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VCE Biology ¾ The Innate Immune System [3.2]

Workbook

Outline:

Introduction to the Innate			
Introduction to the Innate			
<u>Immune System</u>	Pg 3-5		
		The Non-Cellular Components of the	! Innate
Recognition of Pathogens	Pg 6-9	Immune System	Pg 21-25
The Cells of the Innate		The Inflammatory Response	Pg 26-30
Immune Response	Pg 10-20		J
Phagocytes		<u>Examples</u>	Pg 31-32
Natural Killer Cells			
Mast Cells			
Eosinophils			

Study Design Key Knowledge:

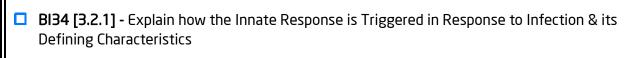
Study Design: Responding to Antigens

The innate immune response including the steps in an inflammatory response and the characteristics and roles of macrophages, neutrophils, dendritic cells, eosinophils, natural killer cells, mast cells, complement proteins, and interferons.

The initiation of an immune response, including antigen presentation.



Learning Objectives:





- **BI34 [3.2.2] -** Identify & Describe the Function of the Cellular Components of the Innate Immune Response Macrophages, Neutrophils, Dendritic Cells, Mast Cells, Eosinophils
- **BI34 [3.2.3] -** Identify & Describe the Role of Non-Cellular Components of the Innate Immune Response Complement Proteins & Interferons
- □ BI34 [3.2.4] Describe Key Innate Immune Processes Phagocytosis, Inflammatory Response
- BI34 [3.2.5] Apply Knowledge of Innate Immune Response to Unfamiliar Contexts such as Pathogen Infection
- BI34 [3.2.6] Explain the Symptoms Associated with the Inflammatory Response

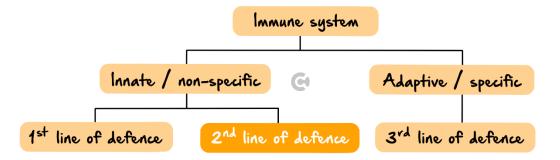


Section A: Introduction to the Innate Immune System

Overview

Definition

- The innate immune system is the first layer of defence against pathogens.
 - Barriers prevent the entry of the pathogen, this lesson will focus on what occurs next.
- The innate immune system is _____ and delivers a _____ response to any pathogens that make it through to the intracellular space.



Exploration: What do we mean by non-specific?



Why might this be detrimental to the long-term prevention of pathogenic infection?

Exploration: Why is it necessary and important to have a fast response to pathogenic invasion?



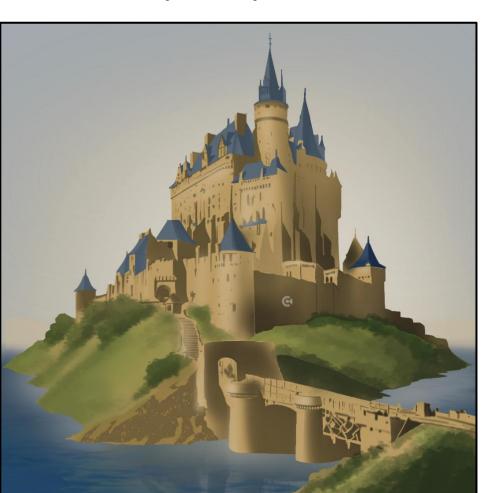


Exploration: Summarise the function of the innate immune system!



Analogy: The Castle

Let's say you are a medieval lord and you've found yourself in a castle.



To protect against your enemies, what kind of defences would you have? Would these defences change depending on the enemy? What would happen if you just had these primary defences and nothing else?





Introduction to the Innate Immune System



- ☑ Innate immunity acts immediately after pathogen entry.
- ☑ The response is non-specific and does not adapt based on pathogen type.
- ✓ Innate immunity lacks the long-term memory of pathogens.
- ✓ The main functions include preventing pathogen entry, eliminating invaders, activating adaptive responses, and recruiting immune cells.
- ✓ Non-specificity may lead to future infections if pathogens adapt.
- ✓ Fast response prevents pathogens from establishing infection and multiplying.





