HWA CHONG INSTITUTION
JC2 Preliminary Examinations
Higher 2

CANDIDATE NAME		CT GROUP	21S7__

CENTRE NUMBER					INDEX NUMBER				

BIOLOGY

9744/02

Paper 2 Structured Questions

22 August 2022

Candidates answer on the Question Paper.

2 hours

No Additional Materials are required.

INSTRUCTIONS TO CANDIDATES

Write your **name**, **CT group, Centre number** and **index number** in the spaces provided at the top of this cover page.

There are **eleven** questions.

Answer **all** questions in the spaces provided on the Question Paper.

INFORMATION FOR CANDIDATES

The use of an approved scientific calculator is expected, where appropriate.

You may lose marks if you do not show your working or if you do not use appropriate units.

The number of marks is given in brackets [ ] at the end of each question or part question.

You are reminded of the need for good English and clear presentation in your answers.

For Examiners' Use	
1	/ 9
2	/ 9
3	/ 11
4	/ 9
5	/ 10
6	/ 10
7	/ 11
8	/ 11
9	/ 9
10	/ 5
11	/ 6
Total	/ 100

This document consists of **30** printed pages.

QUESTION 1

Fig. 1.1 shows the structure of amylose, a component of the polymer starch.

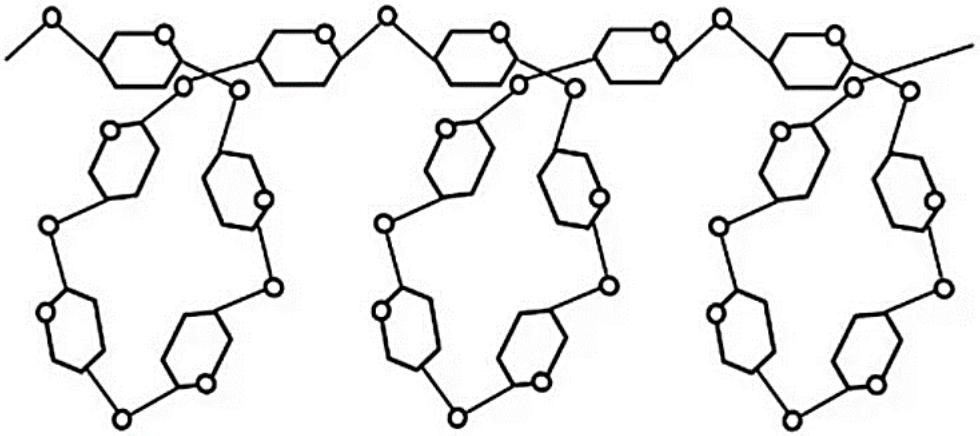

Fig. 1.1

(a) Describe the main features of amylose visible in Fig. 1.1.

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(b) Explain how the structure of amylose makes it suitable for its function.

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Single-stranded amylose in an aqueous solution gradually forms a double helix.

(c) Suggest how the double helix structure of amylose is formed.

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Collagen is another polymer that can be found in living organisms.

(d) (i) State **two** ways in which the structure of collagen differs from the structure of starch.

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(ii) Explain how **one** of the differences stated in **(d)(i)** allows collagen to perform its function.

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[Total: 9]

QUESTION 2

Cell surface membranes are involved with the movement of substances into and out of cells.

Calcium pumps in cell surface membranes maintain a concentration of calcium ions inside the cytoplasm that is a thousand times lower than outside the cell.

Fig. 2.1 shows the movement of calcium ions across a cell surface membrane.

