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Friday 15 October 2021 – Morning

A Level Biology B (Advancing Biology)

H422/02 Scientific literacy in biology

Time allowed: 2 hours 15 minutes

You must have:
- a clean copy of the Advance Notice Article (inside this document)

You can use:
- a ruler (cm/mm)
- a scientific or graphical calculator

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Please write clearly in black ink. **Do not write in the barcodes.**

Centre number | | | | | | Candidate number | | | | |

First name(s) _____

Last name _____

INSTRUCTIONS
- Use black ink. You can use an HB pencil, but only for graphs and diagrams.
- Write your answer to each question in the space provided. If you need extra space use the lined pages at the end of this booklet. The question numbers must be clearly shown.
- Answer **all** the questions.
- Where appropriate, your answer should be supported with working. Marks might be given for using a correct method, even if your answer is wrong.

INFORMATION
- The total mark for this paper is **100**.
- The marks for each question are shown in brackets **[ ]**.
- Quality of extended response will be assessed in questions marked with an asterisk (*).
- This document has **28** pages.

ADVICE
- Read each question carefully before you start your answer.

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Answer **all** the questions.

1 This question is based on the Advance Notice article **'Do Pathogens Gain Virulence as Hosts Become More Resistant?'** on the **Insert**.

(a) The myxoma virus (MYXV) is a pathogen that causes myxomatosis in its hosts.

(i) Describe how a virus replicates.

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(ii) Explain why myxomatosis could not be described as endemic in Australia before 1950.

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(iii) Explain why the myxomatosis outbreak in the 1950s could be described as an epidemic.

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..... **[1]**

(b) HIV is a retrovirus but MYXV is not.

Use this information and your knowledge to complete the following table by placing a tick (✓) if the feature is found in HIV or MYXV.

Feature	**HIV**	**MYXV**
Genetic material is RNA		
Virus particle contains reverse transcriptase		
Virus has a protein capsid		

[3]

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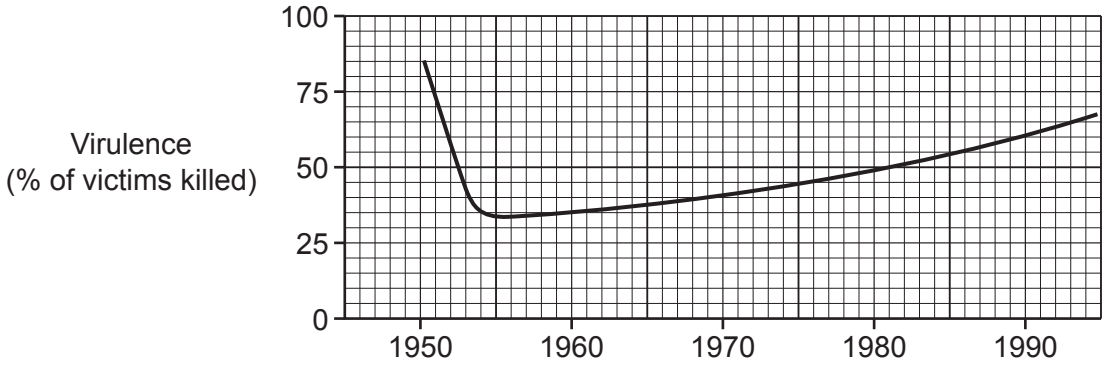
(c) The graph shows how the virulence of MYXV changed over the period from 1950 to 1990.



Describe how the virulence of MYXV strains varied during the period 1950 to 1990.

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..... **[2]**

(d) The article describes the interactions between pathogen virulence and host resistance to infection.

(i) Explain how immunological and genetic factors would allow a population of wild rabbits to become more resistant to infection by MYXV.

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(ii) The article discusses how resistance to infection can be affected by two common agricultural practices: vaccination and selective breeding.

Explain how vaccination is used to protect poultry against pathogens such as Marek's disease virus (MDV).

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(iii) Explain why vaccination might **not** prevent epidemics of Marek's disease in poultry.

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(iv) Evaluate the suggestion that birds should be bred for susceptibility to MDV rather than resistance.

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2 **(a)** The faecal occult blood test (FOBT) is a screening method that is now used routinely in people over the age of 65 years.

The presence of blood in faeces (a positive result) is thought to be caused by chronic inflammation of the gut and indicates an increased risk of developing colorectal cancer (CRC).

A Scottish study looked at 133 921 individuals who were tested with FOBT and then followed for up to 16 years.

- 131 207 had a negative FOBT
- 2714 had a positive FOBT

(i) Outline a method that a doctor could use to confirm that a person with a positive FOBT has CRC.

