SUGGESTED TEXTBOOK ANSWERS

Chapter 11 Specific resistance to infection

The following are suggested answers only. Other answers to the same questions may also be correct.

Science inquiry

Activity 11.1 A briefing paper

Your task is to compile a briefing paper for the minister, including all the information that you think will be necessary to engage in a meaningful debate in the parliament.

Answer: Student responses will vary; however, teachers should ensure that students include at least the first four points listed in the introduction to this activity in their answers. Students should make mention of herd immunity and the need for a high proportion of individuals being immunised.

Activity 11.2 Should animal testing be used in the manufacture of vaccines?

After listening to the opinions expressed during the discussions, prepare a list of arguments for and against the use of animals for the manufacture and testing of vaccines.

Answer:

Some points that students may make include the following:

For

- Testing of some sort is necessary before a trial in humans, and animals are the only alternative.
- It is not necessary to get informed consent from animals.
- It is safer to test on animals first before trialling on humans.
- It is easier to test large numbers of animals than humans.
- It is easier to provide controlled conditions for a trial with animals than with humans.
- Genome of animals may be manipulated so that genetic effects on results are reduced or eliminated.

Against

- Researchers are unable to predict the effect a trial may have on the animal.
- Animals may suffer as a result of the trial.
- Animal physiology is different from humans, so trial results may not be transferrable to humans.
- Researchers are likely to take less care with animals than with human subjects.
- Animals are unable to communicate their opinions about the testing.

Review questions

1 a Why is the immune response said to be a specific response?

Answer: The immune response is said to be a specific response since it is directed towards a particular pathogen. As such it is one of the body's specific defences. For example, if you get infected (or vaccinated) with chickenpox virus the body will make antibodies to combat that virus. Those antibodies are only effective against chickenpox virus and will not work against any other virus or bacterium. Thus the antibodies are specific for that pathogen.

b What are the two parts to the immune response and what is the main difference between them?

Answer: There are two parts to the immune response. One part, called the humoral response or antibody-mediated immunity, involves the production of special proteins called antibodies, which circulate around the body and attack invading agents. The second part, called the cell-mediated response, involves formation of special lymphocytes that destroy invading agents. Both these aspects of the immune response involve lymphoid tissue.

2 Why are B-cells and T-cells so named?

Answer: Both B-cells and T-cells are produced in the bone marrow, and both end up in the lymphoid tissue, but they mature by following two different routes between bone marrow and lymphoid tissue. T-cells are so named because they mature in the thymus, and B-cells because they mature in the bone marrow.

3 a What is an antigen?

Answer: An antigen is any substance that is capable of causing a specific immune response.

b Explain the difference between self-antigens and non-self-antigens.

Answer: Large molecules produced in a person's own body are called self-antigens because they do not cause an immune response. Compounds that do trigger an immune response are non-self-antigens. The immune system becomes programmed to distinguish between self-antigens and non-self-antigens before birth. From then on, it normally only attacks non-self-antigens.

4 a What is an antibody?

Answer: An antibody is a specialised protein that is produced in response to a particular non-self-antigen.

b Explain how an antibody can be specific to a particular antigen.

Answer: The antibody produced in response to an antigen can combine with that antigen to form an antigen–antibody complex. Antigen molecules have specific active sites and at these sites the antibody can combine with the antigen. The active site on the antigen and the active part of the antibody fit together like a key in a lock. Each antibody can combine with only one particular antigen, in the same way that a key will only open one particular lock.

5 Describe the events that occur in a humoral immune response.

Answer: The humoral response involves the production and release of antibodies into the blood and lymph. This is antibody-mediated immunity. It provides resistance to viruses, bacteria and bacterial toxins before these micro-organisms or substances enter the body's cells.

Lymphoid tissue contains thousands of different types of B-cells. Each type is capable of responding to a specific antigen. When that antigen activates the appropriate B-cells, they enlarge and divide into a group of cells called a clone. Most of the clone become plasma cells, which secrete the specific antibody capable of attaching to the active site of the antigen. These antibodies circulate in the blood, lymph and extracellular fluid to reach the site of the invasion of micro-organisms or foreign material. The B-cells of the clone that did not differentiate into plasma cells remain as memory cells. These memory cells spread to all body tissues to allow the response to occur more rapidly should the antigen enter the body again in the future.