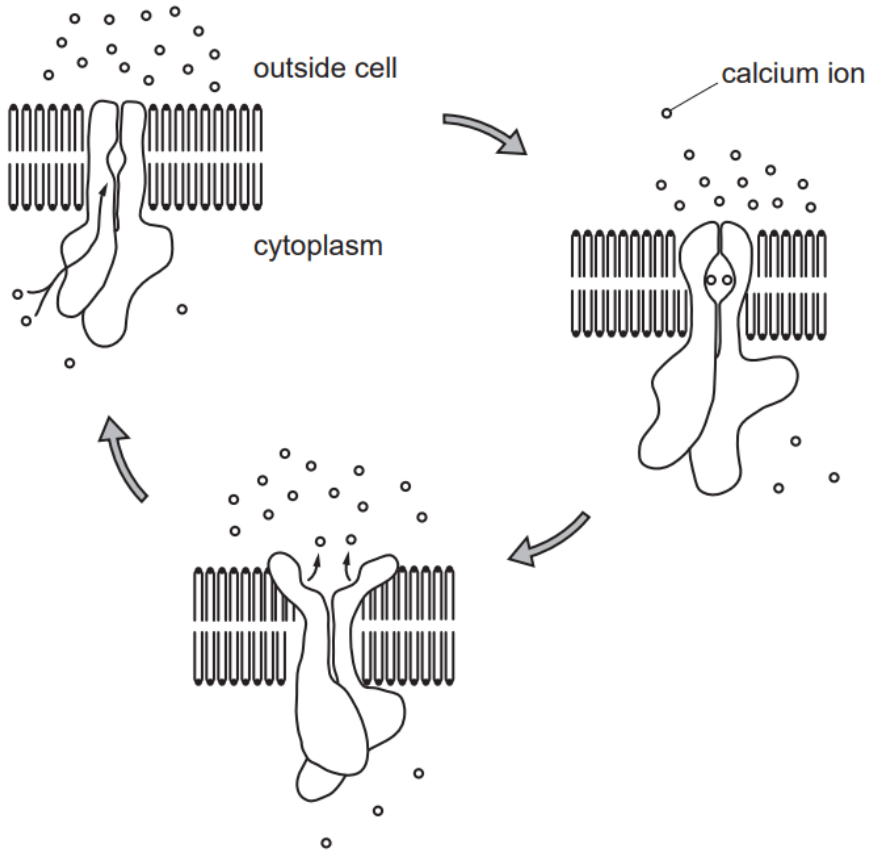

Fig. 2.1

(a) With reference to Fig. 2.1,

(i) explain why calcium ions do not pass through the phospholipid bilayer.

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(ii) state and describe the process by which calcium ions are moved across the membrane.

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(b) With reference to the fluid mosaic model, discuss how high temperature affects membrane permeability.

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[Total: 9]

QUESTION 3

(a) State the central dogma of molecular biology.

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Telomeres are repeating sequences of bases located at the ends of DNA molecules. These repeating sequences do not code for proteins.

The enzyme telomerase ensures that telomeres do not shorten each time DNA is replicated.

Fig. 3.1 shows the end of a DNA molecule during replication. DNA polymerase cannot attach to the region labelled **X**, so it cannot complete the synthesis of the new strand without the action of telomerase.

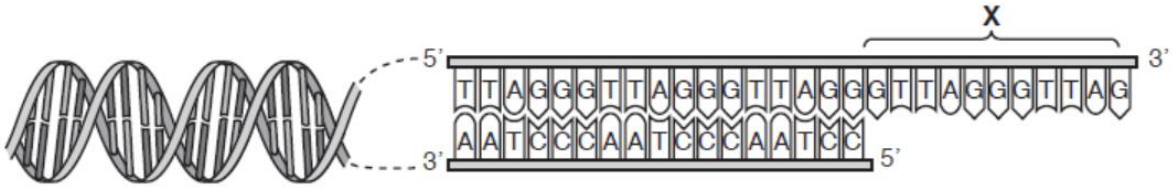

Fig. 3.1

Telomerase synthesises additional lengths of DNA that are added to the telomere. These additional lengths are used by DNA polymerase to complete the process of replication.

Fig. 3.2 is an enlarged view of region **X** to show the action of the enzyme telomerase.

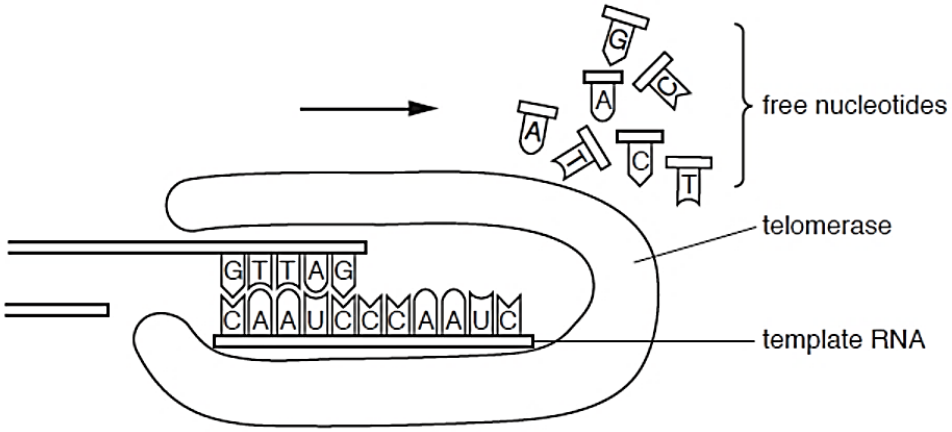

Fig. 3.2

Telomerase contains a short length of RNA that acts as a template for the synthesis of DNA as shown in Fig. 3.2.

(b) Explain how a molecule of telomerase synthesises additional lengths of DNA.

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(c) Explain why the action of telomerase challenges the central dogma of molecular biology.

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(d) Telomerase is not present in prokaryotic cells.

Suggest why prokaryotes do not have telomerase.

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[Total: 11]

QUESTION 4

Influenza and COVID-19 are both contagious respiratory illnesses caused by different viruses. COVID-19 is caused by infection with a coronavirus, SARS-CoV-2, first identified in 2019. Flu is caused by infection with an influenza virus.

Fig. 4.1 shows the structures of the SARS-CoV-2 and influenza virus respectively.

Both **S** and **HA** are glycoproteins embedded in the viral envelope of the respective viruses and serve the same function.