Section B: Recognition of Pathogens

PAMPs and DAMPs

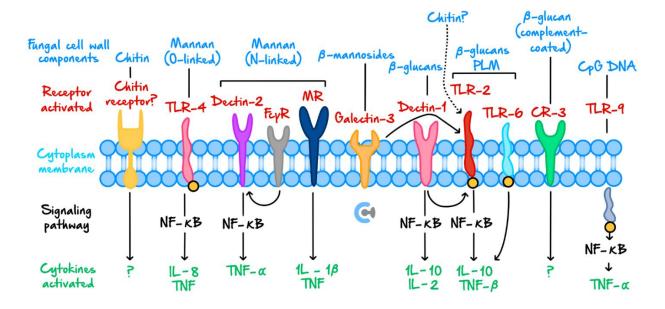
- The innate immune response has to still be able to tell the difference between foreign and non-foreign materials.
- What would happen if the innate immune response couldn't do this?
- This recognition doesn't use the MHC markers. Why?
- Instead, there are some general common molecules that are associated with pathogens and damage.
 - PAMPs Pathogen Associated Molecular Patterns. Can you think of any examples?

DAMPs – Damage Associated Molecular Patterns.



Exploration: By what principle do you think that PAMPs and DAMPs are recognised?





Don't be intimidated - this isn't what is required knowledge.

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Analogy: Police Profiling

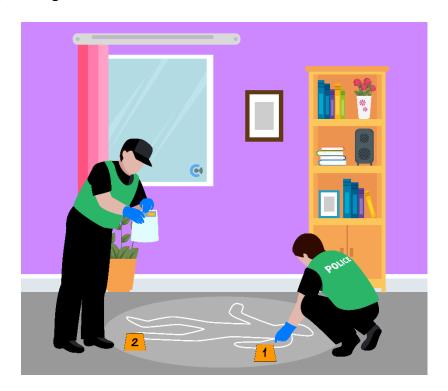


- Innate immune cells (Police officers):
 - Patrol your body continuously, looking for threats or signs of trouble. To do this efficiently, they need rapid methods to recognise potential problems.
- PAMPs Pathogen-Associated Molecular Patterns (General Suspect Profiles):

These are common characteristics consistently associated with pathogens, much like general suspect profiles used by police. Just as police look for suspicious behaviours, attire, or patterns frequently exhibited by criminals, immune cells detect shared features of pathogens (like bacterial cell wall components or viral RNA). They don't identify the exact pathogen immediately but quickly recognise danger based on these familiar patterns.

DAMPs - Damage-Associated Molecular Patterns (Signs of Disturbance):

Similar to how police respond urgently to signs like broken windows, activated alarms, or smoke, DAMPs indicate internal cellular damage or distress. While these signs don't specifically reveal the exact cause, they clearly signal that something harmful has happened internally, prompting immune cells to rapidly investigate and address the issue.



Exploration: What happens next?





Recognition of Pathogens



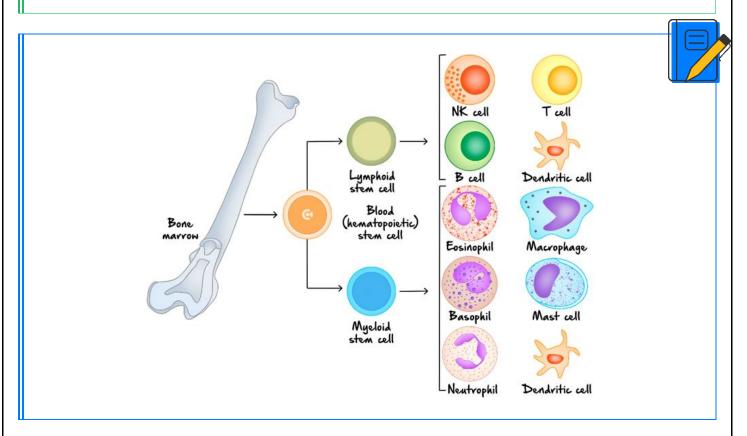
- ✓ Innate system identifies threats using general molecular patterns.
- ✓ Pathogen-associated molecular patterns (PAMPs) are found on microbial surfaces.
- ☑ Damage-associated molecular patterns (DAMPs) originate from stressed or injured host cells.
- ✓ Pattern recognition receptors (PRRs) on immune cells detect these patterns.
- ☑ Recognition relies on conserved structural features rather than specific antigens.



Section C: The Cells of the Innate Immune Response

Where do these cells arise from?





