11. Immunity

11.2 Antibodies and Vaccination

Paper 2

Question Paper

1 Antibodies are produced by plasma cells.

Fig. 6.1 shows antigens bound to antigen-binding sites of an antibody molecule.

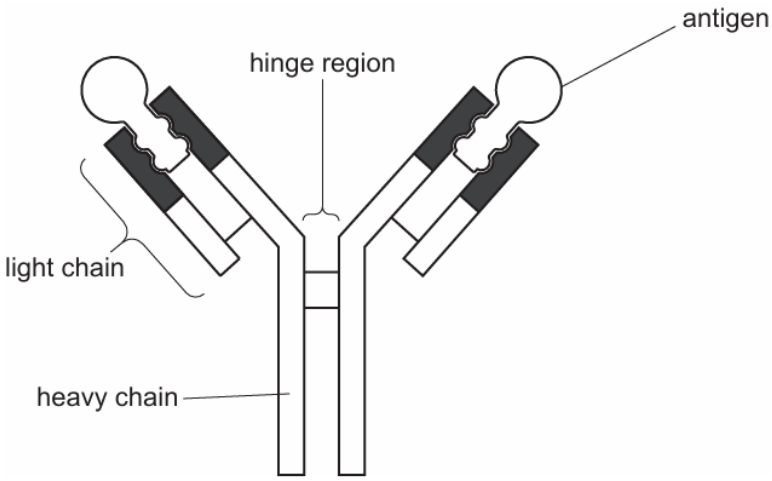


Fig. 6.1

(a) (i) Explain how the structure of an antigen-binding site makes it specific to a particular antigen, as shown in Fig. 6.1.

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(ii) State the function of the hinge region of the antibody shown in Fig. 6.1.

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(iii) Antibodies can bind to membrane receptors on cells of the immune system, such as macrophages.

Suggest an advantage of antibodies binding to receptors on macrophages.

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2 Alveolar macrophages are cells of the immune system that remain in the alveolar region of the gas exchange system. The macrophages protect against infection caused by pathogens that have been inhaled.

(c) Research has shown that vaccination programmes are cost effective and are very helpful in the prevention and control of TB. The programmes may be aimed at particular groups of people that are at a high risk of getting the disease, or they may be aimed at an entire population because the country has a high number of cases of TB.

The Bacillus Calmette-Guérin (BCG) vaccine is freeze-dried and contains live, weakened (attenuated) *Mycobacterium bovis*.

Apart from being cost effective, suggest **and** explain the advantages of using the BCG vaccine for the prevention and control of TB.

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3 **(b)** Tuberculosis (TB) is an infectious disease that affects the human gas exchange system.

The pathogen that causes TB secretes a protein that can be detected in saliva.

Early diagnosis of TB is important in reducing the transmission of the pathogen.

Scientists have developed a test strip for TB that uses monoclonal antibodies. Monoclonal antibodies are specific in their action.

This test strip contains:

- mobile monoclonal antibodies that bind to one part of the protein secreted by the pathogen
- immobilised monoclonal antibodies.

Fig. 3.2 shows a simplified diagram of the test strip.

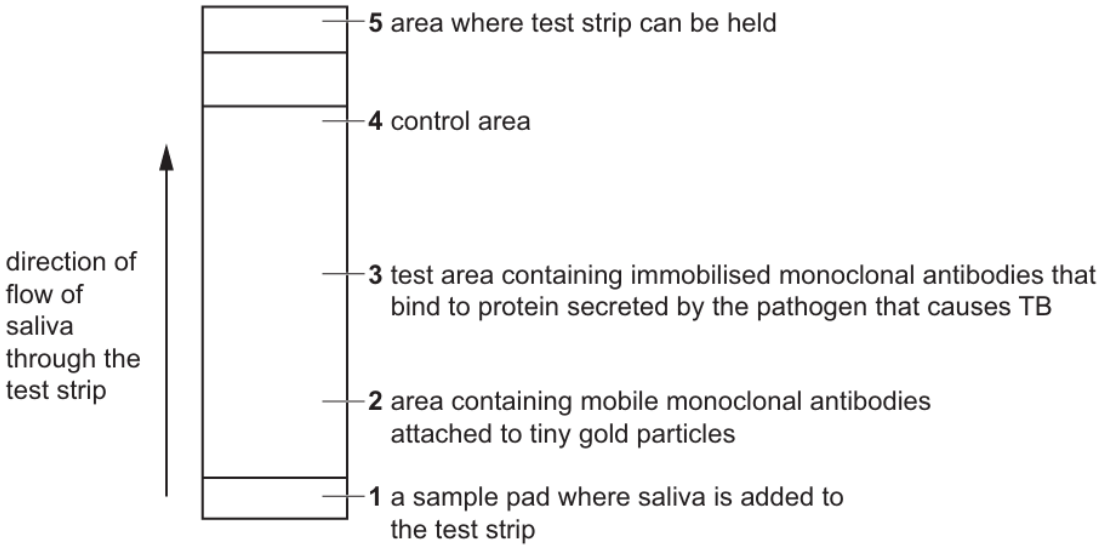


Fig. 3.2

A sample of saliva is collected and put onto the sample pad in the test strip.