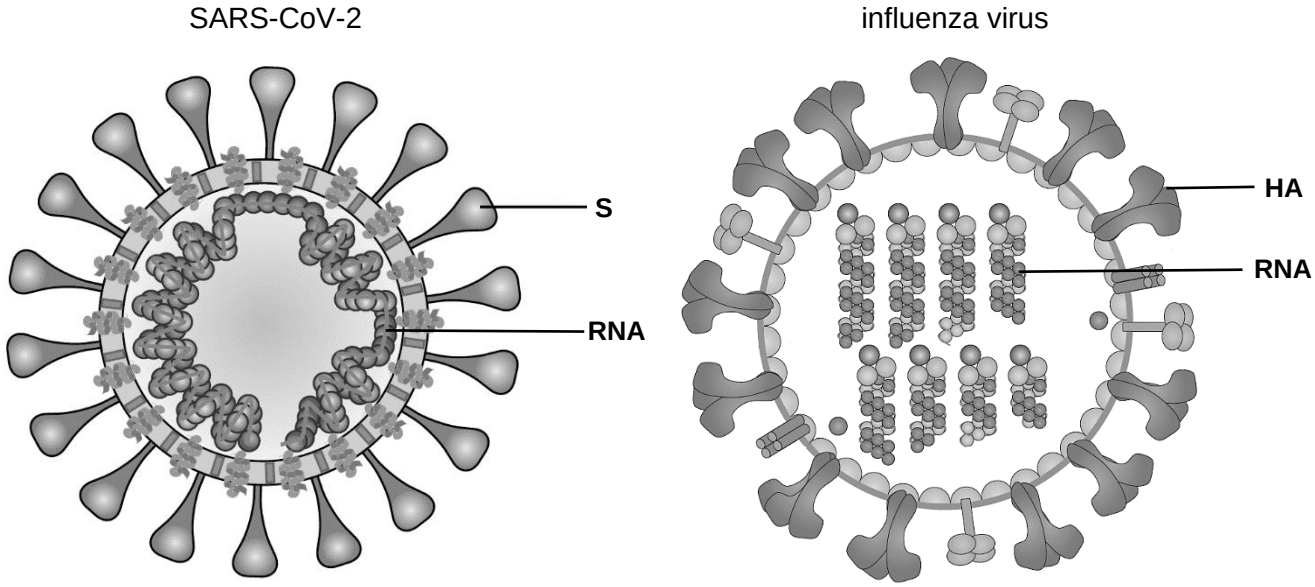

Fig. 4.1

(a) Compare the structures of SARS-CoV-2 and influenza virus.

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Fig. 4.2 shows part of the reproductive cycle of SARS-CoV-2 virus, where the entry of the virus is facilitated by host cell surface receptors, ACE2 and PRS2.

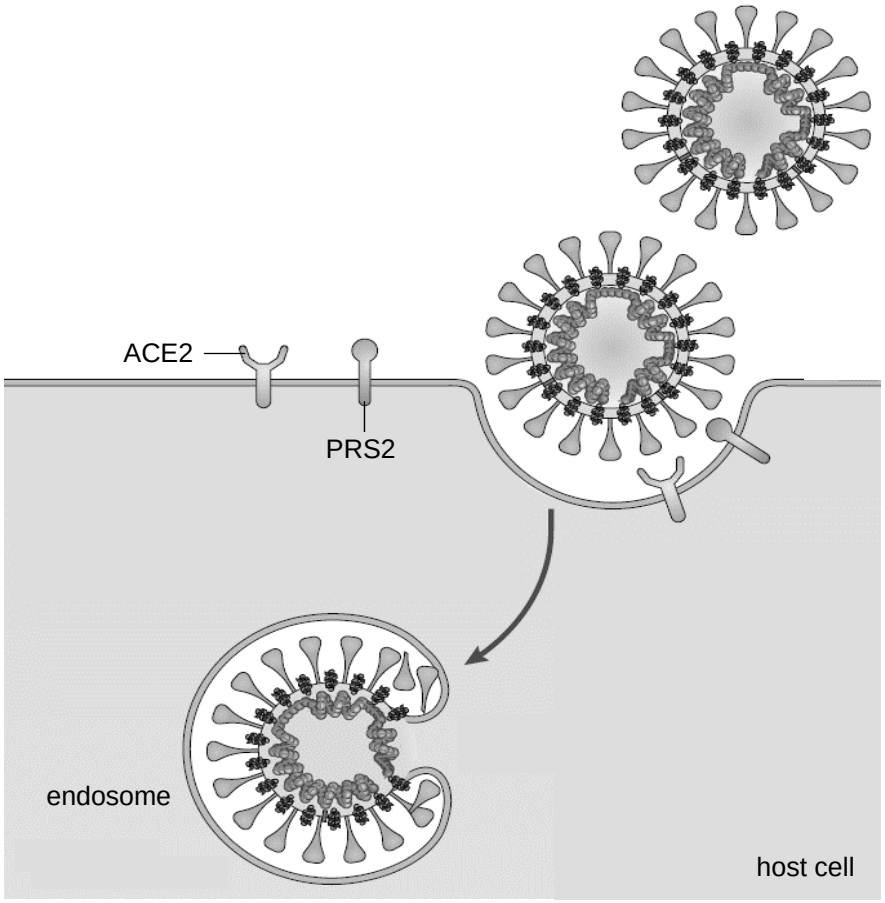

Fig. 4.2

(b) Describe how the SARS-CoV-2 virus enters a host cell.

