Q1.

(a) A drug is delivered to diseased body cells by a monoclonal antibody. The monoclonal antibody is attached to a drug to form an antibody–drug complex (ADC).

Figure 1

Complete **Figure 1** to show a monoclonal antibody attached to the drug.

Label **one** structural feature of the monoclonal antibody in your drawing of the ADC.

(2)

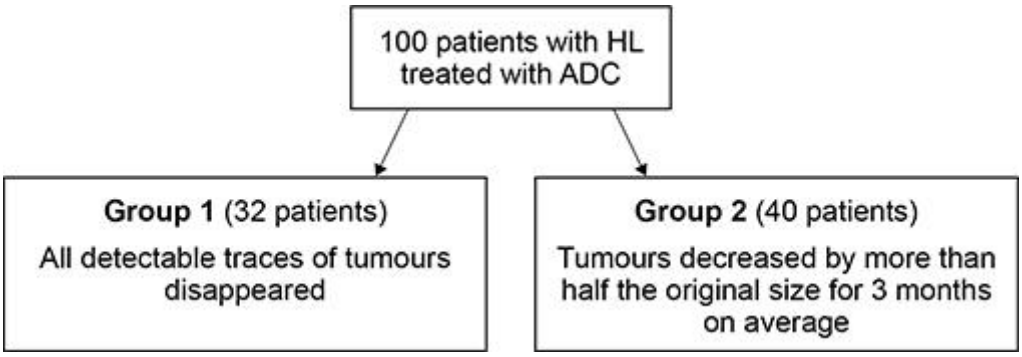
(b) Scientists used a clinical trial to test an ADC designed to treat people diagnosed with the cancer, Hodgkin lymphoma (HL).

In the clinical trial, the patients with HL:

- were selected at random
- had tumours of a similar size at the start of the trial
- received identical doses of the ADC.

Figure 2 shows some of the results from the clinical trial.

Figure 2



Use all the information to evaluate the effectiveness of the ADC in treating people with HL.

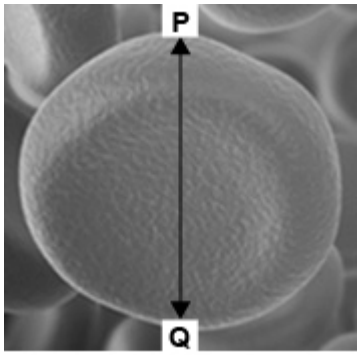
Do **not** refer to statistical tests in your answer.

(4)

(Total 6 marks)

Q2.

(a) The photograph below shows an image of a red blood cell at a magnification of × 5500



Calculate the actual diameter in μm of the red blood cell between points **P** and **Q**.

Show your working.

Answer _____ μm

(2)

(b) A haemocytometer is a special microscope slide that can be used to determine the mean number of red blood cells in 0.004 mm^3 of blood.

- A researcher prepared a 10^{-3} dilution of a sample of blood from an adult.
- Using a haemocytometer, the researcher determined that the mean number of red blood cells in 0.004 mm^3 of the diluted blood sample was 21

The volume of blood in the body of the adult was 4.8 dm^3

Calculate the total number of red blood cells in the body of this adult.

Show your working.

Answer _____

(2)

(c) The solution used to dilute the blood had to have the same water potential as the blood.

Explain why.

_____

_____

_____

_____

_____

_____

(2)

(d) There are four main blood groups in the human ABO blood group system.

The table below shows the basis on which each of these blood groups is classified.

ABO blood group	Antigens present on red blood cells	Antibodies present in blood plasma
A	A	Anti-B
B	B	Anti-A
AB	A and B	No anti-A and no anti-B
O	No A and no B	Anti-A and anti-B

A transfusion of blood from a blood group **A** donor to a blood group **B** recipient would cause agglutination of the donated red blood cells.

Use information in the table above to explain why.

_____

_____

_____

_____

_____

_____

(2)

(e) Using the table above, give the blood groups of people who could accept a donation of blood group **O** without causing agglutination of the **donated** red blood cells.

