Oxford Cambridge and RSA

Thursday 6 June 2019 – Morning

A Level Biology B (Advancing Biology)

H422/01 Fundamentals of biology

Time allowed: 2 hours 15 minutes

You must have:
- the Insert (inserted)

You may 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
- The Insert will be found inside this document.
- Use black ink. You may use an HB pencil for graphs and diagrams.
- Answer **all** the questions.
- Where appropriate, your answers should be supported with working. Marks may be given for a correct method even if the answer is incorrect.
- Write your answer to each question in the space provided. If additional space is required, use the lined page(s) at the end of this booklet. The question number(s) must be clearly shown.

INFORMATION
- The total mark for this paper is **110**. There are **30 marks** in Section **A** and **80 marks** in Section **B**.
- The marks for each question are shown in brackets **[ ]**.
- Quality of extended responses will be assessed in questions marked with an asterisk (*****).
- This document consists of **36** pages.

Turn over

SECTION A

You should spend a maximum of 40 minutes on this section.

Write your answer to each question in the box provided.

Answer **all** the questions.

1 Which of the options, **A** to **D**, is a property of the phosphate group in phospholipids?

A hydrophilic

B hydrophobic

C non-polar

D saturated

Your answer ☐

[1]

2 Which of the options, **A** to **D**, is a type of reaction involved in the breakdown of a phospholipid?

A condensation

B dehydrogenation

C hydrolysis

D phosphorylation

Your answer ☐

[1]

3 Which of the options, **A** to **D**, is the net gain in ATP molecules following the glycolysis of **one** glucose molecule?

A 1

B 2

C 4

D 6

Your answer ☐

[1]

4 Which of the options, **A** to **D**, is the number of molecules of triose phosphate required to produce **two** molecules of glucose?

A 1

B 2

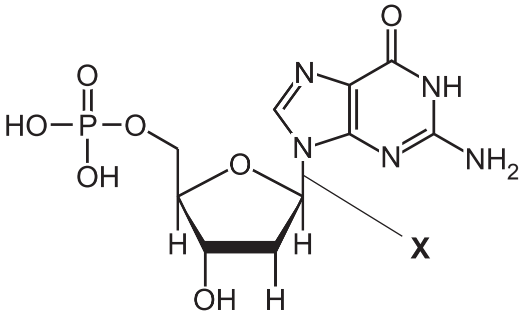
C 4

D 8

Your answer ☐

[1]

5 The diagram below shows the structure of a nucleotide. A bond is labelled **X**.



Which of the following statements is/are correct?

1 **X** is a phosphodiester bond.

2 The sugar is deoxyribose.

3 The base is a purine.

A 1, 2 and 3 are correct

B only 1 and 2 are correct

C only 2 and 3 are correct

D only 1 is correct

Your answer ☐

[1]

6 Which of the options, **A** to **D**, is the location of ATP synthase in a chloroplast?

A inner membrane

B stroma

C thylakoid lumen

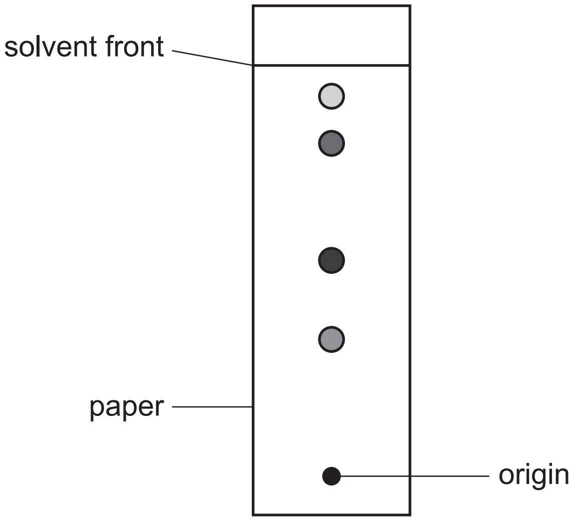
D thylakoid membrane

Your answer ☐

[1]

7 Photosynthetic pigments in a leaf were separated using paper chromatography.

The resulting chromatogram is shown below.