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(c) There are at least three variants of the SARS-CoV-2 virus since its discovery in 2019.

Identify and describe one type of variation in viral genomes that may lead to the formation of new strains of the SARS-CoV-2 virus.

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[Total: 9]

QUESTION 5

Sickle cell anaemia is an autosomal recessive disorder:

- allele Hb^A codes for the normal β-globin polypeptide of haemoglobin
- allele Hb^S, caused by a base substitution mutation, codes for an abnormal β-globin polypeptide.

People who are heterozygous (Hb^AHb^S) have sickle cell trait (SCT). For a child to inherit sickle cell anaemia (Hb^SHb^S), both parents must have SCT.

The mutation which produces Hb^S changes the sixth codon of the β-globin gene from GAG to GTG.

The abnormal haemoglobin molecules (HbS) form fibres in low partial pressures of oxygen.

(a) Explain how this mutation causes the HbS to form fibres.

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DNA profiling can be used in genetic screening programme for chronic diseases like sickle cell anaemia.

Polymerase chain reaction (PCR) is usually carried out before the extracted DNA can be profiled.

(b) Suggest why PCR may be needed before the extracted DNA can be profiled.

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To test for the presence of Hb^S, PCR is carried out on the extracted DNA with two specific primers. The normal-specific primer detects GAG whereas the mutant-specific primer detects GTG.

(c) (i) Describe the role of primers in PCR.

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(ii) Explain how the use of two specific primers allows the detection of the normal, sickle cell anaemia, and SCT genotypes.

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[Total: 10]

QUESTION 6

Cancer is a disease in which normal control over cellular processes in humans are lost and malignant tumours formed.

(a) Outline how cancer is caused.

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The BRCA2 protein is involved in suppressing the development of tumours. It is encoded for by the tumour suppressor gene, *BRCA2*.

(b) Describe the normal role of the *BRCA2* gene.

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…… [3]

Fig. 6.1 is a pedigree showing the occurrence of cancers in four generations of a family.

The presence of a faulty *BRCA2* allele was confirmed in person 15. The other individuals with cancer were not tested for the presence of the faulty *BRCA2* allele. Individuals 24 to 30 are all under twelve years old.

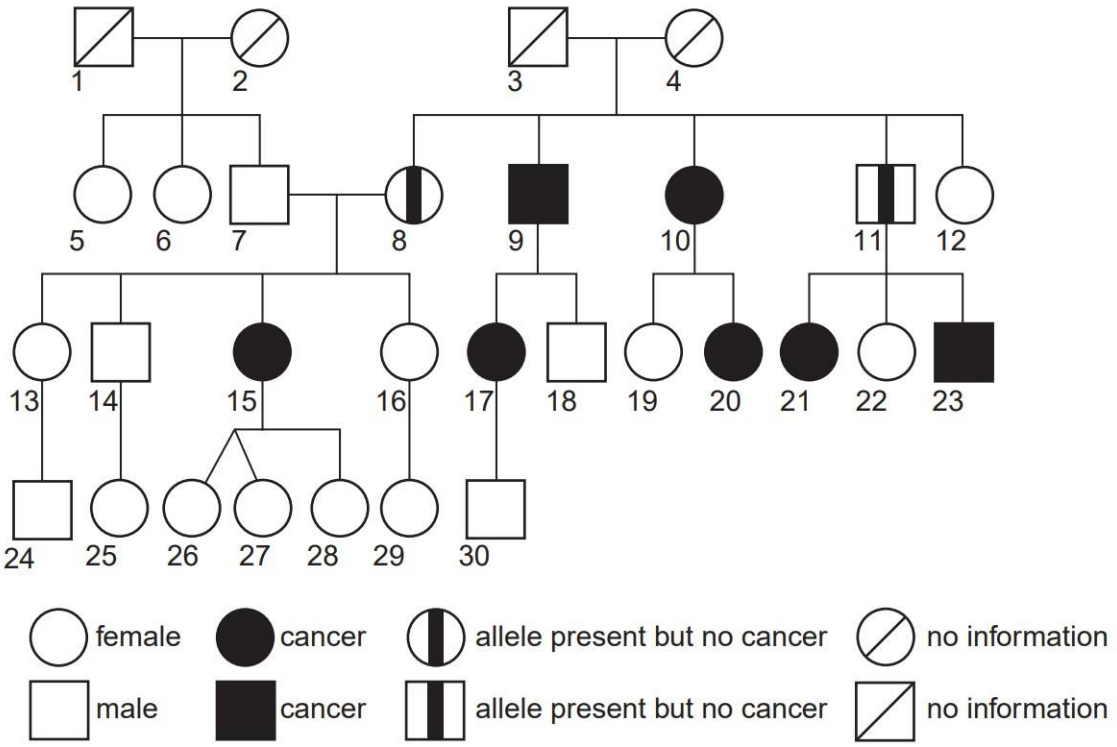

Fig. 6.1

(c) Discuss the extent to which Fig. 6.1 provides evidence that a faulty *BRCA2* allele increases the risk of a person developing cancer.

