



Oxford Cambridge and RSA

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



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

Centre number

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Candidate number

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First name(s)

Last name

StemUp Model Solution

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.

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.

The virus attaches to and enters a host cell. It takes over the host cell's metabolism; the viral DNA / RNA (genetic material) replicates and viral proteins are made using the cell's mechanisms; new virus particles are assembled and released.

[2]

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

Endemic means present in the population at a baseline level all the time, but before 1950 MYXV was not present in the wild rabbit population; it was only present in the test sites.

[1]

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

There was a sudden, rapid increase in incidence, spreading across the whole country within six months.

[1]

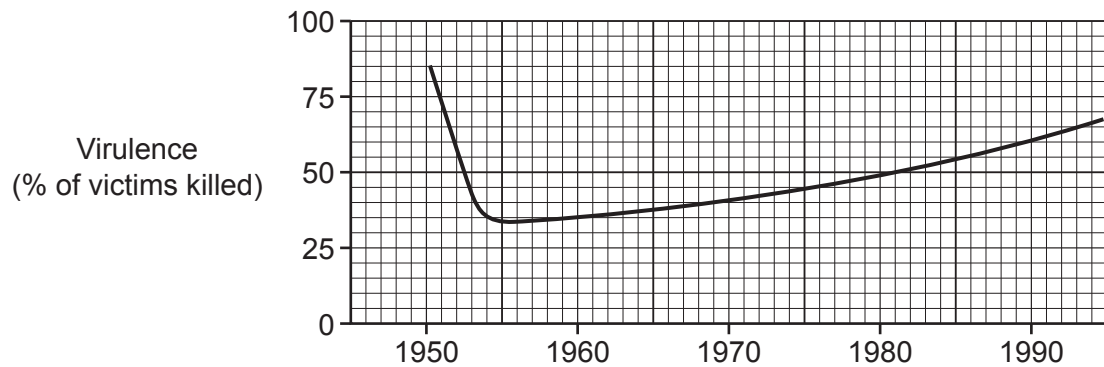
(b) HIV is a retrovirus but MYXV is not.

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]

- (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.

Virulence decreased steeply from 85% in 1950 to about 35% in 1955.
It then increased gradually (slowly and steadily) from 1955 to about 60%
in 1990.

[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.

Immunological: rabbits that survive infection produce memory T and B
cells, so they are immune if reinfected.
Genetic: rabbits with alleles for resistance to MYXV survive and
reproduce, so these advantageous alleles are selected for and passed on,
and the allele frequency increases in the population.

[2]

- (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).

Vaccination involves giving the poultry antigens from the pathogen, e.g. a live attenuated (weakened) MDV vaccine, an inactivated virus or a subunit vaccine. This causes a primary immune response in which memory T and B cells are formed. If the birds are later exposed to MDV, there is a rapid secondary immune response with fast production of large amounts of antibodies, which destroys the pathogen before it can cause disease or death. [3]

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

Vaccinated birds can still be infected and transmit the virus (the vaccine does not destroy it), so unvaccinated birds or flocks could become infected. Also, MDV has a high mutation rate, leading to antigen variability, so antibodies produced by vaccination are no longer specific. [2]

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

For: susceptible birds would die before they could infect other birds, so hypervirulent strains could not be transmitted or persist. Resistant birds (imperfect resistance) are more likely to encourage the evolution of more virulent pathogens, as happened with MYXV in rabbits.

Against: evolution of virulence may not matter for resistant (vaccinated) birds, as losses today are lower despite hypervirulent MDV. Hypervirulent pathogens could threaten non-resistant (non-GMO) flocks, e.g. organic farms, which raises ethical issues. Susceptible birds may also be susceptible to related or similar pathogens.

[4]

- 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.