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Question 2(a)(ii) begins on page 8

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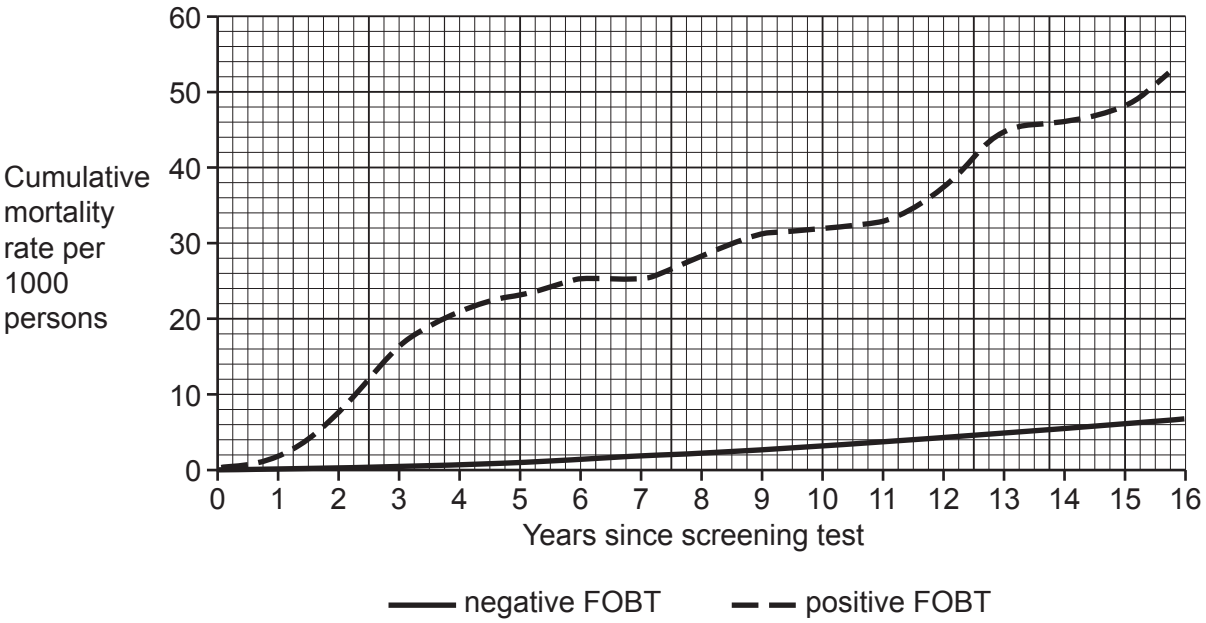
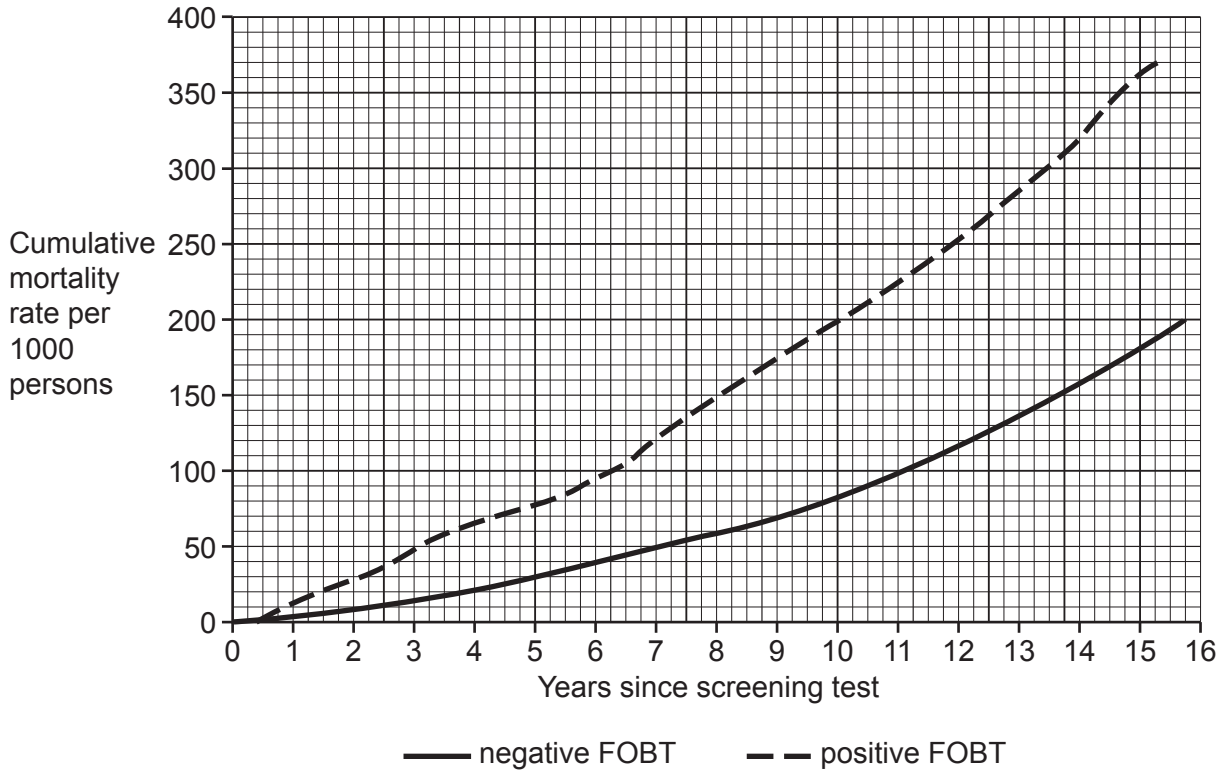
(ii) The graphs show cumulative mortality rate from CRC and cumulative mortality rate from all causes except CRC in the two groups studied over the 16-year period.

Cumulative mortality rate from CRC



Cumulative mortality rate from all causes except CRC



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The scientists who carried out this study concluded that a positive FOBT was an indicator of increased risk of death from other (non-cancerous) diseases linked to inflammation of the gut.