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[Total: 10]

QUESTION 7

In humans, the control of hair colour involves an epistatic gene interaction.

Allele **M** codes for the production of the pigment eumelanin, which results in black hair. It is dominant to **m**, which codes for the pigment phaeomelanin that results in red hair.

Allele **T** codes for the transporter that is required for the deposition of pigments in hair. Individuals that express the genotype **tt** are unable to deposit pigments and are albinos.

(a) Explain the term *epistatic gene interaction* in this context.

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(b) A couple with black hair has three children, each with a different hair colour.

Draw a genetic diagram to explain these results.

[4]

The cross between two black-haired individuals in part **(b)** is expected to follow a 9:3:4 ratio.

However, scientists believe that the distribution of people with black hair may be more concentrated towards the equator where black hair offers some protection against the sun's stronger UV rays.

A chi-square (χ^2) test was then carried out on 960 volunteers living at the equator to test this hypothesis.

Table 7.1 shows the distribution of hair colour among these 960 individuals.

(c) (i) Complete Table 7.1 to show the expected numbers of individuals with each phenotype.

Table 7.1

hair colour	observed number of individuals	expected number of individuals
black	579	
red	165	
albino	216	

[1]

A chi-square (χ^2) test was carried out to compare the observed results with the expected ratio. The formula for the chi-square (χ^2) test is given as follows:

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

Table 7.2 is the table of probabilities.

Table 7.2

degrees of freedom	probability		
	0.10	0.05	0.01
1	2.71	3.84	6.64
2	4.69	5.99	9.21
3	6.25	7.82	11.35
4	7.78	9.49	13.28

(ii) Using the formula above, calculate the χ^2 value for the observed results. Show your working clearly.

χ^2 value: …… [1]

(iii) Explain the conclusion that may be drawn from your χ^2 value in **(c)(ii)**.

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[Total: 11]

QUESTION 8

Photosynthesis is a complex process involving the transfer of light energy into chemical energy.

It consists of a light-dependent stage and a light-independent stage.

(a) Explain the role of proteins involved in the light-dependent stage.

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(b) The rate of photosynthesis is affected by many environmental factors.

A student carried out an experiment to investigate the relationship between the concentration of carbon dioxide available to an aquatic plant, *Cabomba caroliniana*, and its rate of photosynthesis.

Fig. 8.1 shows the experimental set-up for this investigation.

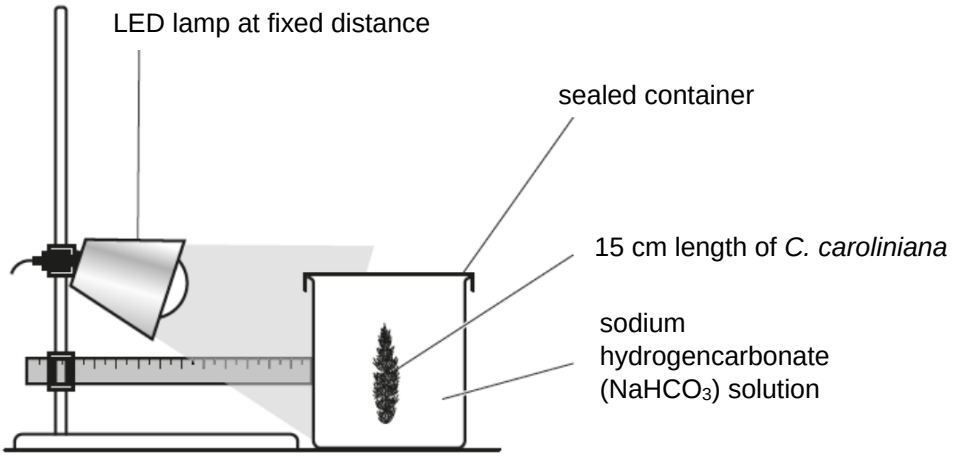

Fig. 8.1

The concentration of carbon dioxide was varied using six different concentrations of sodium hydrogencarbonate ($NaHCO_3$) solution. The rate of photosynthesis was obtained by calculating the percentage change in dissolved oxygen concentration in the solution over five minutes.

Fig. 8.2 shows the results of the investigation.

