H2

MINISTRY OF EDUCATION, SINGAPORE
in collaboration with
CAMBRIDGE INTERNATIONAL EDUCATION
General Certificate of Education Advanced Level

CANDIDATE NAME	

CENTRE NUMBER	S					INDEX NUMBER					

0123456789

BIOLOGY **9477/02**

Paper 2 Structured Questions **For examination from 2026**

SPECIMEN PAPER **2 hours**

You must answer on the question paper.

No additional materials are needed.

INSTRUCTIONS

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and index number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen. Do **not** use correction fluid or tape.
- Do **not** write on any bar codes.
- You may use an approved calculator.

INFORMATION

- The total mark for this paper is 90.
- The number of marks for each question or part question is shown in brackets [ ].

This document has **28** pages. Any blank pages are indicated.

Answer **all** questions.

1 Peptic cells from the lining of the mammalian stomach secrete the enzyme precursor pepsinogen. Some of these cells were isolated and maintained in a culture solution containing radioactively labelled amino acids. Samples of the cells were taken at regular intervals and prepared for electron microscopy. Figure 1.1 shows a drawing from an electron micrograph of a peptic cell treated in this way. The time taken, in minutes, for radioactivity to be detected in the various cell organelles viewed under the electron microscope is shown in brackets after each label.