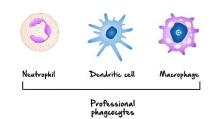
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Sub-Section: Phagocytes



These are cells involved responsible for **phagocytosis**, as the name suggests!



What are neutrophils?



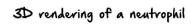
What role do neutrophils play in the innate response?

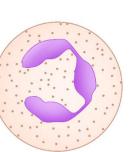
Definition

Neutrophils

- They are classed as a phagocyte ______
 - The vast majority of the immune cells in your body are neutrophils ______
- First responders, but also are very expendable.
- Common component of pus.







How else might neutrophils eliminate pathogens?





Analogy: The Expendable Foot Soldier

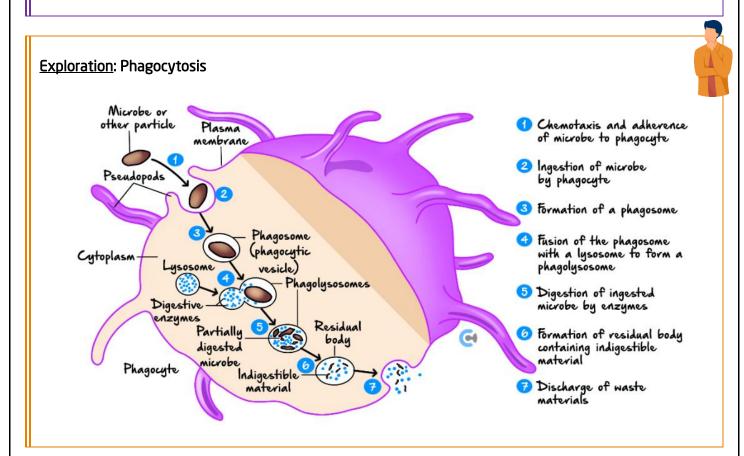


- Medieval soldiers, like Ali pictured below, were often mere pawns in the larger scheme of war and conquest, sacrificed for mere metres of land.
- You could say that neutrophils are like Ali, the common soldier, sacrificed for the greater good!



The body can generate neutrophils every 2-3 days, so it can just sacrifice them on the field of battle!

Any resemblance to real persons is purely coincidental 🥹!

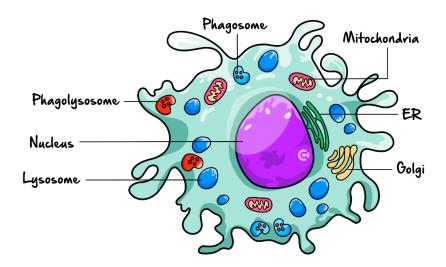




Macrophages

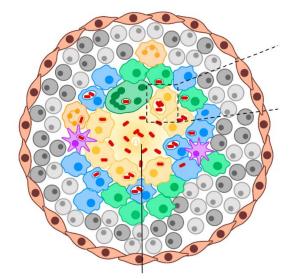


- These are larger immune cells also ______
 - Broader range of functions and longer lived than compared to neutrophils.
 - Can be found as a permanent part of some tissues.
 - Can also release cytokines to induce other responses of the immune system.
- Involved with antigen presentation.



Exploration: Tuberculosis



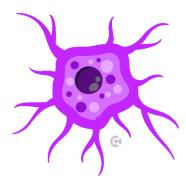




Dendritic Cells

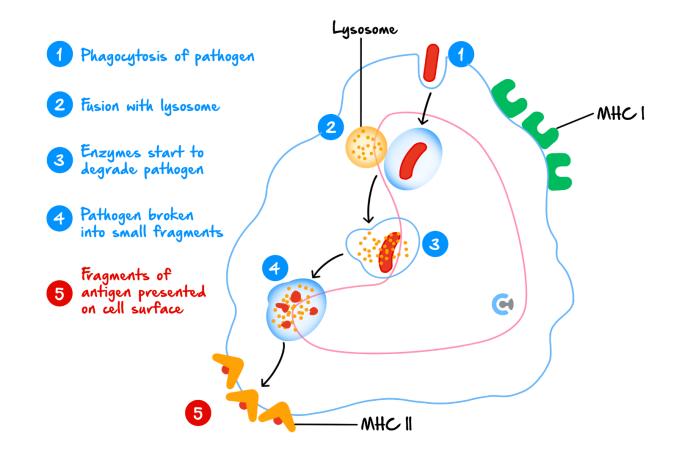


- Another cell that engages in phagocytosis, primarily found in tissues, but can travel through the bloodstream.
 - More specialised for the process of antigen presentation. Why?