Explain whether the data in the graphs support their conclusion.

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(iii) An FOBT kit is sent to everyone in England between 60 and 74 years of age.

Using your own knowledge and the data in the graphs, evaluate the effectiveness of FOBT in screening for CRC.

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(b)* CRC is one of more than 100 forms of cancer.

Describe, with examples, how mutations in genes that control cell division can lead to cancer.

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Additional answer space if required.

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3 (a) **Fig. 3.1** is a diagram of a section through the human brain.

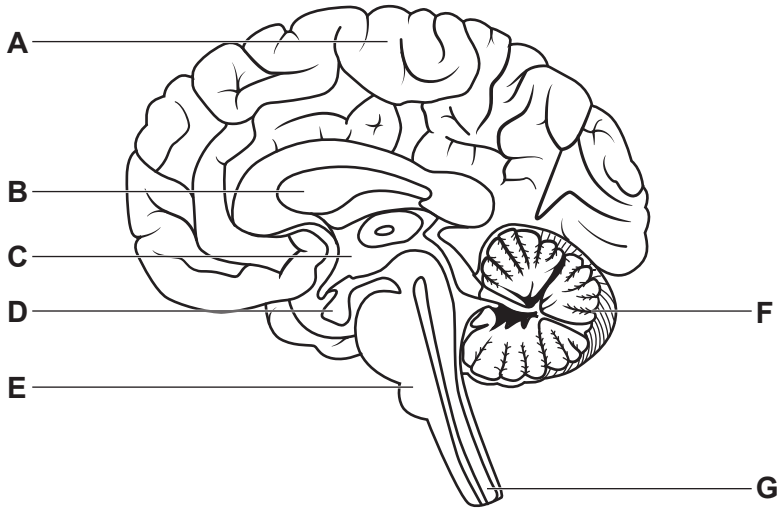

Fig. 3.1

The following table contains statements about areas of the brain shown in **Fig. 3.1**.

Complete the table using the most appropriate letter from **Fig. 3.1**. Each letter may be used once, more than once, or not at all.

Statement	Letter
fMRI shows this area of the brain to be active when playing a musical instrument.	
Temperature-sensitive neurones are located in this area of the brain.	
Traumatic injury to this area can lead to over- or under-production of sex hormones.	
This region of the brain controls heart rate and breathing rate.	
Stroke affecting part of this area of the brain could cause loss of conscious control of muscles in the arms or legs.	

[4]

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(b) The brain contains the structures responsible for coordination of the control of body temperature.

An 80-year-old man was found in an unheated room when the outside temperature was below 0ºC. The man had a weak pulse. A paramedic measured the man's core body temperature as 34.2ºC.

(i) Explain how the paramedic could obtain an accurate measurement of core body temperature.

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(ii)* The paramedic concluded that the man was suffering from hypothermia.

Describe the biological processes that lead to hypothermia and the treatment for hypothermia.

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(c) **Fig. 3.2** shows monthly data for the treatment of cases of hypothermia (**Fig. 3.2a**) and hyperthermia (**Fig. 3.2b**) in the United States over a two-year period.

