Key Stage 4

Control of Immunity: Cascades of Shape

Student worksheet

Introduction

The immune system includes a powerful and intricate network of cells with the capacity to target and destroy disease causing microorganisms (pathogens).

For the immune system to function effectively it must be carefully coordinated; the system must be able to identify pathogens and neutralise them. In each case, immune cells rely on the interaction of molecules with specific shapes to bring about their effect. In the following activities you will examine the importance of shape in the functioning of the immune system.

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The Importance of Shape

The action of enzymes is often compared to that of a lock and a key. Use your understanding of enzyme action, and the key words below, to explain how enzymes work.

Complimentary **Specific** **Active site**

Enzyme-substrate-complex **Catalyses**

Reused **Activation energy** **Substrate** **Shape**

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Draw a cartoon diagram to support your answer above.

Introduction to the immune system

The immune system is comprised of many different cells that all work together to perform the complex task of recognising pathogens as 'non-self' and coordinating an appropriate response to destroy them.

While there are many different cells involved, at GCSE level you are introduced to the two major categories of immune white blood cell; phagocytes and lymphocytes.

Use the information in the video to answer the following questions about the action of phagocytes and lymphocytes. **BE AWARE:** the video refers to a number of different immune cells which are further subcategories of phagocytes and lymphocytes. For the purposes of this exercise you need only consider the broader categories of phagocytes and lymphocytes.

Outline the key differences between the innate and adaptive immune systems. Be sure to state which category of white blood cell is associated with each and to contrast their specificities (how many different pathogens they can attack) and mechanisms by which they neutralise pathogens.

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Cascades of shapes – a story of the immune system

Instructions

- Read the information about each activity of the immune system. Use this information to draw a cartoon of what is going on.
- Remember that the shape of molecules will be important and at points these will be required to fit together. Consider these carefully.

1) Recognising pathogens

The immune system is reliant on the ability of immune cells to recognise pathogenic invaders as non-self. This is achieved as immune cells have special proteins on their surface that are able to interact with specific characteristic molecules on the surface of pathogens (antigens). These antigens act like a barcode which white blood cells are able to scan to tell if the cell is from your own body, or is non-self. In reality though, it is due to the different shapes of these antigen molecules that white blood cells are able to recognise pathogens as different from your own cells.

Although phagocytes and lymphocytes are both able to recognise pathogens, lymphocytes are more specific. Phagocytes will recognise any pathogen while lymphocytes are usually only able to identify and act against a single pathogen type (e.g. chickenpox virus). This difference in specificity is due to the types of antigen they respond to. Phagocytes respond to generic antigens common to nearly all pathogens while lymphocytes respond to antigens unique to that pathogen. For

this reason, phagocytes are said to act as part of the innate (non-specific) immune system while lymphocytes help make up the adaptive (specific) immune system.

Draw a group of different pathogens (all with shared generic antigens each with their own specific antigens)

2) Phagocyte activation

Phagocytes are the first immune cells to act. They are rapidly activated as they have protein receptors on their surface able to respond to the generic antigens shared by most pathogens. As phagocytes travel in the blood, it does not take them long to come across pathogens in the body and to identify and start acting against them. Any phagocyte will be able to respond to most pathogens and so there is little delay waiting for the 'right' phagocyte to come along.

Draw a phagocyte interacting with the group of pathogens drawn in part 1. Think carefully about the shape to the protein receptors the phagocyte will have on its surface and which antigen it will be interacting with.

