Oxford Cambridge and RSA

Friday 14 June 2024 – 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 scientific or graphical calculator
- a ruler (cm/mm)

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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1 This question is based on the Advance Notice Article **'The Eye'**.

(a) A person's genotype determines their eye colour phenotype.

(i) Define the term **genotype**.

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

(ii) Define the term **phenotype**.

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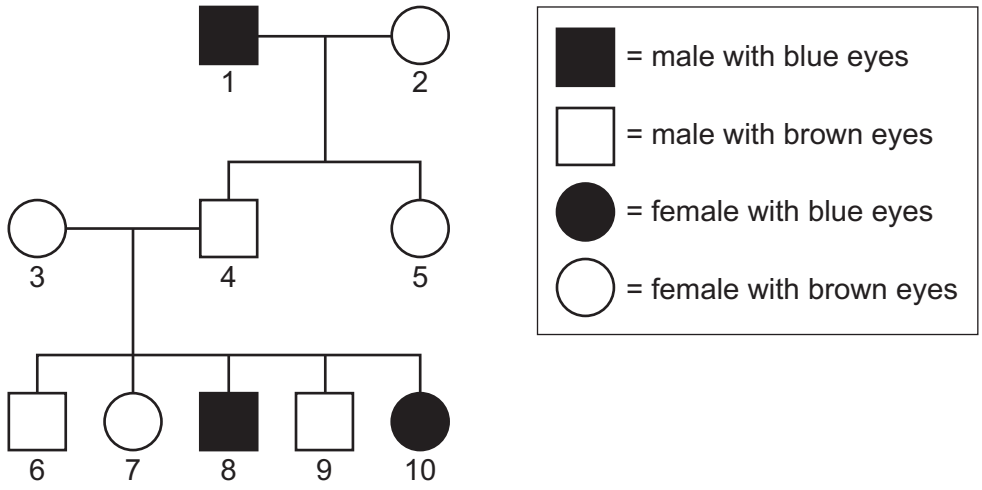
..... **[2]**

(b) **Fig. 1.1** shows the inheritance of eye colour in one family.

Squares represent males and circles represent females.

Filled shapes represent individuals with blue eyes and unfilled shapes represent individuals with brown eyes.

Fig. 1.1



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(i) Explain **one** piece of evidence from **Fig. 1.1** that indicates the allele for blue eyes is recessive.

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

(ii) Explain **one** piece of evidence from **Fig. 1.1** that indicates the allele for blue eyes is located on an autosome and not the X chromosome.

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

(iii) The chi squared (χ^2) test is used to determine whether the results of genetic crosses are statistically significant.

Explain why the χ^2 test is appropriate for use in genetic crosses.

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

(iv) Suggest why the χ^2 test would **not** be appropriate for analysing the data in **Fig. 1.1**.

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

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(c) A couple with blue eyes had a child with brown eyes.

A friend suggested that a mutation must have caused the child to have brown eyes.

(i) Use the information in the Advance Notice Article to explain why this conclusion is not supported.

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

(ii) Suggest an explanation for the child's brown eyes that is supported by the information in the Advance Notice Article.