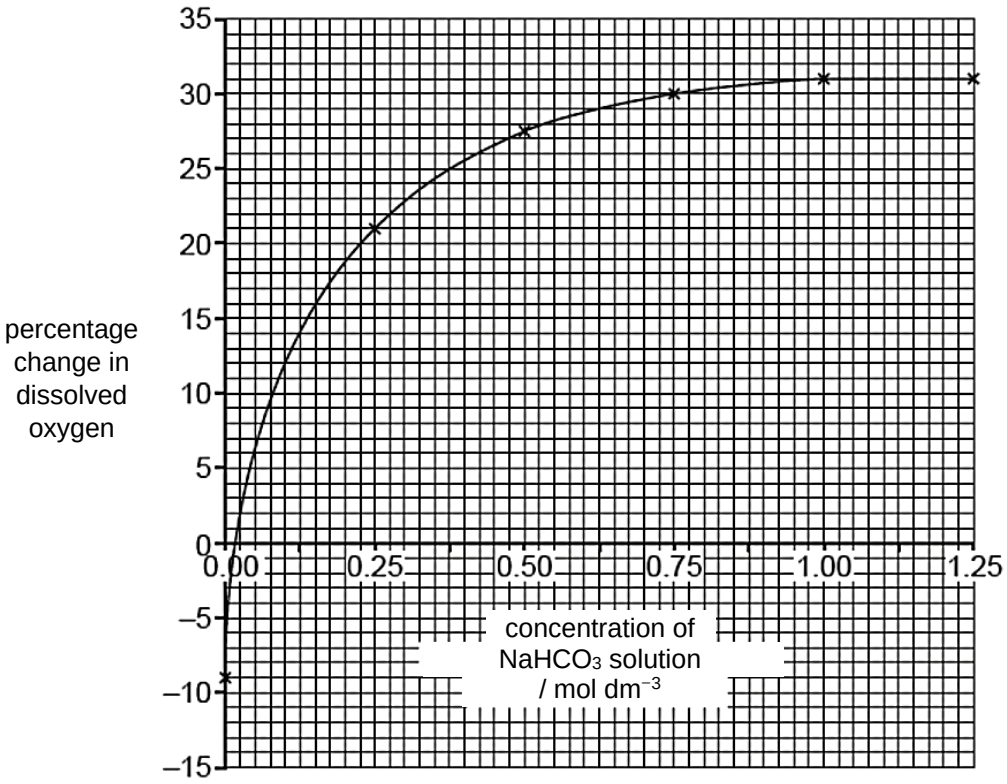

Fig. 8.2

(i) Describe and explain the pattern of results obtained between 0.25 mol dm^{-3} and 1.25 mol dm^{-3} of $NaHCO_3$ solution.

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(ii) The percentage change in dissolved oxygen for *C. caroliniana* at 0.00 mol dm^{-3} of $NaHCO_3$ solution is negative.

Suggest reasons for this negative value.

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(iii) To minimise temperature changes, the student decided to use an LED lamp as a light source. LED lamps release very little heat energy.

Explain the importance of minimising temperature changes in this experiment.

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[Total: 11]

QUESTION 9

Bombus pratorum and *Bombus terrestris* are two British species of bumble bees.

These bumble bees live in colonies founded by a female queen bee who lays eggs. The eggs develop into female worker bees, who collect food (nectar and pollen) and look after the young and the nest.

When the number of worker bees starts to decrease, young queens and males are produced and they mate. The mated queens survive winter underground and start new colonies the following spring.

(a) (i) State why the two bee species share the first name *Bombus*.

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(ii) Describe how it is possible to confirm, over a long period of time, whether *Bombus pratorum* and *Bombus terrestris* belong to different species.

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Fig. 9.1 shows the number of worker bees of *B. pratorum* and *B. terrestris* observed at one location over a year.

