

Organism exchange substances with their environment – A2 Biology

1. No.4

0 4 . 1

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 marks]

Damage to the cells lining the ileum reduce surface area over which absorption takes place. So, there will be fewer co-transporter to facilitate the diffusion of ions and smaller molecules across the cell membrane. This will decrease water potential in the ileum.

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

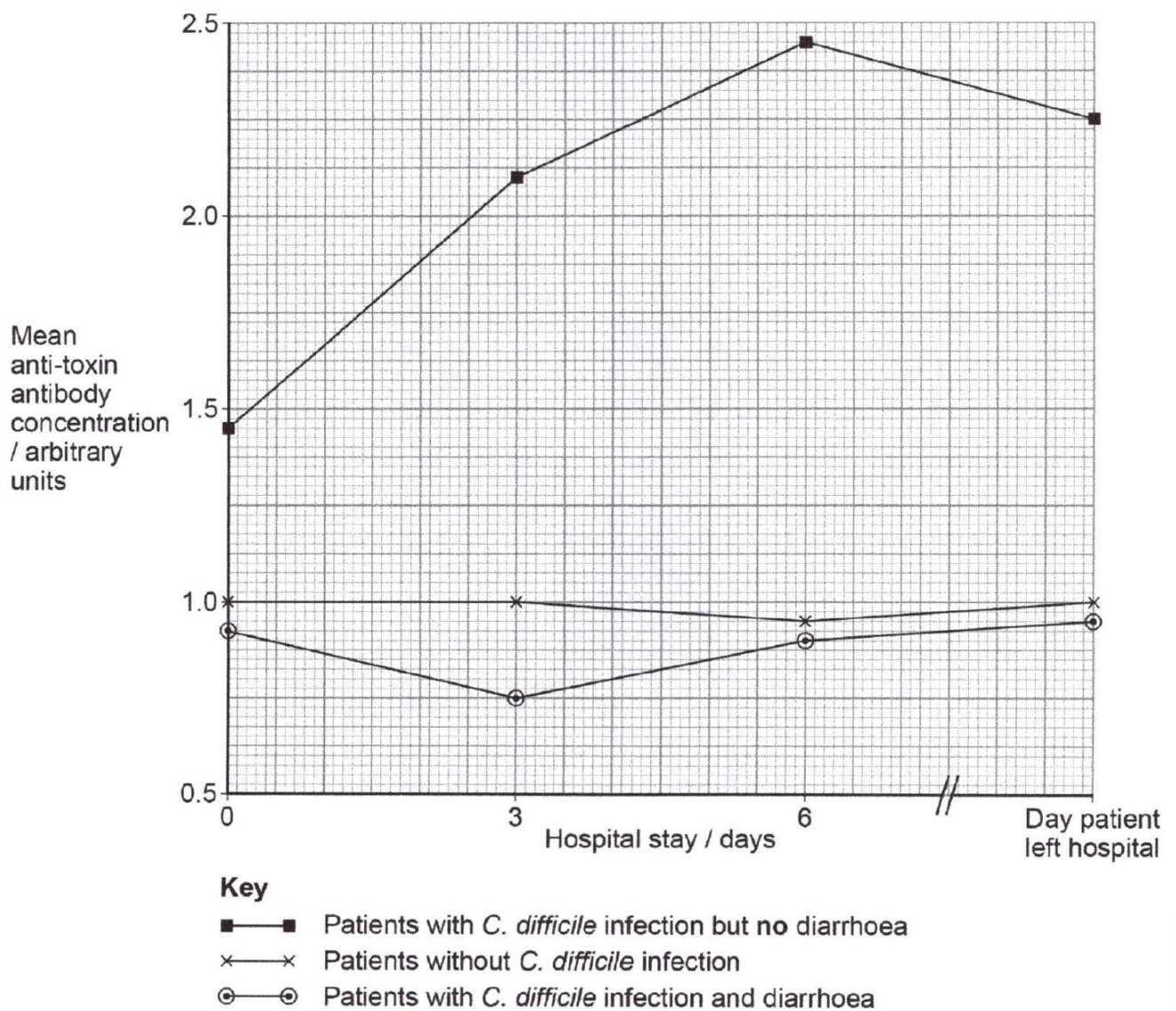
Scientists measured the anti-toxin antibody concentration in hospital patients with and without *C. difficile* infection.