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

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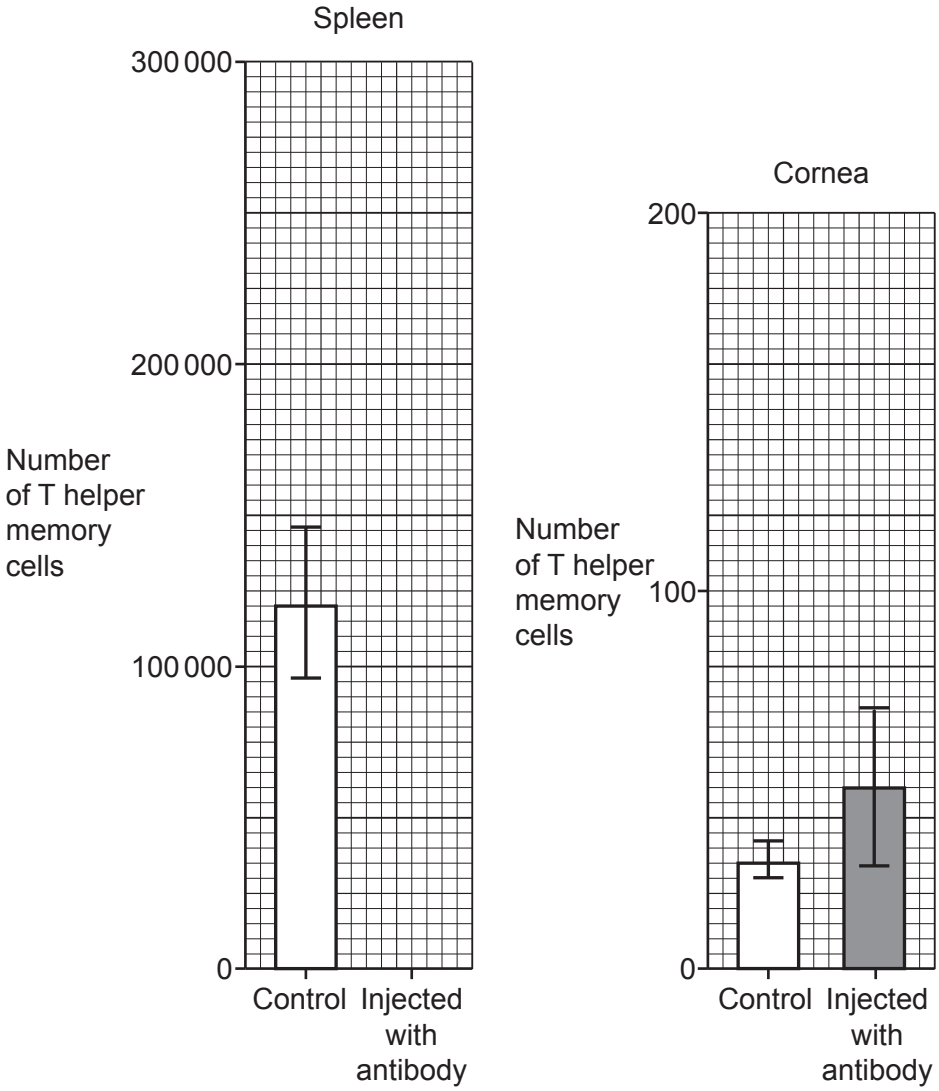
(d) The Advance Notice Article refers to a study that investigated T lymphocyte responses in the cornea of mice after herpes simplex virus (HSV) infection. The researchers performed two experiments on groups of mice four weeks after the initial HSV infection.

In the first experiment, the researchers injected a group of mice with an antibody that caused the removal of circulating T lymphocytes from the blood.

They then measured the number of T helper memory cells in the spleen and cornea of a control group and in the mice injected with antibody. The results are shown in **Fig. 1.2**.

