Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME

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6144955431

BIOLOGY **9700/42**

Paper 4 A Level Structured Questions **February/March 2023**

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 candidate 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 or correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working and use appropriate units.

INFORMATION

- The total mark for this paper is 100.
- The number of marks for each question or part question is shown in brackets [ ].

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

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1 **(a)** Fig. 1.1 is a drawing of a longitudinal section (LS) of a human kidney.

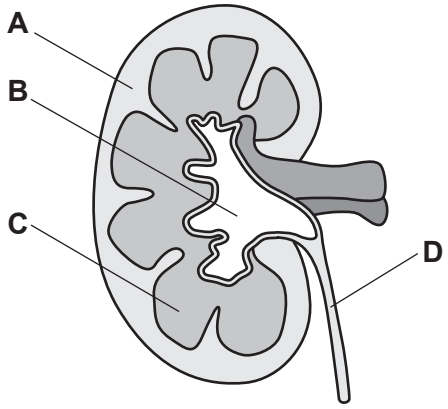


Fig. 1.1

Use the letters **A**, **B**, **C** and **D** in Fig. 1.1 to complete Table 1.1.

Each letter may be used once, more than once or not at all.

For each description, list **all** the letters that are correct.

Table 1.1

description	region of kidney
location of loops of Henle	.....
location of Bowman's capsules	.....
location of glomeruli	.....
contains urine at final concentration	.....

[4]

(b) The volume and water potential of the urine produced by the kidney vary according to the water potential of the blood. This is a result of osmoregulation.

Describe the role of aquaporins in osmoregulation.

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..... [3]

(c) Describe the role of the brain in osmoregulation when the water potential of the blood **increases** above the set point.

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..... [3]

[Total: 10]

Question 2 starts on page 5.

2 Interferon-alpha (IFN-α) can be produced as a recombinant human protein to treat some types of cancer. The gene *IFNA2* codes for IFN-α.

One method of producing recombinant IFN-α uses genetically engineered *Escherichia coli* bacteria that contain recombinant plasmids. Each recombinant plasmid contains:

- the gene *IFNA2*
- three regulatory sequences of the *lac* operon (promoter, operator and *lacI*)
- a gene for antibiotic resistance, AMP^R.

Each of the sequences for the *lacI* gene and AMP^R gene contains its own promoter. As a result, these genes are always expressed in *E. coli* bacteria that contain this recombinant plasmid.

Fig. 2.1 is a diagram of the recombinant plasmid. The promoter regions of the *lacI* gene and AMP^R gene are **not** shown.

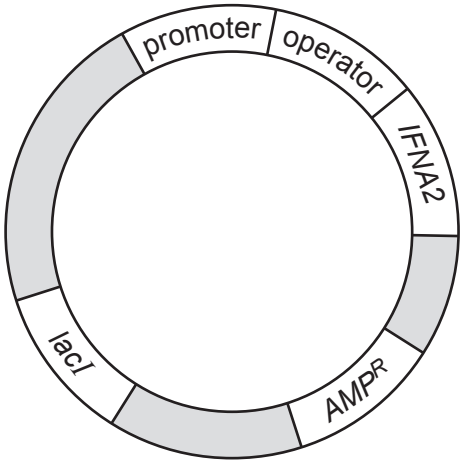


Fig. 2.1

(a) The start of transcription of the gene *IFNA2* by *E. coli* with the recombinant plasmid shown in Fig. 2.1 needs to be controlled to obtain an optimum yield of IFN-α.

Scientists investigated the effect of two inducers of transcription on the production of recombinant IFN-α:

- lactose, which is converted to allolactose in *E. coli*
- IPTG, which is a synthetic molecule with a very similar structure to allolactose. IPTG **cannot** be broken down by *E. coli*.

The scientists grew three cultures of *E. coli* containing the recombinant plasmid in the same growth medium. The growth medium contained glucose, amino acids, essential vitamins and minerals. The growth medium did **not** contain lactose.

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After four hours, either lactose or IPTG at the same concentration was added to two of the cultures of *E. coli*. As a control, the third culture of *E. coli* was grown without adding lactose or IPTG.

The concentration of recombinant IFN-α in the cultures was measured at different times over a period of 28 hours. The results are shown in Fig. 2.2.