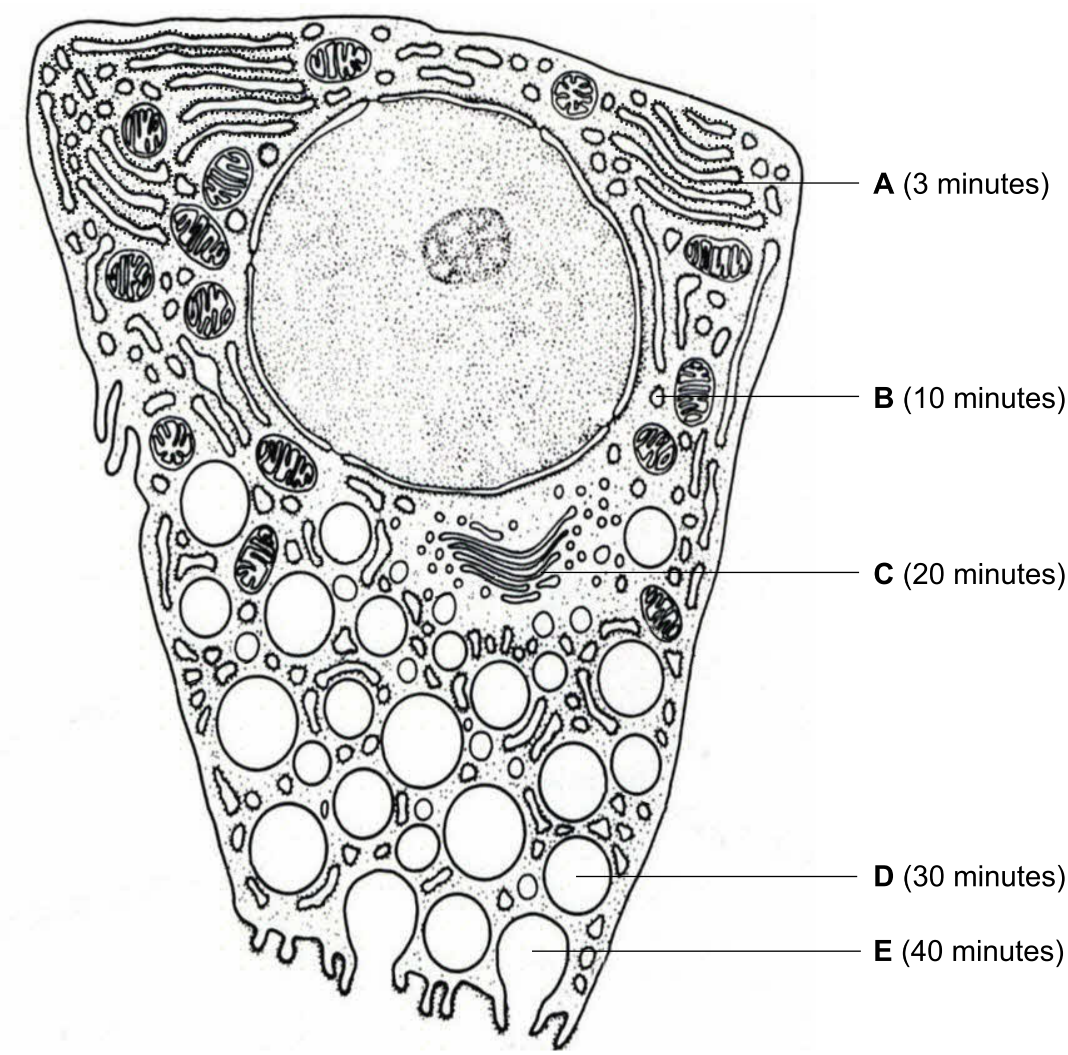

Figure 1.1

(a) State the names of the organelles labelled **C** and **D** in Figure 1.1.

C ....

D ....

[2]

(b) Explain the detection of radioactivity at different times in the organelles labelled **A** and **B**.

....

....

....

....

....

....

....

....

.... [4]

(c) Describe how the material in the organelle labelled **D** passes out of the cell.

....

....

....

....

....

....

.... [3]

[Total: 9]

2 Figure 2.1 shows the results of an experiment investigating the effect of temperature on an enzyme catalysed reaction. The same starting concentration of substrate and the same starting concentration of enzyme were used for each temperature tested. Reactions were kept at different temperatures for periods of one, two and five hours, after which the quantities of product formed were determined.

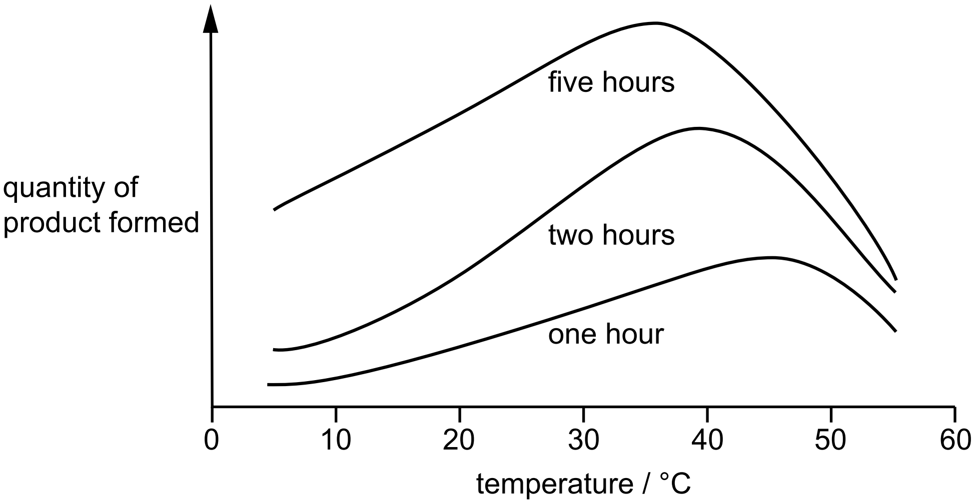

Figure 2.1

(a) Explain the effect of increasing temperature on the quantity of product formed after one hour.

....

....

....

....

....

....

....

.... [4]

(b) Explain the change in the optimum temperature of the reaction as the time increases from one hour to five hours.

....

....

....

....

.... [2]

(c) Figure 2.2 shows the effect of increasing substrate concentration on the initial rate of an enzyme catalysed reaction. All other variables were unchanged.

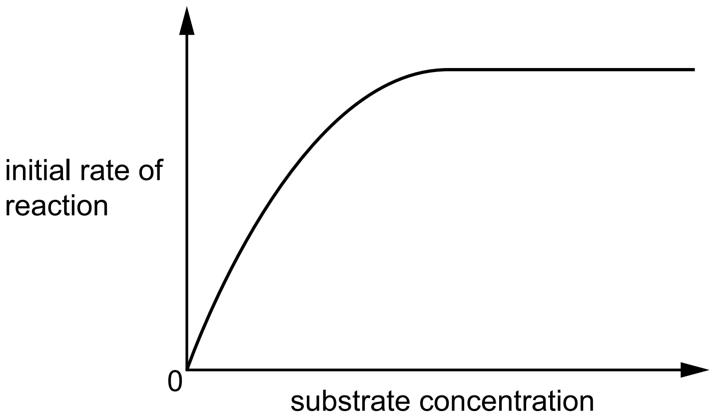

Figure 2.2

Explain why, at high substrate concentrations, an increase in substrate concentration does not increase the initial rate of reaction.