The saliva moves up the test strip through area **2**.

The mobile monoclonal antibodies are attached to tiny gold particles. If these antibodies collect in test area **3**, a gold line becomes visible on the test strip.

A gold line that becomes visible in area **4** confirms that the test strip is working and that the results are valid.

(ii) Name the part of the monoclonal antibody that binds to the protein from the pathogen.

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(iii) Saliva is added to a test strip to test for the presence of the protein secreted by the TB pathogen.

Fig. 3.3 is a diagram showing some of the molecules in area **3** of the test strip when a positive result for TB is obtained.

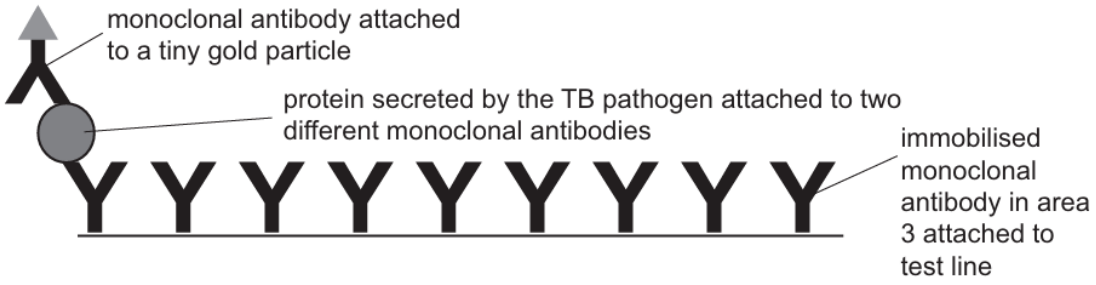


Fig. 3.3

Use the information in Fig. 3.3 to suggest **and** explain why this test is specific for TB.

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(iv) Area **4** contains different immobilised antibodies to those in area **3**.

The mobile monoclonal antibodies bound to tiny gold particles will bind to these immobilised monoclonal antibodies in area **4**.

If the test has functioned correctly, a gold line will be visible in area **4**.

Suggest how the structure of immobilised monoclonal antibodies in area **3** differs from the structure of the immobilised monoclonal antibodies in area **4**.

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4 Cholera is a life-threatening and infectious disease caused by the bacterium *Vibrio cholerae*. One of the symptoms of the disease is severe diarrhoea.

V. cholerae O1 and *V. cholerae* O139 are the two forms of the pathogen that are associated with cholera epidemics (large outbreaks). These two forms have different antigens that can be detected.

(b) Rapid diagnostic testing (RDT) can be used to diagnose cholera by detecting the presence of *V. cholerae*. One type of RDT involves using a dipstick that contains mobile and immobilised monoclonal antibodies.

Monoclonal antibodies (mAbs) are specific in their action.

Fig. 2.1 shows a simplified diagram of an RDT dipstick that can be used to distinguish between *V. cholerae* O1 and *V. cholerae* O139. A faecal sample from a person with suspected cholera is collected and added to a reagent solution to form the test mixture.

