H2

ANDERSON SERANGOON JUNIOR COLLEGE
HIGHER 2

2023 JC2 PRELIMINARY EXAMINATION

CANDIDATE NAME							
CLASS					INDEX NUMBER		

BIOLOGY 9744/02

PAPER 2
SHORT STRUCTURED QUESTIONS

13 SEPTEMBER 2023
WEDNESDAY

Candidates answer on the Question Paper.
No Additional Materials are required.

2 HOURS

READ THESE INSTRUCTIONS FIRST

Write your name and class on all the work you hand in.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graph.
Do not use paper clips, highlighters, glue or correction fluid.

Answer **all** questions.

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.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
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10	
11	
Total	**/100**

This document consists of **32** printed pages.

Answer **all** questions.

1 Archaea are single-celled microorganisms which inhabit extreme environments, such as hot springs and volcanic vents at temperatures over 100 °C.

Fig. 1.1 shows the molecular structure of a phospholipid found in the cell membrane of an archaea and that of a eukaryote.

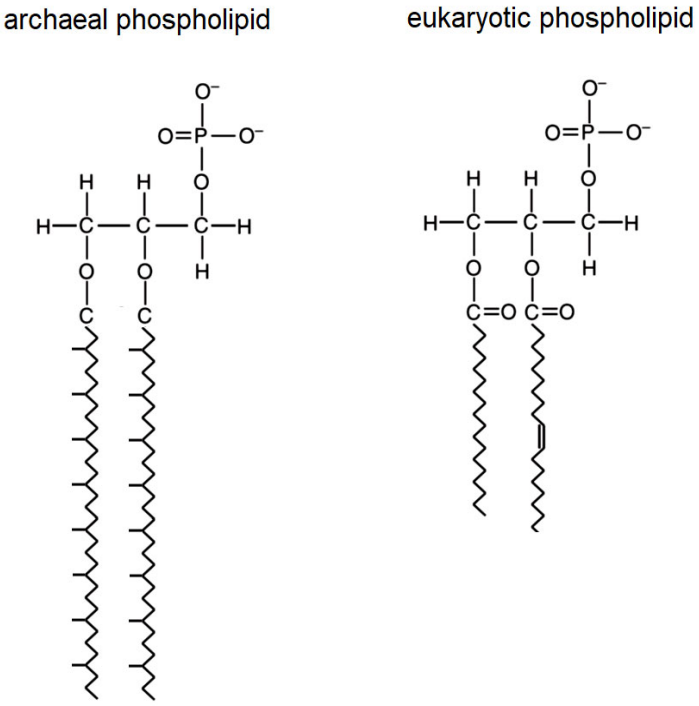

Fig. 1.1

(a) **(i)** With reference to Fig. 1.1, state **two** structural differences between the two phospholipids.

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(ii) Explain why phospholipids are unable to provide structural support.

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(b) In an experiment to investigate the transport of ions into root cells, some pea plants were grown with their roots in a solution of ions. These ions were absent in the root cells at the beginning of the experiment.

The concentration of five ions in the solution and in the cytoplasm of root cells were determined after one hour. The results are shown in Table 1.1.

Table 1.1

ion	concentration of ions / mmol dm^{-3}	
	solution	cytoplasm of root cells
potassium (K^+)	1.0	75.0
magnesium (Mg^{2+})	0.3	3.5
calcium (Ca^{2+})	1.0	1.0
phosphate (PO_4^{3-})	1.0	21.1
sulfate (SO_4^{2-})	0.3	19.7

Explain which components of the cell surface membrane of root cells are responsible for the results shown in Table 1.1.

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[Total: 9]

Question 2 starts on page 6

2 Fig. 2.1 is a photomicrograph of root tip cells at different stages in the cell cycle.

A cell in interphase and telophase are labelled.