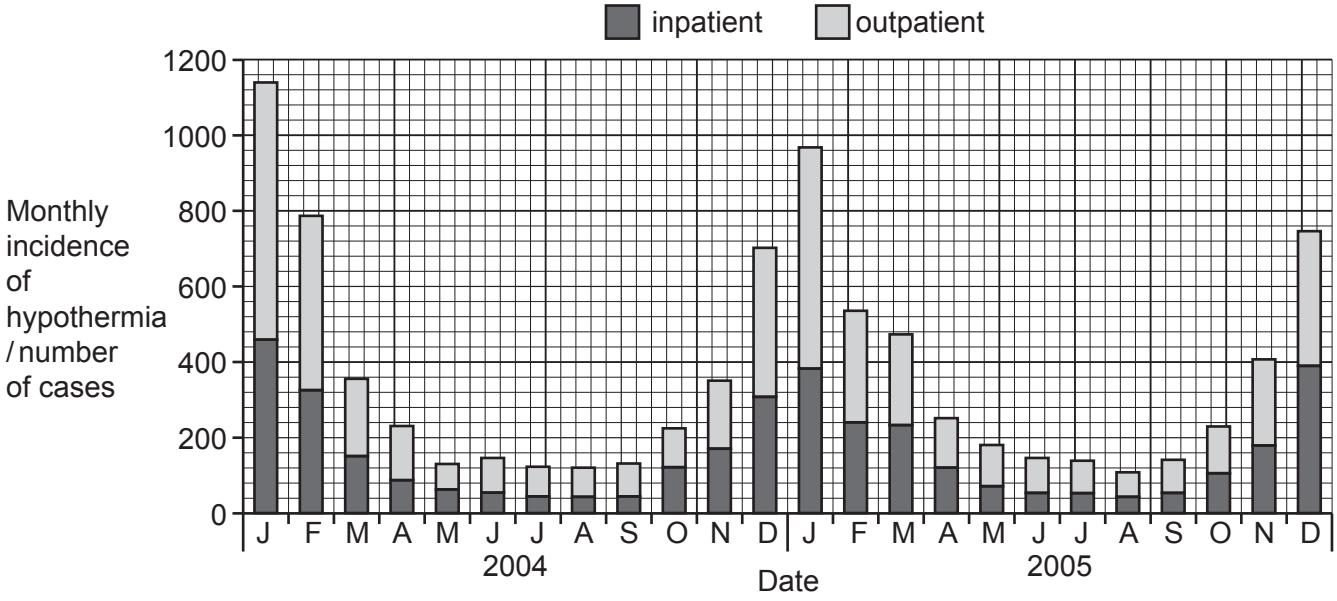

Fig. 3.2a

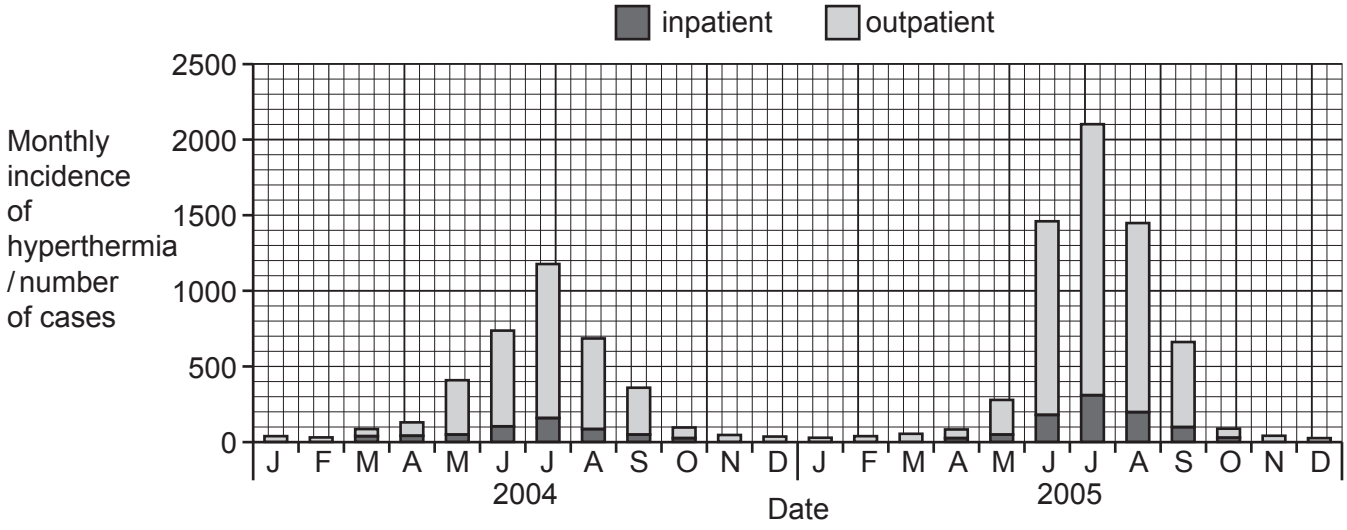

Fig. 3.2b

Some patients were treated as outpatients in a clinic or Emergency Department. Others required admission to hospital as inpatients.

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(i) Describe and explain the seasonal trends shown in the two graphs in **Fig. 3.2**.

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(ii) Suggest why the proportion of inpatient hospital admissions was different for hypothermia and hyperthermia.

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(iii) A student looked at the data for hyperthermia and concluded that this was evidence for climate change.

Discuss the student's conclusion.

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4 **(a)** **Fig. 4.1** shows a graph of rate of reaction plotted against substrate concentration for an enzyme that converts a colourless substrate into a coloured product.

V_{max} represents the maximum rate of reaction.