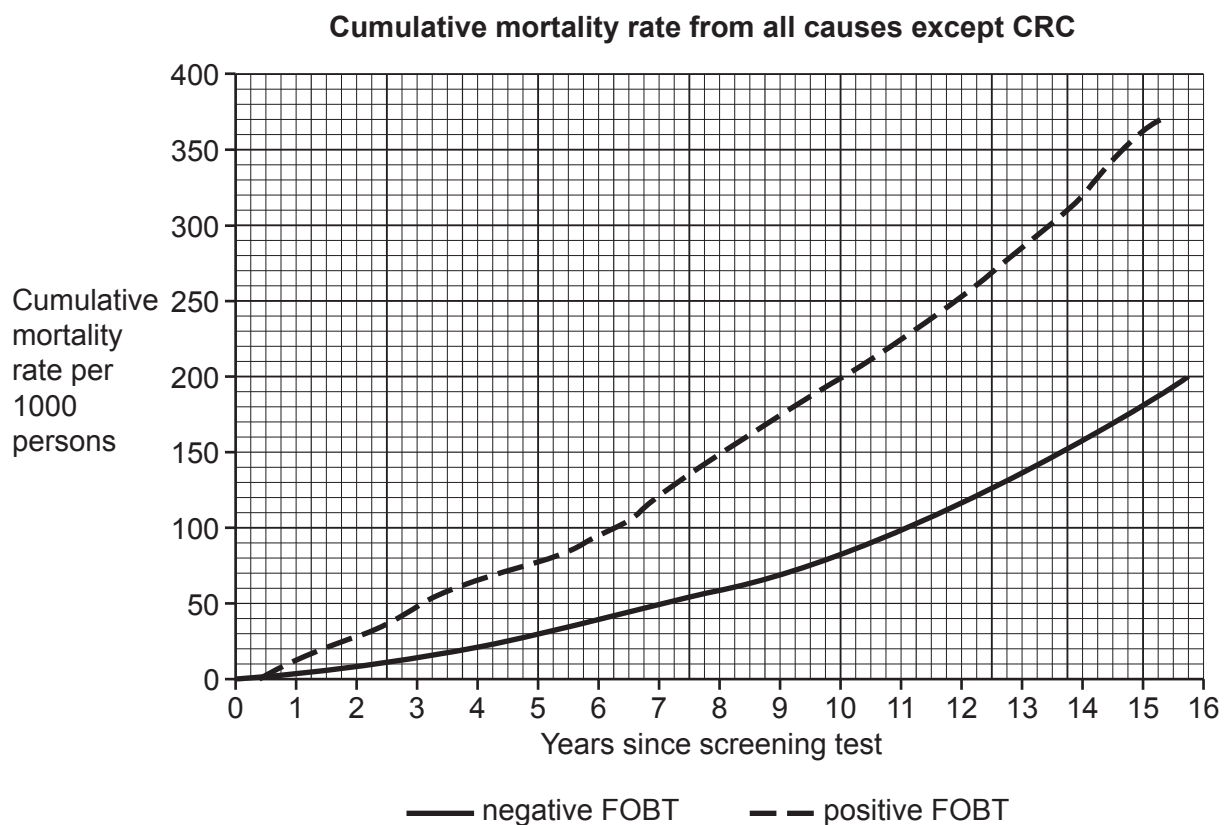
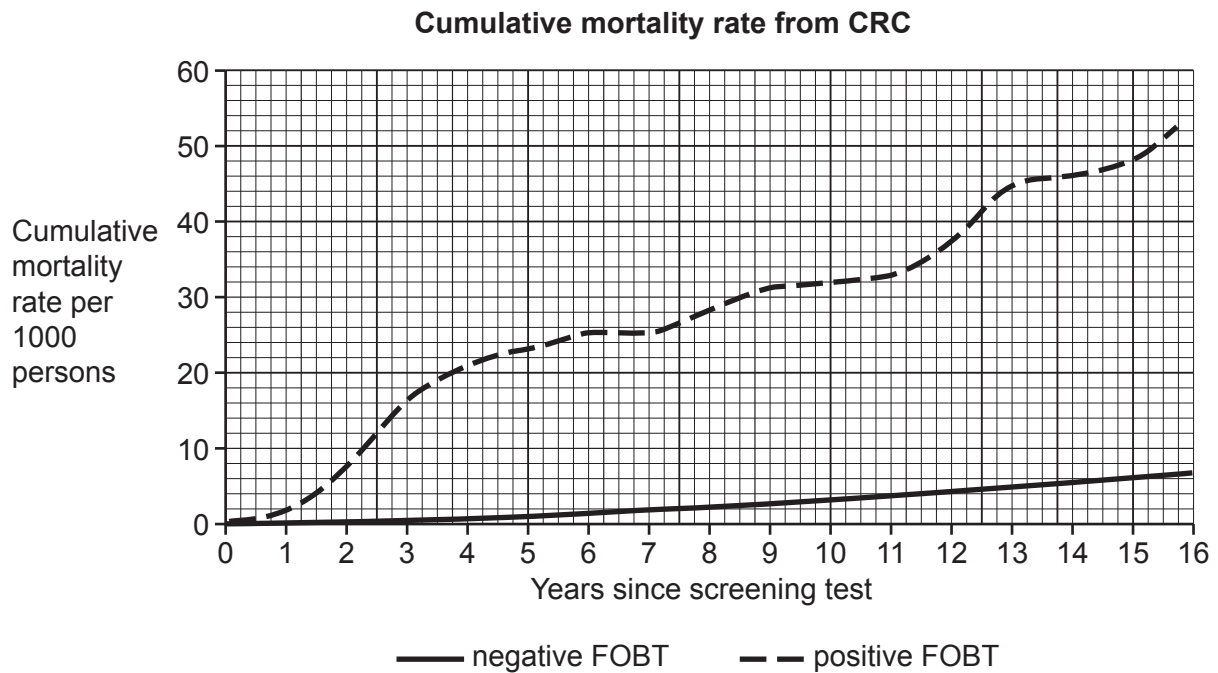
Use a colonoscopy (endoscopy) to look inside the colon and remove a
 biopsy sample of tissue.
 Examine the sample under a microscope (histology) to observe
 cancerous cells.