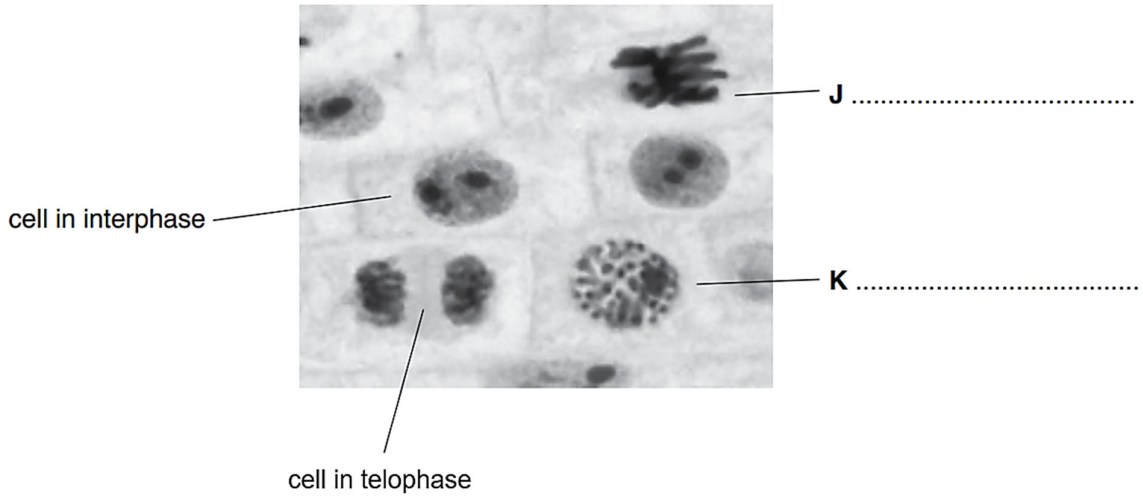

Fig. 2.1

(a) **(i)** Complete Fig. 2.1 by naming the stage of mitosis shown in each of cells **J** and **K.** [1]

(ii) State **one** feature of the cell in interphase, **visible** in Fig. 2.1, that shows this cell is **not** in early interphase.

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(b) Describe the events that occur in telophase.

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(c) Reduction division happens in meiosis.

(i) Describe the events that cause reduction division.

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(ii) Explain the need for reduction division during meiosis.

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[Total: 9]