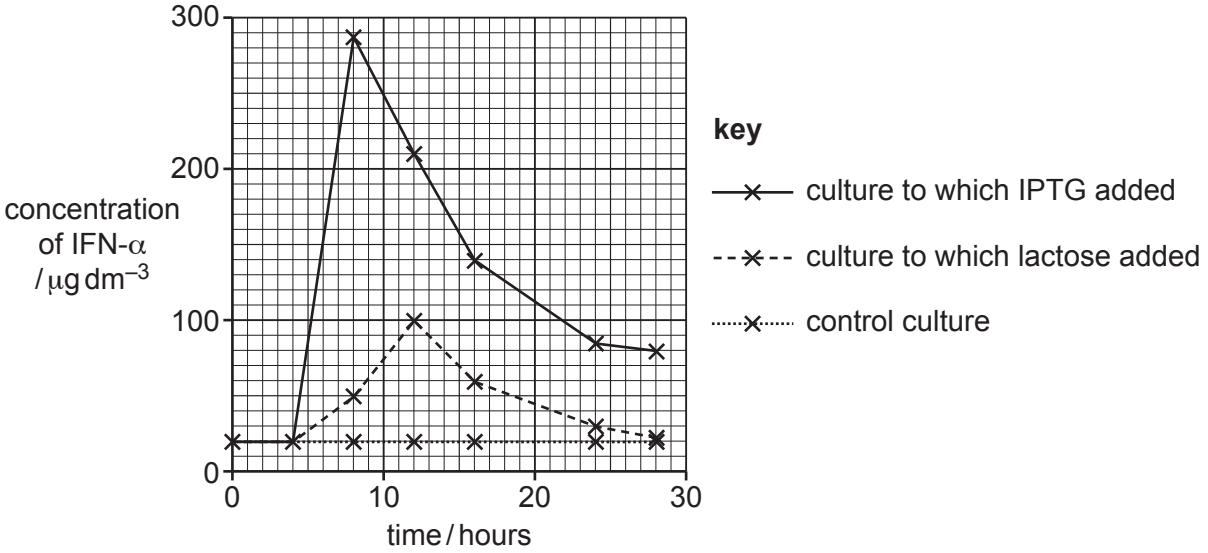


Fig. 2.2

(i) The regulatory sequences of the *lac* operon contained in the recombinant plasmid are involved in the control of transcription of the gene *IFNA2*.

Explain the role of the gene *lacI* in the control of transcription of the *IFNA2* gene between **0 hours** and **4 hours**.

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..... [2]

(ii) With reference to Fig. 2.2, describe the changes in the concentration of recombinant IFN-α in the culture containing IPTG from when IPTG was added at **4 hours** to the end of the experiment at **28 hours**.

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..... [3]

(iii) Suggest **one** reason for the difference between the concentration of recombinant IFN-α in the culture at **8 hours** in the presence of lactose and the concentration of recombinant IFN-α in the culture at **8 hours** in the presence of IPTG.

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..... [1]

(iv) Suggest **one** reason for the change in the concentration of recombinant IFN-α in the culture containing IPTG from **12 hours** to **16 hours**.

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..... [1]

(b) The gene *AMP*^{R} in the plasmid shown in Fig. 2.1 codes for a protein that provides resistance to the antibiotic ampicillin.

Suggest how *AMP*^{R} allows genetically engineered *E. coli* containing the recombinant plasmid to be identified.

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..... [1]

(c) Bacteria can evolve antibiotic resistance through natural processes.

Outline how bacteria can evolve to become resistant to antibiotics.

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..... [5]

[Total: 13]

Question 3 starts on page 10.

3 Salmon can be genetically modified (GM) to produce increased quantities of growth hormone, which is a protein. GM salmon modified in this way have a faster growth rate and reach their maximum body mass at a younger age than non-GM salmon.

(a) Within any population of salmon there is variation in body mass. This is an example of continuous variation.

Explain what is meant by continuous variation **and** how it can be caused.

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..... [3]

(b) Scientists investigated whether injection of very young non-GM salmon with recombinant growth hormone could cause an increase in the growth rate of the salmon.

The scientists used two groups of non-GM salmon:

- a control group of salmon that were not injected with recombinant growth hormone
- an experimental group of salmon that were injected with 1.0 μg of recombinant growth hormone at the start of the experiment and once a week for the next six weeks.