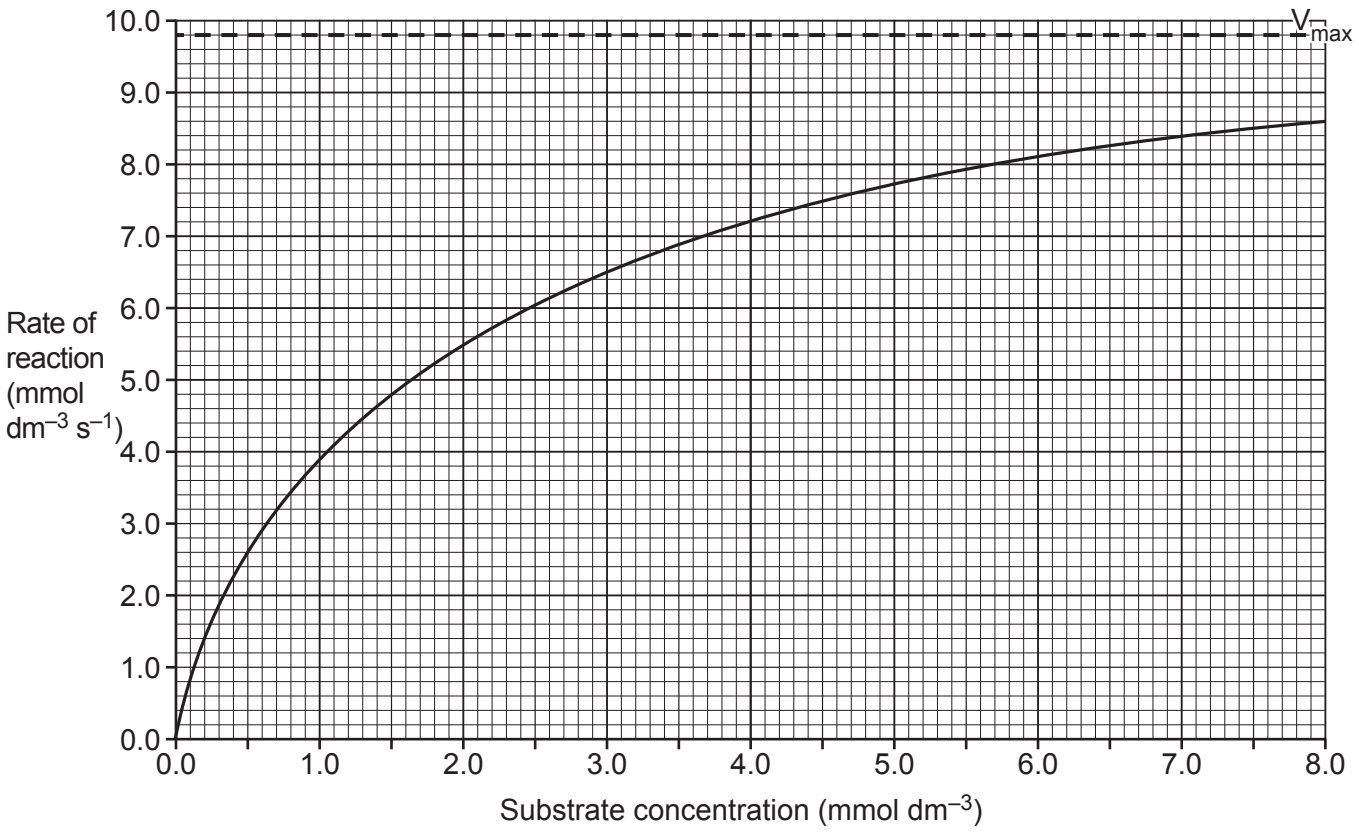

Fig. 4.1

(i) Describe how you could obtain the data for this graph.

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(ii) Explain why the experiments you have described should be carried out with excess enzyme.

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(iii) The Michaelis constant, K_M, is defined as the substrate concentration that gives half the maximum reaction rate ($\frac{1}{2} V_{max}$).

Use **Fig. 4.1** to obtain a value for K_M for this enzyme, including units.

K_M = ... units ..... **[2]**

(iv) Suggest why it is often difficult to determine a value for V_{max} experimentally.

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(b) Because of the difficulty in determining a value for V_{max}, a double reciprocal plot can be used instead.

To prepare this plot, the rate of reaction, V, is measured at different substrate concentrations, [S].

Then, a plot of 1 / V against 1 / [S] is made, as shown in **Fig. 4.2**.

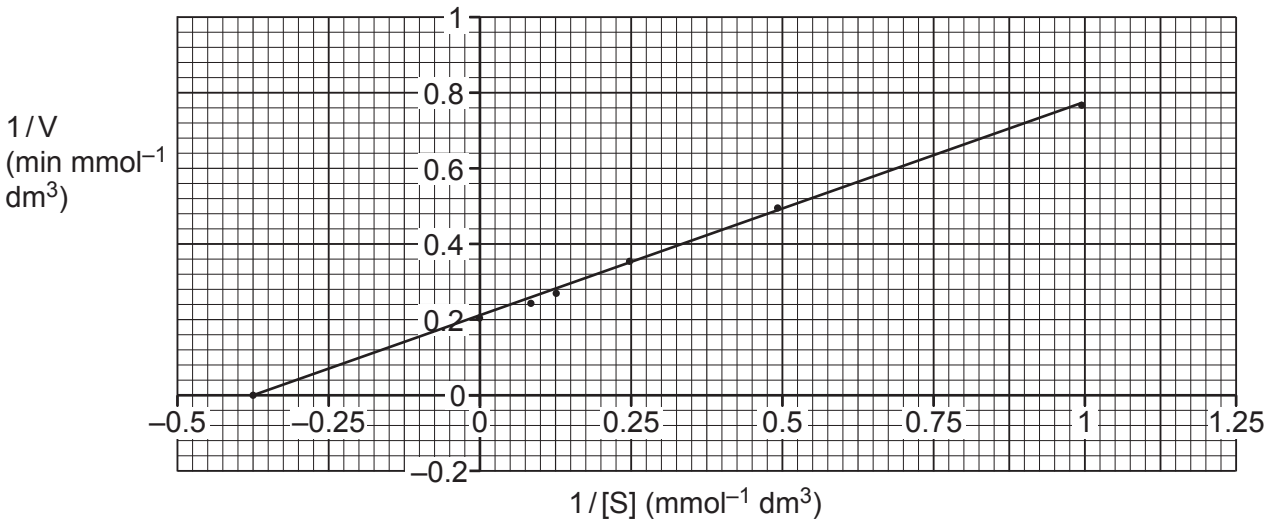

Fig. 4.2

The equation for the graph in **Fig. 4.2** is:

$$\frac{1}{V} = \frac{K_M}{V_{max}} \times \frac{1}{[S]} + \frac{1}{V_{max}}$$

This equation is of the form $y = mx + c$ where

- 1 / V represents y
- K_M / V_{max} represents m
- 1 / [S] represents x
- $1 / V_{max}$ represents c

The double reciprocal plot therefore produces a straight line graph.