3 Fig. 3.1 shows the cell signalling pathways of insulin and glucagon in liver cells.

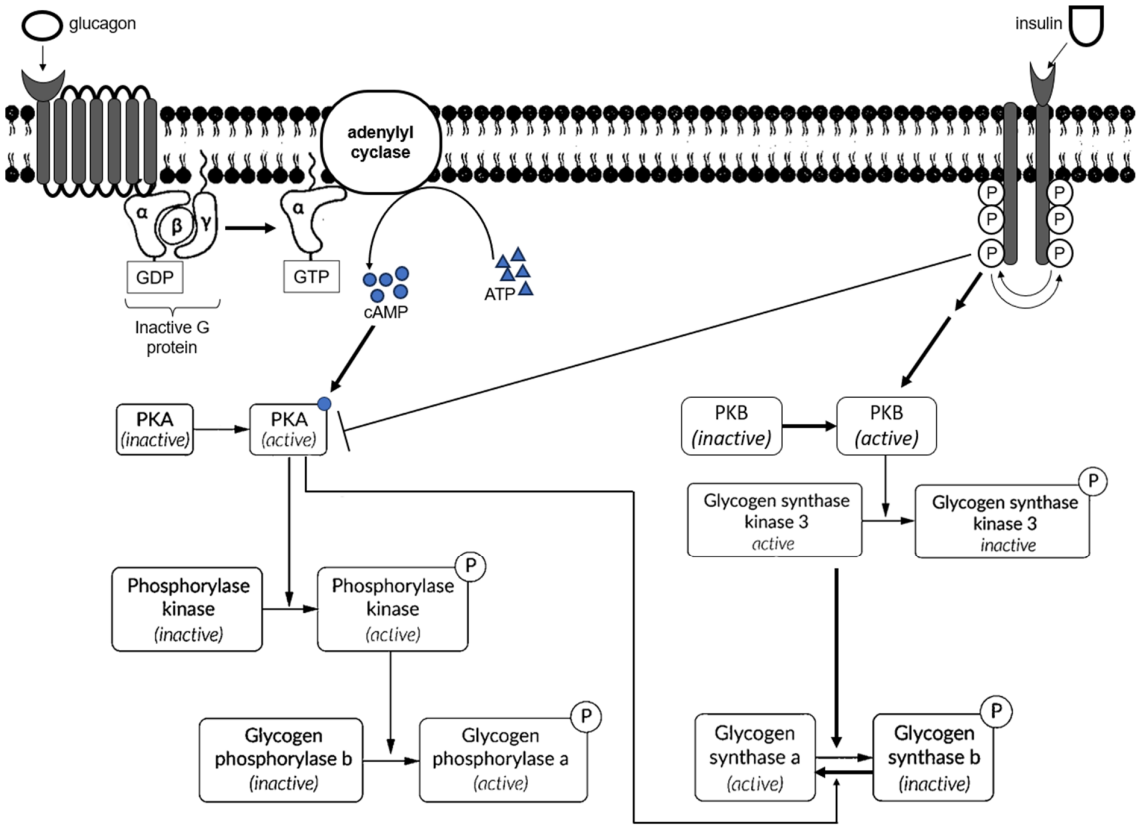

Fig. 3.1

(a) State the role of phosphate in Fig. 3.1.

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(b) Explain how the properties of the cell surface membrane facilitate the cell signalling pathways in Fig. 3.1.

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(c) PKA is an enzyme involved in the signalling pathways in Fig. 3.1.

Explain how the features of PKA allow it to perform its function in cell signalling.

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[Total: 9]

4 Red blood cells are formed from cells called reticulocytes. Stem cells in the bone marrow produce reticulocytes which differentiate into red blood cells.

(a) Identify precisely the stem cells in the bone marrow that produce reticulocytes.

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(b) Suggest how the expression of specific genes is likely to change when stem cells in the bone marrow differentiate ultimately into red blood cells.

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(c) Fig. 4.1 shows the structure of a small section of DNA of a reticulocyte.

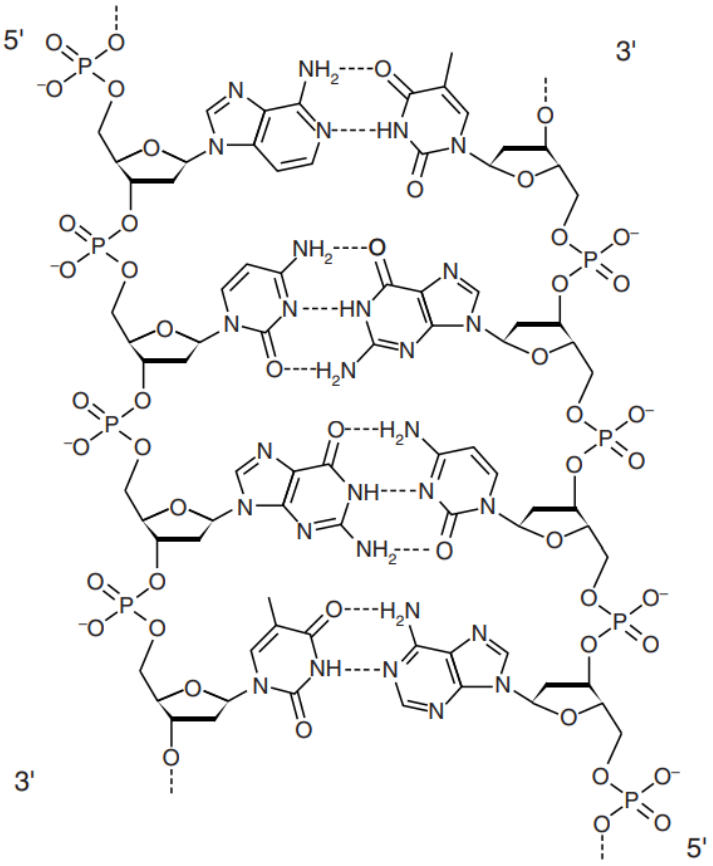

Fig. 4.1

(i) Explain how the features evident in Fig. 4.1 facilitate the replication of reticulocyte DNA.

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(ii) Explain how the replication of DNA is similar to the synthesis of cellulose.

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[Total: 9]

5 The *lac* operon is a segment of DNA on the chromosome of *Escherichia coli*. The structural genes of the *lac* operon are only fully expressed when the bacteria are exposed to high lactose concentrations.

Fig. 5.1 is a diagram showing the *lac* operon and a nearby region of the *E. coli* genome.

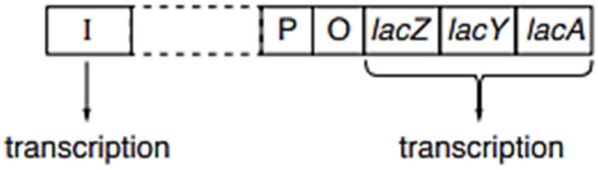

Fig. 5.1

(a) Describe a difference in control between the *lac* operon and the *trp* operon.