Blood groups _____

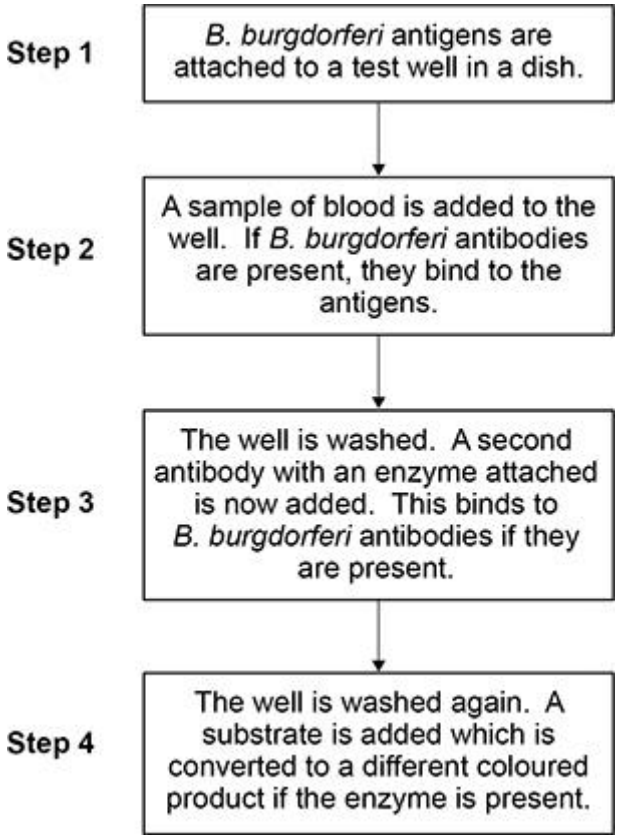
(1)

(Total 9 marks)

Q3.

Lyme disease is most frequently caused by the bacterium *Borrelia burgdorferi*. Lyme disease can be difficult to diagnose.

The figure below shows an ELISA test that is used to find out if a person has antibodies to *B. burgdorferi*.



A false positive in this test is a result which incorrectly indicates that antibodies to *B. burgdorferi* are present.

(a) Failure to thoroughly wash the well in **Step 4** can result in a false positive.

Explain why.

_____

_____

_____

_____

_____

_____

(2)

(b) A false positive can be produced if a person has been infected by another bacterium that causes a disease called syphilis.

Suggest why.

_____

_____

_____

(1)

(c) A false **negative** in this test is often produced if a person is tested within 2 weeks of being infected with *B. burgdorferi*.

Explain why.

_____

_____

_____

_____

_____

_____

(2)

(d) Sometimes, symptoms of Lyme disease can persist for 6 months following antibiotic treatment. This condition is known as Post-Treatment Lyme Disease Syndrome (PTLDS).

Scientists investigated the symptoms experienced by a large number of PTLDS patients and a control group. During a 2-week period, they asked all the participants:

- if they had experienced symptoms of PTLDS
- to record the intensity of these symptoms.

The scientists used a statistical test to determine if there was a difference in the intensity of symptoms of PTLDS between these two groups.

The table below shows some of the scientists' results, including the probability (P) values obtained using the statistical test.

Symptom	Percentage of PTLDS group experiencing symptom	Percentage of control group experiencing symptom	P value for difference in the intensity of symptoms
Fatigue	100	57	<0.001
Joint pain	96	32	<0.001
Depression	40	4	<0.005
Fever	35	3	<0.005
Muscle pain	86	62	<0.001

The scientists concluded that more PTLDS patients than the control group experienced:

- symptoms
- greater intensity of symptoms.

Evaluate the scientists' conclusions.

(4)

(Total 9 marks)

Q4.

(a) In the following passage, each numbered space can be filled with a biological term.

Each type of cell has specific molecules on its ____(1)____ that identify it. An

antibody is a ____(2)____ with two ____(3)____ binding sites. Antibodies

are made and released by ____(4)____ cells.

Vaccines can provide protection for individuals and populations against disease.

The response to a vaccine is an example of ____(5)____ immunity.

____(6)____ immunity occurs when a large proportion of a population becomes

immune to a disease.

Write the correct biological term beside each number below that matches the space in the passage.