Exploration: Antigen Presentation







Sub-Section: Natural Killer Cells



What is the life cycle of a virus?

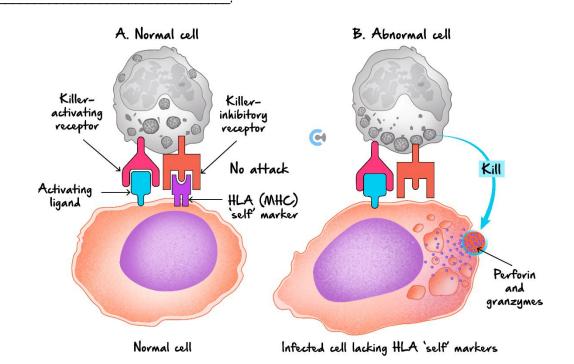


How do they kill these cells?



Natural Killer Cells

- Definition
- These are cells that do not target foreign cells but actually focus on targeting your own unhealthy cells, or infected cells.
 - Why might cells be unhealthy?
 - How could the unhealthy cells be recognised?
- This natural killer cell will then release perforins and granzymes which will trigger the cell's death by





Analogy: The Secret Police





- City → Your body.
- Citizens → Your own cells.
- **Secret Police (NK cells)** → Patrol the body looking for abnormal or suspicious cells.
- **Identification Papers/Social Credit Score (MHC markers)** → Used to distinguish healthy cells from infected or cancerous ones.
- **Action Taken** → Immediate neutralisation (inducing apoptosis) of suspicious cells lacking proper identification.

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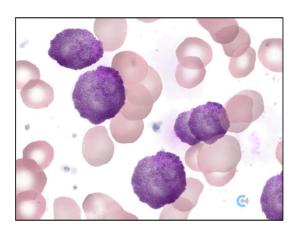
Sub-Section: Mast Cells



Mast Cells



- Immune cell that is primarily responsible for the release of ______ and other mediators that activate the immune system.
 - Not directly involved in the defence but rather stimulates other cells to do so releases other kinds of cytokines as well.
- Remains in tissue.



What triggers the release of histamine?



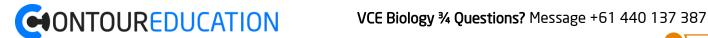
Analogy: Messengers of the Castle



Let's say you have someone attacking the walls - would they be allowed to just attack and break walls without that being reported?

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Sub-Section: Eosinophils



What pathogens do eosinophils target?

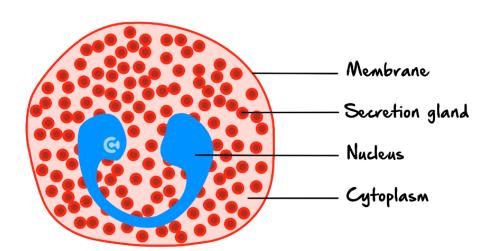


Eosinophils



- Immune cells which release _____ _____ - impacting pathogens which cannot be ingested fully via phagocytosis.
 - Able to phagocytose, but to a very limited extent.
- Degranulate upon contact what process would we call this ordinarily?

Structure of an Eosinophil



Kev Takeaways



- All these components have their own unique specific function the first step should be to remember all the different things and then what they do.
- Answering questions is less systematic than what it was for something like transcription, but it still is repetitive and predictable enough that we can prepare.
- More questions will focus on the holistic impact e.g., "What happens when a virus attacks us?"



VCE Biology ¾ Questions? Message +61 440 137 387

Active Recall: Describe how NK cells function against pathogens	?
Active Recall: Describe the role of mast cells against pathogens.	?
Active Recall: Distinguish between the 3 types of phagocytes.	?
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The Cells of the Innate Immune Response



✓ Phagocytes

- Phagocytes engulf and digest pathogens through phagocytosis.
- Neutrophils are the most abundant white blood cells and act as rapid first responders.
- Neutrophils eliminate pathogens via engulfment, toxic granules, and extracellular traps (NETs).
- Macrophages are larger, longer-lived phagocytes that also release cytokines and perform antigen presentation.
- Dendritic cells act as key antigen-presenting cells, bridging innate and adaptive immunity by activating T-cells.