The mean body mass of the salmon in the two groups at the start of the experiment was the same (5.3 g).

After six weeks, the body mass of every salmon was measured again. The results are summarised in Table 3.1.

Table 3.1

		no injection with recombinant growth hormone	**injected with recombinant growth hormone**
number of non-GM salmon (n)		28	27
body mass / g	range	6.5–8.6	7.2–12.7
	mean ($\bar{x}$)	7.7	9.4
	standard deviation (s)	0.4	1.1

A student decided that a *t*-test should be performed on the results shown in Table 3.1.

(i) Calculate the value of *t* for the results shown in Table 3.1 using the formula for the *t*-test:

$$t = \frac{\left|\bar{x}_1 - \bar{x}_2\right|}{\sqrt{\left(\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}\right)}}$$

Give your answer to **two** decimal places.

Show your working.

t = ...
[3]

(ii) The critical value at $p = 0.05$ for these data is 2.01.

The student used the results in Table 3.1 and the *t*-test to conclude that the injections of recombinant growth hormone cause an increase in the growth rate of the non-GM salmon.

Comment on the extent to which the conclusion made by the student can be supported.

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(iii) Suggest **one** advantage, **other** than cost, of farming GM salmon that produce increased quantities of growth hormone instead of farming non-GM salmon that are injected with recombinant growth hormone each week.

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..... [1]

[Total: 10]

4 Array comparative genome hybridisation (aCGH) is a technique involving the use of a microarray to analyse a genome or sections of a genome.

(a) Outline the steps required to prepare the genome of an individual so that the genome is ready for analysis using a microarray chip.

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..... [3]

(b) DiGeorge syndrome is a dominant inherited disease in humans. DiGeorge syndrome is caused by deletion of a large number of nucleotides from chromosome 22.

The number of nucleotides deleted varies between individuals in a range from 800 000 to 3 100 000. The largest deletions can cause the removal of up to 46 protein-coding genes from the chromosome.

Fig. 4.1 shows the results of aCGH using a microarray specific for the section of chromosome 22 within which the DiGeorge syndrome deletion occurs. The microarray analysed DNA from two individuals:

- one with DiGeorge syndrome
- one who did not have DiGeorge syndrome (control DNA for comparison).

In the aCGH results shown in Fig. 4.1:

- Each small circle represents the results from a single probe on the microarray.
- The *x*-axis shows the position of each probe on chromosome 22. The position is shown as distance along the chromosome in millions of nucleotides.
- A result close to 100% fluorescence on the *y*-axis means that the DNA from the individual with DiGeorge syndrome fluoresces at the same intensity as the control DNA for that probe.
- A result close to 50% fluorescence on the *y*-axis means that the DNA from the individual with DiGeorge syndrome fluoresces half as much as the control DNA for that probe.

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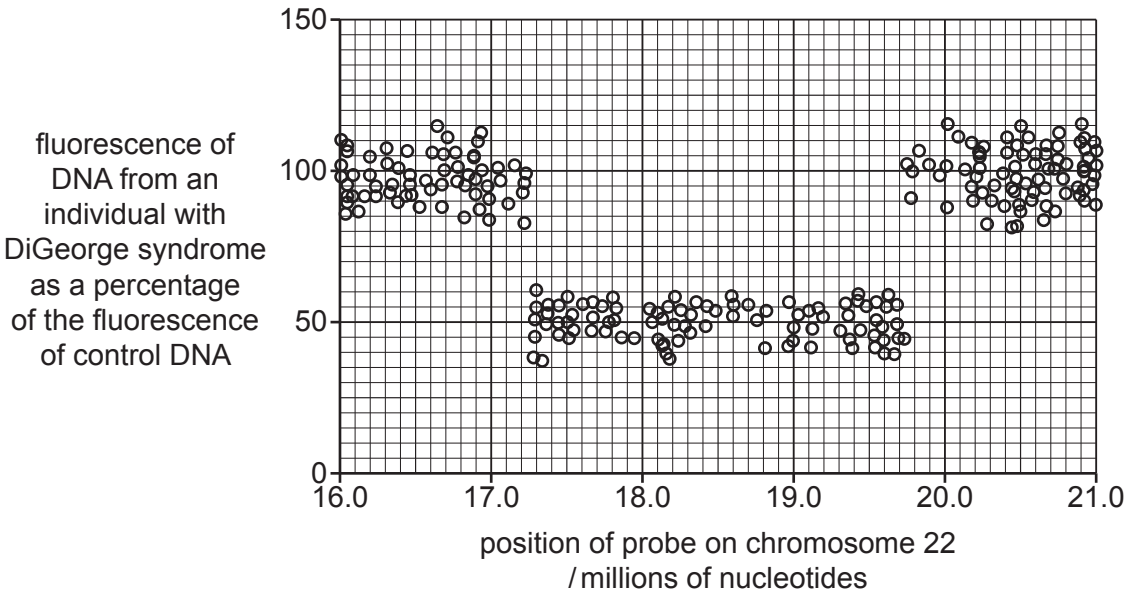