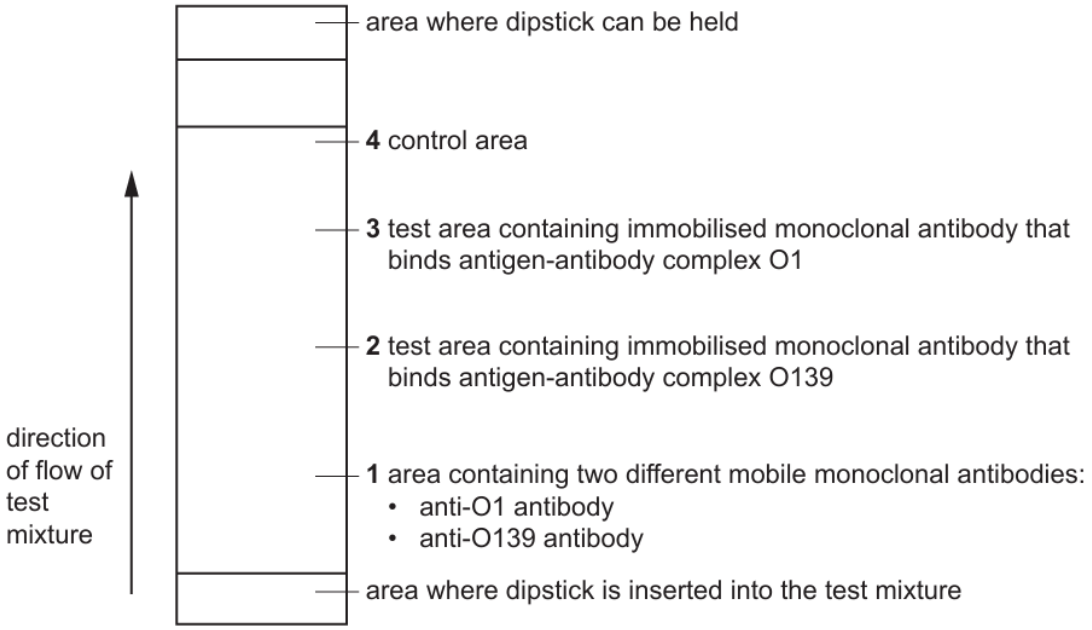


Fig. 2.1

The test mixture moves up the dipstick through area **1**. The mobile monoclonal antibodies are attached to tiny gold particles. If these antibodies collect in test area **2** or **3**, a coloured band becomes visible.

A coloured band that becomes visible in area **4** confirms that the test strip is working and that the results are valid.

(i) Explain how the structure of the monoclonal antibodies in the dipstick allows them to be specific in their action.

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(ii) Fig. 2.2 shows the results for samples taken from two different people, **A** and **B**, who are suspected of having cholera.

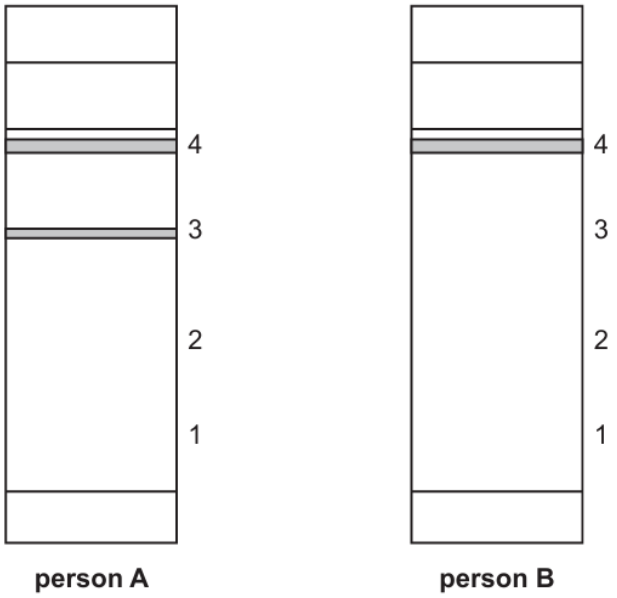


Fig. 2.2

With reference to Fig. 2.2, state **and** explain the conclusions that can be drawn from the results of the RDT dipsticks for each person.

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(c) Table 2.1 shows the results of an investigation to evaluate the effectiveness of an RDT dipstick in diagnosing cholera.

Samples taken from 156 people were tested using a dipstick and compared to the results obtained by culturing the pathogen in a laboratory for accurate identification.

Table 2.1

	number of test results		
	using culture techniques (to obtain accurate identification)	**using dipstick**	
		correct diagnosis	**incorrect diagnosis**
positive results for cholera	102	97	5
negative results for cholera	54	32	22

(i) With reference to Table 2.1, calculate the percentage chance of an RDT dipstick correctly confirming that a person with cholera has the disease.

[1]

(ii) Using an RDT dipstick to diagnose cholera is much cheaper than culturing the pathogen and requires less technical skill.

Suggest **one** additional advantage of using an RDT dipstick, rather than culture techniques, to diagnose cholera.

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5 B-lymphocytes are activated to form plasma cells during immune responses.

Fig. 2.1 is a drawing of a plasma cell made from a transmission electron micrograph.

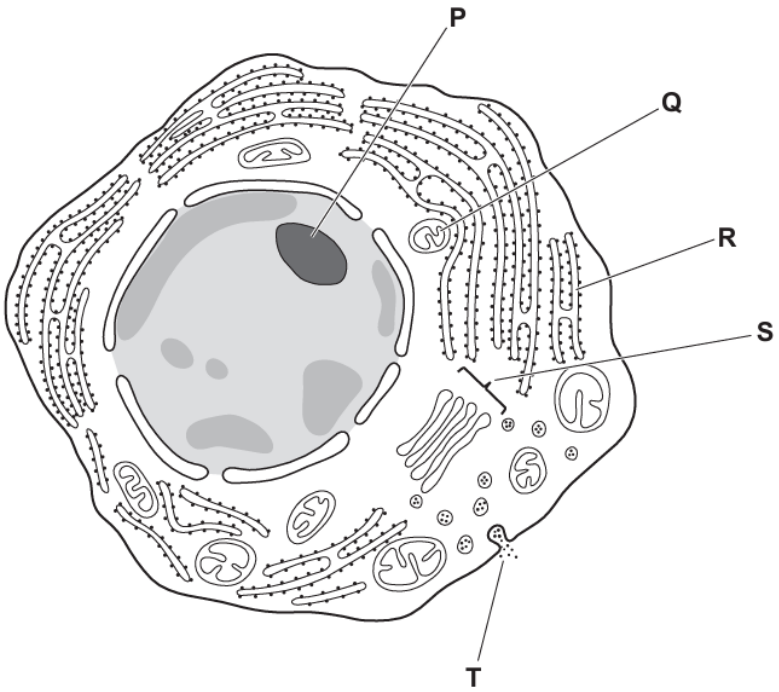


Fig. 2.1

(b) Plasma cells can be used in the commercial production of some monoclonal antibodies.