Which of the options, **A** to **D**, is the retention factor (R_f) for the most soluble pigment?

A 0.33

B 0.93

C 1.07

D 3.04

Your answer ☐

[1]

8 Which of the options, **A** to **D**, is the component of a cereal grain that contains starch?

A aleurone layer

B embryo

C endosperm

D seed coat

Your answer ☐

[1]

9 Which of the statements, **A** to **D**, is a correct description of why plants need transport systems?

A Plants are multicellular.

B Plants have a large surface area:volume ratio.

C The metabolic rate of plants is high.

D The required movement of some molecules cannot be met by diffusion alone.

Your answer ☐

[1]

10 The table below shows some energy data for a forest ecosystem.

total plant biomass	70 000 kcal m^{-2}
total animal biomass	4 300 kcal m^{-2}
gross primary productivity	18 000 kcal m^{-2} yr^{-1}
animal respiration	2 900 kcal m^{-2} yr^{-1}
plant respiration	6 500 kcal m^{-2} yr^{-1}

Which of the options, **A** to **D**, is the net primary productivity of the ecosystem in kcal m^{-2} yr^{-1}?

A 11 500

B 24 500

C 52 000

D 92 300

Your answer ☐

[1]

11 A student investigated biodiversity in adjacent woodland and wetland habitats. The results are summarised in the table below.

Species	**Woodland**	**Wetland**
P	5	11
Q	2	0
R	23	10
S	0	9
total (N)	30	30

Simpson's index of diversity (D): $D = 1 - \left(\sum \left(\frac{n}{N}\right)^2\right)$

Which of the following statements is/are correct?

1 The species richness of woodland and wetland are the same.

2 The wetland area has the greater Simpson's index of diversity.

3 In the formula for D shown above, $\sum \left(\frac{n}{N}\right)^2$ is always less than or equal to 1.

A 1, 2 and 3 are correct

B only 1 and 2 are correct

C only 2 and 3 are correct

D only 1 is correct

Your answer ☐

[1]

12 Which of the biological processes, **A** to **D**, is an example of facilitated diffusion?

A influx of sodium ions into a neurone during an action potential

B loading of sucrose into a companion cell

C movement of protons into the mitochondrial intermembrane space

D movement of acetylcholine across the synaptic cleft

Your answer ☐

[1]

13 A section of plant tissue was examined to determine the percentage of cells in each stage of the cell cycle. There were 115 cells in total. Some of the results are shown in the table below.

Stage of cell cycle	Number of cells
anaphase	4
cytokinesis	2
G_1 phase	41
G_2 phase	17
prophase	3
metaphase	3
S phase	36
telophase	9

Which of the options, **A** to **D**, is the percentage of cells in nuclear division?

A 2

B 17

C 18

D 82

Your answer ☐

[1]

14 A mutation in a gene may cause the protein for which the gene codes to become inactive.

Which of the proteins, **A** to **D**, would promote the development of cancer if it were inactivated?

A EPO

B Myc

C p53

D Ras

Your answer ☐

[1]

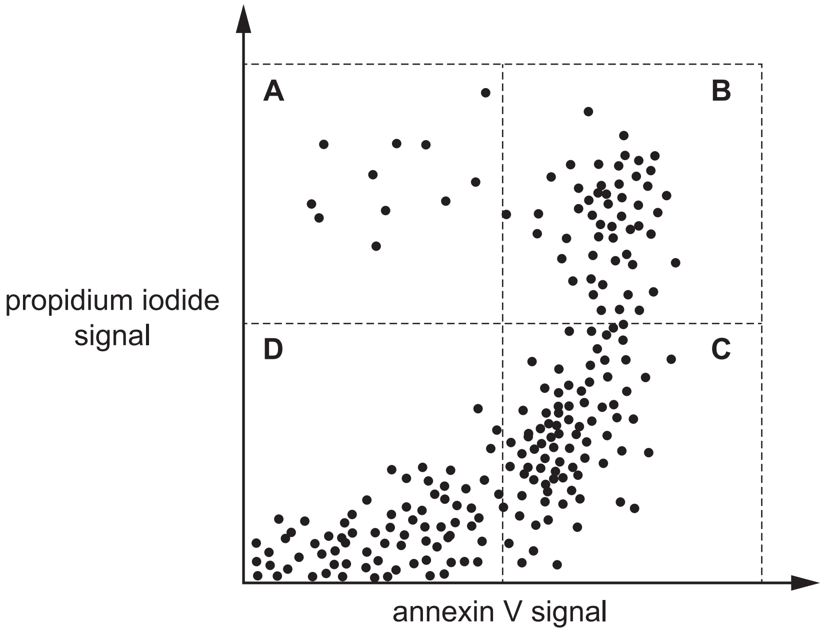
15 Cells undergoing apoptosis can be distinguished from living cells by staining with two reagents:

- annexin V, which binds to phosphatidylserine
- propidium iodide, which binds to DNA.

After staining, a flow cytometer is used to measure the fluorescent signal from each cell.

Neither reagent can diffuse across biological membranes.

The graph below shows the result of a flow cytometry experiment in a population of cells using annexin V and propidium iodide. Four regions are labelled **A** to **D**.



Which of the regions from the graph, **A** to **D**, identifies cells in **late** apoptosis?

Your answer ☐

[1]

16 An initial exposure to an allergen prepares the immune system for a rapid response upon repeated exposure. This process is known as sensitisation.

Which of the options, **A** to **D**, results in sensitisation to an allergen?

A binding of IgE to mast cells

B differentiation of B cells into plasma cells

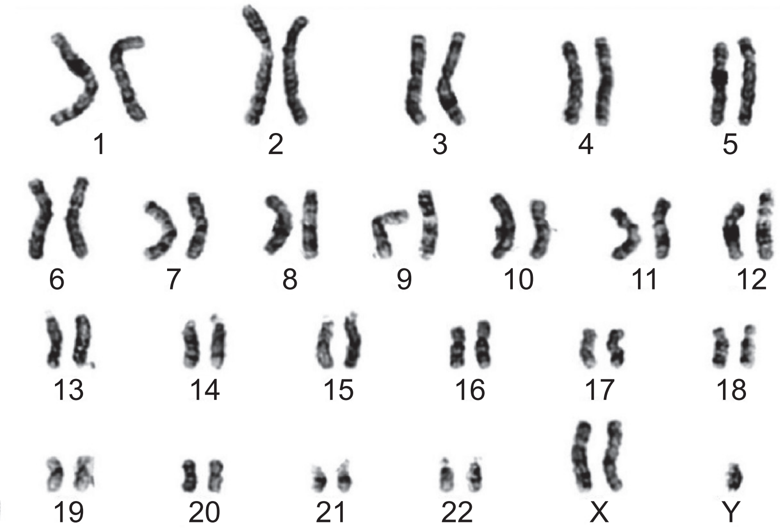
C recognition of allergenic antigen by B and T cells

D secretion of IgE by plasma cells

Your answer ☐

[1]

17 The diagram below is a karyotype prepared from a human cell.



Which of the following statements is/are correct?

1 The cell could have been obtained from amniotic fluid.

2 The karyotype shows evidence of Turner's syndrome.

3 The cell was in interphase.

A 1, 2 and 3 are correct

B only 1 and 2 are correct

C only 2 and 3 are correct

D only 1 is correct

Your answer ☐

[1]

18 A couple have a child. Both parents are heterozygous for the cystic fibrosis allele.

Which of the options, **A** to **D**, is the probability that the child will have cystic fibrosis?