....

....

....

....

.... [2]

[Total: 8]

3 Figure 3.1 shows the DNA base sequences of part of the *H-ras* proto-oncogene and the same part of the *H-ras* oncogene. The *H-ras* oncogene arises from the *H-ras* proto-oncogene by mutation.

Figure 3.1 also shows the corresponding parts of the primary structures of the ras proteins encoded by the *H-ras* proto-oncogene and the *H-ras* oncogene.

DNA base sequence of part of the *H-ras* proto-oncogene:
ATG ACG GAA TAT AAG CTG GTG GTG GTG GGC GCC GGC GGT GTG GGC

corresponding part of the ras protein primary structure encoded by the *H-ras* proto-oncogene:
met thr glu tyr lys leu val val val gly ala gly gly val gly

DNA base sequence of part of the *H-ras* oncogene:
ATG ACG GAA TAT AAG CTG GTG GTG GTG GGC GCC GTC GGT GTG GGC

corresponding part of the ras protein primary structure encoded by the *H-ras* oncogene:
met thr glu tyr lys leu val val val gly ala val gly val gly

Figure 3.1

(a) Explain how the mutation shown in Figure 3.1 may change the structure and function of the ras protein.

....

....

....

....

....

....

.... [3]

(b) Uncontrolled cell division can result from gain of function mutations or from loss of function mutations.

Describe the differences between these two types of mutation.

....

....

....

....

.... [2]

(c) State **two** factors that can cause mutations.

1 ....

2 ....
[2]

(d) Burkitt's lymphoma is a type of tumour of B lymphocytes caused by a mutation that usually involves chromosomes 8 and 14.

In most cases of Burkitt's lymphoma, the proto-oncogene *c-myc* is converted to an oncogene when it is moved from its normal position on chromosome 8 to chromosome 14, as shown in Figure 3.2.

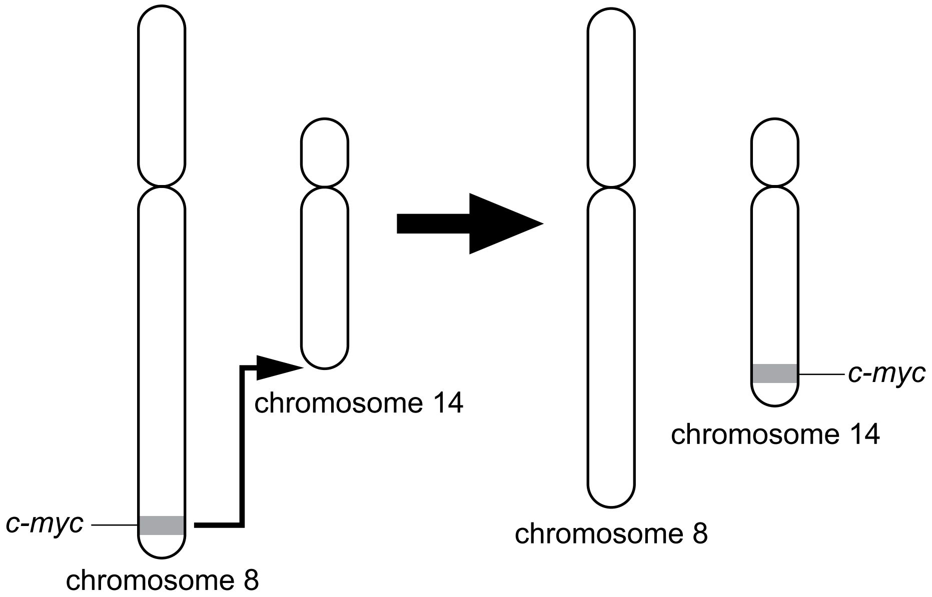

Figure 3.2

This places the *c-myc* gene in a region of highly active gene transcription, resulting in the overproduction of the *c-myc* protein, a transcription factor essential for mitosis of mammalian cells. This turns the lymphocyte cancerous and results in a clone of cancer cells.