The method of production is known as the hybridoma method.

Outline the steps in the production of monoclonal antibodies by the hybridoma method.

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(c) Antibodies can be collected from human blood donors and used to treat people that may have been infected with a pathogen. This prevents them becoming ill with the disease.

Explain why this treatment does not prevent people becoming ill if they are infected again with the same pathogen.

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6 Fig. 2.1 is a simplified diagram of the human circulatory system.

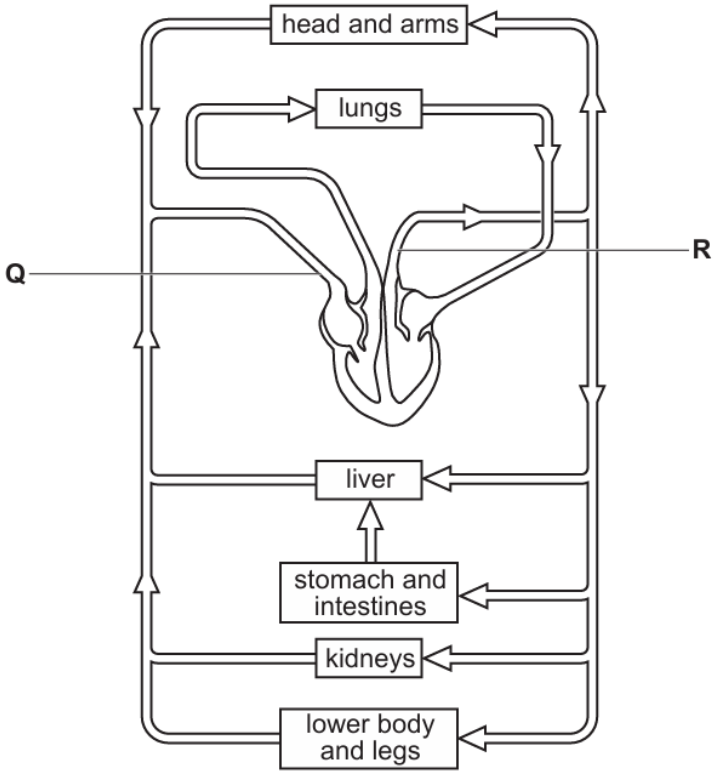


Fig. 2.1

(b) Blood plasma plays an important role in the transport of molecules such as antibodies.

Scientists discovered that some of the antibodies in the blood plasma of sharks have a different structure to the antibodies found in human blood plasma.

Fig. 2.2 shows the structure of an antibody molecule found in the blood plasma of a shark.

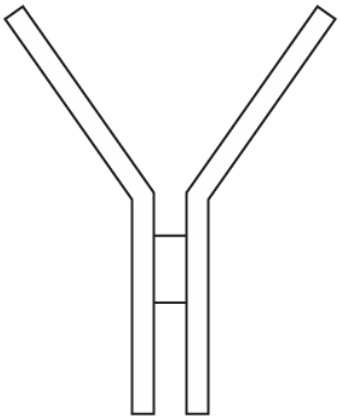


Fig. 2.2

(ii) Human antibodies are used in the treatment of some forms of cancer. However, the antibodies injected into the bloodstream can only reach a small percentage of the cancer cells that form the cancerous tumour.

Shark antibodies are smaller than human antibodies. Scientists are researching the possibility of injecting shark antibodies into the bloodstream to treat cancerous tumours in humans.

Suggest how using the smaller shark antibodies may be more effective in reaching a greater percentage of cancer cells than human antibodies and lead to greater success at treating cancer.

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(iii) Antibodies can also be used in the prevention of infectious diseases.

Explain how injection of antibodies into the bloodstream can protect a person from disease after infection by a pathogen.

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7 **(b)** The glycoproteins haemagglutinin and neuraminidase are found in the influenza virus and in the virosomes used in a vaccine against the influenza virus.

Haemagglutinin binds to a receptor in the cell surface membrane of phagocytes.

Suggest why haemagglutinin is present in virosomes used in the vaccine for influenza.

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8 The diseases myasthenia gravis (MG) and HIV/AIDS both involve disorders of the immune system.

(b) Studies have indicated that T-lymphocytes are involved in stimulating the B-lymphocyte response that causes MG.

Research has been carried out on a vaccine that will provide a person with **active immunity** against these T-lymphocytes and B-lymphocytes.