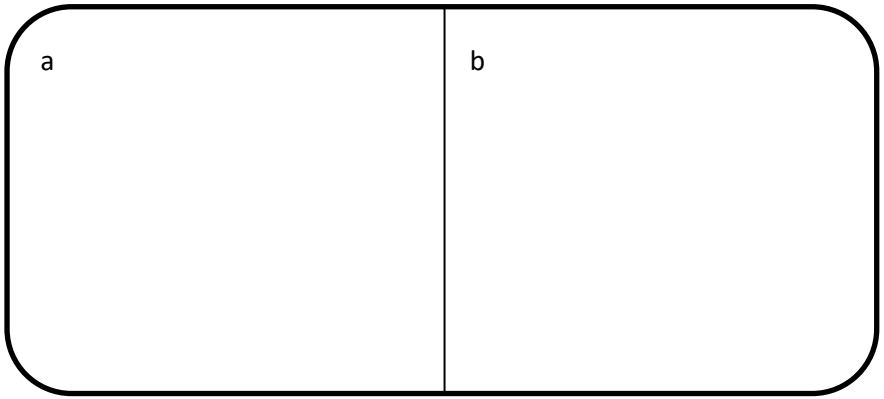
3) Phagocytosis

Once phagocytes have been activated (via the interaction of their surface proteins with generic pathogen antigens), they begin destroying the pathogenic invaders. They do this by moving towards the pathogens and engulfing (eating) them. Once engulfed, the pathogen is kept inside a small membrane bound bubble called a phagosome. Digestive enzymes are released into this phagosome and so the pathogen is destroyed.

Most phagocytes, however, die after consuming only a small number of pathogens. Puss is the accumulation of dead phagocytes. The action of the innate immune system (phagocytes) is therefore rapid but often insufficient to overcome severe infections on their own.

a) Draw a phagocyte engulfing a pathogen. The best illustrations will continue to show the interaction of its surface proteins with the generic antigens of the pathogen.

b) Draw a phagocyte releasing digestive enzymes onto the pathogen trapped within a phagosome.



Using your understanding of the importance of shape in enzyme action, suggest why many different enzymes are required to break down a single ingested pathogen within the phagosome.

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Suggest why pathogen digestion must occur within a phagosome (a special membrane bound organelle).

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4) Activation of lymphocytes

Lymphocytes are significantly more specific than phagocytes and will only recognise and act against specific pathogens. This is because they only interact with and produce molecules to attack antigens unique to the pathogen they target. Unlike phagocytes, they do not have surface proteins complimentary to generic antigens. Rather, they only have surface proteins complimentary in shape to the specific antigens unique to each type of pathogen. This means that lymphocytes take longer to be activated as the body must wait for the 'right' lymphocyte to come along and interact with the pathogen.

In reality this is more complex and activation of the lymphocytes relies on interactions between phagocytes that have already performed phagocytosis, and lymphocytes. You will look into this intricate network of interactions in more detail if you chose to study A-level biology.

Draw a lymphocyte interacting with the group of pathogens drawn in part 1. Think carefully about the shape to the protein receptors the lymphocyte will have on its surface and which antigen it will be interacting with.

Once activated, lymphocytes begin attacking pathogens. Lymphocytes do this by releasing specific molecules called antibodies and antitoxins. Antibodies are protein molecules specific and complimentary to the antigen that activated the lymphocyte. Because they are complimentary in shape to the antigen on the pathogen, they bind to it. Binding of the antibody to the antigen helps to neutralise the pathogen, making it less harmful and making it easier for phagocytes to engulf and phagocytose them. This can often turn the tide of battle against the pathogen in favour of the immune system. Once your lymphocytes are activated and producing antibodies, it is often a sign that you will begin recovering from your illness.

A subset of the antibodies made are called anti-toxins. These molecules are complimentary in shape to the harmful toxins that pathogens can release. When a toxin interacts with an antitoxin, the toxin is neutralised and its harmful effects are reduced. Antitoxins to not help to destroy the pathogen but do help to reduce their harmful effects.

Draw a lymphocyte producing antibodies and antitoxins against the variety of pathogens drawn in part 1. Think carefully about the shape of your antibodies/antitoxins which pathogens/antigens they interact with.

a	b

Extension questions

The type I diabetes problem

Some diseases such as type 1 diabetes are autoimmune diseases in which the body's own immune system misidentifies its own cells (in this case insulin producing cells in the pancreas) as non-self and starts attacking them. Use your understanding of the shape of antigens and immune cell activation to suggest what has happened to cause this.

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Transplants

Suggest why patients who have recently undergone organ transplants need to take immunosuppressants (drugs which dampen the action of the immune system).

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Proteins

We have seen that the shape of molecules is very important in allowing the correct functioning of the immune system. Many of the molecules discussed here are proteins. Using your knowledge of protein structure, suggest why proteins are good molecules for a system that relies on the specific interaction of shapes.

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