Fig. 1.2



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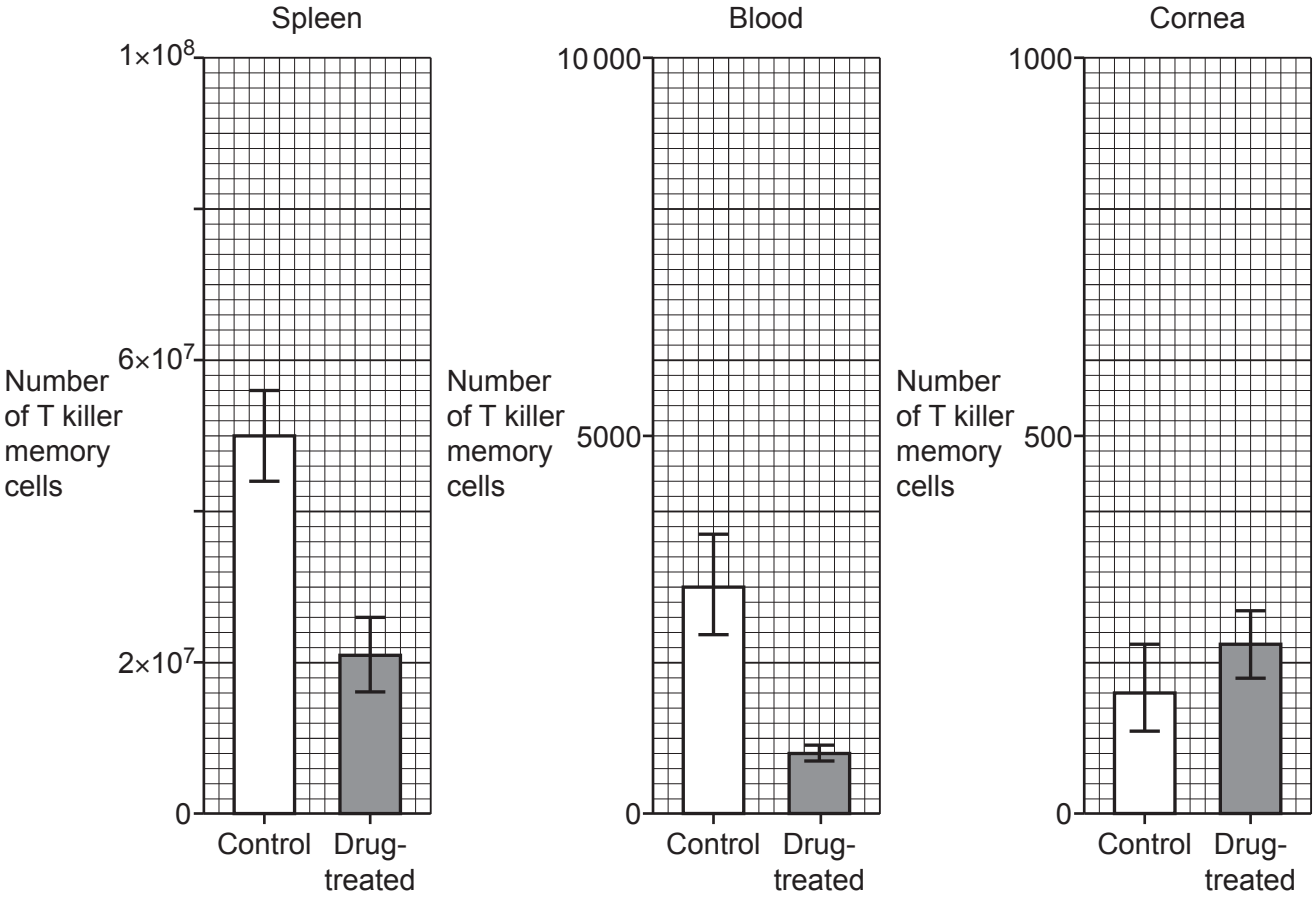
In the second experiment, the researchers treated another group of mice with a drug that is known to reduce the number of T killer memory cells in the spleen and blood.

They then measured the number of T killer memory cells in the spleen, blood and cornea of a control group and the drug-treated mice. The results are shown in **Fig. 1.3**.

Fig. 1.3



(i) State what treatment the mice in the control group would have received in both experiments.

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

(ii) Calculate how many times more T killer memory cells were present in the spleen of control mice compared with the cornea of control mice.

Give your answer in standard form.

..... times more **[2]**

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(iii) The researchers concluded that the corneas of mice four weeks after infection with HSV contained tissue-resident T helper memory cells and tissue-resident T killer memory cells.

Explain how the data in **Fig. 1.2** and **Fig. 1.3** support this conclusion.

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..... **[3]**

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2 Regulation of the menstrual cycle involves interaction between several hormones.

(a) Complete the sentences using the most appropriate words or phrases.

FSH is secreted by the ..... and transported in

the blood to the ovary, where it stimulates follicle development. The mature follicle

releases oestrogen that stimulates a surge in secretion of ..... ,

which causes ..... and development of the follicle into the

..... .