[2]

PLEASE DO NOT WRITE ON THIS PAGE

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

- (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.



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.

Yes: the cumulative mortality rate from all causes except CRC is higher in the positive FOBT group, about 350 per 1000 compared with about 185 per 1000 at 15 years. But there is no evidence that these deaths are linked to inflammation of the gut. [2]

- (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.

For: there is a correlation between a positive FOBT and risk of death from CRC (about 53 compared with 7 per 1000 at 16 years). The initial screening is non-invasive and the test can be done at home. Against: a positive result still needs confirmation by other means, e.g. colonoscopy. There is a risk of false negatives and false positives; the test does not identify all cases of CRC and may not be done correctly. There could be a high cost, many people may not want to do the test and people may not attend follow-up screening. [4]

(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.

Cell division is controlled by proto-oncogenes and tumour suppressor genes. Cancer develops when mutations in these genes cause uncontrolled cell division (mitosis), forming a tumour. Proto-oncogenes normally stimulate cell division: they control the production of growth factors, cyclins and CDKs, and activate DNA replication. A mutation can turn a proto-oncogene into an oncogene that is permanently switched on, so cell division is stimulated all the time, even without growth factors. Examples are Ras, which keeps signalling the cell to divide, and c-Myc. Tumour suppressor genes normally slow the rate of cell division and stimulate apoptosis of cells with damaged or faulty DNA. For example, the p53 gene (TP53 protein) stops the cell cycle at checkpoints so DNA can be repaired, or triggers apoptosis; BRCA1 and BRCA2 code for DNA repair proteins. If a mutation inactivates both alleles, cells with damaged DNA are not stopped or destroyed, so they keep dividing and gain further mutations. [6]

Additional answer space if required.

Usually mutations in several of these genes build up, so the cell loses control of division and a malignant tumour forms.

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

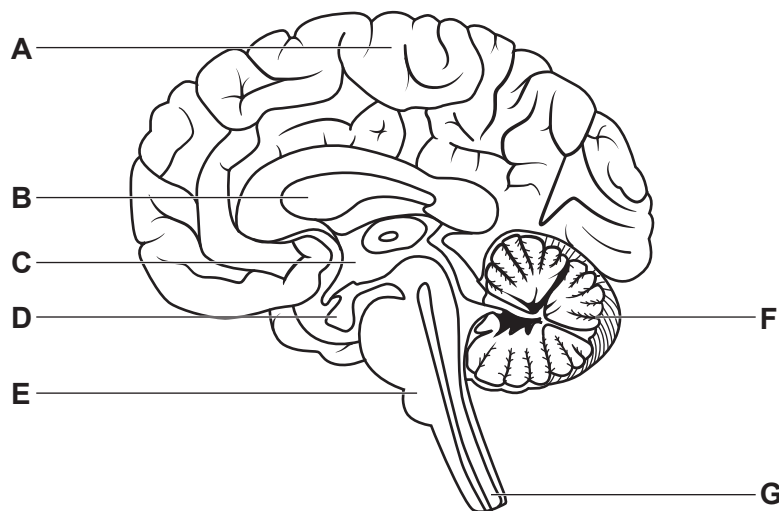


Fig. 3.1

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.	A
Temperature-sensitive neurones are located in this area of the brain.	C
Traumatic injury to this area can lead to over- or under-production of sex hormones.	D
This region of the brain controls heart rate and breathing rate.	E
Stroke affecting part of this area of the brain could cause loss of conscious control of muscles in the arms or legs.	A

[4]

- (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 0°C. The man had a weak pulse. A paramedic measured the man's core body temperature as 34.2°C.