1 _____

2 _____

3 _____

4 _____

5 _____

6 _____

(3)

(b) There is currently no effective vaccine available for HIV.

Suggest **one** reason why.

_____

_____

_____

(1)

(c) The table below shows the action of two antibiotics.

Antibiotic	Action of antibiotic
Ciprofloxacin	Causes double-stranded DNA to break apart
Penicillin	Prevents formation of crosslinks between murein chains

Using the information in the table above, explain why each antibiotic is **not** effective against HIV.

Ciprofloxacin _____

_____

_____

Penicillin _____

_____

_____

(2)

(Total 6 marks)

Q5.

The human papilloma virus contains a double-stranded DNA genome.

(a) Which components are found in a human papilloma virus?

Tick ✓ **one** box.

Capsid and attachment protein	☐
Capsid, attachment protein and reverse transcriptase	☐
Capsule and attachment protein	☐
Cell-surface membrane and attachment protein	☐

(1)

(b) The DNA-replication enzymes of a human cell make copies of the human papilloma virus genome.

Name **two** enzymes that are involved in replicating the DNA of the human papilloma virus and describe their roles in the replication process.

Name of enzyme 1 _____

Role of enzyme 1 _____

_____

_____

Name of enzyme 2 _____

Role of enzyme 2 _____

_____

_____

(3)

(c) Human papilloma virus infects cells that are no longer dividing. The human papilloma virus genome contains genes that code for proteins that cause human cells to restart their cell cycles.

Human papilloma virus infection can cause cancer.

Explain why.

(1)

(d) Human papilloma virus (HPV) is transmitted through sexual contact.

More than 95% of cervical cancers (which only affect females) are due to HPV infection. HPV infection of other tissues increases the risk of cancer but this is rare compared with cervical infection.

A vaccine is available that is over 80% effective at preventing HPV infection, if given before the person has been exposed to HPV. There is evidence of herd immunity when more than 50% of the population have been vaccinated.

Evaluate whether 10- to 12-year-old boys should be given the HPV vaccine.

(4)

(Total 9 marks)

Q6.

(a) Some hospital patients suffer from diarrhoea caused by infection with the bacterium *Clostridium difficile*. The *C. difficile* bacteria release toxins. These toxins cause the diarrhoea.

The toxins damage the cells lining the ileum, causing them to lose their microvilli. The damage to the cells reduces the absorption of the products of digestion and reduces the absorption of water, resulting in diarrhoea.

Explain why the damage to the cells lining the ileum reduces absorption of the products of digestion **and** why this reduces absorption of water.

_____

_____

_____

_____

_____

_____

_____

_____

_____

(3)