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.

Figure 4 shows the scientists' results.

Figure 4



0 4 . 2

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

Use **Figure 4** to suggest how this passive immunity would work **and** which patients should be offered this anti-toxin antibody.

[3 marks]

Antitoxins cause destruction of the toxins by phagocytosis. This reduces chances of diarrhoea. Patients of C difficle with no diarrhoea have the highest concentration of anti-toxin.

0 4 . 3

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 marks]

Antibodies are made of proteins. When swallowed, the peptide bonds in the protein will be hydrolysed to produce amino acids. The endopeptidases break internal peptide bonds while the exopeptidases break terminal peptide bonds. The membrane bound dipeptidases break the dipeptides into amino acids.

2. No.5

0 5

A student investigated the use of cinnamon oil as an antimicrobial substance. She investigated the effect of cinnamon oil on the growth of five different bacterial cultures grown on agar plates.

0 5 . 1

The student added 100 mm³ of each bacterial culture from its glass bottle onto a separate agar plate. She spread each bacterial culture evenly over the agar using a spreader.

Describe the aseptic techniques she should use.

[3 marks]

- Wash hands with soap to prevent contamination
- Disinfect surfaces using antimicrobial solution to prevent contamination.
- Use sterile syringe to transfer bacteria onto agar plates.
- Work close to upward air movement. Lift the lid of agar plate at an angle to keep the lid over plate
- Use sterile spreader to spread bacteria on agar plate. Dip spreader to alcohol to make it sterile.
- Place spreader into disinfectant immediately after use.

0 5 . 2 On each agar plate, the student cut a well (a hole) in the agar.

The well had a diameter of 6 mm. The student added 50 mm^3 of cinnamon oil into the well.

Calculate the minimum depth of the well to allow the addition of 50 mm^3 of cinnamon oil.

Use the following equation in your calculation:

$$\text{Volume of a cylinder} = \pi r^2 \times l$$

Use 3.14 as the value for π .

Show your working.

$$\begin{aligned} l &= ? \\ \text{Radius} &= 6 \text{ mm} \div 2 = 3 \text{ mm} \\ \text{Volume} &= \pi \times 3^2 \times l = 50 \text{ mm}^3 \end{aligned}$$

[2 marks]

$$l = \frac{50}{\pi \times 3^2} = 1.768158992$$

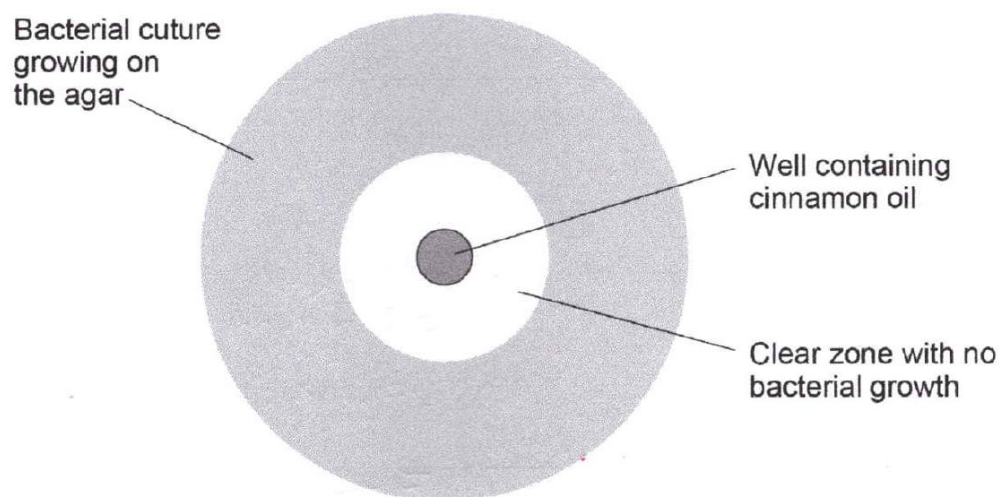
$$l \approx 1.768$$

Answer 1.768 mm

The student kept the plates at 25 °C for 24 hours.

Figure 5 shows what one of her plates looked like after 24 hours.

Figure 5



The student measured the diameter of the clear zone with no bacterial growth around each well. She made these measurements to the nearest whole mm

Table 1 shows her results.