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

Use a tympanic (ear) thermometer, which measures the temperature of the eardrum. This is accurate because the eardrum shares its blood supply with the thermoregulatory centre in the hypothalamus, so it reflects core temperature. [2]

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

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

Hypothermia is when core body temperature falls below the normal range, below 35 °C (his was 34.2 °C). In the cold room he lost heat by radiation, convection and conduction faster than he generated it, and in an elderly person shivering and vasoconstriction are weaker. As body temperature falls, enzyme-controlled metabolic reactions slow down because molecules have less kinetic energy, so there are fewer enzyme-substrate collisions. So less metabolic heat is generated and body temperature falls further: this is positive feedback. Heart rate slows (weak pulse) and shivering stops. Treatment raises body temperature gradually: move him to a warm room, remove any wet clothing and wrap him in warm, dry blankets. Apply warm compresses to the neck, groin and chest, and give warm, non-alcoholic drinks if conscious. Do not heat the arms and legs, as this forces cold blood back towards the major organs. Give expired air resuscitation if he stops breathing. [6]

Additional answer space if required.

(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.

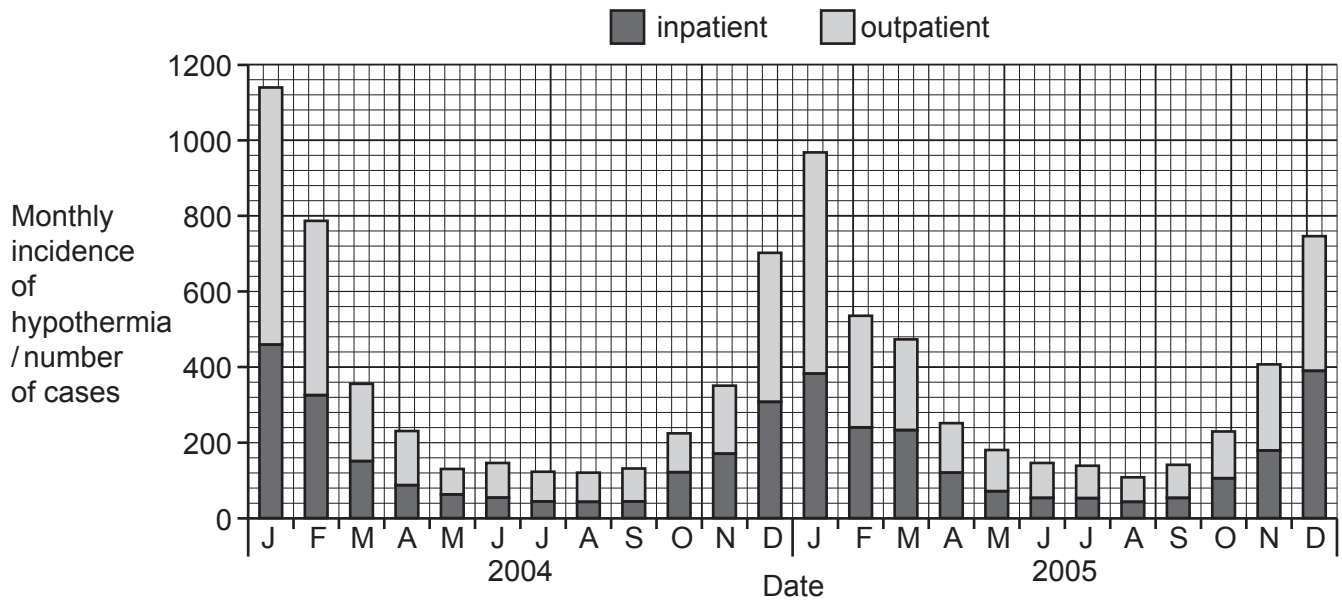


Fig. 3.2a

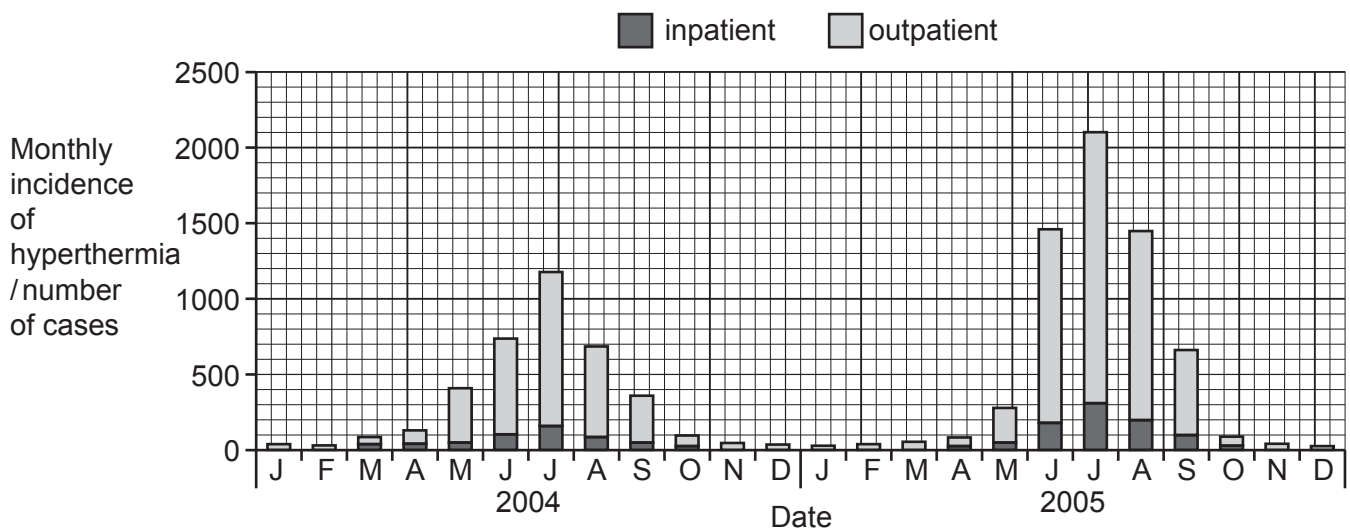


Fig. 3.2b

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

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

Most cases of hypothermia occur in winter (peak in January) and most cases of hyperthermia in summer (peak in July), because of seasonal trends in temperature.

The incidence of hyperthermia is greater: peak about 2100 cases per month compared with about 1140 for hypothermia.

There is still some hypothermia in summer (over 100 cases per month), but almost no hyperthermia in winter.

[3]

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

A higher proportion of hypothermia patients required hospital admission (about 40% compared with about 15%).

Hypothermia is usually more life-threatening, and it is more likely to affect older, more vulnerable patients.

[2]

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

Discuss the student's conclusion.

There was an increase in hyperthermia between 2004 and 2005 (peak 1200 rising to 2100 cases), and climate change (global heating) could increase the incidence of hyperthermia.

However, there is no evidence about average summer temperatures, and only 2 years' data is not enough to draw a valid conclusion; it could be one hot summer or increased reporting.

[3]

- 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.