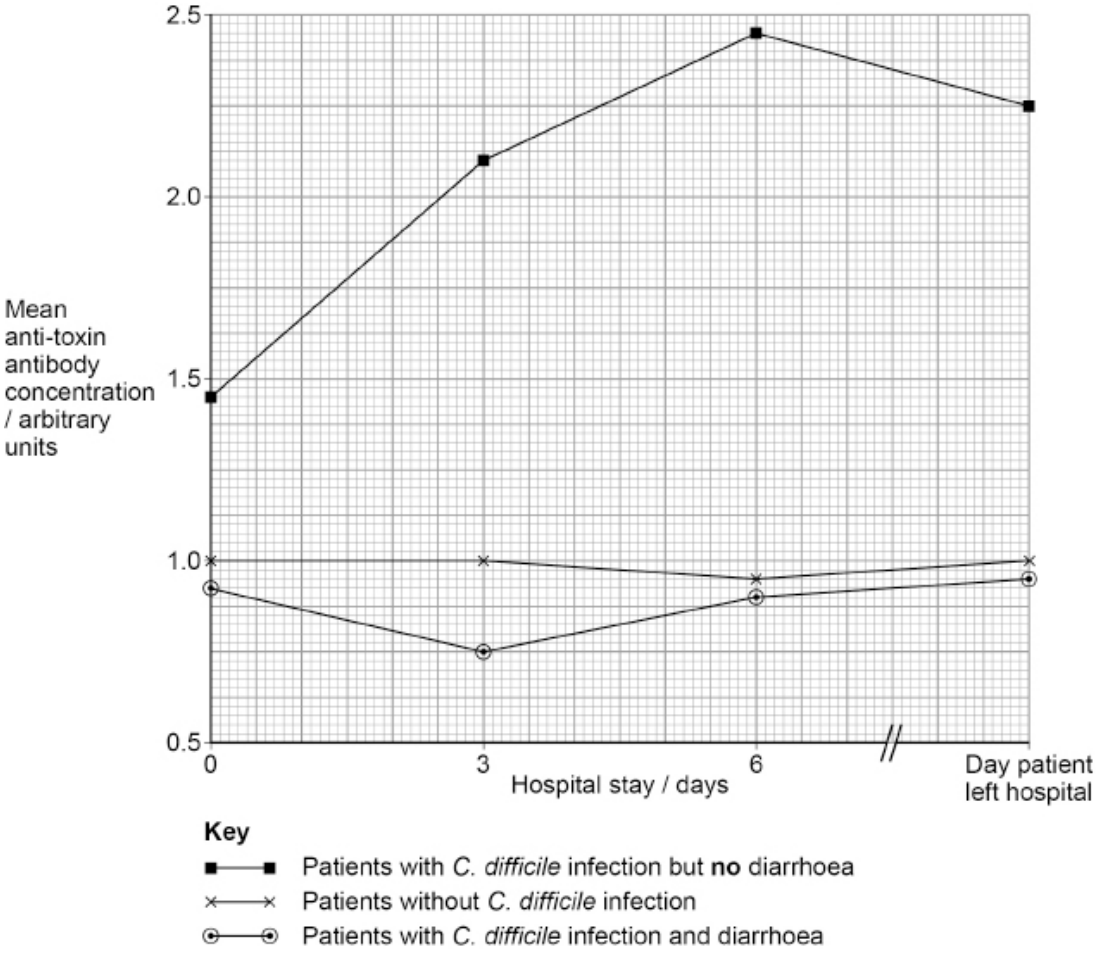
Not all patients in hospital with *C. difficile* develop diarrhoea.

Scientists measured the anti-toxin antibody concentration in hospital patients with and without *C. difficile* infection.

They measured the anti-toxin antibody concentration **four** times:

- on admission to hospital (day 0)
- on day 3
- on day 6
- on the day the patient left the hospital.

The figure below shows the scientists' results.



(b) The scientists suggest that the anti-toxin antibody could be given to some patients as a form of passive immunity.

Use the figure above to suggest how this passive immunity would work **and** which patients should be offered this anti-toxin antibody.

_____

_____

_____

_____

_____

_____

_____

_____

(3)

(c) To be used as passive immunity treatment, the anti-toxin antibody would be injected. If it was given by mouth, it would be digested.

Describe how the anti-toxin antibody would be digested.

_____

_____

_____

_____

_____

_____

_____

_____

_____

(3)

(Total 9 marks)

Q7.

Dengue fever is a human disease caused by the dengue virus.

Scientists designed an ELISA test to detect antibodies to the dengue virus in a patient's blood sample.

Figure 1 shows a diagram of this test and some information about how it works.