(i) Use **Fig. 4.2** to determine the gradient of the line.

Gradient = ... **[1]**

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(ii) Write an expression that connects the gradient of the line, K_M and V_{max}.

..... **[1]**

(iii) A student used **Fig. 4.2** to determine that $V_{max} = 5$.

Use this value and your answer to part **(i)** to determine K_M for this enzyme.

K_M = ... (units not required) **[2]**

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5 **(a)** The following passage describes aspects of epigenetics.

Complete the passage using the most appropriate terms.

A mutation causes a change in the nucleotide sequence of DNA. Epigenetic changes do not change the nucleotide sequence. Instead, they change the extent to which genes are …… .

One epigenetic mechanism involves acetylation of ……., which makes the genes more accessible. Another mechanism involves ……. of the DNA.

Some epigenetic changes can be inherited if they are present in …….. . **[4]**

(b) Twenty zebrafish were exposed to hypoxia (oxygen deprivation) by keeping them in water with a low oxygen concentration for 4 weeks.

All the offspring of these fish had greater resistance to hypoxia than offspring whose parents were kept in well-oxygenated water.

The researchers concluded that this showed evidence for inheritance of epigenetic changes rather than being the result of a mutation.

Evaluate this conclusion.

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(c) *Drosophila simulans* and *Drosophila mauritiana* are two closely related species of fruit fly.

The *OdsH* gene in Drosophila is described as a speciation gene. It causes epigenetic changes to the DNA that regulates the condensation of chromosomes.

(i) Name the stage of the cell cycle in which condensation of chromosomes occurs.

..... **[1]**

(ii) The *OdsH* gene causes male sterility in *D. simulans* – *D. mauritiana* hybrids.

Based on the information provided, suggest how the *OdsH* gene has caused *D. simulans* and *D. mauritiana* to become and remain separate species.

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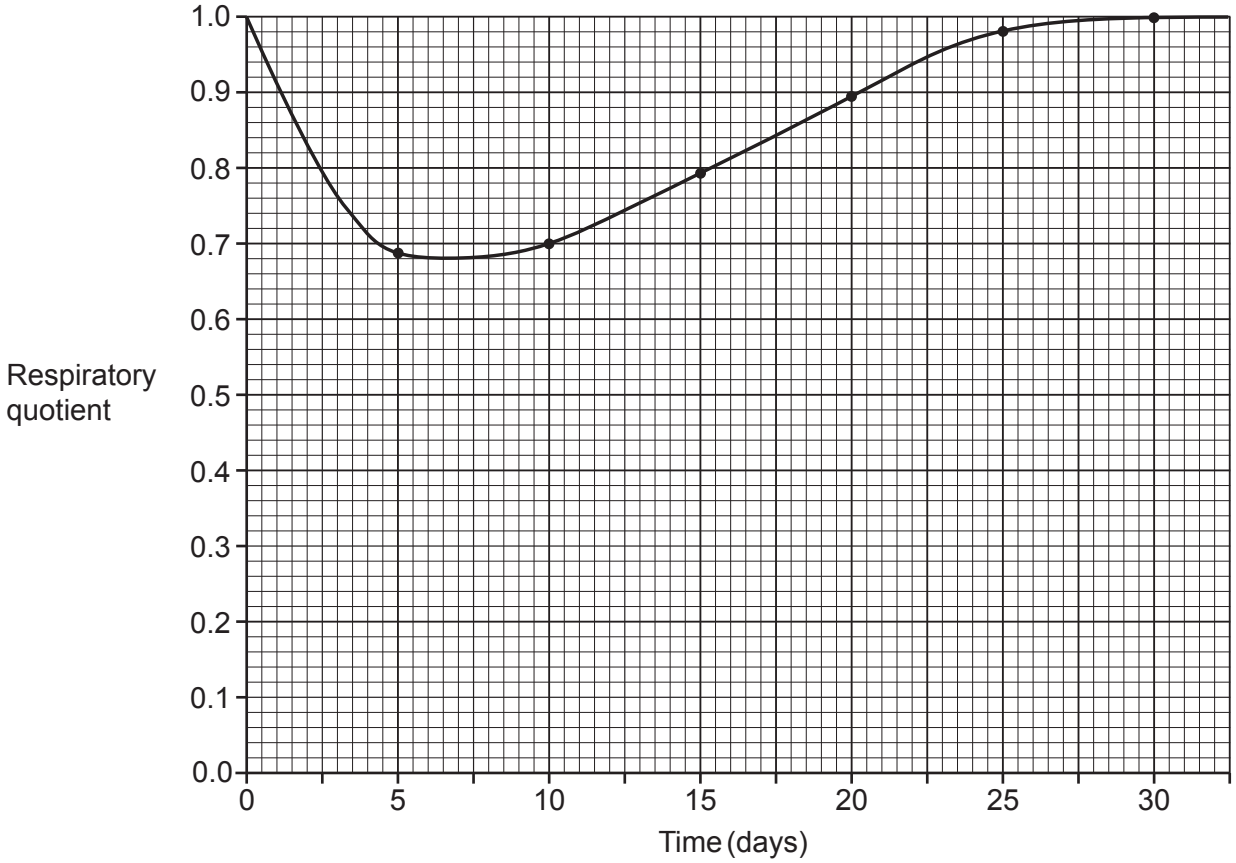
6 **(a)** Barley is a widely grown cereal in the UK. The production of barley malt involves germinating the barley grains (seeds) and then drying them.