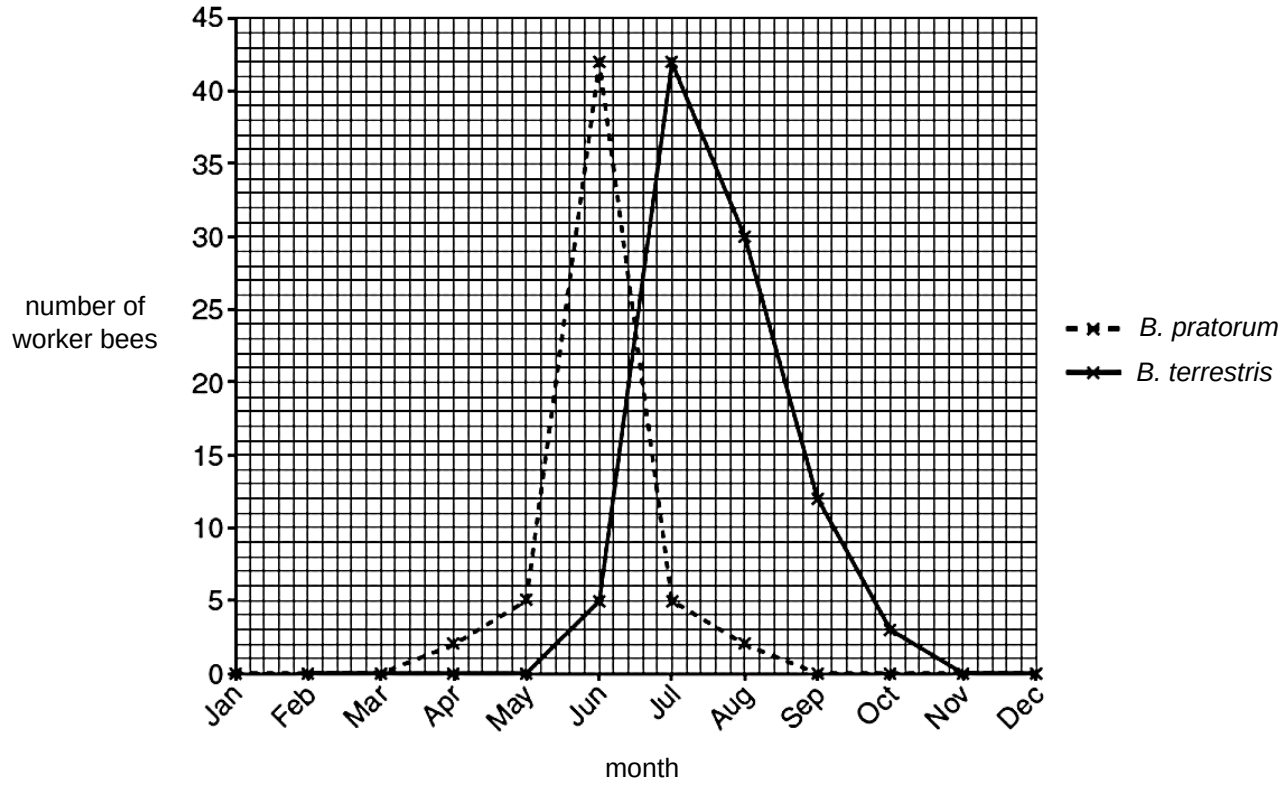

Fig. 9.1

Table 9.1 shows some differences in the food collecting behaviour of worker bees of these species.

Table 9.1

species of bumble bee	mean depth of flower visited / mm	visits to flowers when only nectar is collected / %	visits to flowers when only pollen is collected / %	visits to flowers when both nectar and pollen are collected / %
B. pratorum	7.4	23	10	67
B. terrestris	6.3	80	11	9

B. pratorum and *B. terrestris* both live in Britain. They can often be found in the same location, as their geographical distributions overlap.

(b) (i) Name the process by which new species are formed within the same geographical location.

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(ii) Using Fig. 9.1 and Table 9.1, and the information given, suggest how an ancestral species might have evolved into the two species, *B. pratorum* and *B. terrestris*.

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[Total: 9]

QUESTION 10

(a) Describe the innate immune response.

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Diseases of the immune system can result in the impairment of the

- innate immune response only
- the adaptive immune response only
- or both.

These patients exhibit distinct differences in their ability to detect and eliminate infections.

Fig. 10.1 shows the microorganism count in three patients, A, B and C with infections over time. Patients A and B have differing impairment to their immune systems while patient C does not.

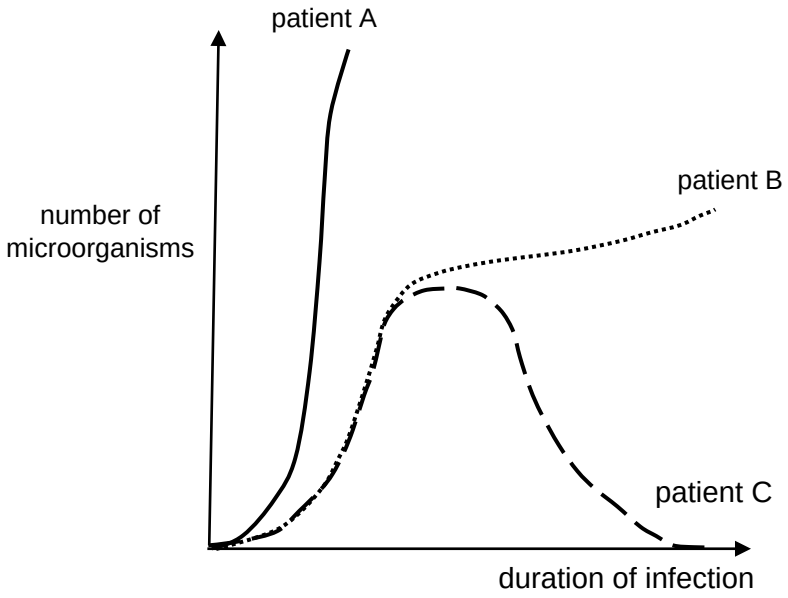

Fig. 10.1

(b) Explain which immune responses are impaired in patients A and B.

patient A ……..…….

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patient B ……..…….

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[Total: 5]

QUESTION 11

The concept of climate change and global warming has been of concern to scientists for many years.

One way to collect data about atmospheric concentrations of greenhouse gases in the past is to study samples of ice from ice sheets in Antarctica. Ice samples from deep in the ice sheets were formed hundreds of thousands of years ago, while those near the surface were formed recently.

As ice forms, small bubbles of air are trapped in the ice. These air bubbles can be analysed to determine the concentration of carbon dioxide present. It is also possible to use chemical techniques to determine when the air bubbles were trapped.

Scientists studying climate change measured carbon dioxide concentrations in air bubbles from ice samples of known age, collected from near the surface.

Fig. 11.1 shows the concentration of carbon dioxide measured in air bubbles that were trapped in ice from 1959 to 1990. Direct measurements of atmospheric carbon dioxide from 1948 to 1978 are also shown.