See also Figure 11.5 on page 147.

6 List the ways in which the antigen–antibody complex helps to overcome the effects of invading micro-organisms.

Answer: All antibodies combine with the antigen for which they are specific to form an antigen–antibody complex. The response that then occurs varies according to the particular antigen and antibody.

Antibodies may:

- combine with foreign enzymes or bacterial toxins, or inactivate them by inhibiting reaction with other cells or compounds
- bind to the surface of viruses and prevent the viruses from entering cells
- coat bacteria so that the bacteria are more easily consumed by phagocytes
- cause particles such as bacteria, viruses or foreign blood cells to clump together – a process known as agglutination
- dissolve organisms
- react with soluble substances to make them insoluble and thus more easily consumed by phagocytes.

7 Describe the events that occur in a cell-mediated immune response.

Answer: Cell-mediated immunity (or cellular immunity) provides resistance to bacterial and viral infections once the pathogens have entered the cells. The T lymphocytes are responsible for cellular immunity. They occur in the same lymphoid tissue as the B-cells but occupy different areas of the tissue. Like the B-cells, there are thousands of different types of T-cells and each type responds only to one particular antigen. When a foreign antigen, such as a virus or bacterium, enters the body, the particular type of T-cells that are specifically programmed for that antigen become activated or sensitised. This only occurs after a B-cell or macrophage encounters the foreign antigen, travels to the nearest lymph node and presents it to the T-cells. The sensitised T-cells enlarge and divide, each giving rise to a clone, a group of identical T-cells. Some cells of the clone remain in the lymphoid tissue as memory cells, which are able to recognise the original invading antigen. If infection with the same antigen should occur again these memory cells can initiate a much faster response to the second and subsequent infections. The other T-cells in the clone can form killer T-cells, helper T-cells or suppressor T-cells. Also see Figure 11.11 on page 150.

8 List the ways in which killer T-cells and helper T-cells can deal with an invading antigen.

Answer: Killer T-cells migrate to the site of infection and deal with the invading antigen. They attach themselves to the invading cells and secrete a substance that will destroy the antigen, and then go off in search of more antigens.

Helper T-cells play an important role in both humoral and cellular immunity. They secrete a number of substances that:

- cause lymphocytes at the infection site to become sensitised, thus intensifying the response
- attract macrophages to the place of infection so that the macrophages can destroy the antigens by phagocytosis
- intensify the phagocytic activity of macrophages.

9 Why is the secondary immune response so much faster than the primary response?

Answer: Some B and T-cells of the original clones that are produced in the primary immune response remain in the lymphoid tissue as memory cells, which are able to recognise the original invading antigen. If infection with the same antigen should occur again these memory cells can initiate a much faster and more intense secondary immune response to the second and subsequent infections, as they recognise the antigen more quickly and thus produce more antibodies at a much faster rate.

10 Why is it rare to get a disease such as measles or chickenpox more than once?

Answer: It is rare to get diseases such as measles or chickenpox more than once as a result of active immunity. Active immunity results when the body is exposed to a foreign antigen, such as the micro-organisms that cause measles and chickenpox, and manufactures antibodies in response to that antigen. This type of immunity is prolonged because, although the amount of the antibody produced gradually decreases, the 'memory' of that antigen persists through the memory cells once the antigen has been dealt with. Should a subsequent infection involving the same antigen occur, the appropriate antibodies can be produced very quickly before the infection can produce any disease symptoms. Such immunity lasts for many years, often for life.

11 What is the difference between:

a natural and artificial immunity?

Answer: Immunity is resistance to infection by invading micro-organisms. Natural immunity occurs without any human intervention; artificial immunity results from giving people an antibody or an antigen.

b active and passive immunity?

Answer: Active immunity occurs when a person makes their own antibodies after being infected with a pathogen or after receiving a vaccine, whereas passive immunity occurs when a person receives ready-made antibodies.

12 a How can passive immunity be gained artificially?