Using the details provided in Figure 3.1 and Figure 3.2, describe how this mutation of the *c-myc* proto-oncogene to an oncogene differs from the mutation of the *H-ras* proto-oncogene to an oncogene.

....

....

....

....

.... [2]

(e) Figure 3.3 shows the effect of different combinations of the oncogenes *c-myc* and *H-ras* in three groups of mice.

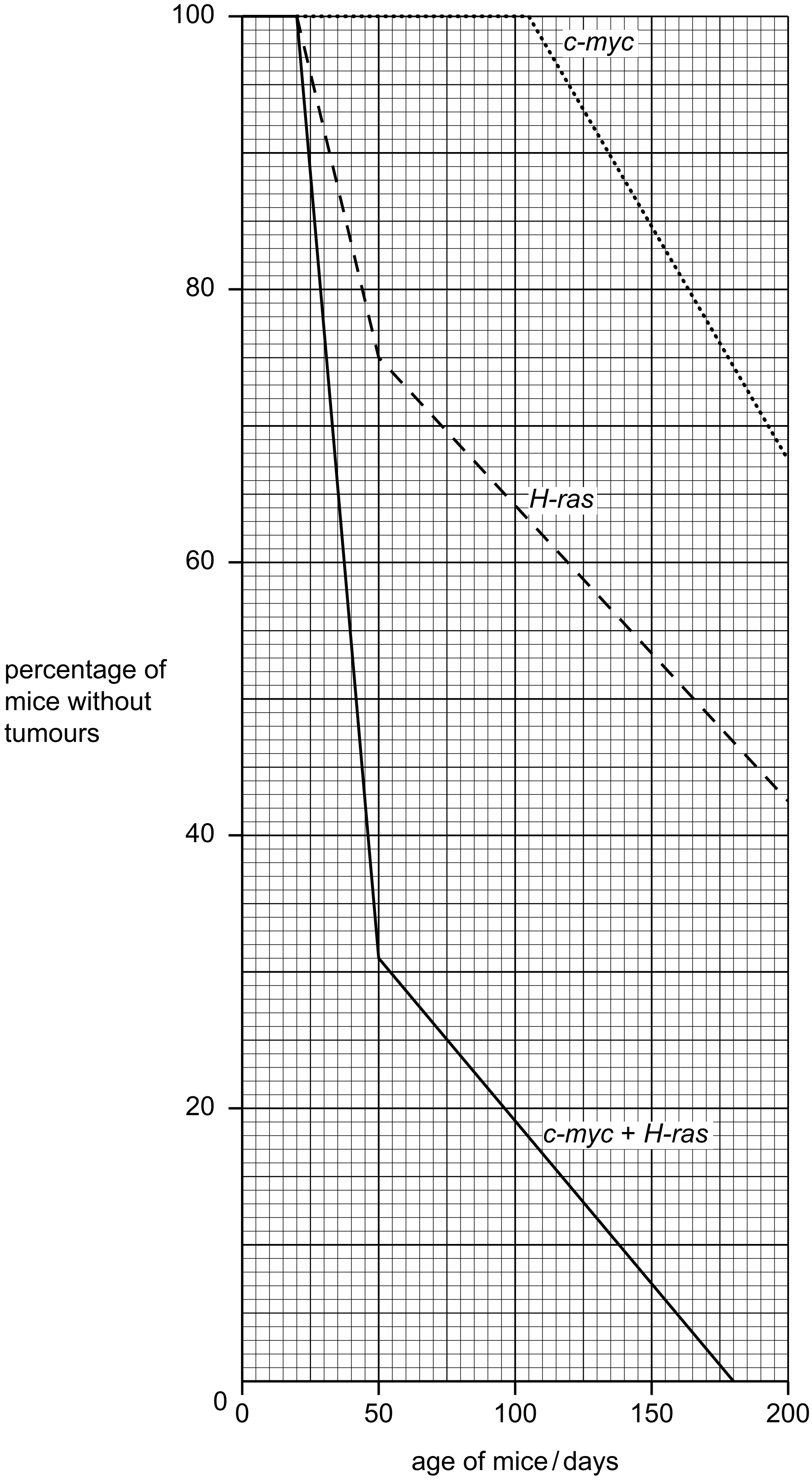

Figure 3.3

With reference to Figure 3.3, describe differences between the effects of *c-myc*, *H-ras* and a combination of *c-myc* and *H-ras* in causing tumours in mice.