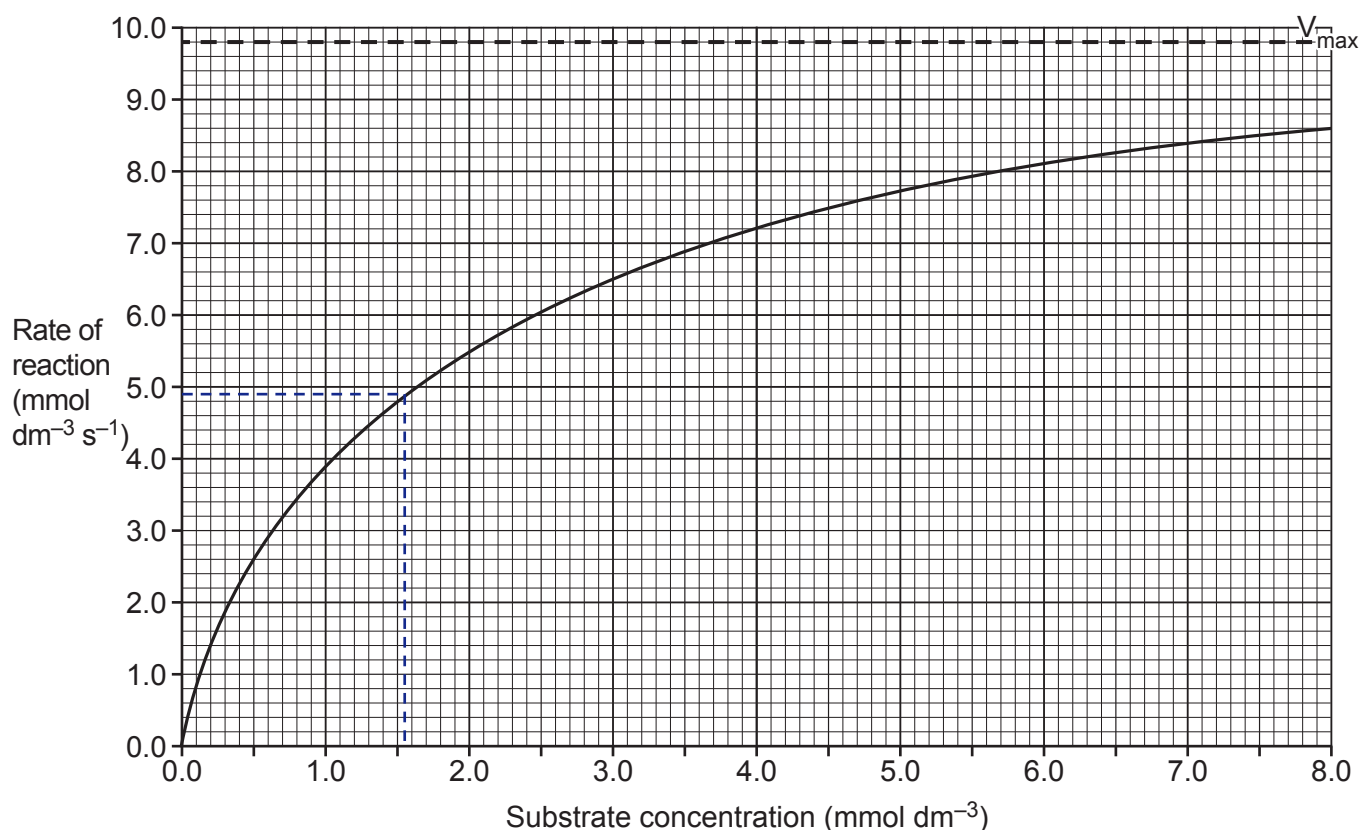


Fig. 4.1

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

Repeat with a range of substrate concentrations, using a colorimeter to measure the absorbance (concentration) of the coloured product. Use a standard (calibration) curve to convert absorbance to concentration. Measure the rate of appearance of product: plot concentration against time and draw a tangent at the start for the initial rate. Keep all other conditions constant, e.g. temperature, pH, enzyme concentration.

[3]

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

So that enzyme concentration is not a limiting factor; only substrate concentration limits the rate. [1]

- (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.

$$V_{\max} = 9.8, \text{ so } \frac{1}{2} V_{\max} = 4.9 \text{ mmol dm}^{-3} \text{ s}^{-1}$$

reading across from 4.9 to the curve and down gives 1.55

$$K_M = \text{.....1.55..... units } \text{mmol dm}^{-3} \text{ [2]}$$

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

The curve never reaches $V_{\max}$; it is asymptotic, flattening out more and more slowly.
It is difficult (impossible) to reach a high enough substrate concentration, e.g. limited substrate solubility, so the maximum rate is never achieved. [2]

- (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**.