✓ Natural Killer (NK) Cells

- NK cells identify and destroy infected or cancerous host cells.
- Recognition depends on detecting missing or abnormal MHC markers in host cells.
- NK cells kill by releasing perforin and granzymes, which induce apoptosis in target cells.

✓ Mast Cells

- Mast cells reside in tissues and are activated by injury or infection.
- Release histamine and other signalling molecules to increase blood flow and vessel permeability.
- Initiate inflammation and recruit other immune cells to the site of infection.

✓ Eosinophils

- Eosinophils target large parasites such as helminths and contribute to allergic responses.
- Release toxic granules that damage or kill pathogens too large for phagocytosis.
- Can perform limited phagocytosis and contribute to inflammation through degranulation.

A

Is the innate immune response ONLY made up of cells?





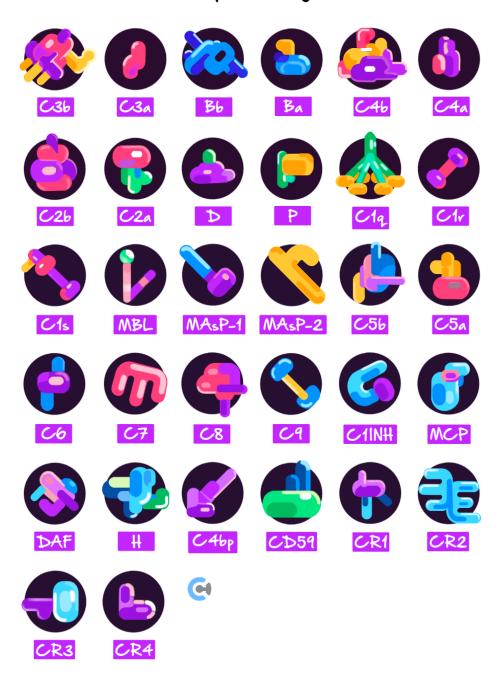
Section D: The Non-Cellular Components of the Innate Immune System

The Complement System



- The complement system is a set of proteins that float around the body in the blood and act as an innate defence against pathogens.
 - Primarily focused on bacteria.

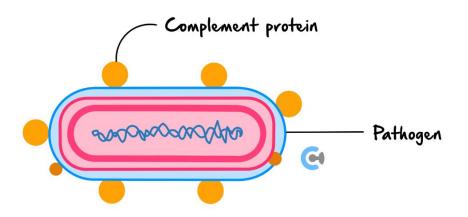
The Complement System



Not very well understood, but there are 3/4 main methods of attack against pathogens.

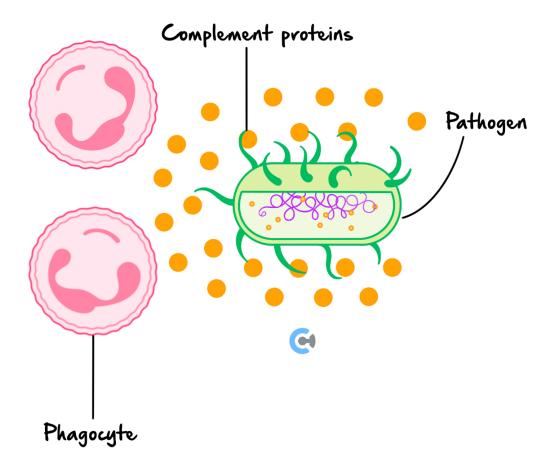


Opsonisation -



Opsonisation of a pathogen by complement proteins

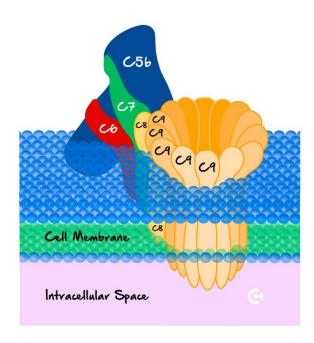
Chemotaxis - _______



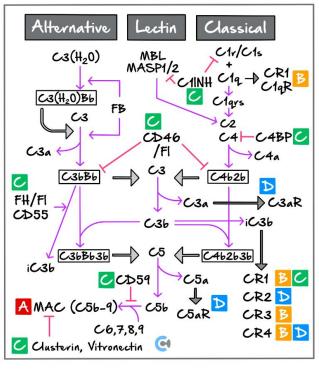
Chemotaxis of phagocytes towards a pathogen

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▶ Lysis - ____



Exploration: If you thought it was that easy.....