Suggest **and** explain how this vaccine will provide a person with active immunity against the T-lymphocytes and B-lymphocytes responsible for causing MG.

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9 Much success was made in reducing the number of cases of malaria between 2000 and 2015.

(b) Diagnostic test strips for malaria contain monoclonal antibodies. The test strips detect antigens produced by the pathogens that cause malaria.

Fig. 5.1 shows stages in the production of monoclonal antibodies. The information in three of these stages is incomplete.

Complete Fig. 5.1.

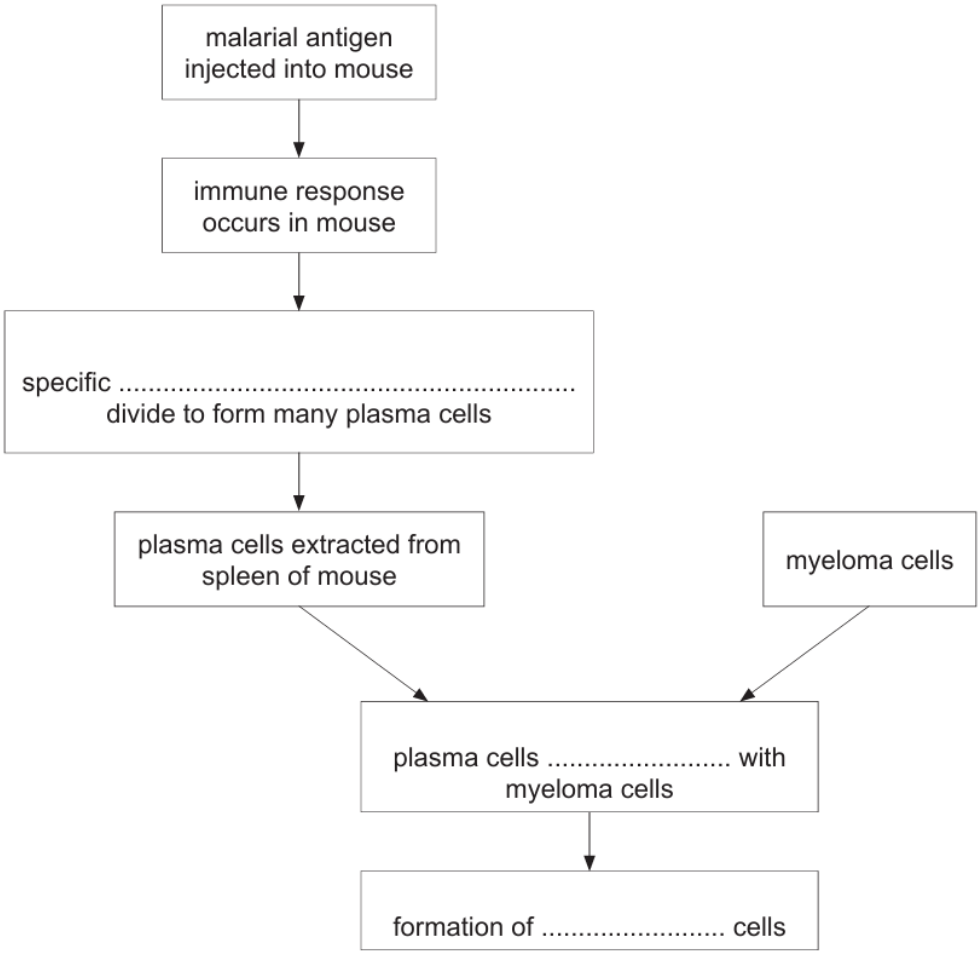


Fig. 5.1

[3]

(c) Fig. 5.2 shows two diagnostic test strips for malaria.

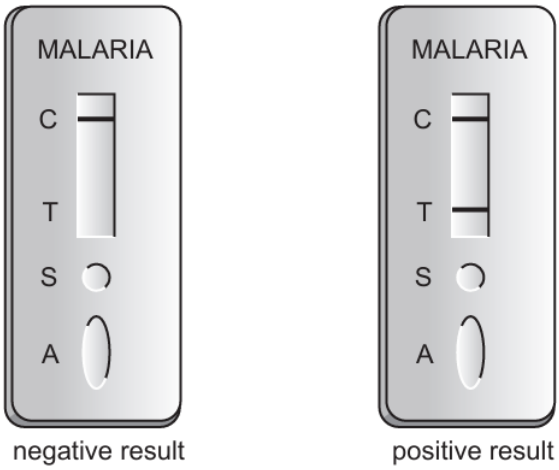


Fig. 5.2

- A sample of blood from a person suspected of having malaria is put into the well labelled **S**.
- A buffer solution is put into the well labelled **A**.
- The buffer solution moves the blood towards the results window.
- A line at position **C** indicates that the test is working correctly.
- A line at position **T** indicates a positive result for malaria.

State **three** advantages of using test strips for malaria, such as those shown in Fig. 5.2.