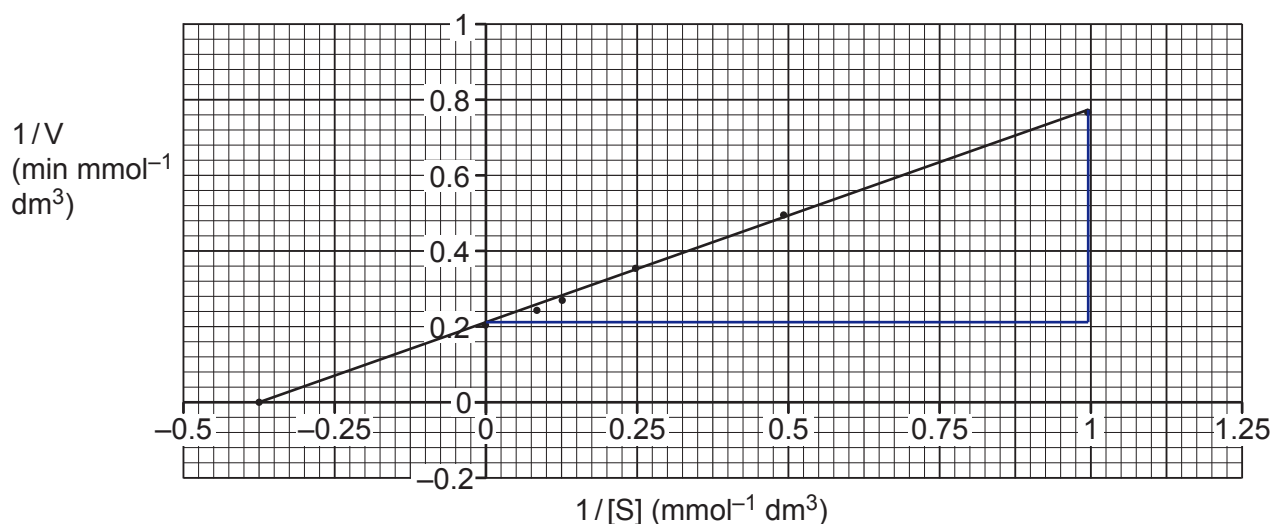


Fig. 4.2

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.

$$\begin{aligned} \text{gradient} &= \Delta y \div \Delta x \\ &= (0.75 - 0.20) \div (1.00 - 0) \\ &= 0.55 \end{aligned}$$

Gradient = ...0.55..... [1]

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

$\text{gradient} = K_M / V_{\max}$ [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.

$$K_M = \text{gradient} \times V_{\max}$$

$$= 0.55 \times 5$$

$$K_M = \text{.....} 2.75 \text{..... (units not required) [2]}$$

- 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 *expressed*.

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

Some epigenetic changes can be inherited if they are present in *gametes*..... [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.

Supports: a mutation is unlikely to have occurred in many parents or to affect all the offspring, whereas DNA methylation or acetylation of histones could have occurred in all 20 parents exposed to hypoxia. This could activate or inhibit expression of genes related to resistance to hypoxia. But lack of oxygen is a selective pressure, and biochemical evidence of epigenetic changes in the offspring is needed.

..... [3]

- (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.

prophase (of mitosis) [1]

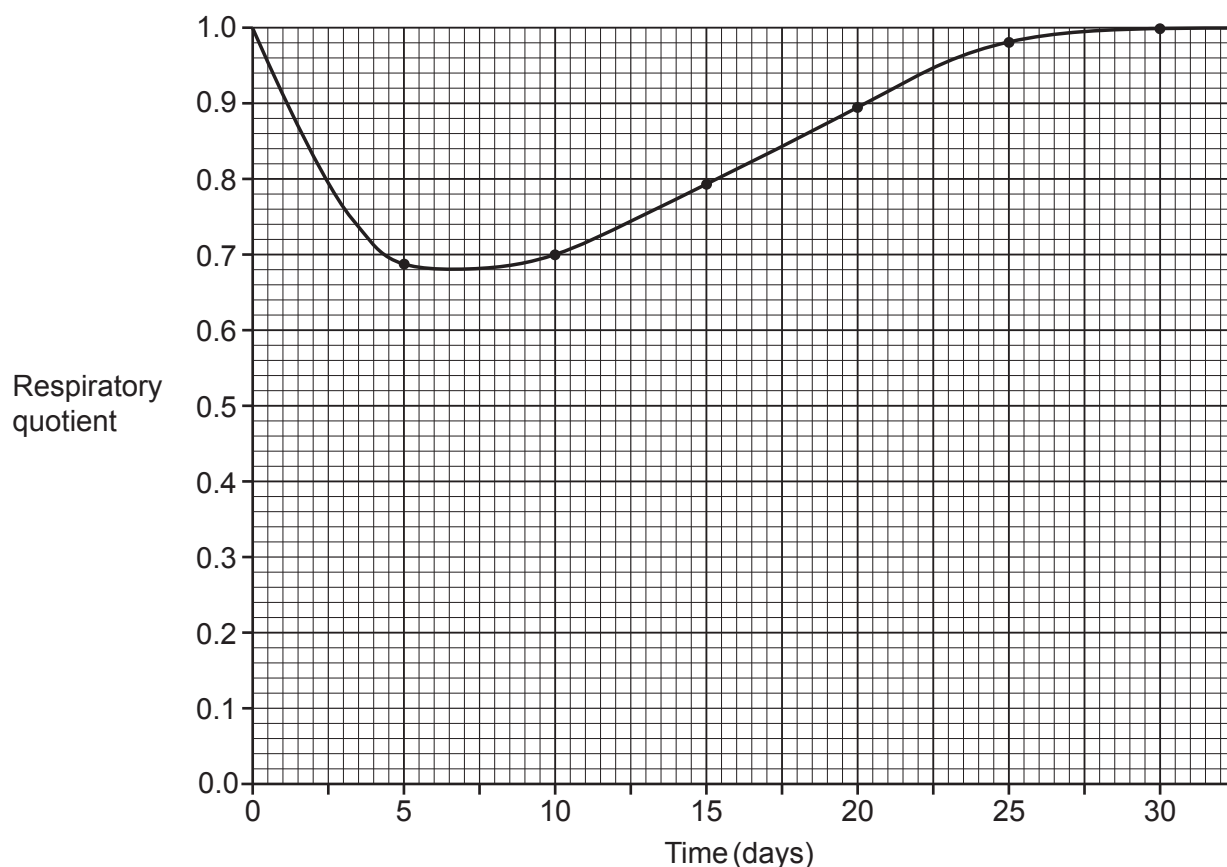
- (ii) The *OdsH* gene causes male sterility in *D. simulans* – *D. mauritiana* hybrids.