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(b) In an experiment, β-galactosidase concentration was measured in the presence of different concentrations of lactose and glucose. The results are shown in Fig. 5.2.

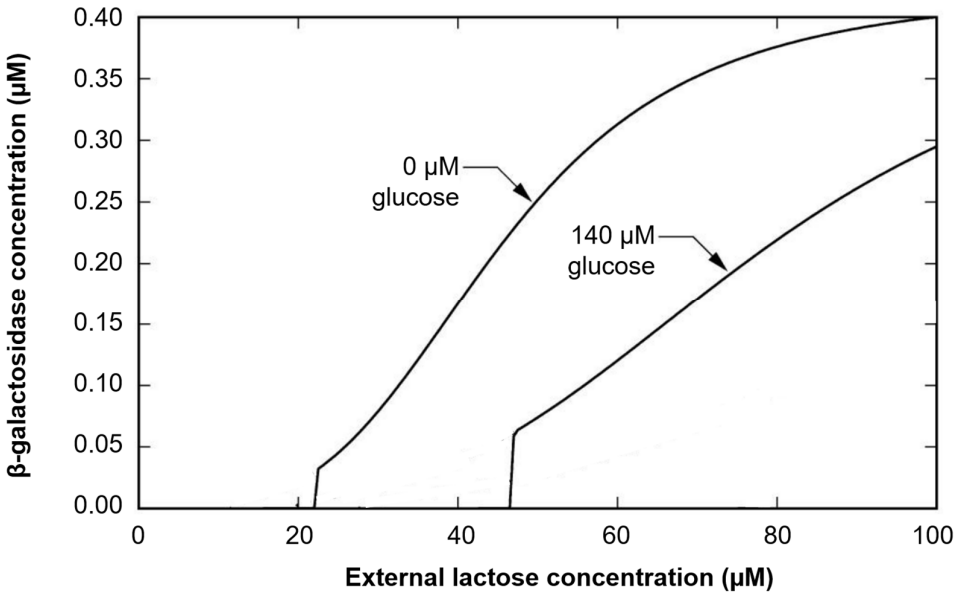

Fig. 5.2

With reference to Fig. 5.2, explain the effect of increasing glucose concentration on the *lac* operon.

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(c) A student claimed that if a mutant *E. coli* strain had a mutated *lacZ* gene where one nucleotide was added, no functional β-galactosidase and permease would be produced.

Discuss the validity of his claim.

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[Total: 9]

6 A plant breeder crossed a plant from a pure-bred line of tomato plants with red fruit with uniform pigmentation with a plant from another pure-bred line of plants with orange-coloured fruit, but with unattractive dark patches. The resulting generation all produced red fruit with dark patches.

Plants from this generation were interbred. The resulting progeny showed the following numbers of plants in each of the three phenotypes:

red fruit with dark patches	98
red fruit with uniform pigmentation	46
orange fruit with dark patches	44

The height of the plants was also measured and the data collected is shown in Table 6.1.

Table 6.1

height / cm	number of tomato plants
131 – 135	3
136 – 140	9
141 – 145	21
146 – 150	12
151 – 155	2

(a) Distinguish between the two types of variation shown in fruit colour and height in the tomato plants.

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(b) The genes involved in the cross above are hypothesised to be completely linked. State the meaning of the term ‘complete linkage’.

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……..[1]

(c) Using the symbols **R**/**r** for the gene for colour and **D**/**d** for the gene for pigmentation, draw a genetic diagram to show how the second cross could lead to the three phenotypes.

[4]

(d) The χ^2 distribution table (Table 6.2) and equation to calculate χ^2 are shown below. Using the formula, the calculated χ^2 value for the cross was 0.38.

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

Table 6.2

degree of freedom	probability, p				
	0.10	0.05	0.02	0.01	0.001
1	2.71	3.84	5.41	6.64	10.83
2	4.61	5.99	7.82	9.21	13.82
3	6.25	7.82	9.84	11.35	16.27
4	7.78	9.49	11.67	13.28	18.47

(i) State the null hypothesis.

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…….[1]

(ii) Using the calculated value of χ^2 and Table 6.2, explain what conclusion can be drawn from the data.

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[Total: 10]

Question 7 starts on page 18

7 Cystic fibrosis (CF) is a genetic disease caused by mutations of the gene that encodes the cystic fibrosis transmembrane conductance regulator (CFTR).