Fig. 4.1

(i) With reference to Fig. 4.1, estimate the number of nucleotides deleted from the affected chromosome 22 in the individual with DiGeorge syndrome.

Give your answer to the nearest 100 000 nucleotides.

..... [1]

(ii) Explain how the microarray technique works to give the results shown in Fig. 4.1.

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(iii) Suggest why the phenotypes of two individuals with DiGeorge syndrome can be different.

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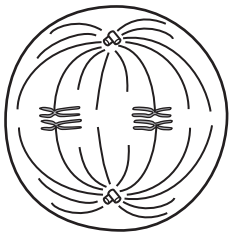
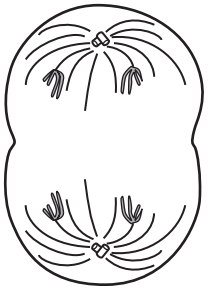
[Total: 10]

Question 5 starts on page 16.

5 Meiosis is described as a reduction division because the number of chromosomes in the daughter cells is reduced by half.

(a) Table 5.1 describes some of the events that take place during four of the different stages of meiosis in an animal cell.

Table 5.1

stage of meiosis	spindle fibres	diagram
metaphase I	attach to centromeres and arrange homologous pairs of chromosomes at the equator of the cell	
anaphase I		
	re-form spindle in daughter cells	
telophase II	disassemble	

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Complete Table 5.1 by:

- outlining the behaviour of the spindle fibres during anaphase I
- identifying the stage of meiosis in which spindle fibres re-form the spindle in daughter cells
- drawing a diagram to show telophase II.

You do **not** need to add labels to your diagram showing telophase II.

[4]

(b) Explain the need for a reduction division during meiosis.

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[Total: 8]

6 **(a)** Fig. 6.1 is a diagram of a section through a mitochondrion.

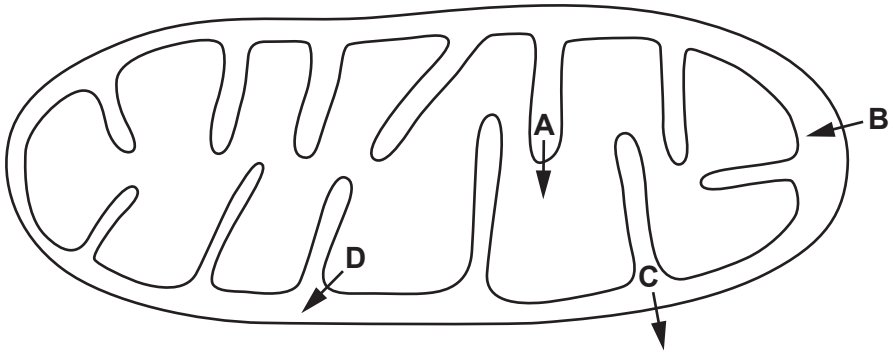


Fig. 6.1

The four arrows, **A**, **B**, **C** and **D**, show the movement of molecules and ions.

Use the letters to identify **all** the arrows (one or more) that show:

(i) active transport of protons

..... [1]

(ii) diffusion of carbon dioxide.

..... [1]

(b) Outline the role of the mitochondrial matrix in respiration.

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..... [3]

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(c) Explain how a lack of oxygen affects oxidative phosphorylation.