Table 1

Bacterial culture	Diameter of clear zone / mm		
	Cinnamon oil	Positive control	Negative control
<i>Bacillus</i> spp. ✓	15	14	0
<i>Staphylococcus aureus</i> ✓	20	17	0
<i>Listeria monocytogenes</i> ✓	18	12	0
<i>Escherichia coli</i> ✓	16	12	0
<i>Klebsiella</i> spp. ✓	14	12	0
Median for all cultures	16	12	0
Mean for all cultures	17	13	0
Standard deviation for all cultures	2.4	2.2	0

0 5 . 3

Suggest exactly what the student added to the wells to get the positive control and negative control results.

[2 marks]

- For positive control, the student added antimicrobial solution.

- For negative control, the student added sterile water.

0 5 . 4

Complete Table 1 to show the median and mean diameters.

[1 mark]

0 5 . 5

The mean $\pm$ 2 standard deviations includes over 95% of the data.

Use this information to consider whether the standard deviations suggest the differences in means are likely to be due to chance.

Explain your answer, including at least one calculation.

use t test

$$s = \text{deviation} = \sqrt{\frac{\sum (x_i - \bar{x})^2}{n-1}} = 2.4$$

$$t = \frac{x_1 - x_2}{\sqrt{\frac{(s_1)^2}{n_1} + \frac{(s_2)^2}{n_2}}} = \frac{17 - 13}{\sqrt{\frac{(2.4)^2}{5} + \frac{2.2^2}{5}}} = \frac{4}{\sqrt{\frac{5.76}{5} + \frac{4.84}{5}}} = \frac{4}{\sqrt{1.152 + 0.968}} = 1.58$$

[2 marks]

The standard deviations overlap. So, the difference is likely due to chance. There is no significant difference in means.

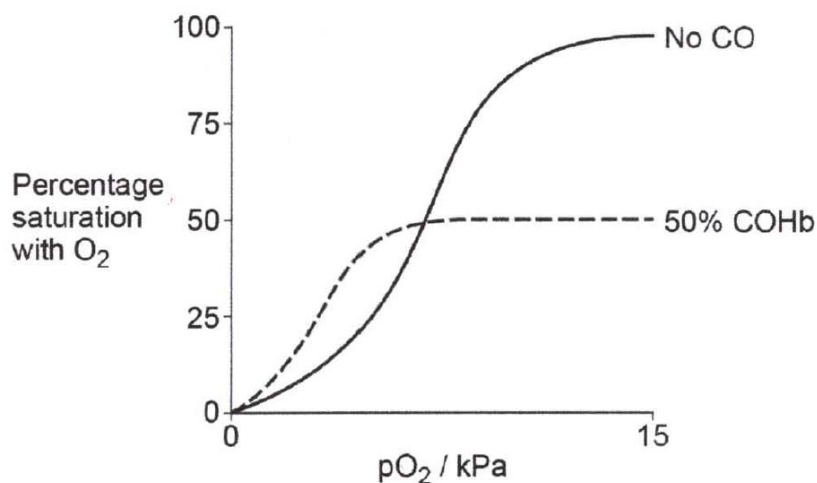
3. No.7

07.1

Carbon monoxide (CO) is released during incomplete combustion of fossil fuels.

Figure 7 shows the dissociation curve for oxyhaemoglobin when:

- not exposed to CO
- exposed to CO such that 50% of the oxygen binding sites are occupied by CO (50% COHb).

Figure 7

Using **Figure 7**, what can you conclude about how exposure to CO affects the loading and unloading of oxygen by haemoglobin?

Explain your answer.

[3 marks]

Less oxygen is loaded to haemoglobin exposed to carbon monoxide. Haemoglobin saturation with oxygen is 50% when exposed to carbon monoxide.

At low partial pressure for oxygen, haemoglobin has higher affinity for oxygen.

07.2

The World Health Organisation (WHO) suggests that to avoid long-term health effects, COHb concentrations should be kept below 2.5%.

WHO recommends that people should not be exposed to:

- air with $> 10 \text{ mg m}^{-3}$ CO for more than 8 hours
- air with $> 30 \text{ mg m}^{-3}$ CO for more than 1 hour.

Scientists have used a mathematical model to calculate the exposure to carbon monoxide that would result in 2.5% COHb in both adults and children.