[4]

(b) During each cycle, FSH stimulates the development of multiple follicles.

One of these, known as the dominant follicle, grows faster than the others and produces more oestrogen.

Suggest how oestrogen produced by the dominant follicle leads to a reduction in the development of the other follicles.

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

(c) Oestrogen also thickens the lining of the uterus in preparation for implantation of the blastocyst after fertilisation by a sperm cell.

Describe **two** functions of the acrosome in fertilisation.

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2 .....

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[2]

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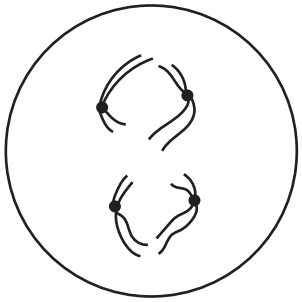
(d) The diagrams show three stages of meiosis in a model cell with two pairs of chromosomes.

Identify the stage of meiosis shown in each diagram. For each diagram, explain the evidence that indicates which stage is shown.



Stage .....

Explanation .....

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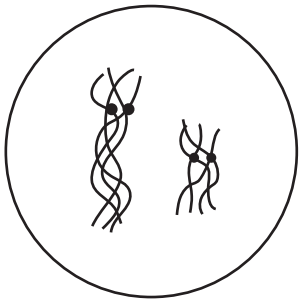

Stage .....

Explanation .....

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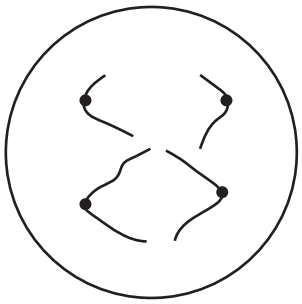

Stage .....

Explanation .....

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[6]

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(e)* Explain the importance of meiosis and fertilisation in increasing genetic variation.

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..... **[6]**

Extra answer space if required.

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3

(a) Water has some unique properties that make it particularly important as a biological molecule.

The table lists some properties of water.

Complete the table to describe how each of the properties is important in biological systems.

Property of water	**Description of how the property is important in biological systems**
Is a polar solvent	
Has a high specific heat capacity	
Has a high latent heat of vaporisation	
Has adhesive and cohesive properties	

[4]

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(b) The table shows the total concentration of solutes and electrolytes in different biological fluids.

Fluid	**Concentration (mmol dm^{-3})**
Blood plasma	175
Tissue fluid	165
Cytosol	205

(i) Explain why the different fluids have different total concentrations of solutes and electrolytes.

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..... **[3]**

(ii) Based on the values in the table, state **and** explain the direction you would expect water to move between the tissue fluid and cytosol.

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

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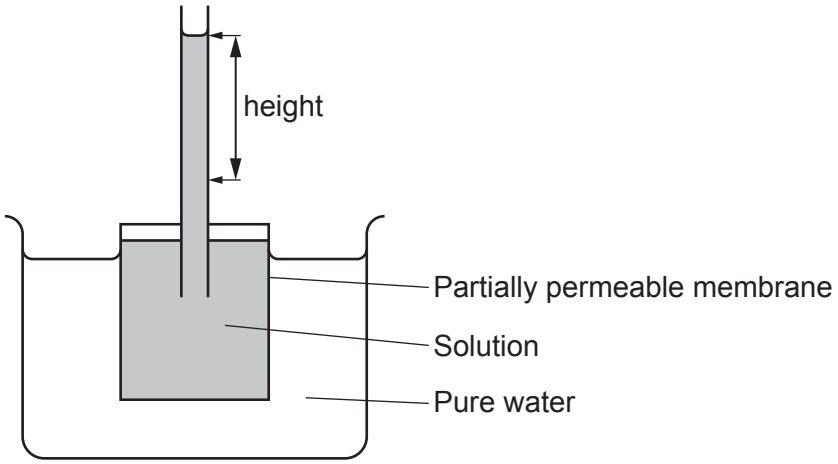
(c) Wilhelm Pfeffer was a German scientist who studied osmosis. In 1877, Pfeffer published the design of an apparatus that included a partially permeable membrane. He used this apparatus to demonstrate osmosis and measure osmotic pressure.