The graph shows the results of an investigation into changes in respiratory quotient (RQ) of barley seeds during the first 30 days of germination.



(i) Name the apparatus that could have been used to measure RQ in this investigation.

..... **[1]**

(ii) Barley grains contain about 12% by mass of storage proteins. A student stated that the graph was evidence that these proteins are used as respiratory substrates throughout germination.

Suggest whether the student's statement is likely to be correct.

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(iii) Describe how you could extend this experiment to test the student's hypothesis.

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(iv) What can you conclude from the graph about the respiratory substrates, other than protein, that are used during germination?

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(b) After being used in brewing, spent grain can be used as an animal feed.

Approximately 50% by mass of the fatty acids in spent grain are linoleic acid, $C_{18}H_{32}O_2$.

(i) Calculate the respiratory quotient, RQ, of linoleic acid when respired aerobically.

RQ = ... **[2]**

(ii) State the effect on RQ if the linoleic acid were respired by a mixture of aerobic and anaerobic respiration. Explain your answer.

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..... **[2]**

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7 **(a)** Immunity can be categorised as

- active or passive
- natural or artificial.

Complete the following table by putting ticks (✓) in the correct boxes to show whether each example is active or passive **and** natural or artificial.

Example	Active	Passive	Natural	Artificial
Snake antivenoms consist of sheep or horse antibodies to snake venom proteins. They are given to treat snake bite.				
A mixture of proteins purified from the *Haemophilus influenzae* virus is used to reduce the risk of a person getting the flu.				
Following infection by a pathogen, a person develops memory T and B cells.				
A calf receives antibodies from its mother in colostrum.				

[4]

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(b) Scientists investigated the link between breastfeeding in mice and the risk of offspring developing asthma.

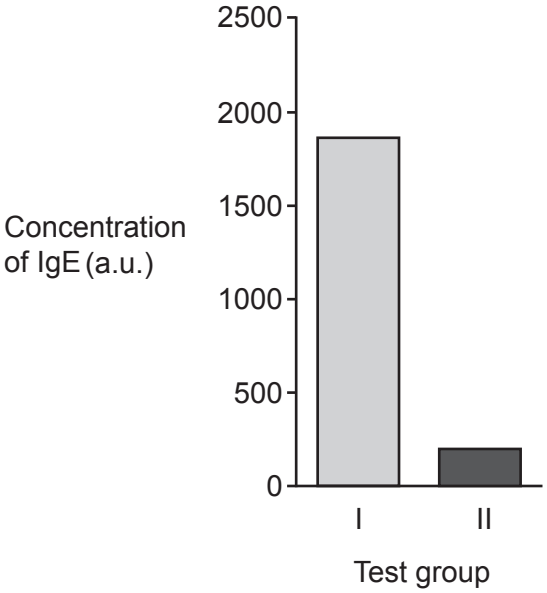
They used a model system of asthma called allergic airway disease (AAD).

Two groups of mice were compared:

- Group I: mice who were born to normal mothers (no AAD) and then breastfed by their own mothers.
- Group II: mice who were born to normal mothers but then breastfed by foster mothers with AAD.

After 4 weeks the offspring were exposed to a protein to induce AAD.

The concentration of IgE in the blood of the offspring was determined. IgE is a type of antibody that increases in concentration during allergic reactions. The results are shown in the graph.



(i) Name a statistical test the scientists could have used to compare the results of the two groups. Give a reason for your choice.

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(ii) State which group of offspring showed more AAD. Give a reason for your choice.

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..... **[2]**

(iii) The statistical analysis showed there was a significant difference in the concentrations of IgE antibodies in the two groups.

Breastfeeding is associated with a reduced risk of asthma in children.

Explain whether the results support the conclusion that breastfeeding could reduce the risk of asthma in children.

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END OF QUESTION PAPER

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ADDITIONAL ANSWER SPACE

If additional space is required, you should use the following lined page(s). The question number(s) must be clearly shown in the margin(s).

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Friday 15 October 2021 – Morning

A Level Biology B (Advancing Biology)

H422/02 Scientific literacy in biology

Advance Notice

Time allowed: 2 hours 15 minutes

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- Do **not** send this Insert for marking. Keep it in the centre or recycle it.

INFORMATION
- This Insert contains the Advance Notice.
- This document has **4** pages.

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Do Pathogens Gain Virulence as Hosts Become More Resistant?

One of the most remarkable events in the history of infectious diseases occurred in 1950. The myxoma virus (MYXV) was being tested as a biological control agent for the invasive rabbit populations in Australia. The virus escaped from test sites and caused an outbreak of unprecedented scale, speed, and carnage. Within just six months, it was affecting rabbit populations across the country, causing a disease known as myxomatosis. This was a surprising gift for farmers, whose crops were being eaten by hordes of rabbits. Over the next decade, rabbit populations across the country were reduced by 90%[1]. Populations have since recovered, but the number of rabbits remains much lower than before the release of MYXV.