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..... [4]

[Total: 9]

7 **(a)** Fig. 7.1 is a diagram representing a synapse between a chemoreceptor cell from a human taste bud and a dendrite of a sensory neurone.

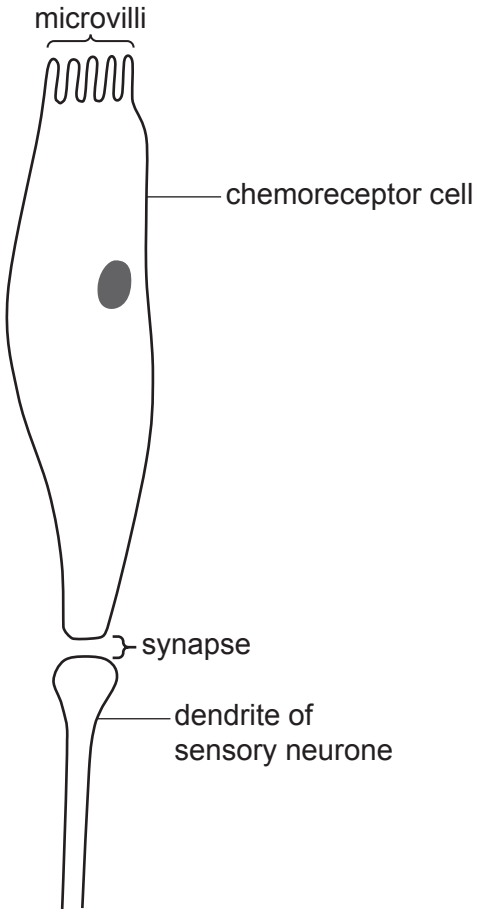


Fig. 7.1

In an experiment, different concentrations of sodium chloride solution were applied to the microvilli of the chemoreceptor cell. The membrane potential of the chemoreceptor cell and the membrane potential of the dendrite of the sensory neurone were recorded for each concentration.

The resting potential of this chemoreceptor cell is –50 mV and the resting potential of the dendrite of this sensory neurone is –70 mV.

The results are shown in Table 7.1.

Table 7.1

concentration of sodium chloride solution / g dm^{-3}	membrane potential / mV	
	chemoreceptor cell	dendrite of sensory neurone
0.1	–50	–70
1.0	+30	+40
10.0	+30	+40

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Explain the results shown in Table 7.1.

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.....[4]

(b) Describe the differences in structure **and** function between sensory neurones and motor neurones.

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..... [3]

[Total: 7]

8 **(a)** Describe the functions of the internal membranes of the chloroplast in photosynthesis.

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..... [7]

(b) Rubisco activase (RA) is an enzyme that has an effect on the activity of rubisco.

An investigation was carried out on the effect of RA on the activity of rubisco.

- Solutions of rubisco and RuBP were added to two tubes, **A** and **B**.
- RA was added to tube **A**.
- Both tubes were incubated at 25 °C for 6 minutes.
- The activity of rubisco was measured every 30 seconds.

All conditions were kept the same, except for the addition of RA to tube **A**.

The results are shown in Fig. 8.1.

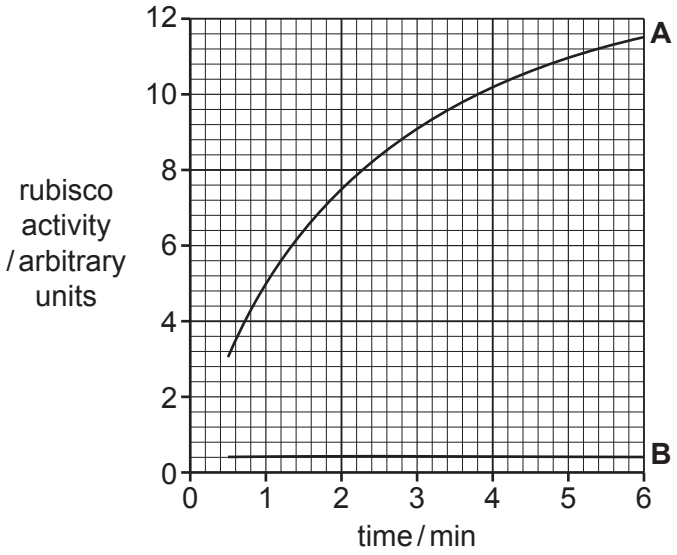


Fig. 8.1

Describe the results shown in Fig. 8.1 **and** suggest an explanation for the effect of RA on the activity of rubisco.

