Cell recognition and the immune system

Specification reference

- 3.2.4

Learning objectives

After completing this worksheet you should be able to:

- understand the concept of self and non-self
- relate the structure of an antibody to its function
- understand the roles of the cells of the immune system
- understand how an immune response occurs
- recall how antibodies, including monoclonal antibodies, can be used in clinical tests.

Introduction

A good knowledge and understanding of the immune system is essential in Biology: how the body recognises foreign antigens and how it deals with them. You should already be familiar with antibodies, which are protein molecules. This support sheet introduces the cells of the immune system, which you will know as white blood cells, and how immunology can be used in diagnostic tests.

Background

The immune system is our body’s way of detecting and dealing with foreign antigens. In order to do this, it must have some way of recognising what is foreign. We call this self / non-self recognition. When a non-self antigen is detected, it will trigger an immune response, which may involve the production of antibodies or the use of specialised cells to render it harmless. The immune system can also recognise when our own cells become a threat: either when infected with a virus, or when they turn into tumour cells.

What is an antigen?

Antigens are usually made of protein or glycoprotein and are the molecules that the immune system recognises and responds to. They are found on the surface of:

- pathogens (disease-causing microorganisms)
- abnormal cells (virus-infected cells or tumour cells)
- cells from other organisms of the same species (important in transplants)
- toxins (like those produced by some bacteria)

Some pathogens, such as the malaria parasite, have adapted to evade our immune system by constantly changing their antigens!
The cells of the immune system

You will already have heard of white blood cells. Together, these are the cells of the immune system. They can be divided into lymphocytes and phagocytes.

Lymphocytes

These can again be divided into two types: B and T lymphocytes.

The B lymphocytes are:
- plasma cells – responsible for making and releasing antibodies
- memory B cells – responsible for long-term memory of antigens.

The T lymphocytes are:
- T helper (TH) cells – these stimulate other cells of the immune system
- cytotoxic (TC) cells – these can kill abnormal cells in the body.

Phagocytes

These carry out phagocytosis – engulfing pathogens that have antibodies attached to them.

The immune response

There are two types of immune responses:
- primary responses occur when an antigen is encountered for the first time – when you get infected or vaccinated
- secondary responses occur when we have memory B cells for the antigen already in circulation – this is a faster response, producing a higher concentration of antibody and it is how vaccinations work, as they cause us to produce the memory B cells.

The primary immune response is summarised in Figure 1.

Figure 1 The stages of the primary immune response.
Antibodies

Antibodies are protein molecules with quaternary structure. They have two heavy polypeptide chains and two light chains joined with disulfide bonds, as shown in Figure 2.

![Antibody structure](image)

**Figure 2 The structure of an antibody**

Antibodies work in two different ways:

- **agglutination** – they can bind antigens and clump them together (the antibody has two antigen binding sites) which makes them easier to engulf or disables viruses from infecting cells
- **helping with phagocytosis** – binding to pathogens then the constant part is recognised by phagocytes which then engulf the “marked” pathogen.

When an antibody is bound to an antigen, this is called an antigen-antibody complex.

Types of immunity

We can become immune to an antigen in two ways:

- **Active immunity** – this is where we encounter the antigen and make antibodies and memory B cells for it. This happens when we get infected or vaccinated.
- **Passive immunity** – this is where we do not encounter the antigen, but get ready made antibodies for it. These can either be injected or we can get them from our mothers before birth across the placenta.

Vaccination

Vaccines work by exposing us to the antigen for a particular pathogen in a harmless way. We undergo a primary immune response and memory B cells remain in the blood in case we ever encounter the “real” pathogen, then we can undergo a faster secondary immune response. Not everyone in a population needs to be vaccinated to prevent an epidemic: if enough people are immune, then the pathogen cannot spread. We call this concept herd immunity. For measles, herd immunity requires about 95% of the population to be immune.
HIV / AIDS

The human immunodeficiency virus (HIV) infects TH cells, so has the ability to greatly weaken the immune system. Infection by the virus may not cause symptoms for up to 10 years, so many people do not know they are infected, and spread the virus.