....

....

....

....

....

....

.... [3]

[Total: 12]

BLANK PAGE

4 Following self-pollination, an isolated maize plant produced a total of 380 grains with four different phenotypes.

The expected phenotypic ratio of the offspring (grains) of this cross was:

9 purple, smooth : 3 purple, shrunken : 3 yellow, smooth : 1 yellow, shrunken

(a) Draw a genetic diagram in the space provided to show the genotype of the isolated maize plant and how self-pollination of this maize plant could produce the expected phenotypic ratio of grains.

Use these symbols to represent the alleles:

A	purple	**a**	yellow
B	smooth	**b**	shrunken

[4]

(b) Some plants grown from purple, smooth grains produce only purple, smooth grains when self-pollinated. These plants are said to be true breeding.

Other plants grown from purple, smooth grains produce grains with a variety of phenotypes when self-pollinated.

Using your genetic diagram from **(a)**, calculate the percentage of the purple, smooth grains that would be expected to grow into true breeding maize plants.

percentage expected to grow into true-breeding maize plants = ...% [1]

Table 4.1 shows the actual number of grains with each phenotype obtained when the isolated maize plant was self-pollinated.

Table 4.1

phenotype	number
purple, smooth grains	216
purple, shrunken grains	78
yellow, smooth grains	65
yellow, shrunken grains	21
total	380

A chi-squared test was carried out to test whether the observed numbers of each phenotype (O) were significantly different from the expected numbers (E) for a phenotypic ratio of 9 : 3 : 3 : 1.

The equation used to calculate the chi-squared value (χ^2) is shown:

$$\chi^2 = \sum \frac{(O - E)^2}{E}$$

The steps in this calculation are shown in Table 4.2. Not all of Table 4.2 has been completed.

Table 4.2

column 1 grain phenotype	column 2 observed number (O)	column 3 expected ratio	column 4 expected number (E)	column 5 $\frac{(O - E)^2}{E}$
purple, smooth	216	9		0.024
purple, shrunken	78	3		0.639
yellow, smooth	55	3		
yellow, shrunken	31	1		
total	380	16	380	χ^2 =

(c) Complete Table 4.2 to show:

(i) the expected number (E) for each of the **four** phenotypes in **column 4** [1]

(ii) the **two** missing values for yellow, smooth grains and yellow, shrunken grains in **column 5** [1]

(iii) the chi-squared (χ^2) value in **column 5**. [1]

space for working

(d) Table 4.3 shows part of the table of probabilities for the chi-squared test.

Table 4.3

degrees of freedom	**probability**						
	0.50	**0.20**	**0.10**	**0.05**	**0.02**	**0.01**	**0.001**
1	0.45	1.64	2.71	3.84	5.41	6.63	10.83
2	1.39	3.22	4.61	5.99	7.82	9.21	13.82
3	2.37	4.64	6.25	7.81	9.84	11.34	16.27
4	3.36	5.99	7.78	9.49	11.67	13.28	18.47

The number of degrees of freedom is calculated using this equation.

$$v = c - 1$$

where
v = degrees of freedom
c = number of classes

Use your calculated chi-squared value in Table 4.2 and the data in Table 4.3 to conclude whether the observed number of each phenotype is significantly different to the expected number of each phenotype.

Explain your conclusion.

....

....

....

....

....

....

.... [3]

[Total: 11]

Turn over

5 The unicellular green alga *Chlorella*, a photosynthetic protoctist, has been studied for its potential as a food source.

In one study into the productivity of *Chlorella*, carbon dioxide concentration was varied to investigate its effect on the light-independent stage of photosynthesis.