Functions

A Cell lysis

Killing of pathogens

B Opsonization / Phagocytosis

- Clearance of apoptotic cells and debris (CR1/CR3/CR4/ClqR)
- Synaptic pruning (CR3)

C Regulation

Inhibition of the complement cascade

D Other functions

- Promotion of cell differentiation and recruitment (C3aR/C5aR)
- · Modulation of immune cell migration (C3aR)
- · Regulation of B-cell functions (CR2)
- · Leukocyte adhesion (CR4)
- The immune system gets much more complicated!

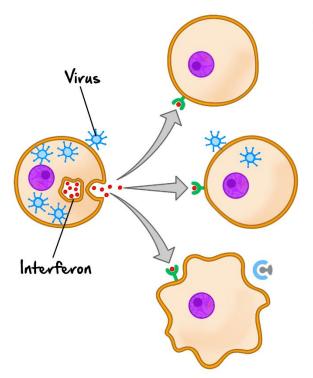


Interferons



These are signalling molecules that are released by virally infected cells – ______

• What could a cell do to reduce its risk of viral infection?



Signals neighbouring uninfected cells to destroy RNA and reduce protein synthesis

Signals neighbouring infected to cells to undergo apoptosis.

Activates immune cells

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The Non-Cellular Components of the Innate Immune System



Complement Proteins

- Complement proteins are inactive in the bloodstream until triggered by pathogens.
- Activation occurs via multiple pathways but always results in a targeted innate response.
- Opsonisation tags pathogen surfaces to enhance recognition and engulfment by phagocytes.
- Chemotaxis involves the recruitment of additional immune cells to the site of infection.
- Lysis is achieved by forming a membrane attack complex (MAC) that creates pores in the pathogen membrane, leading to cell death.
- Most effective against bacterial pathogens.

✓ Interferons

- Interferons are released by cells infected with viruses.
- These signalling molecules act locally to prepare neighbouring cells for potential viral invasion.
- G Stimulate the production of antiviral proteins in surrounding cells.
- Slow down viral replication and signal for immune responses like NK cell activation.
- Do not directly destroy viruses but enhance resistance across nearby tissues.



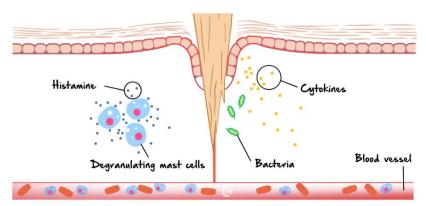


Section E: The Inflammatory Response

Definition

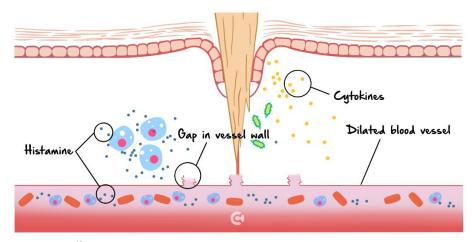
Overview of the Inflammatory Response

- The inflammatory response is an innate response to pathogenic infection and injury, which serves to rapidly shut down further infections and damage by increasing blood flow to the affected tissue.
 - There are three main aspects to it ______
- A classic example is a splinter.
- Initiation When the splinter pierces the protective layer of the skin, it damages skin cells and _____ may have been present in the splinter to the body. Damaged cells release cytokines, mast cells degranulate releasing _____.



Initiation of inflammation involves cytokines being secreted from damaged cells and activation of mast cells, causing the release of histamine.

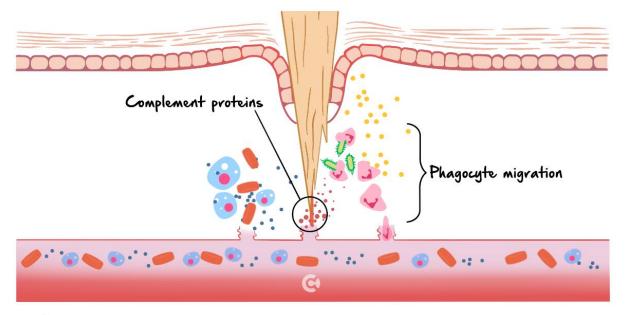
Vasodilation – ______ travels from the mast cells to the nearby blood vessels, binding to specific receptors which trigger vasodilation – ______. The permeability of the vessel wall also increases – _____.