The diagram below shows a version of Pfeffer's apparatus.



Pfeffer measured the increase in height of the solution to calculate the hydrostatic pressure and osmotic pressure of the solution.

(i) Explain **one** variable that should be controlled in an experiment to measure the osmotic pressure of different solutions.

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

(ii) Describe **one** improvement to the method to increase the accuracy of the individual measurements.

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

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(iii) A student plans to use Pfeffer's method to study the formation of tissue fluid.

A textbook gave the osmotic pressure of blood as 780 kPa at 25 °C.

The relationship between the concentration of a solution and its osmotic pressure is given by the equation:

osmotic pressure = c × i × RT

where:
the osmotic pressure is in kPa
c is the concentration in $mol\,dm^{-3}$
i is the van't Hoff factor (for sucrose, i = 1)
R is the gas constant = $8.314\,m^3\,Pa\,K^{-1}\,mol^{-1}$
T is the absolute temperature in Kelvin (K), 25 °C = 298 K.

The student plans to use a sucrose solution with the same osmotic pressure as blood.

Use this information to calculate the concentration of sucrose, in $mol\,dm^{-3}$, that the student should use.

Concentration = ... $mol\,dm^{-3}$ **[2]**

(iv) The student also plans to use a sodium chloride solution with the same osmotic pressure as blood.

The van't Hoff factor takes account of the number of particles formed when a substance dissolves. 1 mol of sodium chloride forms 2 mol of particles (Na^+ and Cl^-) when it dissolves. This means that the van't Hoff factor for sodium chloride is 2.

Estimate the concentration of sodium chloride that would be required to make a solution of the same osmotic pressure as blood.

Concentration = ... $mol\,dm^{-3}$ **[1]**

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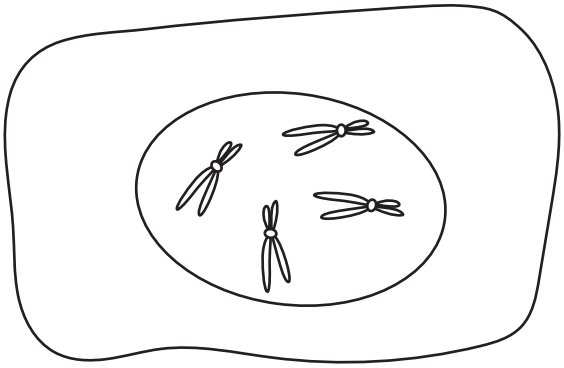
4 Tumour formation is the result of uncontrolled mitosis.

Uncontrolled mitosis can occur when processes that regulate mitosis and the cell cycle stop functioning.

Cancer treatments often target these processes.

(a) The diagram shows a cell with two pairs of chromosomes.



In the space below, draw an annotated diagram of this cell in the anaphase stage of mitosis.

Indicate the features that show the cell is in anaphase.

[4]

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(b) Discuss the advantages and disadvantages of the use of plants as sources of anti-cancer drugs.

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..... **[3]**

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(c) Paclitaxel and topotecan are two anti-cancer drugs. Both drugs were initially isolated from natural sources.

Paclitaxel interferes with microtubule formation during cell division.

Topotecan causes breaks in the DNA double strand during DNA replication.

Researchers carried out a clinical trial to compare the efficacy of paclitaxel and topotecan.

They selected patients with advanced epithelial ovarian cancer who had not responded to previous anti-cancer treatments.

The patients were then treated with either paclitaxel or topotecan.

(i) Describe how patients would be assigned to the two treatment groups **and** explain why they were assigned in this way.

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

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(ii) The results of the clinical trial are shown in the table.

	Paclitaxel group	**Topotecan group**	**Statistical significance**
Median time to progression of disease (weeks)	14	23	p = 0.002
Median survival (weeks)	43	61	p = 0.515

The researchers concluded that topotecan has efficacy at least equivalent to that of paclitaxel.