Answer: Passive immunity is when a person is given antibodies produced by someone else. The individual's body plays no part in the production of antibodies. It can be gained *artificially* when a person is injected with antibodies to combat a particular infection. This is often done when a person is exposed to pathogens that cause serious diseases, such as tetanus, diphtheria and rabies. Antibodies are given so that immunity is established immediately.

b How can active immunity be acquired naturally?

Answer: Active immunity results when the body is exposed to a foreign antigen and manufactures antibodies in response to that antigen. Such immunity lasts for many years, often for life, and can be gained naturally from an infection of the disease-causing organism.

13 a What is a vaccine?

Answer: A vaccine is the antigen preparation used in artificial immunisation. The antigen is strong enough to provoke an immune response but does not produce symptoms of the disease.

b Describe three ways in which older types of vaccines are produced.

Answer: One type contains living attenuated micro-organisms – micro-organisms of reduced virulence – that is, micro-organisms with a reduced ability to produce disease symptoms, so that the immunised person does not contract the disease but does manufacture antibodies against the antigen.

A second type of vaccine contains dead micro-organisms.

The third type of vaccine is made from toxins. In cases where bacteria produce their effects in humans by liberating toxins, it is not necessary to use living or dead bacteria for immunisation; inactivated toxins (toxoids) can be used instead.

c How are modern vaccines developed?

Answer: Developers of modern vaccines try to produce vaccines that are effective for prolonged periods and produce no side effects. One approach that has been used is to modify the characteristics of the pathogen by slightly changing the DNA in the micro-organism's cell so that the pathogen is less virulent. Another method is to insert certain DNA sequences from the pathogen into harmless bacterial cells. The DNA sequence chosen causes the production of antigens that are characteristic of the pathogen. Vaccination with the harmless bacterium results in immunity against the pathogen. It is likely that a great many future vaccines will be made using this recombinant DNA method.

d List the risks associated with the manufacture of vaccines.

Answer: The main risk associated with the manufacture of vaccines is that new vaccines have to be trialled. The vaccine may not work and the trial subjects may suffer from the disease. There may be unacceptable side effects caused by the new vaccine.

One of the main risks of vaccination is an allergic reaction. This may occur not so much from the vaccine itself, but from a reaction to the medium in which the vaccine was cultured.

In the manufacture of vaccines, certain chemicals are used as preservatives. Preservatives used include formaldehyde, phenol (carbolic acid), aluminium phosphate, alum and acetone. Individuals concerned about vaccination claim that these preservatives are able to affect the nervous system and can lead to other health issues.

14 What is herd immunity? Why is it of interest to the health professions?

Answer: Herd immunity is a term used to refer to the proportion of a population that is immune to a particular disease. Some vaccination programs not only reduce the chance of disease in the most susceptible individuals but also increase the immunity of the population. Such immunity is referred to as herd immunity and depends on a high proportion of individuals being immunised. When there is a large number of immune individuals in a population, there is less chance of the disease being transmitted between them. This is of major interest to the health professions as it will help to reduce the number of patients and hospital admissions, thus taking the strain off the health system.

15 List some of the social, economic and cultural factors that may lead to some people deciding not to participate in vaccination programs.

Answer: Social factors that may influence an individual deciding not to participate in an immunisation program are a lack of education and therefore an understanding of the benefits of being immunised. More recently, the rise of social media has resulted in a lot of misinformation being spread about the risks of immunisation.

The major economic factor in many developing countries is the cost of being immunised, even if the immunisation is provided at no cost by the government, the cost of travel to a medical centre may be prohibitive.

One of the main cultural factors that prevents participation is religion. In Australia none of the major religions are opposed to immunisation. However, this is not the case in other countries, and in some, traditional medicine is considered superior to modern techniques such as immunisation. In Australia, the popularity of complementary and alternative medicine is gradually increasing, and this has led to some proponents refusing to be immunised.

16 What is the difference between:

a an antibiotic and an antiviral?

Answer: The term antibiotic is used to refer to drugs that fight infections caused by bacteria. Antivirals are drugs that specifically treat viral infections.

b a bactericidal and a bacteriostatic antibiotic?

Answer: Bactericidal antibiotics kill bacteria (by changing the structure of the cell wall or cell membrane, or by disrupting the action of essential enzymes). Bacteriostatic antibiotics do not kill the bacteria but stop them from reproducing (usually by disrupting protein synthesis).

c a broad-spectrum and a narrow-spectrum antibiotic?