- A cell suspension of *Chlorella* was illuminated using a bench lamp.
- The suspension was supplied with carbon dioxide at a concentration of 1% for 200 seconds.
- The concentration of carbon dioxide was then reduced to 0.03% for a further 200 seconds.
- The concentrations of RuBP and PGA were measured at regular intervals.
- Throughout the investigation, the temperature of the suspension was kept at 25 °C.

The results are shown in Figure 5.1.

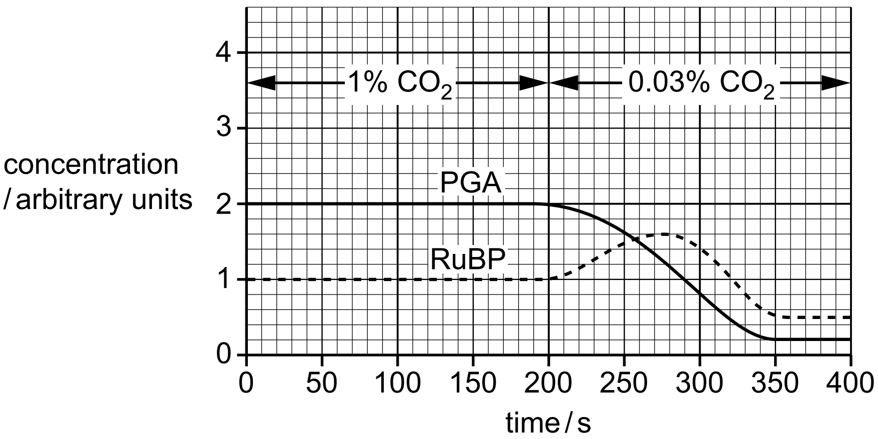

Figure 5.1

(a) State **precisely** where in the chloroplast RuBP and PGA are synthesised.

.... [1]

(b) Explain why the concentration of RuBP changed between 200 seconds and 275 seconds.

....

....

....

....

.... [2]

(c) Calculate the mean rate of decrease in the concentration of PGA between 200 seconds and 350 seconds.

Show your working and give your answer to **two significant figures**.

mean rate of decrease = ... arbitrary units s^{-1} [2]

(d) Explain how the decrease in the concentration of PGA leads to a decreased harvest for commercial suppliers of *Chlorella*.

....

....

....

....

.... [2]

[Total: 7]

6 Figure 6.1 shows movements that take place in a cell during two stages of mitosis in an animal cell. The three curves show changes in distance between:

A the centromeres and the poles of the spindle

B the centromeres of sister chromatids

C the poles of the spindle.

On the time scale, 0 minutes corresponds to the time when chromosomes line up on the equator of the cell.

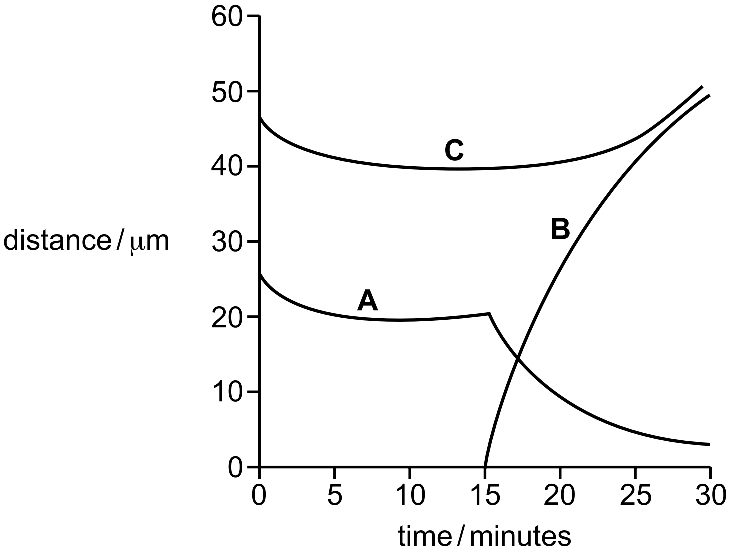

Figure 6.1

(a) With reference to Figure 6.1:

(i) identify the **two** stages of mitosis shown

....

.... [2]

(ii) describe what happens to sister chromatids after 15 minutes.

....

....

....

....

.... [2]

(b) Outline the roles of centromeres.