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10 Cholera is an infectious disease caused by the bacterial pathogen *Vibrio cholerae*.

(c) Vaccination can be used to prevent the spread of cholera. The vaccine used contains part of the choleragen molecule and also contains dead cells of *V. cholerae*.

(ii) Suggest the advantage of having a vaccine that includes dead cells of *V. cholerae* and part of the choleragen molecule.

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11 The Bacillus Calmette-Guérin (BCG) vaccine is the only vaccine used to provide protection against the infectious bacterial disease tuberculosis (TB). Most countries of the world have a BCG vaccination programme.

(d) There is evidence that the BCG vaccine has also provided protection against the disease leprosy.

Leprosy is caused by a bacterium that is closely related to the bacteria that cause TB.

Suggest why the BCG vaccine can also provide protection against leprosy.

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(e) A baby can gain artificial active immunity to TB after having the BCG vaccine. A baby can also gain natural passive immunity to TB.

State the differences between **artificial active** immunity and **natural passive** immunity.

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12 **(b)** Immunotherapy is a form of treatment for cancer which aims to stimulate the immune system to destroy tumour cells.

One form of immunotherapy for cancer uses a vaccine which contains one specific type of TSA.

(ii) Vaccines that contain tumour cells instead of a TSA are being developed for use during immunotherapy. Tumour cells are removed from a patient's body and used in a vaccine for the patient.

Suggest **one** advantage and **one** disadvantage of using a patient's tumour cells in a vaccine rather than a TSA.

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disadvantage .....

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[2]

13 Fig. 2.1 is a transmission electron micrograph showing the bacterial pathogen that causes tuberculosis (TB).

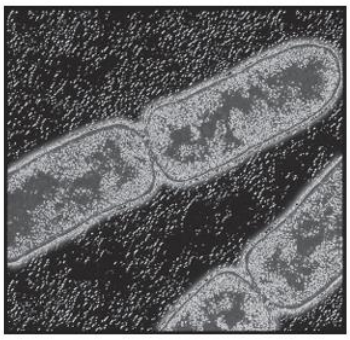


Fig. 2.1

(a) (i) Name the pathogen shown in Fig. 2.1 that causes TB.

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The World Health Organization (WHO) introduced a strategy in 2015 to end the global TB epidemic.

An important part of the strategy is to:
- identify people at risk of becoming infected with TB
- use methods to prevent transmission of TB.

The BCG vaccination is one method of prevention recommended for use in countries where TB is common. The BCG vaccine contains a non-pathogenic, living form of the microorganism that causes TB.

(ii) Complete Table 2.1 by using a tick (✓) to identify the type of immunity that develops in a person who has been given the BCG vaccination.

Table 2.1

artificial active immunity	
artificial passive immunity	
natural active immunity	
natural passive immunity	

[1]

14 Myasthenia gravis is a condition that results in muscle weakness by affecting the immune response.

(c) Rituximab is a monoclonal antibody used in the treatment of myasthenia gravis.

Rituximab acts against the cell surface membrane protein CD20. This protein is found on the surface of the B-lymphocytes that cause myasthenia gravis.

Explain the advantages of using monoclonal antibodies in the treatment of diseases such as myasthenia gravis.

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15 Countries that have a high number of cases of malaria also have problems with diseases caused by bacteria. This means that many people in these countries are prescribed antibiotics, such as penicillin, for the treatment of bacterial infections.

(e) After many years of intense research and development, WHO reported in 2016 that a pilot vaccination programme would be trialled between 2017 and 2020.

The programme uses a vaccine acting against the most widespread species of *Plasmodium*.

Explain the difficulties faced by researchers in developing a malaria vaccine.

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16 **(b)** Fig. 1.2 is a transmission electron micrograph of a hybridoma cell.