The most common cystic fibrosis mutation, ΔF508, is a three-base-pair (bp) deletion of codon 508 at exon 10 of the *CFTR* gene.

Another cystic fibrosis mutation is the G551D mutation. This mutation creates a recognition site for the restriction enzyme *Mbo*I at codon 551. This recognition site is not present in the normal allele.

The *CFTR* gene is amplified via the polymerase chain reaction (PCR) and digested with a restriction enzyme, *Mbo*I.

(a) Explain the role of primers in the PCR used to amplify the *CFTR* gene.

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(b) Fig. 7.1 shows the results of agarose gel electrophoresis of *Mbo*I digest products.

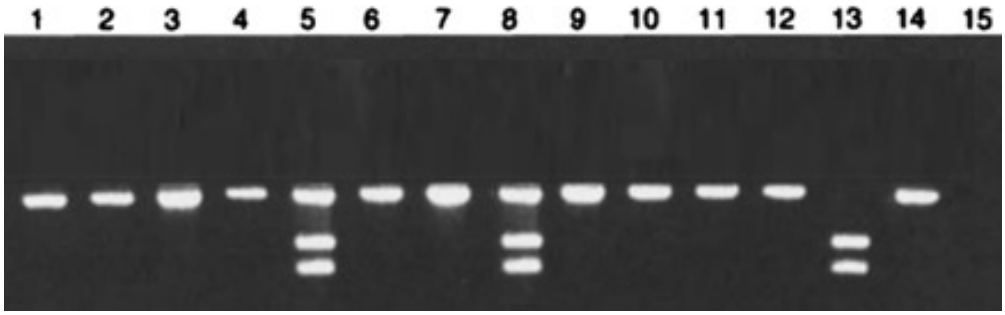

Fig. 7.1

Explain which individual(s) is/are carrier(s) of the disease.

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……..[2]

(c) To detect cystic fibrosis in individuals, a modified Southern hybridisation technique is used.

Target DNA is amplified using PCR and then denatured and labelled with biotin and streptavidin-alkaline phosphatase.

The amplified target DNA is then allowed to hybridise with a specific probe that is attached to a nitrocellulose membrane strip. When a chromogen is added, it is converted to a purple precipitate by alkaline phosphatase.

If the allele is present, it will hybridise with the respective probe. This leads to the conversion of the chromogen to a purple precipitate by alkaline phosphatase. This will then show up as a band on the strip.

Fig. 7.2 shows the PCR products of seven individuals (in lanes A – G) which are tested with four different probes. The following probes are used for the respective alleles:

probes	alleles to detect
W.ΔF508	ΔF508 wild-type allele
M.ΔF508	ΔF508 mutant allele
W.G551D	G551D wild-type allele
M.G551D	G551D mutant allele

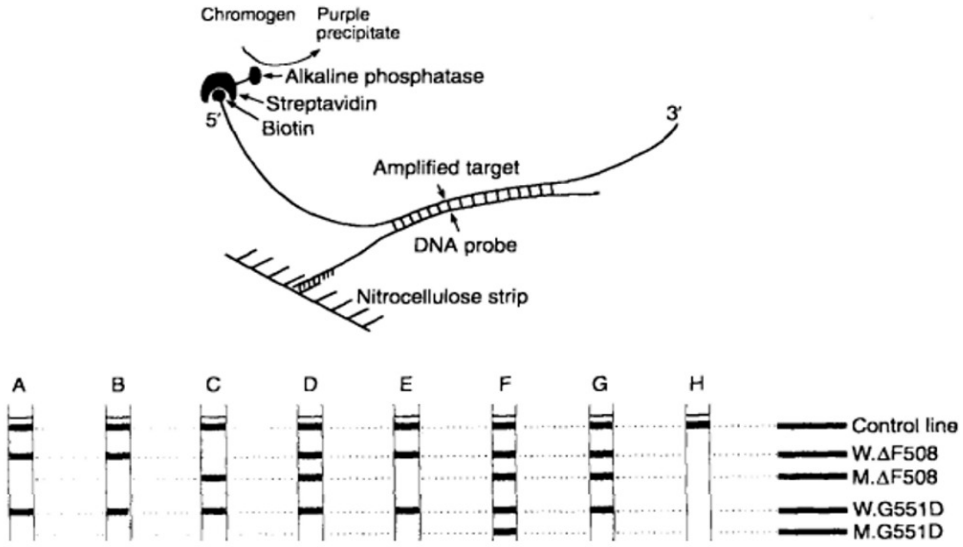

Fig. 7.2

With reference to the information provided in Fig. 7.2,

(i) describe the characteristics of the probes used.