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..... [4]

[Total: 11]

9 **(a)** Fig. 9.1 is a diagram of a relaxed sarcomere in striated muscle.

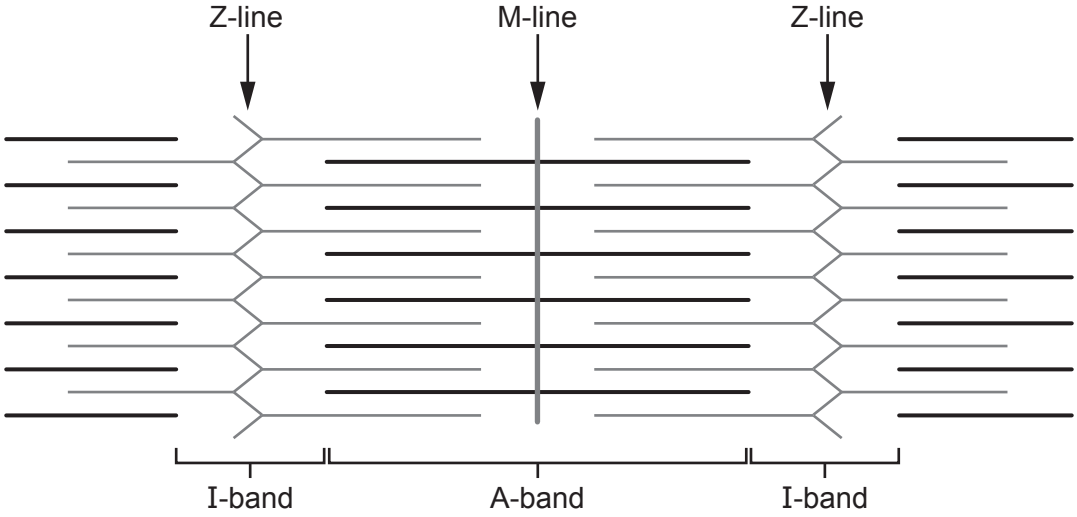


Fig. 9.1

(i) On Fig. 9.1, use label lines and letters to label:
- an actin filament with the letter **P**
- a myosin filament with the letter **R**.

[2]

(ii) State what happens to the A-band and the I-band when the sarcomere contracts.

A-band .....

I-band .....

[2]

(b) The plant *Strychnos toxifera* produces the toxin curare, which can cause muscle paralysis in mammals.

The toxin acts by binding to receptors on the cell surface membranes (sarcolemma) of muscle cells at neuromuscular junctions.

(i) Suggest how binding of curare to receptors may cause muscle paralysis.

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..... [4]

(ii) Suggest why the action of curare may lead to the death of a mammal.

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..... [2]

[Total: 10]

10 (a) The passage in Fig. 10.1 is about biodiversity.

Complete the passage by using the most appropriate scientific terms.

Biodiversity within an area can be assessed at different levels, including the species diversity, genetic diversity and ecological diversity.

Species diversity can be assessed by determining the number of different species and the relative ..... of different species in a given area. From this information, species diversity can be estimated using ..... index of diversity.

Organisms of the same species can show much genetic diversity even though they share the same ..... . This is because they can have different combinations of ..... .

The greater the genetic diversity, the greater the ability of a species to ..... to a changing environment.

Ecological diversity is a measure of the number and range of different ecosystems and ..... within a given area.

Fig. 10.1

[6]

(b) The International Union for Conservation of Nature (IUCN) Red List of Threatened Species is updated regularly.

Table 10.1 shows the numbers of endangered animal species counted every three years between 2007 and 2019.

Table 10.1

year	number of endangered species
2007	7851
2010	9618
2013	11212
2016	12630
2019	14234

(i) Calculate the rate of increase in the number of endangered species between 2007 and 2019.

Show your working.

Give your answer to the nearest whole number.

rate of increase = ... per year
[2]

(ii) More species of fish were listed as endangered in 2019 than species of mammals.

Suggest reasons why more fish species than mammal species are endangered.

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..... [4]

[Total: 12]

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