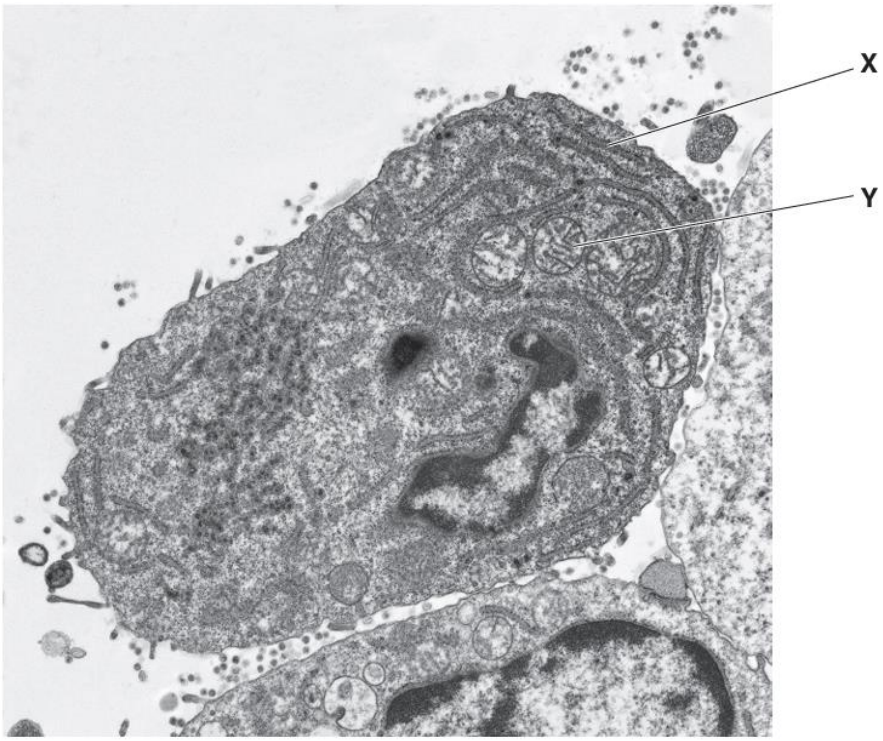


Fig. 1.2

(ii) The hybridoma method for the production of monoclonal antibodies involves a number of stages. One of these stages is the formation of hybridoma cells.

Outline the stage in which hybridoma cells are formed.

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(iii) Outline the use of monoclonal antibodies in the treatment of disease.

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17 Enzyme inhibitors and monoclonal antibodies can be used in the treatment of disease.

(b) Outline the use of monoclonal antibodies in the treatment of disease.

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18 **(a)** The toxins released by some pathogenic bacteria can be altered chemically so that they are harmless. These harmless toxins are called toxoids.

Toxoids are used in vaccines to provide protection against some infectious diseases.

Describe the response of the immune system to the injection of a toxoid.

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(b) Myasthenia gravis (MG) is described as an autoimmune disease. It is a long-term condition that results from a failure of the immune system.

(i) Explain why MG is known as an autoimmune disease.

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(ii) Suggest why MG is a long-term condition.

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19 Viruses share common structural features. Some viruses, such as human immunodeficiency virus (HIV), also have an outer envelope as part of their structure.

(c) In a person who has been infected with HIV-1, the most common strain of HIV, a sample of blood can be tested for the presence of the virus.
One test that can only be used in the early stages of infection involves a monoclonal antibody specific for p24, a structural protein present in the virus.

Fig. 4.2 is a flow chart outlining the steps in the production of anti-HIV p24 monoclonal antibody.

