milk); important in mucosal immunity.
  - **IgE**: Binds to mast cells and triggers allergic reactions; helps defend against parasitic infections.
  - **IgD**: Present in small amounts on immature B cells; role in immune regulation not fully understood.
- Mechanisms by which antibodies eliminate or weaken pathogens:
  - **Neutralisation**: Block pathogen binding to host cells by coating active sites.
  - **Agglutination**: Clump multiple pathogens together, making them easier for phagocytes to engulf.
  - **Immobilisation**: Bind to flagella or cilia, reducing motility.
  - **Opsonisation**: Tag pathogens to enhance uptake by phagocytes.
  - **Complement activation**: Initiate a cascade that forms membrane attack complexes, lyses cells, and recruits immune components.

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Contour Check

Learning Objective: [3.3.1] – Identify the structure of the lymphatic system, including primary & secondary lymphatic tissue

Key Takeaways

- The lymphatic system transports a clear fluid known as _____.
  - This fluid originates from leaked plasma in the [interstitial / intracellular] space.
- Lymphatic capillaries collect this fluid and transport it through vessels back to the [heart / lungs].
  - These vessels contain [one-way / two-way] valves.
  - Movement of lymph relies on [skeletal muscle / cardiac muscle] contractions.
- The lymphatic system includes primary and secondary lymphoid tissues.

Solution Pending

  - **Primary lymphoid tissues** include the _____ and _____.
    - These are sites of lymphocyte development and maturation.
  - **Secondary lymphoid tissues** include _____ and _____.
    - These are sites where lymphocytes encounter antigens and initiate immune responses.
- Lymph nodes filter lymph and contain clusters of immune cells like _____ and _____.
  - These nodes are classified as [primary / secondary] lymphoid tissue.

Learning Objective: [3.3.2] – Identify the role of the lymphatic system in fighting infections

Key Takeaways

- The lymphatic system serves as a transport network for _____.
  - It moves antigen-presenting cells (APCs) to _____ lymphoid tissues for immune activation.
- It supports immune function by:

  Solution Pending
  - Filtering _____ for pathogens.
  - Housing lymphocytes that can detect and respond to _____.
- It maintains fluid balance by returning leaked fluid to the circulatory system.
  - Without this return, tissues would experience _____.
- The system prevents systemic spread of pathogens by trapping them in _____ before they return to the bloodstream.

Learning Objective: [3.3.3] – Explain antigen presentation as a means to initiate the adaptive immune response

Key Takeaways

- Antigen presentation occurs when an APC engulfs a pathogen and presents its antigen on an _____ molecule.
  - The molecule involved is [MHC-I / MHC-II].

Solution Pending

- This antigen is recognised by a _____ with a complementary receptor.
  - The cell that recognises this antigen is a [helper T / cytotoxic T] lymphocyte.
- This interaction activates the helper T cell to release _____, triggering the adaptive response.
- Only lymphocytes with a receptor that fits the presented antigen are _____.
  - This process ensures [specificity / generality] in immune activation.

Learning Objective: [3.3.4] – Identify the characteristics of the adaptive response which differentiate it from the innate response

Key Takeaways

- The adaptive immune system is the [third / second] line of defence.
- Two key features that differentiate it are:
  - _____: Each cell targets one unique antigen.
  - _____: Allows quicker and stronger response on re-exposure.
- The adaptive system involves lymphocytes that undergo _____ when activated.
- Helper T cells coordinate immune responses by activating _____ and _____ cells.
- Unlike the innate system, the adaptive response takes [longer / shorter] to initiate but is more precise and lasting.

Solution Pending

Learning Objective: [3.3.5] – Identify & explain the humoral response as a response to extracellular pathogens, including the role of B and T Helper lymphocytes

Key Takeaways

- The humoral immune response targets [extracellular / intracellular] pathogens.
- B cells are activated through a two-step process:
  - First, an antigen binds directly to a B cell receptor (_____).
  - Second, a helper T cell that has recognised the same antigen on an APC secretes _____.
- These cytokines trigger B cell _____ and differentiation.
- Differentiated B cells become:
  - _____ cells that produce antibodies.
  - _____ cells that persist in the tissue for future response.
- B cells can also act as APCs through _____ endocytosis.
- This response is most effective before pathogens enter [cells / tissues].
- The helper T cell involved in this process is a [Th / Tc] cell.

Solution Pending

Learning Objective: [3.3.6] – Explain the significance of memory cells to generate immunological memory, & how that prevents future infections

Key Takeaways

- Memory cells are formed during the [primary / secondary] immune response.
- They are long-lived and remain in [blood / tissue], providing faster activation upon re-exposure.
- On second exposure, memory cells produce a [faster / slower] and [stronger / weaker] immune response.

Solution Pending

- This quicker response prevents the pathogen from causing significant _____.
- Immunological memory is the biological basis for effective _____.

Learning Objective: [3.3.7] – Differentiate between extracellular & intracellular threats

Key Takeaways

- **Extracellular threats** exist [outside / inside] host cells.
  - Examples: Most _____ and free-floating _____.
  - Targeted by the _____ immune response.
- **Intracellular threats** reside [outside / inside] host cells.

Solution Pending

  - Examples: _____ replicating within host cells.
  - Targeted by the _____ immune response.
- Different immune cells are specialised to deal with each type:
  - B cells produce antibodies to neutralise [extracellular / intracellular] antigens.
  - Cytotoxic T cells destroy infected cells hosting [extracellular / intracellular] pathogens.

Learning Objective: [3.3.8] – Explain how antibodies are used to fight against infections, and draw their structure

Key Takeaways

- Antibodies are secreted by _____ cells and bind specifically to antigens.
- Their structure is shaped like a _____, with variable regions that determine antigen binding.
- Types of antibodies:
  - **IgG**: Crosses placenta; high in circulation; performs _____ and _____ activation.
  - **IgM**: First produced; effective at _____ and activating complement.
  - **IgA**: Found in secretions (e.g., tears, saliva); protects _____ surfaces.
  - **IgE**: Binds to mast cells; involved in _____ reactions and parasite defence.
  - **IgD**: Found on immature _____ cells; function unclear.

Solution Pending

- Antibody functions:
  - **Neutralisation**: Block pathogen entry into cells by coating _____.
  - **Agglutination**: Clump pathogens for easier _____ by phagocytes.
  - **Opsonisation**: Tag pathogens to enhance uptake by _____.
  - **Immobilisation**: Bind to flagella or cilia to reduce _____.
  - **Complement activation**: Initiate cascade leading to cell _____ and inflammation.

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