Figure 1

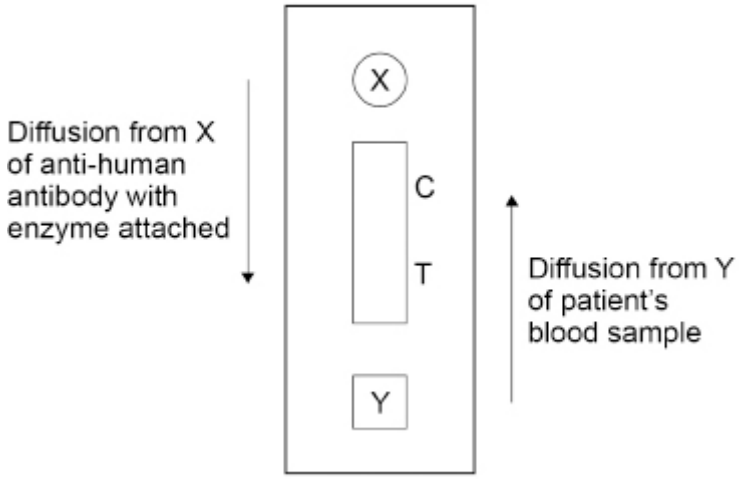
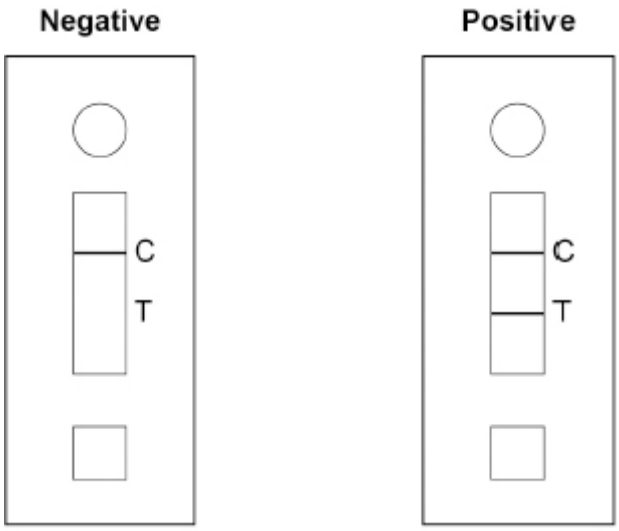


Figure 2 shows the negative and positive results that were produced 20 minutes after the use of the test shown in **Figure 1**.

Figure 2



(a) Suggest what is on the test at line **T** and explain what causes the line to appear in a positive test.

_____

_____

_____

_____

_____

_____

(2)

(b) A line at **C** shows that the test has worked.

Suggest **one** reason why a line at **C** shows the test has worked.

_____

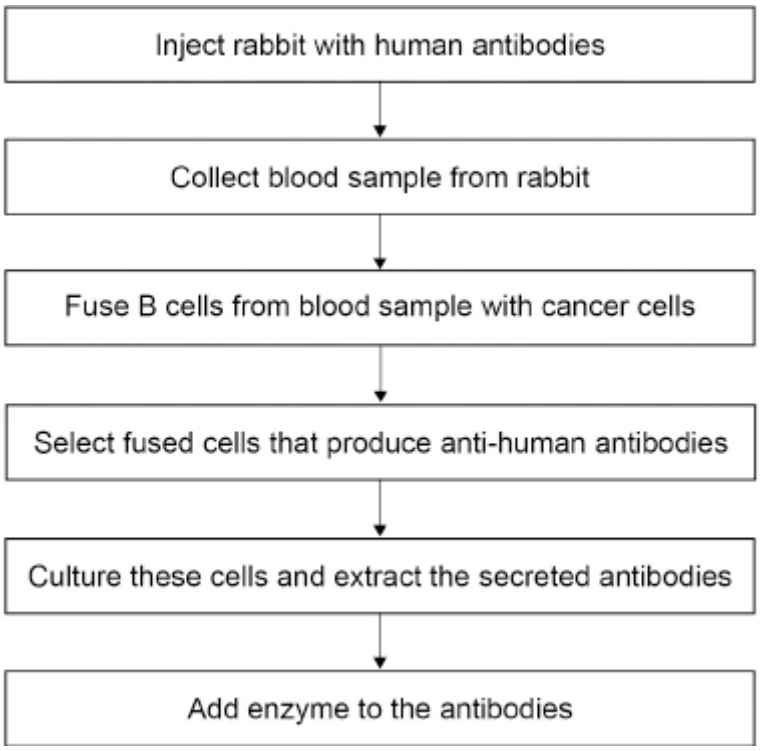
_____

_____

(1)

Figure 3 shows a flowchart of how the anti-human antibodies with enzyme attached are produced.

Figure 3



(c) Suggest why the fused cells allow continuous production of monoclonal antibodies.

_____

_____

_____

_____

_____

_____

(2)

(d) Evaluate the ethics of the production process shown in **Figure 3**.

_____

_____

_____

(1)

Early identification of dengue fever can be difficult as many other diseases produce the same symptoms. Early identification is important because people suffering with dengue fever can become ill very quickly and may need hospital treatment.

Scientists compared the effectiveness of three diagnostic tests for dengue fever.