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(ii) explain which of the individual(s) is/are affected by the disease.

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(iii) explain the purpose of H.

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[Total: 9]

Question 8 starts on page 22

8 A group of students investigated the growth of yeast in their school laboratory.

The students learned that the respiration rate is proportional to the rate of growth of a yeast culture.

Respiration rates can be measured using the redox indicator TTC.

- During respiration, hydrogen ions are removed from glucose to reduce hydrogen carriers in yeast cells.
- TTC can be used as a hydrogen carrier in experimental conditions instead of the hydrogen carriers in yeast cells.
- TTC changes from colourless to pink when it is reduced. The colour change can be measured using a colorimeter.

The students carried out a preliminary experiment using TTC to monitor the growth of a yeast culture over time. The yeast was grown in a liquid culture in a conical flask, as shown in Fig. 8.1. TTC was added to the flask, which was incubated at a constant temperature for a fixed period of time.

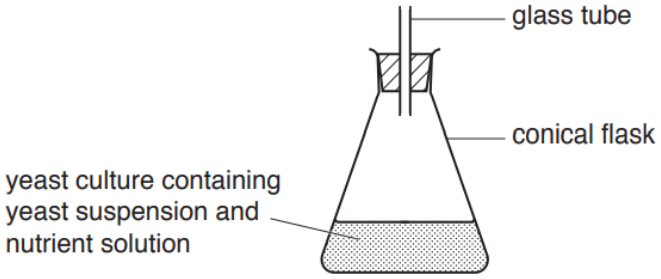

Fig. 8.1

(a) Explain why respiration rate is proportional to the rate of growth of a yeast culture.

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(b) Identify the hydrogen carriers that are found in yeast cells.

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(c) Besides the removal of its hydrogen ions, outline the fate of a glucose molecule during aerobic respiration in a yeast cell.

Your answer should include the specific location(s) within the yeast cell.

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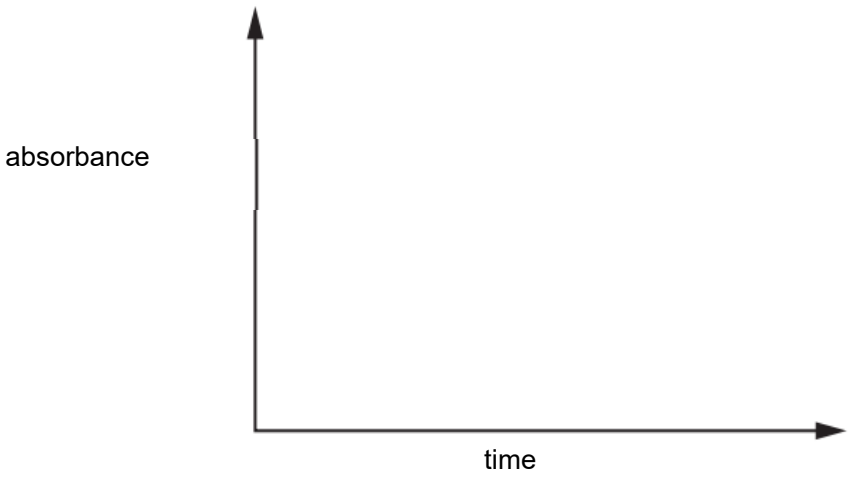
(d) Samples were taken from the flask at intervals and the absorbance was measured in the colorimeter.

A colorimeter passes a beam of light through a coloured filter into a solution and measures the light absorbance of that solution. A standard solution is used to set the colorimeter scale to zero before taking any measurements.

Complete the graph below to show the expected change in absorbance over time during the incubation of yeast.



[1]

[Total: 9]

9 The zebra finch, *Taeniopygia guttata castanotis*, and the budgerigar, *Melopsittacus undulatus*, are two species of songbirds found in Australia.

Fig. 9.1 shows photographs of the physical appearance of these songbirds, and of their skulls.