Table 2 shows the scientists' results.

Table 2

Exposure duration at rest / hours	CO concentration in the air / mg m^{-3} resulting in 2.5% COHb	
	Child	Adult
1	31.2	40.2
8	9.6	10.6

The scientists suggest that the WHO recommendations for carbon monoxide concentrations resulting in 2.5% COHb should be reduced.

Evaluate the scientists' conclusion.

[3 marks]

- Children exposed to CO for 8 hours have 10.6 2.5% COHb. This is against scientists suggestion. This claim is invalid assumption.

- Adults exposed to CO for 1 hour and 8 hours in air have 40.2. This implies that the Model did not use people and so it is inaccurate. People vary in ethnicity, age sex. The data given does not take this into account.

No statistical test was done to show if the differences in the data is significant. This makes the data to be invalid.

4. No.1

0 1 . 1

Describe how stimulation of a Pacinian corpuscle produces a generator potential.

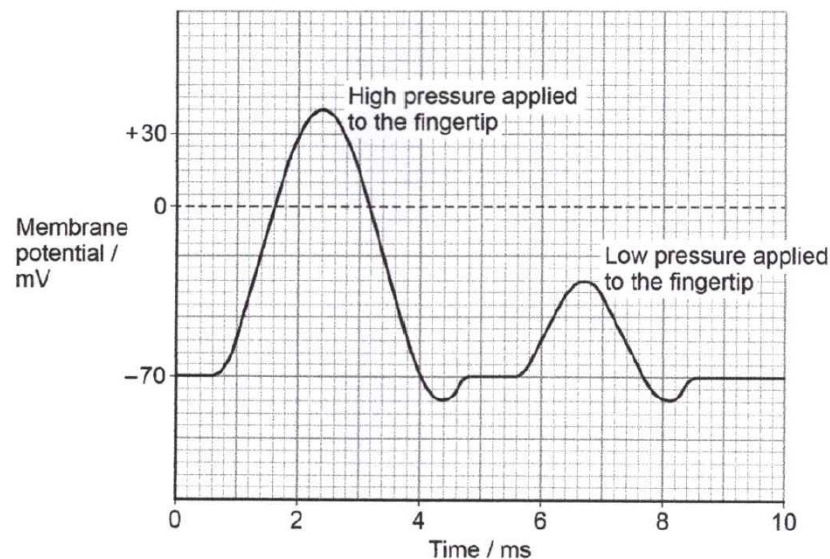
[3 marks]

There are stretch-mediated sodium ion channels in the membrane of the Pacinian corpuscle. Increase in pressure charges sensory neurone so that sodium ion channels open. Then Na^+ diffuse in causing depolarisation. This generates a potential.

Scientists investigated the stimulation of a Pacinian corpuscle in the skin of a fingertip. The scientists applied two different pressures to the fingertip and recorded the changes in membrane potential of the Pacinian corpuscle's sensory neurone.

Figure 1 shows the scientists' results.

Figure 1



0 1 . 2

Use **Figure 1** to describe what is meant by the all-or-nothing principle.

[2 marks]

A condition where an action potential is only generated when a threshold is reached.
High pressure generates an action potential.

0 1 . 3

On **Figure 1**, from 0.6 ms to 4.0 ms, no new generator potential could be produced. What is this time period called?

[1 mark]

The refractory period.

5. No.6

0 6 . 1

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

[2 marks]

- 1 Antigen-presenting cells
- 2 Abdominal body cells

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 2 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 2

Type of mice	Sex of mice	Mean increase in ear thickness / $\text{cm} \times 10^{-3}$	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)

0 6 . 2

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

[1 mark]