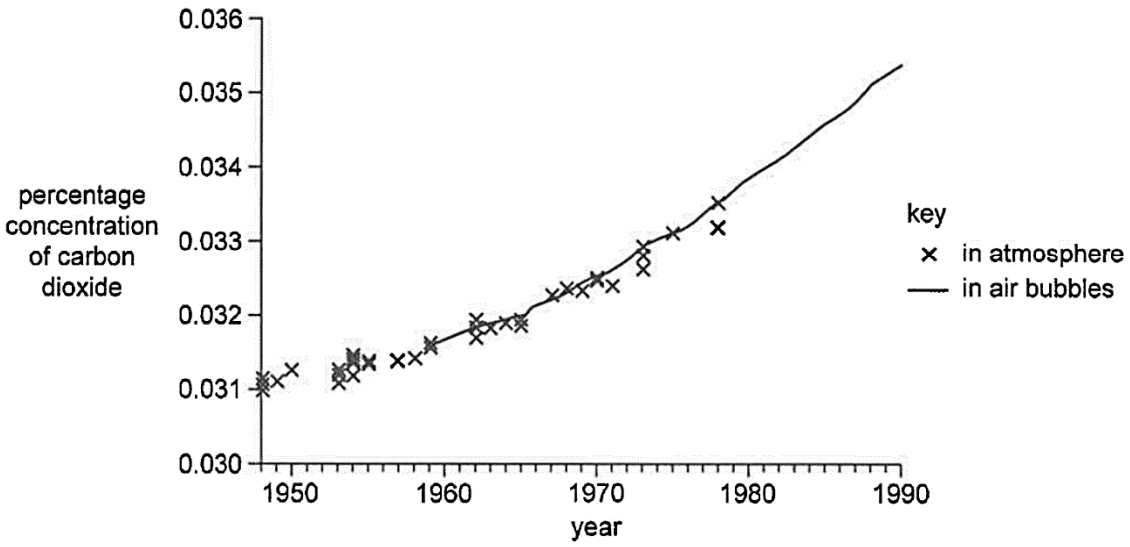

Fig. 11.1

(a) With reference to the information provided, suggest and explain how climate change scientists can estimate atmospheric carbon dioxide concentrations 10 000 years ago.

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It is possible to estimate past temperatures by analysing the ratio of the hydrogen isotope ^{1}H to the hydrogen isotope ^{2}H in ice samples. The ratio of the ^{1}H to ^{2}H increases as the temperature increases.

Fig. 11.2 shows the ratio of ^{1}H to ^{2}H in ice samples formed over the last 800 000 years and the corresponding atmospheric carbon dioxide concentrations.

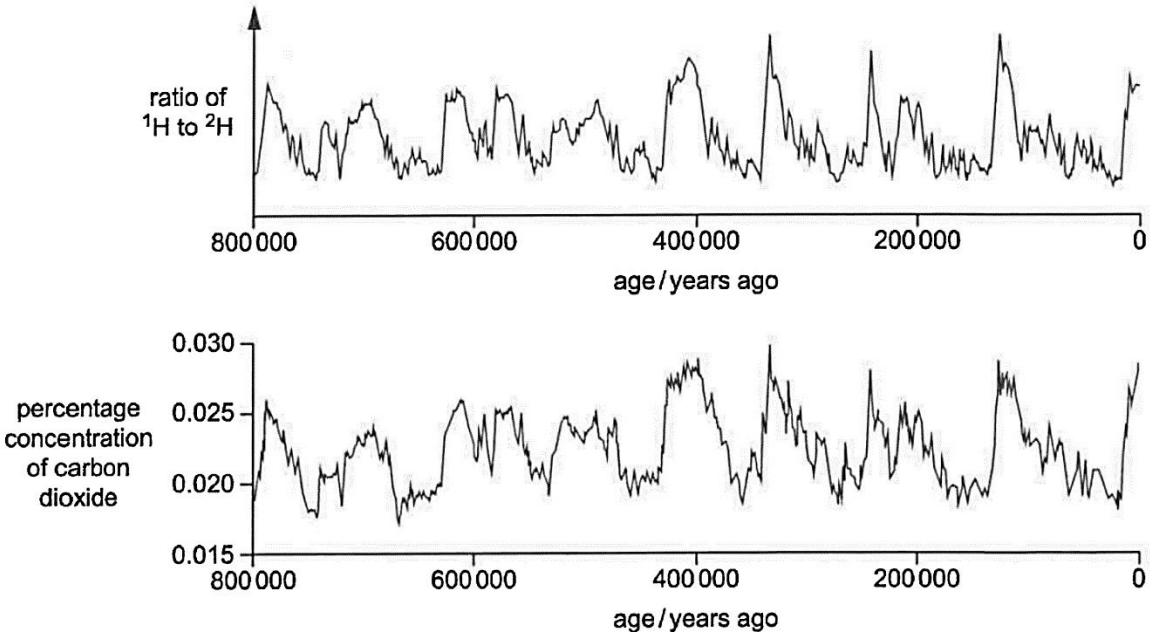

Fig. 11.2

(b) Use Fig. 11.2 to comment on changes in temperature over the last 800 000 years.

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(c) Explain why the data in Fig. 11.2 do **not** provide enough evidence to conclude that increased concentrations of greenhouse gases cause climate change.

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[Total: 6]

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