- Laboratory-based test – a patient's blood sample is sent from the doctor's clinic to a laboratory for testing.
- Current test used in the doctor's clinic.
- New test to be used in the doctor's clinic – the ELISA test shown in **Figures 1** and **2**.

The scientists' results are shown in the table below.

A blood sample from each patient with confirmed dengue fever at each time after onset of symptoms was tested with all three diagnostic tests.

Time after onset of symptoms / days	**Number of confirmed dengue fever patients tested**	**Number of positive results**		
		Laboratorybased test	Current test	New test
1–2	14	10	0	6
3–4	38	28	6	24
5–7	18	8	14	14

(e) The scientists recommend that the new test is used for the identification of dengue fever in all countries around the world.

Discuss this recommendation. Use all the information given.

(3)

(f) The dengue virus causes damage to capillaries so that blood proteins move out of the capillaries into the tissue fluid.

Explain how this would affect the return of tissue fluid into the capillaries.

(2)

(Total 11 marks)

Q8.

(a) Give **two** types of cell that can stimulate an immune response.

1 _____

2 _____

(2)

An autoimmune disease causes the immune system to attack healthy body tissues. Scientists investigated the immune responses of healthy mice and mice with autoimmune disease.

The chemical OXA causes an immune response in mice and can make their skin swell. Mice had olive oil applied to their left ear and OXA in olive oil applied to their right ear.

The immune response was recorded in two ways:

- the cellular response by measuring the mean increase in ear thickness 24 hours after exposure to OXA
- the humoral response by measuring the mean concentration of anti-OXA antibody in blood 14 days after exposure to OXA.

Table 1 shows the results of this investigation. The values in the brackets show ± 2 standard deviations. A value of ± 2 standard deviations from the mean includes over 95% of the data.

Table 1

Type of mice	Sex of mice	Mean increase in ear thickness / cm × 10^{-3}	Mean concentration of anti-OXA antibody / arbitrary units
Healthy	Male	17.9 (±4.1)	16 (±3)
	Female	18.5 (±2.9)	14 (±4)
Autoimmune disease	Male	25.9 (±4.5)	14 (±2)
	Female	16.7 (±3.0)	26 (±7)

(b) Suggest and explain **one** reason why olive oil was applied to the left ear of the mice.