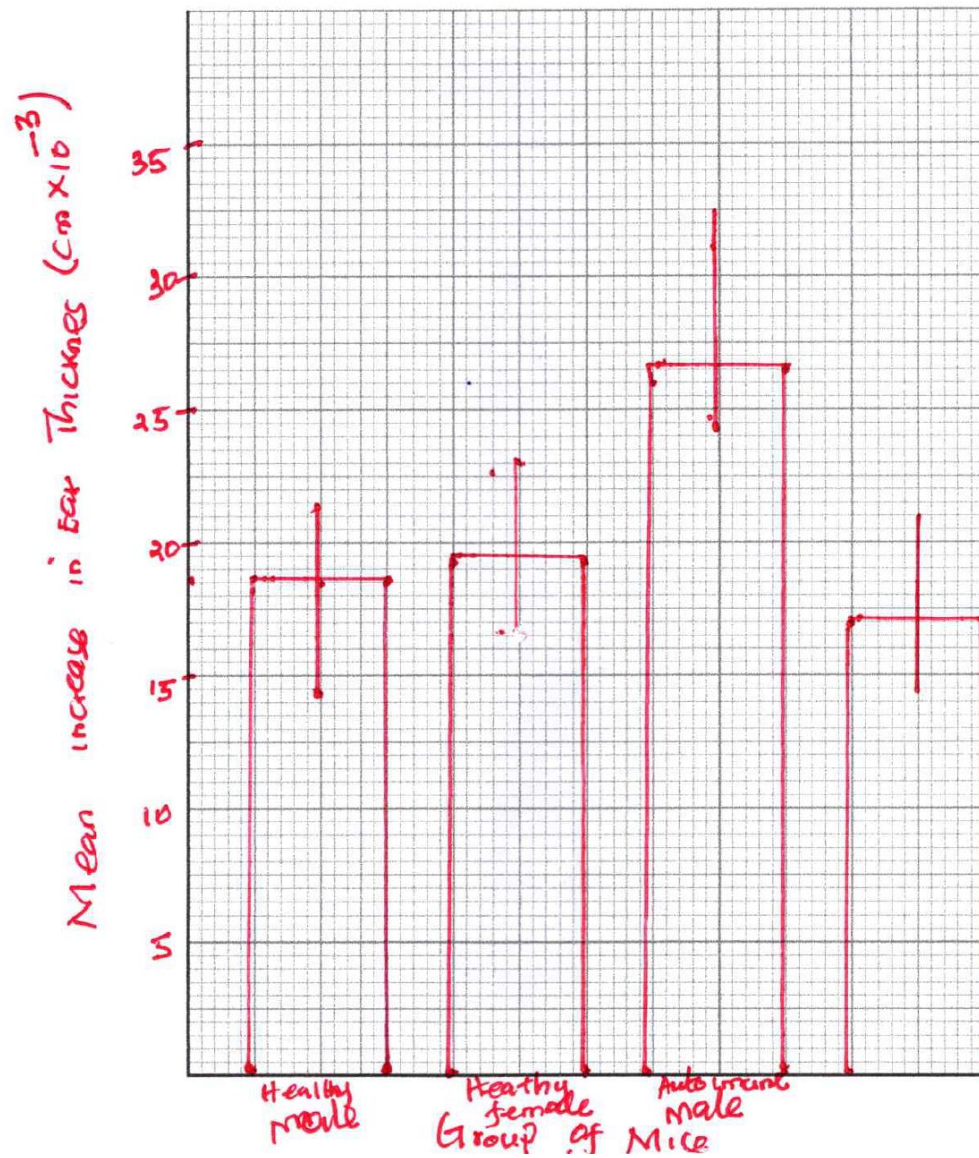
it was used as control experiment, to show that it is OXA affecting the immune response

06.3

Plot a suitable graph for mean increase in ear thickness for each group of mice in Table 2.

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

[3 marks]



0 6 4

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 marks]

- Male to female cellular response has no significant difference because the standard deviations overlap. There is significant increase in cellular response in autoimmune male compared with autoimmune female because standard deviations do not overlap.
- There is significant increase in humoral response in autoimmune female compared with autoimmune male as standard deviations do not overlap.

0 6 5

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 3 shows the scientists' results.

Table 3

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 marks]

- Oestrogen increases the humoral response that produces antibody. Production of more antibodies could increase the progression of SLE. Oestrogen decreases cellular response and this will slow down progression of RA. Mice and humans are mammals, so the effect is similar in both. This makes conclusions valid.
- However, investigation was done in mice and not humans. So, results would be different. Decrease in cellular response could also mean fewer antigen presenting cells and not just T_C cells. This makes the conclusions invalid.

06.6

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 marks]

- No. Mice with autoimmune disease will be unlikely survive and reproduce. It will be selected against naturally
- Hardy-Weinberg principle would hold because allele frequency remain constant as long as mice's ability to reproduce is not affected.