....

....

....

....

....

....

.... [3]

(c) State **four** ways in which the behaviour of chromosomes in meiosis is different from their behaviour in mitosis.

....

....

....

....

....

....

....

....

.... [4]

[Total: 11]

7 During cellular respiration, NAD is reduced.

(a) Describe the role of NAD in cellular respiration.

....

....

....

....

....

....

.... [3]

(b) Explain why NAD cannot be regenerated from reduced NAD in mitochondria in the absence of oxygen.

....

....

....

....

....

....

.... [3]

(c) Figure 7.1 is a diagram of ATP synthase in the inner mitochondrial membrane.

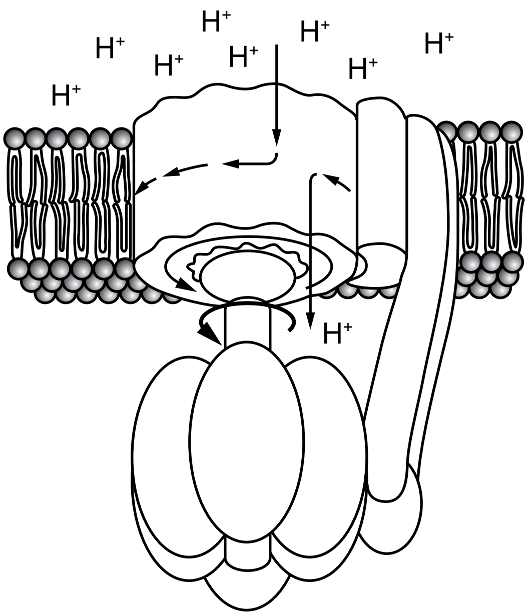

Figure 7.1

(i) Explain how the proton gradient that drives ATP synthesis is produced.

....

....

....

....

....

....

.... [3]

(ii) With reference to Figure 7.1, outline how the proton gradient drives ATP synthesis.

....

....

....

....

....

....

.... [3]

[Total: 12]

BLANK PAGE

8 Over thousands and millions of years, the Earth's climate is subject to natural periods of warming and cooling. Figure 8.1 is a diagram representing two mountains in the tropics during a warm phase and a cool phase in the Earth's climate. The shape of the lines corresponds to a vertical section through the mountains to show their height and shape. The distribution of rain forest vegetation with altitude is shown by the hatched shading.

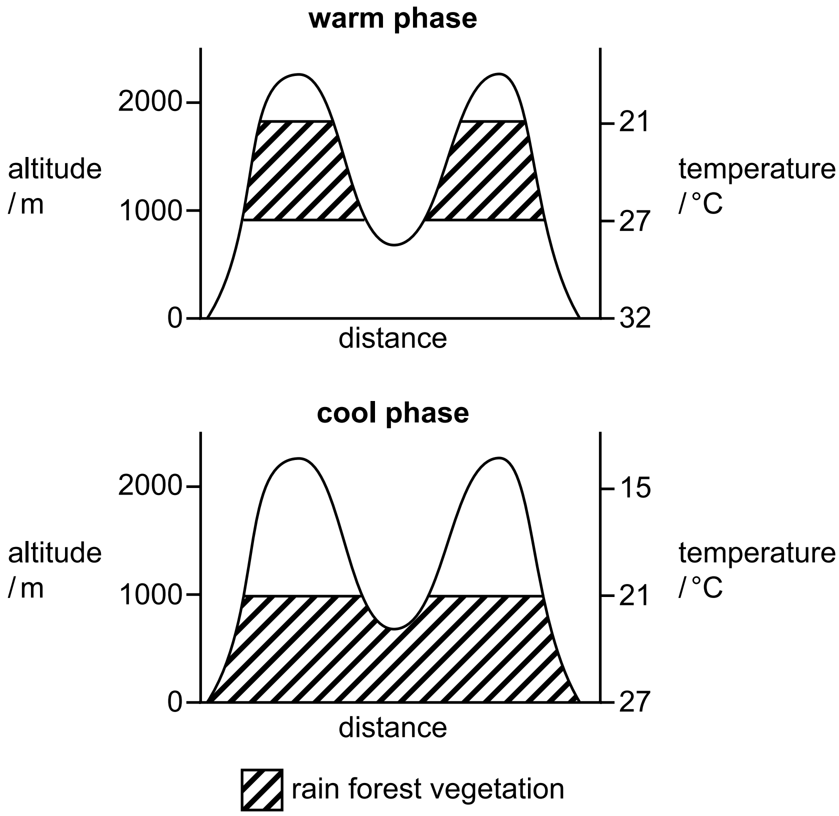

Figure 8.1

(a) Suggest how repeated changes in climate between the warm phase and cool phase shown in Figure 8.1 may lead to the evolution of new species and greater species diversity.