Answer: Broad-spectrum antibiotics are effective against a wide range of different bacteria (for example, those that cause a chest infection). Narrow-spectrum antibiotics only affect specific types of bacteria.

17 a Explain how strains of bacteria can become resistant to an antibiotic.

Answer: The widespread use of antibiotics has led to some strains of bacteria becoming resistant to some of the more commonly used antibiotics. Resistance has gradually evolved in many strains of bacteria, frequently through the overuse of antibiotics in medicine and in agriculture, and through recipients of the antibiotic not following instructions on their use. Some bacteria survive the antibiotic treatment. These bacteria have natural resistance to the antibiotic and when they reproduce they pass the resistance on so that a strain of resistant bacteria develops.

b What are some of the problems that arise from bacterial resistance?

Answer: Bacterial resistance has led to some strains of bacteria becoming resistant to all the available types of antibiotics. This is a serious problem, as the rise of such 'super bugs' means that there is no way of treating them with current drug therapies.

18 Why has it been difficult to develop drugs that are effective against viral infections?

Answer: The way in which viruses replicate has made it difficult to develop drugs that are effective against them. Viruses use a host cell for their replication, so that any drug that interferes with virus replication is likely to affect the host cell as well. To avoid these problems, current research is aimed at identifying viral proteins that can be disabled by specially designed proteins.

Apply your knowledge

1 Why do people tend to get fewer colds as they get older?

Answer: People tend to get fewer colds as they get older as each time they are exposed to a disease, their immune system will activate a certain number of B-cells. These cells will multiply and some will produce antibodies. Others will become memory cells. Memory cells can last for decades in a person's body and are able to produce the necessary antibody when exposure to the micro-organism occurs again. Each time a person gets a cold they will become immune to the particular strain of the virus that causes the cold. With age, a person will have a greater variety of memory cells and be in a better position to ward off infection.

2 Why is it that diseases such as diphtheria and chickenpox have not been completely eliminated from Australia?

Answer: To completely eliminate diseases such as diphtheria and chickenpox from Australia, all members of the population would need to be either resistant to such infection, or be in a position never to be exposed to it. Therefore, vaccination is most important. However, one of the important choices that parents must make is whether to have their children vaccinated in infancy. Childhood vaccination is not compulsory in Australia but 90% of infants have been vaccinated by the age of 12 months. In Australia most people are vaccinated against the diseases for which vaccines are available. These diseases are not completely eliminated from Australia because approximately 10% of the population is not immunised so suffer the disease and can easily spread it to others. Also, through immigration and tourism, people who have not been immunised are constantly entering the population and may bring infecting pathogens with them.

3 Typhoid is caused by a bacillus. To make a positive diagnosis of typhoid, a sample of the patient's blood is taken and mixed with typhoid bacilli. If the bacilli agglutinate (clump together), the patient has typhoid.

a Why is this a positive diagnosis for the disease?

Answer: It is a positive diagnosis since it means that the patient has been exposed to the disease and has produced antibodies to the antigen. When the blood that contains the antibodies is mixed with the typhoid bacilli, the antibodies react with it, resulting in agglutination.

b Could the person be suffering from some other disease?

Answer: No, it is very unlikely because antibodies are highly specific for the antigen, in this case, typhoid bacilli, that they were produced to combat.

4 Investigate and report on the issues surrounding the use of vaccines to protect against human papilloma virus (HPV). In your report ensure that you provide a balanced discussion of both sides of the subject.

Answer: Students should present a report outlining the advantages of vaccination against the human papilloma virus as well as presenting the ethical concerns many parents have about having their child immunised. As HPV is a sexually transmitted virus that causes genital warts and cervical cancer, the most effective way for the vaccine to be used is with girls who have yet to become sexually active. Many parents and health professionals believe that girls of this age, around eleven or twelve, are too young to be discussing such matters, while others are concerned that immunising young women with the vaccine may encourage promiscuous behaviour.

5 In October 2014 a new vaccine for meningococcal B was approved for use in the United States.

a Use references to find out if the vaccine is to be used in Australia.