Fig. 9.1

(a) Discuss whether the evidence in Fig. 9.1 is sufficient to conclude that *Taeniopygia guttata castanotis* and *Melopsittacus undulatus* are two distinct species of songbird.

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(b) Scientists have found very little evolutionary change in populations of zebra finch in Australia.

The number of eggs a bird lays in its nest is called the clutch size. Eggs that hatch in each clutch give chicks, which develop into adult finches ultimately if they manage to survive.

The variation in clutch size was investigated in the zebra finch over several years. The data are shown in Fig. 9.2.

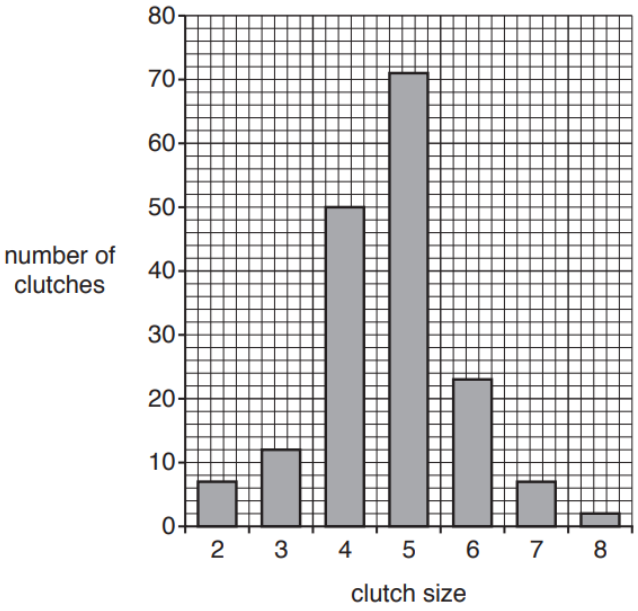

Fig. 9.2

(i) Describe the pattern shown by the data in Fig. 9.2.

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(ii) The data in this investigation were collected over 60 years ago. The same investigation, carried out today, would produce the same pattern of results.

Suggest how the selection factors acting on zebra finches would maintain the same pattern of results.

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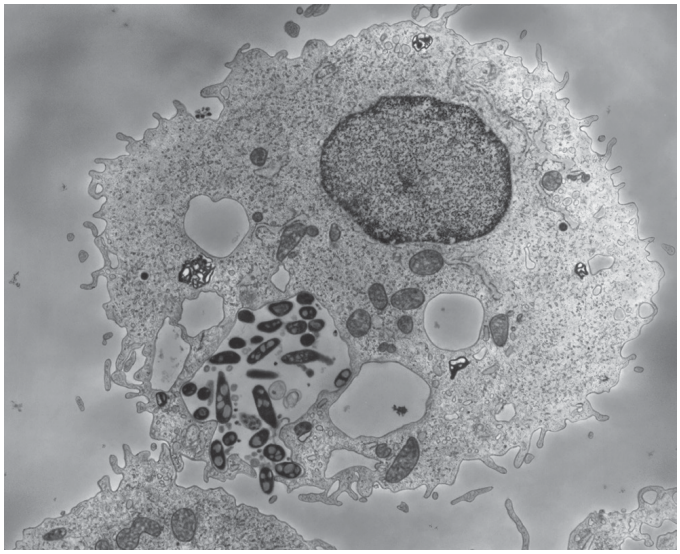
[Total: 9]

Question 10 starts on page 28

10 Fig. 10.1 shows a macrophage engulfing the pathogen that causes tuberculosis (TB).



magnification ×4400

Fig. 10.1

(a) **(i)** Name the pathogen that causes TB.

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(ii) Describe how this pathogen is transmitted.

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(b) Explain how the innate immune system minimises TB infections.

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(c) Antigen presentation occurs during the immune response against the pathogen that causes TB.

Describe **three** ways in which antigen presentation differs in phagocytes and B lymphocytes.

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[Total: 9]

11 The Himalayan region, one of the world's biodiversity hotspots, has the highest concentration of medicinal herb species. About 2000 recorded species of medicinal herbs are found in Nepal, one of the Himalayan countries.

Fig. 11.1 shows the altitude ranges and the temperatures at which three different species of medicinal herbs belonging to the family of Ranunculaceae can be found growing in the wild mountainous regions in Nepal.