Explain why the researchers reached this conclusion.

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..... **[3]**

(iii) Other researchers have proposed that paclitaxel and topotecan could be more effective if they are used at the same time in a combined treatment of advanced cancers.

Suggest why the two drugs may be more effective when used together in a combined treatment.

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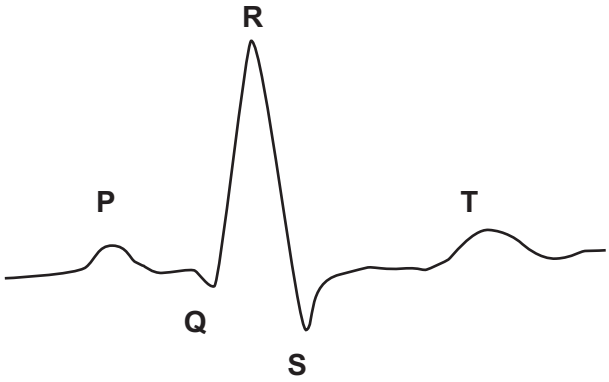
5

(a) **Fig. 5.1** shows an electrocardiogram (ECG) of one beat of a healthy heart.

Fig. 5.1



Describe the cause of the two waves labelled **P** and **T** in **Fig. 5.1**.

P .....

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T .....

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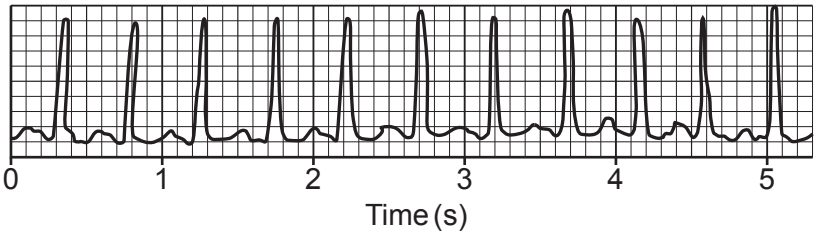
[2]

(b) **Fig. 5.2** shows an ECG of a faulty heartbeat in a resting patient.

Fig. 5.2



(i) Use **Fig. 5.2** to calculate the resting heart rate of this patient.

Heart rate = ... beats min^{-1} **[2]**

(ii) Identify the heart problem indicated by the ECG in **Fig. 5.2**.

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

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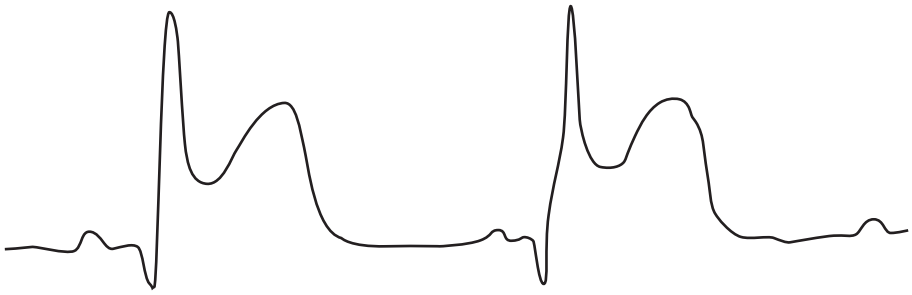
(c) **Fig. 5.3** shows part of an ECG of a patient undergoing myocardial infarction (heart attack).

Fig. 5.3



(i) Describe the feature of this ECG that shows the patient is having a myocardial infarction.

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(ii) Explain the circumstances in which a defibrillator should be used.

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

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(d) ECG can be used to predict the risk of mortality from heart failure.