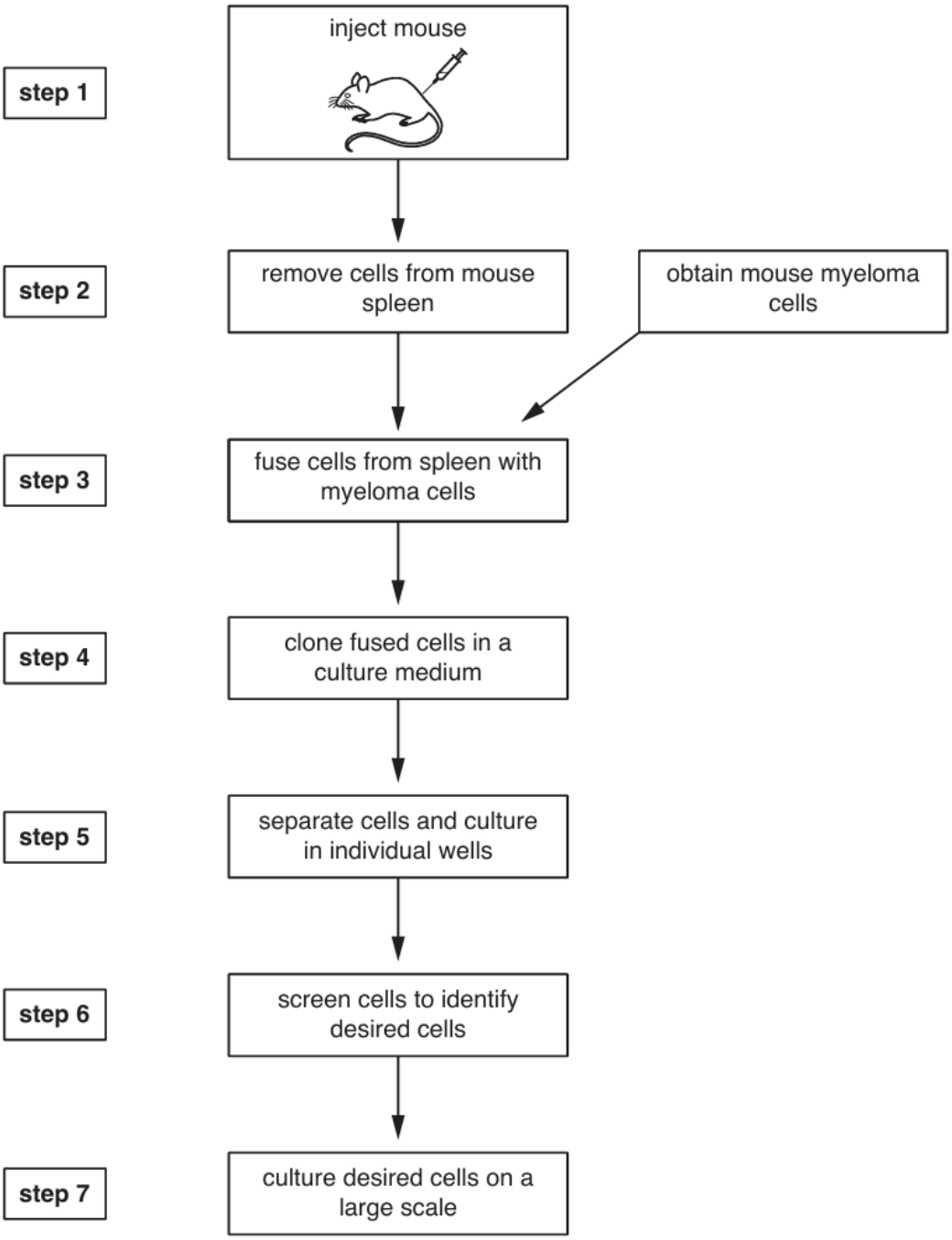


Fig. 4.2

(i) State what is being injected into the mouse in **step 1**.

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(ii) Explain why several weeks, rather than several days, separates **step 1** and **step 2**.

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(iii) State **one** feature of the myeloma mouse cells, used in **step 3**, that is essential for this production process.

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(iv) Name the fused cells formed in **step 4**.

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(v) Suggest why **step 6** is necessary.

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20 Fig. 4.1 is a photomicrograph of a cross-section of a tubular structure in the kidney made from epithelial cells.

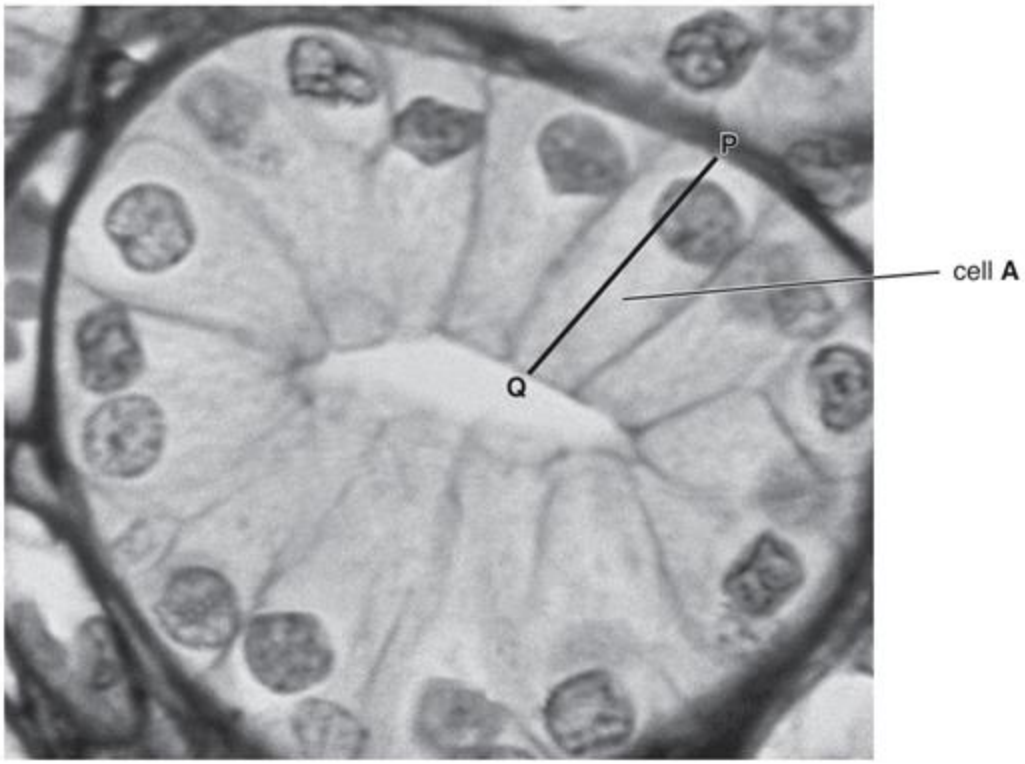


Fig. 4.1

(c) Uncontrolled cell division may result in a tumour. Tumour cells in the kidney respond to VEGF.

Kidney cancer can be treated with monoclonal antibodies. These monoclonal antibodies bind to VEGF.

Outline the hybridoma method for the production of monoclonal antibodies that will target the VEGF protein.

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(d) Monoclonal antibodies used as a treatment need to be given more than once. Repeated treatment can cause side effects to the person or can become less effective.

Suggest why repeated treatment with monoclonal antibodies may have these effects.

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