_____

_____

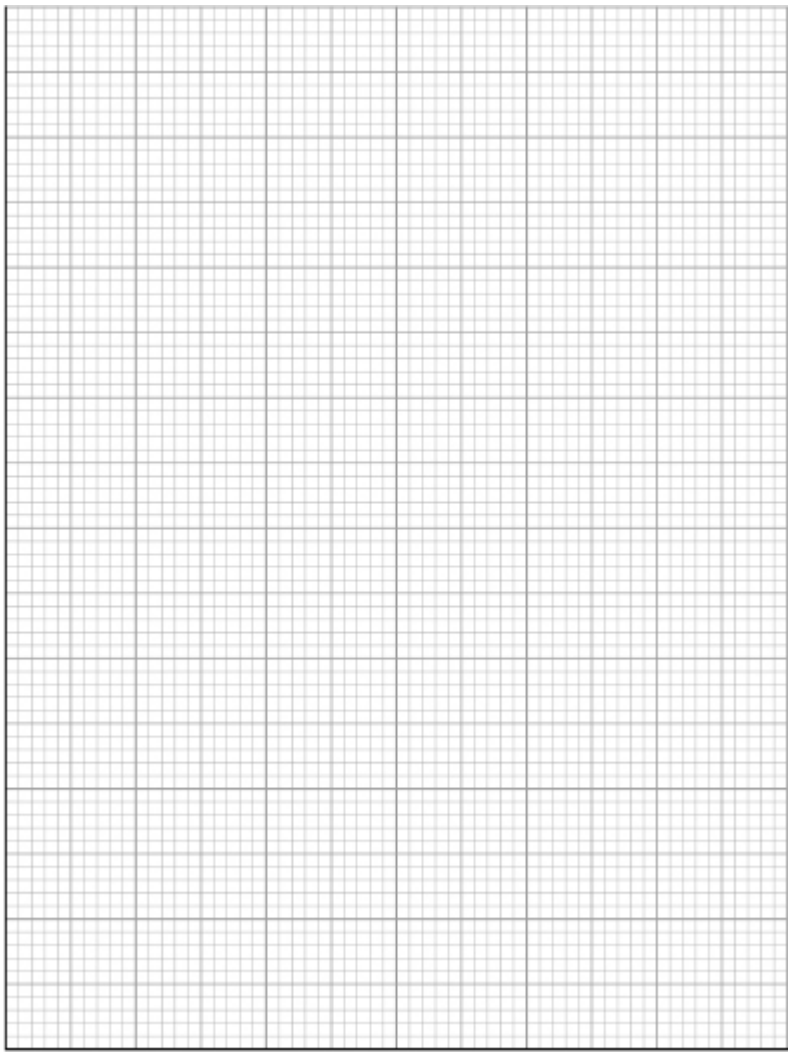
_____

_____

(1)

(c) Plot a suitable graph for mean increase in ear thickness for each group of mice in **Table 1**.

Include the data for ± 2 standard deviations on your graph.



(3)

(d) What can you conclude about the effects of autoimmune disease on the cellular response and the humoral response in male and female mice?

Use the data to justify your conclusions.

(3)

(e) Some studies have shown that **in humans**, oestrogen has the opposite effect on two different autoimmune diseases. Oestrogen:

- accelerates the progression of systemic lupus erythematosus (SLE)
- prevents the progression of rheumatoid arthritis (RA).

The scientists investigated the effect of oestrogen on the immune response in healthy mice and mice with autoimmune disease.

Table 2 shows the scientists' results.

Table 2

Type of mice	Effect of oestrogen on humoral response	Effect of oestrogen on cellular response
Healthy	No effect	No effect
Autoimmune disease	Increase in response	Decrease in response

A student studying these data made the following conclusions.

1. In humans, SLE is caused by an overproduction of antibodies.
2. In humans, RA is caused by an overproduction of cytotoxic T cells (T_C cells).

Evaluate the student's conclusions.

(4)

(f) In mice, one type of autoimmune disease is inherited as a dominant allele. Would the Hardy–Weinberg principle hold true for a population of mice, some of which had this autoimmune disease?

Explain your answer.

(2)

(Total 15 marks)

Q9.

Read the following passage.

The placenta is a specialised exchange surface.

In the placenta, substances are exchanged between the blood of a fetus and the blood of its mother. Gas exchange for the fetus occurs in the placenta.

There is also transfer of IgG antibodies in the placenta between the mother's blood and fetal blood. These IgG antibodies protect the fetus against the pathogens that infect its mother during pregnancy. The IgG antibodies can circulate at high concentration in the mother's blood for months or years. A fetus does not produce IgG antibodies.

The UK immunisation programme vaccinates as many babies as possible to protect the UK population against pathogens such as measles viruses and tetanus bacteria. Measles viruses spread quickly from infected people. Despite the efforts of the NHS, there has been a recent increase in the number of children catching measles.

Tetanus bacteria enter the body through skin wounds. Tetanus bacteria do not spread from infected people. In order to develop good immunity against tetanus, children are given three tetanus vaccinations at regular intervals before they reach their first birthday.

Use the information in the passage and your own knowledge to answer the following questions.

(a) Gas exchange for the fetus occurs in the placenta (line 3).

Describe how the composition of blood in the pulmonary artery of a fetus is different from the composition of blood in the pulmonary artery of its mother.

Give **one** reason for this difference.

_____

_____

_____

_____

_____

_____

(2)

(b) Explain how a fetus is protected against the pathogens that infect its mother during pregnancy (lines 5–6).

Do **not** give details of an active immune response in the mother.

(3)

(c) Suggest how vaccinating as many babies as possible protects the UK **population** against pathogens such as measles viruses and tetanus bacteria (lines 9–11).

Protection against measles

Protection against tetanus

(2)

(d) Suggest why there has been a recent increase in the number of children catching measles (lines 12–13).

(1)

(e) Explain why giving children more than one tetanus vaccination develops good immunity against tetanus (lines 15–17).

(2)

(Total 10 marks)