People who show HIV / AIDS symptoms become susceptible to many other infections that their immune system cannot respond to. The structure of the virus is shown in Figure 3.

![Human Immunodeficiency Virus structure](image)

**Figure 3** The human immunodeficiency virus

**Antibiotics**

Antibiotics are drug compounds which inhibit enzymes in bacteria. Usually, these are enzymes for bacterial cell wall or protein synthesis. They do not affect people or animals because we do not have the same enzymes as bacteria. Viruses also do not have these enzymes, so antibiotics are not effective against virus infections.

**Monoclonal antibodies**

Monoclonal antibodies (MAbs) are antibodies produced especially for certain medical uses. MAbs are different to natural antibodies in that they bind to only one specific part of an antigen. Therefore they can target parts of cells or parts of antigens, whereas natural antibodies would bind to many places on the one cell or antigen.

MAbs can be used to deliver drugs to specific cells, or used in laboratory tests to diagnose diseases.

**Ethical issues**

Some people object to the use of some vaccines and MAbs. This is mainly because some vaccines are developed and tested in animals. All MAbs are produced in laboratory animals. Some people, usually in remote parts of the world, are suspicious of being vaccinated and do not volunteer because they do not understand, or misunderstand, the purpose.

Not all vaccines are completely effective. Some require boosters to increase the number of memory B cells, while others, at best, give only limited protection against the disease.
ELISA test
The ELISA test is carried out in hospitals and diagnostic laboratories to determine whether someone has antibodies against a certain antigen. This can show:

- whether they have ever encountered the antigen
- if they are infected with a pathogen that is difficult to detect
- the concentration of antibodies for a certain antigen in their blood.

The ELISA test is commonly used to determine whether someone has been infected with HIV. They will only have antibodies against the virus if they have been infected by it. They are classed as HIV positive if antibodies against HIV are detected.

Questions

1. a The diagram shows an antibody molecule.
   i. Name the type of biological molecule represented by A. (1 mark)
   ii. Name the type of covalent bond labelled B. (1 mark)
   iii. State the function of the region labelled C. (1 mark)
   iv. Describe the part played by the region labelled D in the destruction of bacteria. (2 marks)

b Rabies is a virus disease transmitted by bites from infected animals. An effective vaccine against rabies is available. A person, who has not been vaccinated against rabies is bitten by an infected animal. Explain why injecting the person with ready made antibodies against rabies is a more effective treatment than vaccination after receiving the bite. (3 marks)

c If a human cell turns into a tumour cell, it displays different antigens on its surface membrane.
   i. Name the type of molecules on the surface membrane that act as antigens. (1 mark)
   ii. Name the type of cell from the immune system which can kill a tumour cell. (1 mark)

2. HIV / AIDS is a human disease which is transmitted sexually and by blood-to-blood contact.
   a. Name the cells which HIV infects. (1 mark)
   b. Name the laboratory test which is carried out to determine if someone is HIV positive. (1 mark)
   c. Explain why antibiotics are not effective against HIV. (2 marks)

3. a Measles is a human disease caused by a virus. An effective vaccine for measles is available.
   i. Outline the immune response that occurs when someone who has been vaccinated then gets infected with the measles virus. (4 marks)
   ii. Suggest two reasons why measles vaccination programmes can fail to prevent measles epidemics. (2 marks)
b HIV / AIDS is another human disease caused by a virus.
   i State one difference between the genetic material in HIV and the genetic material in a human cell. (1 mark)
   ii When a person becomes infected with HIV, the virus circulates in their blood. Explain why their immune system cannot effectively respond to the virus. (2 marks)

c Monoclonal antibodies can be used in medicine.
   Explain why some people object to the use of monoclonal antibodies. (1 mark)