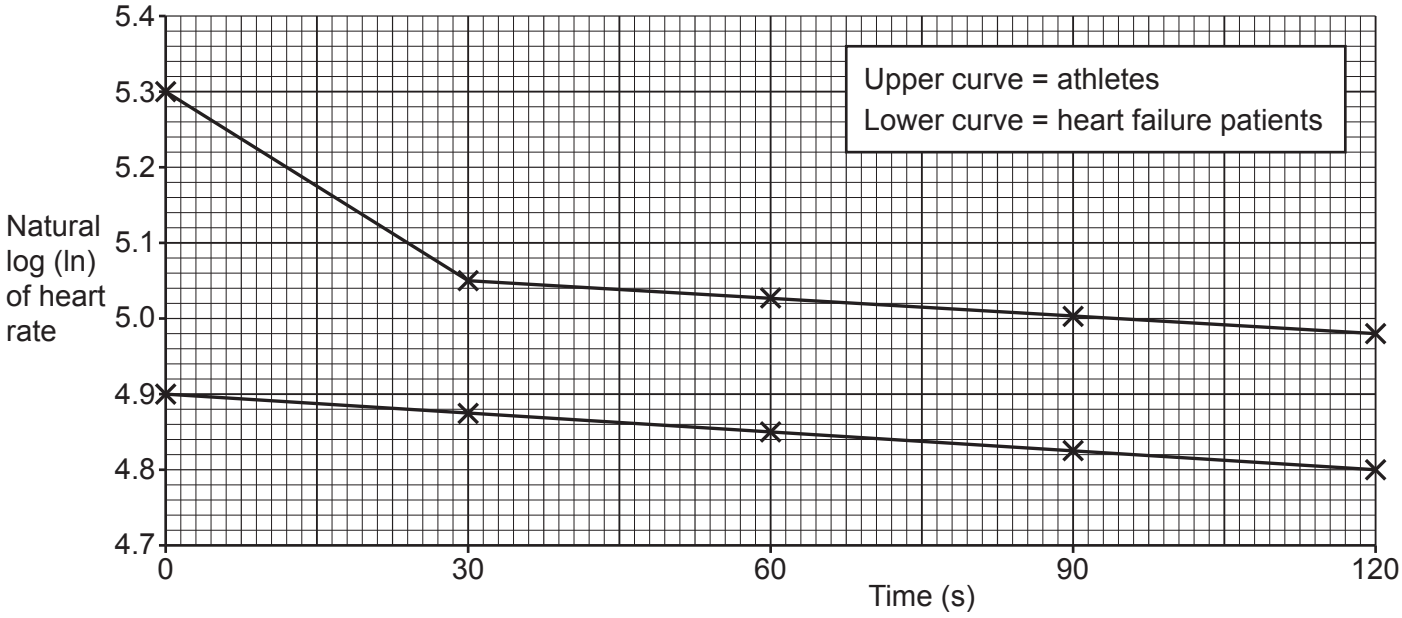
Patients with heart failure were monitored by ECG for a few minutes after exercising on a treadmill.

This group was compared with a group of trained athletes.

The researchers analysed the results by plotting a graph of the natural log (ln) of heart rate against time.

The results are shown in **Fig. 5.4**.

Fig. 5.4



Compare the results in **Fig. 5.4** for the athletes and heart failure patients.

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6

(a)

(i) State the name of a test that can be used to diagnose red-green colour blindness.

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

(ii) Explain why rod cells in the retina are described as receptors and transducers.

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

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(b)* The eye has structures and mechanisms that:

- protect it against light
- provide physical protection
- provide chemical protection.

Describe the structures and mechanisms that protect the eye from potential harm.

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Extra answer space if required.

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7

(a) State the **two** products of the light-dependent stage of photosynthesis that are used in the Calvin cycle.

1 .....

2 .....