Histamine signals the blood vessel to dilate and become leaky.



Migration - Signals and permeability increase allow innate immune cells to travel to the site of infection. What cells and components would be present and what would they do? Pus?



Various components of the innate immune system are able to access the site and destroy pathogens and remove debris.

<u>Discussion:</u> How does this process relate to the symptoms of inflammation?



- Ali, the soldier has sprained his ankle running to the battlefield! What symptoms might he get?
- -
- -
- **>**
- -
- -

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<u>Fever</u>



- Increasing central body temperature to disrupt the function of pathogens. How?
 - Can fevers be bad for us too?

NOTE: Technically speaking fevers are not part of the inflammatory response, I have grouped them together as they often can go hand in hand.



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Key Takeaways



✓ The Inflammatory Response:

- Inflammation is a rapid innate immune reaction to tissue damage or microbial invasion.
- Aims to isolate pathogens, limit spread, and begin tissue repair.

✓ Initiation:

- Triggered by physical injury or pathogen entry.
- Damaged cells release cytokines to signal immune activity.
- Mast cells in local tissues degranulate and release histamine.

✓ Vasodilation:

- Histamine causes nearby blood vessels to widen (vasodilation).
- Increased blood flow delivers more immune cells and nutrients to the site of damage.
- Vessel walls become more permeable, allowing plasma and immune cells to exit into tissues.

Migration:

- Increased permeability allows immune cells like neutrophils and macrophages to move from the bloodstream into the affected area.
- These cells begin engulfing pathogens and releasing further signalling molecules.
- Accumulation of dead cells and debris forms pus at the site.

Fever:

- Cytokines released during inflammation may travel to the brain, resetting the hypothalamus to a higher temperature.
- Fever slows down pathogen replication and boosts immune efficiency.
- Excessively high fevers can be harmful and need to be regulated.



V	Symptoms	:
*		٠.

- Redness and heat occur due to increased blood flow.
- Swelling results from fluid leaking into tissues.
- Pain is caused by pressure on nerve endings and inflammatory signals.
- Loss of function can occur due to swelling, pain, or tissue damage.

✓ Overall Role:

- Localises infection, recruits immune cells and initiates the repair process.
- If unregulated, inflammation can damage healthy tissue or lead to chronic inflammatory conditions.

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Section F: Examples

Definition

COVID Infection

What type of pathogen is COVID-19?

How does this infect cells?

Where in the body does COVID-19 target?

What are the first line of defence barriers?

What are some of the second line of defence barriers?



➤ How does the immune system recognise the virus?
What overall response might occur? Relate this to symptoms.
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0	Le	earning Objective: [3.2.1] - Explain how the innate response is triggered in response to infection & its defining characteristics
	Int	Key Takeaways roduction to the Innate Immune System
	0	Innate immunity acts immediately after pathogen entry.
	0	Response and does based on pathogen type.
	0	Innate immunity lacks long-term of pathogens.
	0	Main functions include preventing pathogen entry, eliminating invaders, activating, and recruiting
	0	Non-specificity alone may lead to future infections if pathogens adapt.
	0	Fast response prevents pathogens fromand multiplying.
	Re	cognition of Pathogens
	0	Innate system identifies threats using general molecular patterns.
	0	are found on microbial surfaces.
	0	
		originate from stressed or injured host cells.
	0	Pattern recognition receptors (PRRs) on immune cells detect these patterns.
	0	Recognition relies on conserved structural features rather than



C			rning Objective: [3.2.2] - Identify & describe mponents of the innate immune response - I dentify & describe	macrophages, neutrophils,	
			Key Takeaways		
	Th	e Ce	ells of the Innate Immune Response		
	0	Ph	nagocytes		
			Phagocytes engulf and digest pathogens through phag	gocytosis.	
			Neutrophils are the wh	hite blood cells and act as	
			Neutrophils eliminate pathogens viaextracellular traps (NETs).	, toxic granules, and	
			Macrophages are,, release and perform antigen prese		
			Dendritic cells act as key innate and adaptive immunity by activating T cells.	, bridging	i ,
	0	Na	atural Killer (NK) Cells		
			NK cells identify and destroy infected or cancerous hos	est cells.	
			Recognition depends on detecting	on host cells.	
			NK cells kill by releasing and and	, which induce	
	0	Ma	ast Cells		
			Mast cells reside in tissues and are activated by injury	or infection.	
			Release and other signalling mo	olecules to	
				o the site of infection.	