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

OdsH causes epigenetic changes that alter gene expression, affecting
chromosome condensation, which stops meiosis (gamete formation) in
the hybrids.
So the hybrid males are infertile (sterile), and no gene flow occurs
between the two species: they are reproductively isolated.
So the species diverge and remain separate.
 [3]

- 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.

respirometer..... [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.

*Partly: protein could be the respiratory substrate between 0 and 5 days
and 10 and 25 days, where an RQ between 0.72 and 1.0 might be
due to a mixture of substrates.
But it is not the substrate at the start of germination or after 25
days, as RQ = 1.0.*..... [2]

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

Take samples of seeds at different times during germination and
 measure their protein content,
 e.g. using the Biuret test (with a colorimeter) or protein test strips.
 [2]

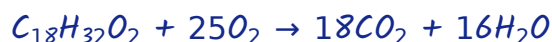
- (iv) What can you conclude from the graph about the respiratory substrates, other than protein, that are used during germination?

At the start of germination (time zero) $RQ = 1.0$, so carbohydrate
 (starch) was being respired.
 Between 5 and 10 days RQ is about 0.7, so fats (lipids, oils) are
 being respired.
 Between 0 and 5 days and 10 and 25 days a mixture of substrates is
 respired.
 From about 25 days onwards $RQ = 1.0$, so carbohydrate is being
 respired. [3]

- (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.



$$RQ = CO_2 \text{ produced} \div O_2 \text{ used}$$

$$= 18 \div 25$$

$$RQ = \dots\dots\dots 0.72 \dots\dots\dots [2]$$

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

RQ would increase (above 0.72).

Because less oxygen would be used: anaerobic respiration produces CO_2

without using oxygen.

..... [2]

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 <i>Haemophilus influenzae</i> 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]

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

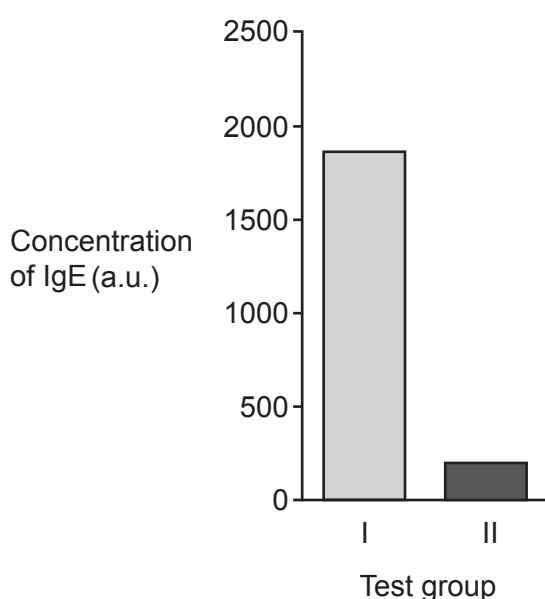
They used a model system of asthma called allergic airway disease (AAD).

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.

Student's t-test,
because they are testing for a difference between the means of two
groups (mean data).

[2]

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

Group 1,
because they had the highest concentration of IgE, meaning the
highest allergic response.
[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.

Yes: breastfeeding by mothers with AAD (allergic mothers) reduces the
degree of AAD in offspring, so something in breast milk, e.g.
antibodies, must protect against allergic reactions.
But humans may not respond in the same way as mice, and the
results may only apply to allergic mothers passing on immunity to
allergy, not to all breastfeeding.
[3]

END OF QUESTION PAPER

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