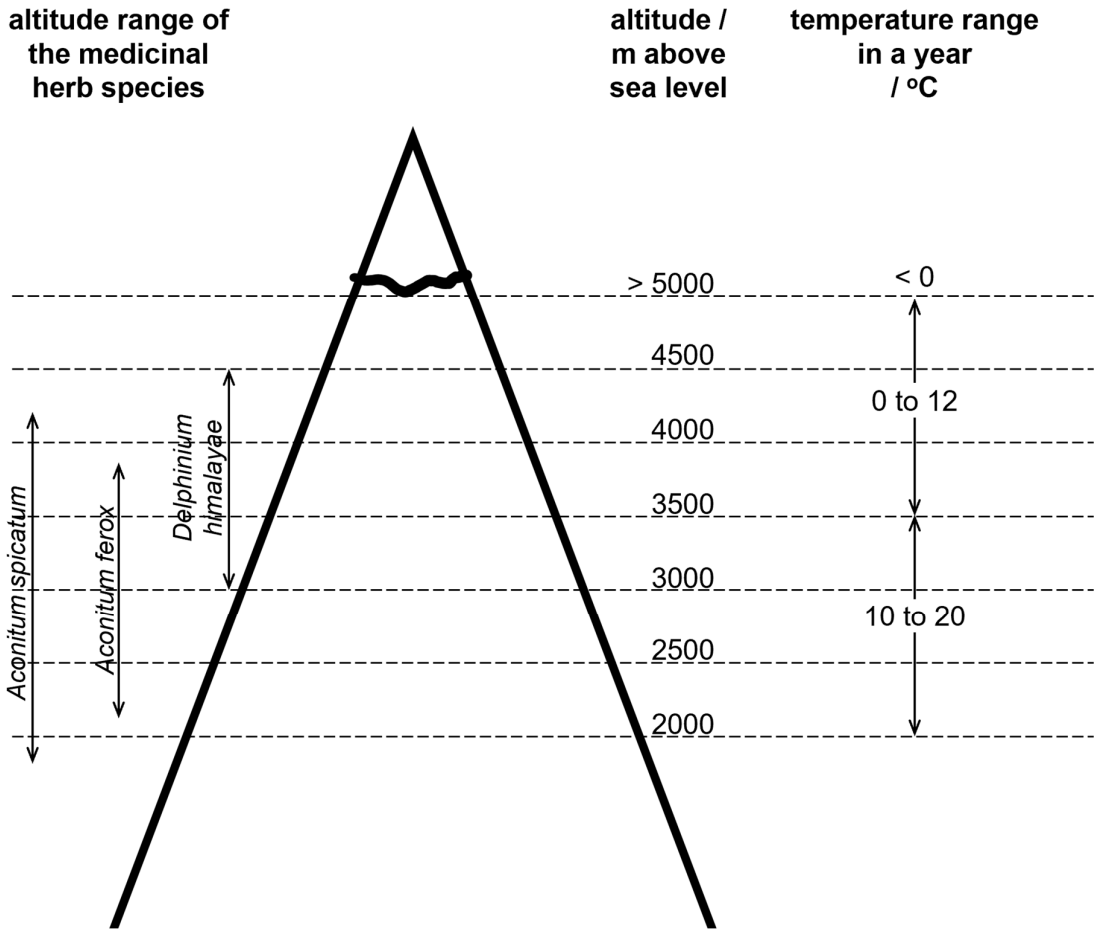

Fig. 11.1

The survival and distribution of these medicinal herbs have been under increasing pressure from the effects of climate change. The future impacts are shown in Table 11.1.

Table 11.1

species	altitude range / m above sea level	suitable land area in the mountainous region for growth and survival / km^2		
		under current climate	under future climate	percentage change
Aconitum spicatum	1800 – 4200	4010	3817	- 4.8
Aconitum ferox	2100 – 3800	4664	3359	
Delphinium himalayae	3000 – 4500	2648	970	

(a) Complete Table 11.1 by calculating the change in suitable area in the mountainous region for growth and survival of two of these species. [1]

(b) Outline how human activities contribute to global warming.

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(c) Due to global warming, the largest increase in mean annual temperature of Nepal is expected to be about 4 ^{o}C by the end of 2100.

Using the data given in Fig. 11.1 and Table 11.1, predict and explain the effect of climate change on the distribution of the three medicinal plant species at the different altitudes.

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(d) Suggest how the melting of snow and glaciers on the Himalayan mountains could increase stress on freshwater supplies.

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[Total: 9]