Cosinoprilis
Eosinophils target large parasites such as helminths and contribute to allergic responses.
Release toxic granules that damage or kill pathogens too large for phagocytosis.
Can perform limited phagocytosis and contribute to inflammation through degranulation.
Learning Objective: [3.2.3] - Identify & describe the role of non-cellular components of the innate immune response - complement proteins & interferons
Key Takeaways
□ The Non-Cellular Components of the Innate Immune System
O Complement Proteins
Complement proteins are inactive in the bloodstream until triggered by pathogens.
Activation occurs via multiple pathways but always results in a targeted innate response.
tags pathogen surfaces to enhance recognition and engulfment by phagocytes.
involves the recruitment of additional immune cells to the site of infection.
 is achieved by forming a (MAC) that creates pores in the
pathogen membrane, leading to cell death.
Most effective against bacterial pathogens.



Interferons
Interferons are released by cells infected with
These signalling molecules act locally to prepare neighbouring cells for potential viral invasion.
Stimulate the production of antiviral proteins in surrounding cells.
Slow down viral replication and signal for immune responses like NK cell activation.
Do not directly destroy viruses but enhance resistance across nearby tissues.
 <u>Learning Objective</u>: [3.2.4] - Describe key innate immune processes - phagocytosis, inflammatory response
Key Takeaways
Key Takeaways The Inflammatory Response
 The Inflammatory Response Type of Response: Inflammation is a [rapid] / [delayed] innate immune reaction to tissue
 The Inflammatory Response Type of Response: Inflammation is a [rapid] / [delayed] innate immune reaction to tissue damage or microbial invasion. Primary Aim: Aims to [isolate pathogens] / [spread infection], limit spread, and begin tissue
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Vasodilation

- Effect of Histamine: Histamine causes nearby blood vessels to [widen] / [constrict].
- O Blood Flow Role: Increased blood flow delivers more [immune cells and nutrients] / [waste products] to the site of damage.
- Vessel Permeability: Vessel walls become more [permeable] / [rigid], allowing plasma and immune cells to exit into tissues.

Migration

- Movement Pathway: Increased permeability allows immune cells like neutrophils and macrophages to move from the [bloodstream] / [lymph] into the affected area.
- Function at Site: These cells begin engulfing pathogens and releasing further [signalling molecules] / [antibodies].
- O Byproduct Formation: Accumulation of dead cells and debris forms [pus] / [lymph] at the site.

Fever

- Fever Mechanism: Cytokines released during inflammation may travel to the brain, resetting the [hypothalamus] / [amygdala] to a higher temperature.
- Effect on Pathogens: Fever slows down [pathogen replication] / [immune cell production] and boosts immune efficiency.
- O Risk of Fever: Excessively high fevers can be [harmful] / [beneficial] and need to be regulated.

Overall Role

- System Goal: Localises infection, recruits immune cells, and initiates the [repair process] / [adaptive memory response].
- Risk of Dysregulation: If unregulated, inflammation can damage [healthy tissue] / [bacterial colonies] or lead to chronic inflammatory conditions.



□ <u>Learning Objective</u>: [3.2.6] - Explain the symptoms associated with the inflammatory response

Key Takeaways

- Symptoms of Inflammation
 - Cause of Redness and Heat: Redness and heat occur due to increased [blood flow] / [white blood cell count].
 - Cause of Swelling: Swelling results from fluid leaking into [tissues] / [vessels].
 - Cause of Pain: Pain is caused by pressure on [nerve endings] / [antibodies] and inflammatory signals.
 - Cause of Loss of Function: Loss of function can occur due to swelling, pain, or [tissue damage]
 / [fever].

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VCE Biology ¾

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Be Sure to Make the Most of These (Free) Services!

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Booking Link for Consults
bit.ly/contour-biology-consult-2025



Number for Text-Based Support +61 440 137 387