....

....

....

....

....

....

....

....

....

.... [5]

In the last 200 years, the Earth has undergone a new kind of global warming as a result of anthropogenic activities that increase the amount of greenhouse gases in the atmosphere. Some of these activities, such as generating electricity, act directly by releasing greenhouse gases into the atmosphere. Others act indirectly to contribute to increases in greenhouse gases in the atmosphere.

(b) State **one** anthropogenic activity that **indirectly** contributes to increases in greenhouse gases in the atmosphere **and** explain how the activity results in these increases.

activity ....

explanation ....

....

.... [2]

(c) Table 8.1 shows one measure for assessing the carbon footprint of six different energy sources when used to generate electricity. This measure is calculated over the entire life of the device used to generate electricity and is expressed as the total mass of greenhouse gases (grams of carbon dioxide equivalent) released for each megajoule (MJ) of electricity generated ($g\ CO_2e\ MJ^{-1}$).

The figures presented in Table 8.1 are approximate.

Table 8.1

source of energy	carbon footprint / $g\ CO_2e\ MJ^{-1}$
oil	1000
coal	800
gas	500
hydroelectric	25
bioethanol	12
wind	12

(i) Suggest why the carbon footprint in Table 8.1 is measured in terms of an equivalent mass of carbon dioxide.

....

....

....

....

.... [2]

(ii) Bioethanol, oil, coal and gas all release large amounts of carbon dioxide during combustion to generate electricity. However, bioethanol has a much lower carbon footprint than oil, coal and gas.

Explain why bioethanol has a much lower carbon footprint than oil, coal and gas.

....

....

....

....

.... [2]

(iii) At the point of generating electricity, no carbon dioxide is released from hydroelectric power stations or wind turbines.

State **two** reasons why wind power and hydroelectric power have carbon footprints that are greater than zero.

....

....

....

....

.... [2]

[Total: 13]

9 Antibodies and antibiotics are both important in fighting infectious diseases.

(a) State a named example of each.

antibody ....

antibiotic ....
[2]

(b) Figure 9.1 shows the molecular structures of an antibody and an antibiotic drawn to the same scale.

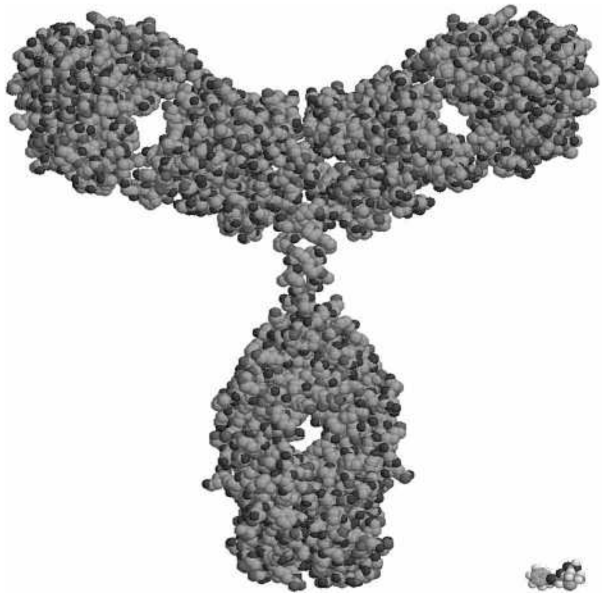

Figure 9.1

Explain how the size and shape of antibody molecules and antibiotic molecules relate to their modes of action and functions.

....

....

....

....

....

....

....

....

....

....

.... [5]

[Total: 7]

BLANK PAGE