[2]

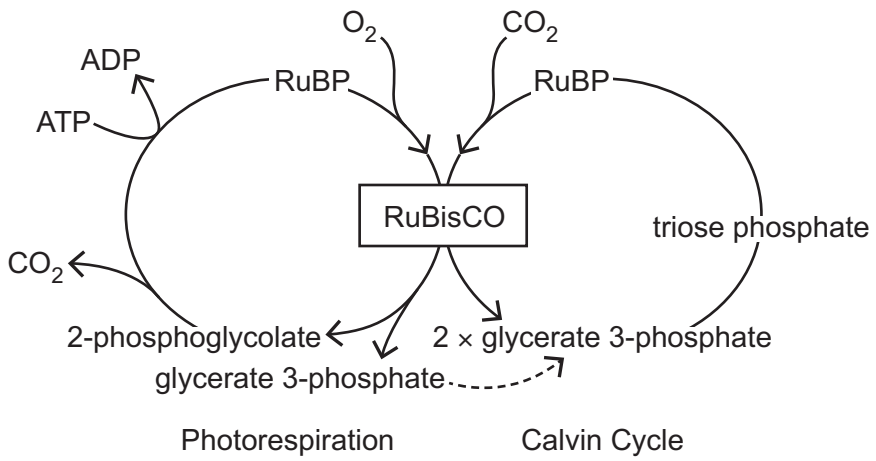
(b) In photorespiration, RuBisCO catalyses the reaction of oxygen with RuBP to produce one molecule of 2-phosphoglycolate and one molecule of glycerate 3-phosphate.

The glycerate 3-phosphate can enter the Calvin cycle.

2-phosphoglycolate is converted to RuBP.

These pathways are summarised in **Fig. 7.1**.

Fig. 7.1



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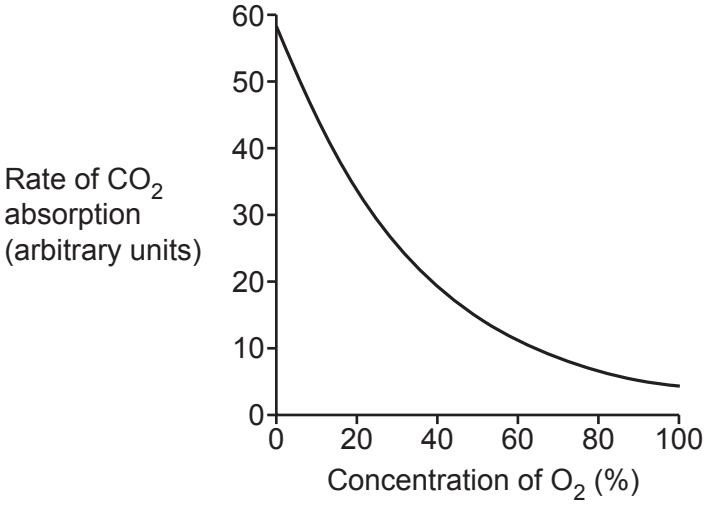
(i) **Fig. 7.2** shows the effect of oxygen concentration on the rate of absorption of carbon dioxide by the leaves of a crop plant.

Fig. 7.2



Use the information in **Fig. 7.1** to explain the results shown in **Fig. 7.2**.

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

(ii) Use your knowledge of the Calvin cycle and the information in **Fig. 7.1** and **Fig. 7.2** to explain why higher concentrations of oxygen reduce the yield of this crop plant.

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

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(c) Melvin Calvin and his co-workers studied the reactions of the Calvin cycle by injecting a suspension of photosynthesising algae with radioactive CO_2 ($^{14}CO_2$).

They took samples of the suspension after 2 s, 5 s and 30 s.

They then used paper chromatography to identify the compounds that had taken up the radioactive carbon (^{14}C).

(i) The table shows different compounds that had taken up ^{14}C during the course of the experiment.

Compound(s)	
Amino acids	**A**
Glucose phosphates	**B**
Glycerate 3-phosphate (GP)	**C**
Triose phosphate (TP)	**D**

Use the **letters** in the table to indicate the order in which ^{14}C would have appeared in the compounds.

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

(ii) Explain the order you have listed the compounds in part **(i)**.

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..... **[3]**

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(iii) Explain how ^{14}C would be incorporated into triglycerides in a plant.

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..... **[3]**

END OF QUESTION PAPER

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EXTRA ANSWER SPACE

If you need extra space use this lined page. You must write the question numbers clearly in the margin.

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