The release of MYXV presented an opportunity to study the evolutionary arms race between a pathogen and its host animal. Australian microbiologist Frank Fenner took advantage: he set up experiments that ran for more than 35 years[2]. His work has revealed the evolution that happens when a virus emerges in a new host population. Fenner's work has also shed light on how pathogens may evolve in the face of vaccination and genetic engineering, which make hosts more resistant to their infections.

Viral virulence

Virulence is a measure of the severity of the disease caused by a pathogen. The original strain of MYXV was highly virulent: almost every infected rabbit died within two weeks. Fenner wanted to know what happens when such a virulent virus spreads through a very susceptible host species on a continental scale. He focused on two possibilities. First, the highly lethal virus may evolve to become less lethal. Second, the highly susceptible rabbits may evolve resistance to infection. We now know Fenner's answer: they both happen.

Let's start with the virus. Fenner's work showed that the original, highly virulent MYXV strain was replaced within a few years by strains with fatality rates of 70–95%. Fenner showed that the most virulent virus strains killed rabbits remarkably quickly. The less virulent strains were able to infect more new victims and spread throughout the population. However, the most benign strains of MYXV were also less infectious; host immunity was able to control and clear them more rapidly. As a result, there was a limit to the reduction in MYXV virulence.

Wild Australian rabbits also evolved in the 1950s. Resistance to infection is the ability of an organism to defend itself against pathogens. It can include immunity to pathogens, but other factors may also be involved. The genetic disease resistance some rabbits evolved meant that they could clear MYXV infections more rapidly, and this reduced virus transmission. However, the resistance is not perfect: it does not prevent infection or transmission. The virus was therefore able to evolve in resistant rabbit populations. Viral mutants that were better able to overcome enhanced antiviral host defenses are favoured by natural selection. As a consequence, the virulence of MYXV began to increase again.

Implications for agriculture

Intensive farming is only possible if infectious diseases can be controlled. Enhancing the resistance of farm animals to infectious disease is an aspiration of veterinary medicine and most agricultural industries. Selective breeding, genetic engineering, and immunisation can all be used to make animals more resistant to infections. However, is it possible that such efforts will unintentionally select for the more virulent pathogens?

If hosts are completely resistant, onward transmission of pathogens will stop, and their evolution will cease as well. But artificially enhanced resistance is often imperfect. Many vaccines used on farms do not render hosts impervious to infection, and animal breeders have yet to produce animals that are 100% resistant to various infections. Given what scientists now know about pathogen-host arms races, we should take seriously the possibility that resistance in farm animals may trigger the evolution of greater virulence in pathogens.

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In fact, this may have already happened. Marek's disease virus (MDV) is a highly contagious, cancer-causing pathogen that infects poultry. MDV has become more virulent over the last 50 years[3]. When the poultry industry began to grow in the 1950s, MDV caused mild disease and had little economic impact. Nowadays, some MDV strains can kill all unvaccinated birds within 10 days. Unless birds are vaccinated, the losses are devastating. Critically, and for reasons not fully understood, MDV vaccines protect against disease, but they do not destroy the virus.

In a series of experiments, scientists found that hypervirulent strains of MDV can exist only in vaccinated flocks. In unvaccinated birds, the hypervirulent strains kill before they have a chance to be transmitted. Vaccines keep infected birds alive, but vaccination creates the conditions for hypervirulent strains to emerge and persist[4].

There is no question that MDV has become substantially more virulent over the last 50 years. Yet industry losses to Marek's disease are much lower than they were when less virulent strains circulated. Today's hypervirulent MDV strains cause less severe disease in vaccinated birds than milder MDV strains caused in unprotected birds. Current viral strains cause problems only when they infect unvaccinated flocks—for example, organic farms, small outdoor flocks, or farming systems with faulty vaccination practices.

Breeding companies often use selective breeding, in addition to vaccination, in an attempt to enhance resistance in poultry. Particular major histocompatibility complex (MHC) alleles in poultry reduce the severity of symptoms caused by MDV. There are concerted efforts to spread these alleles through flocks of poultry. This selective breeding, as well as the development of genetically engineered resistance[5], may further encourage the evolution and spread of virulent strains. For example, some transgenic chickens suppress the replication and transmission of avian influenza, but don't block it entirely. This is analogous to the antiviral effects of MYXV resistance that arose in Australia's rabbits. Were these GM chickens to become widespread, it is easy to imagine that, just like the rabbits in Australia, they would cause the evolution of hypervirulent viruses. For this reason, some scientists suggest that breeders and engineers try to do something that may seem counterintuitive: breed and engineer birds that are highly susceptible to pathogens.

References

1. F. Di Giallonardo, E.C. Holmes, "Viral biocontrol: Grand experiments in disease emergence and evolution," Trends Microbiol, 23:83–90, 2015.
2. F. Fenner, B. Fantini, Biological Control of Vertebrate Pests (Wallingford, U.K: CABI Publishing, 1999).
3. R.L. Witter, "Increased virulence of Marek's disease virus field isolates," Avian Dis, 41:149–63, 1997.
4. A.F. Read et al., "Imperfect vaccination can enhance the transmission of highly virulent pathogens," PLOS Biol, 13: e1002198, 2015.
5. L. Tiley, "Transgenic animals resistant to infectious diseases," Rev Sci Tech, 35:121–32, 2016.

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