Answer: The U.S. Food and Drug Administration approved Bexsero, a vaccine to prevent invasive meningococcal B disease in individuals aged 10 to 25 years of age on 23 January 2015. Bexsero was the second vaccine approved by the FDA to prevent this disease. The agency approved the first meningococcal serogroup B vaccine in October 2014.

Bexsero is available in Australia on the private market and was approved for use by the Therapeutic Goods Administration in November 2013. The Australian Technical Advisory Group on Immunisation provided advice regarding use of the vaccine in March 2014.

The United Kingdom approved the vaccine for use in late March 2015.

b What are the symptoms of the disease?

Answer: A person showing the early signs of meningococcal disease might not have all of the following symptoms and they might not all show at once.

- Sudden onset of fever
- Severe headache
- Drowsiness, confusion or coma
- Neck stiffness, joint pains
- Rash of red-purple spots or bruises
- Sensitivity to bright lights
- Vomiting

Additional signs to look for in babies include the following.

- Fretfulness
- High-pitched moaning cry
- Difficulty in waking baby
- Refusal to eat
- Pale or blotchy skin.

c If you were vaccinated against meningococcal B, could you still get meningitis?

Answer: Yes, because there are 13 different strains of the disease. In Australia, group B is the most common cause of the disease.

6 Find out why it is difficult to prepare vaccines for viral infections such as the common cold or HIV.

Answer: These viruses have protein coats that constantly change their properties and appearance, thus a vaccine would lose its effectiveness each time the person is either exposed to a different strain of the virus or the virus mutates in the patient.

7 In this chapter, ethical concerns about the manufacture of the vaccine to protect against rubella were discussed. The manufacture of other vaccines, such as that for chickenpox, has also caused anxiety among some members of society. Find out the basis for these concerns.

Answer: The rubella vaccine is manufactured using cells from tissues of aborted human foetuses. This raises moral questions for people who are opposed to abortion. Parents opposed to abortion have to make the difficult decision whether to have their child immunised with a vaccine made from an aborted foetus. Others would argue that, unpleasant as the facts are, the moral principle that ought to govern all decision making is what is best for the health of the child.

It has been suggested that the chickenpox vaccine can be manufactured in a similar way to the rubella vaccine. One concern in many countries is whether using the vaccine would increase the rate of shingles in adults. Shingles, which is evidenced by a rash, blisters and pain, can lead to nerve damage called postherpetic neuralgia, which can last for weeks or months and cause excruciating pain, even from the touch of a shirt against the skin.

8 Antibiotics were first developed in the 1940s, whereas antiviral drugs have only become available in relatively recent times. Suggest possible reasons for this situation.

Answer: Bacteria are living single-celled organisms. They can be seen with a light microscope and can be cultured. Potential antibiotic substances can be relatively easily tested on the cultures.

Viruses do not themselves reproduce, but they enter living cells and cause them to produce new virus particles. This makes it difficult to culture viruses and difficult to test any potential antiviral substances. Any substance that stops the replication of virus particles is likely to adversely affect the host cells. Viruses have the ability to mutate and quickly form different strains that may not respond to any antiviral substance used against them.

9 A person was prescribed an antibiotic for a bacterial infection of the throat. While taking the antibiotic tablets the patient developed a bacterial infection in their big toe. Explain why the antibiotics that the patient was taking for the sore throat did not prevent the growth of bacteria in the toe.

Answer: The bacterium causing the toe infection would have been a different type from the one that was causing the throat infection. Many antibiotics are specific; that is, they will only kill certain types of bacteria (narrow-spectrum antibiotics). The bacteria in the toe were not affected by the antibiotic used to treat the sore throat.

10 Multiple drug resistance is an increasingly serious problem. List some strategies that could be used to help overcome it.

Answer: Strategies that could be used to overcome multiple drug resistance of bacteria are the:

- development of new compounds that are effective against the resistant strains of bacteria
- isolation of patients infected with resistant bacteria so that the resistant strains do not spread
- better education of doctors and the public on the correct use of antibiotics to ensure that the development of resistance is minimised
- controlling or eliminating the use of antibiotics in agriculture
- prohibiting the sale of antibiotics 'over the counter' as occurs in some countries.