A 0.25

B 0.5

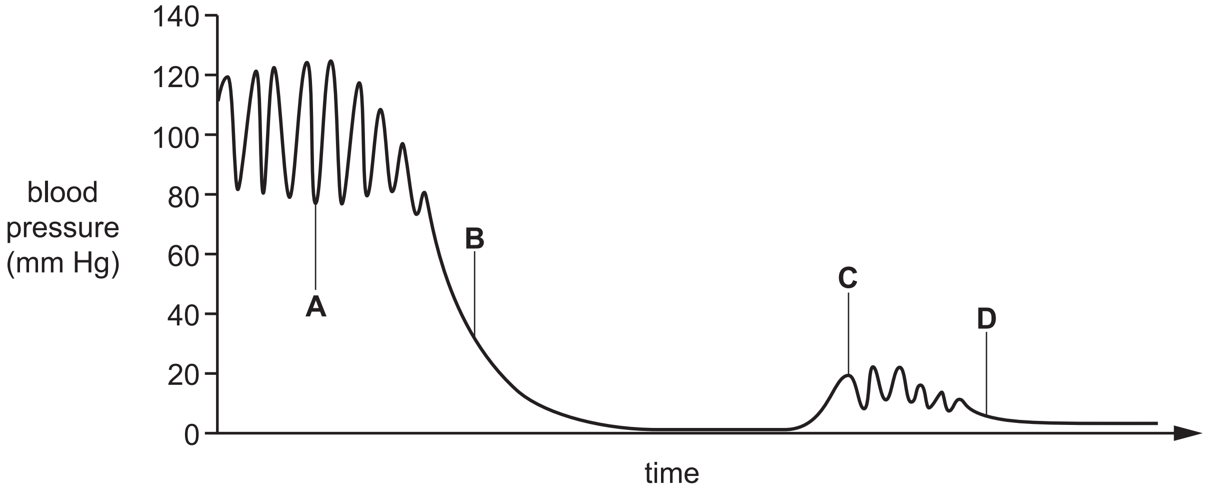
C 0.75

D 1

Your answer ☐

[1]

19 The graph below shows the normal variation in blood pressure across different regions of the human circulatory system. Four regions are labelled **A** to **D**.



Which of the regions on the graph, **A** to **D**, is the region in which blood becomes oxygenated?

Your answer ☐

[1]

20 Which of the options, **A** to **D**, causes an increase in stroke volume following regular exercise?

A atrial hypertrophy

B decrease in blood pressure

C increase in heart rate

D ventricular hypertrophy

Your answer ☐

[1]

21 Heart rate is affected by the sympathetic and parasympathetic nervous systems.

Which of the options, **A** to **D**, is an event that stimulates the accelerator nerve?

A decrease in blood pH

B increase in blood pressure

C release of adrenaline into the blood

D release of glucose into the blood

Your answer ☐

[1]

22 The tail of a sperm cell generates whipping movements that enable the cell to swim.

Which of the options, **A** to **D**, is the component that generates movement in the tail of a sperm cell?

A actin

B microtubule

C myosin

D troponin

Your answer ☐

[1]

23 Which of the following statements about DNA replication in eukaryotes is/are correct?

1 Helicase exposes the templates required by DNA polymerase.

2 Free nucleotides are polymerised in the 3’ to 5’ direction.

3 Polymerisation of free nucleotides is continuous on both templates.

A 1, 2 and 3 are correct

B only 1 and 2 are correct

C only 2 and 3 are correct

D only 1 is correct

Your answer ☐

[1]

24 The contraceptive pill is used to prevent pregnancy. The pill contains synthetic forms of oestrogen and progesterone.

Which of the options, **A** to **D**, is a mechanism by which the pill prevents pregnancy?

A destruction of the corpus luteum

B inhibition of FSH and LH secretion

C thickening of the uterine lining

D stimulation of GnRH secretion

Your answer ☐

[1]

25 Head circumference (HC) is a key indicator of fetal size and is estimated from two ultrasound measurements:

- biparietal diameter (BPD)
- occipitofrontal diameter (OFD).

HC = 1.62 × (BPD + OFD)

The table below shows BPD and OFD measurements from a fetus.

Measurement	**Length (mm)**
BPD	76 ± 4.2
OFD	98 ± 6.5

Which of the options, **A** to **D**, is the percentage uncertainty for the HC measurement of this fetus?

A 6.1

B 10.7

C 12.2

D 37.0

Your answer ☐

[1]

26 Trisodium citrate is a compound used for the long-term preservation of whole blood. The compound prevents blood clotting by reacting with an ion.

Which of the options, **A** to **D**, is the ion with which trisodium citrate reacts to prevent blood clotting?

A calcium (Ca^{2+})

B chloride (Cl^-)

C magnesium (Mg^{2+})

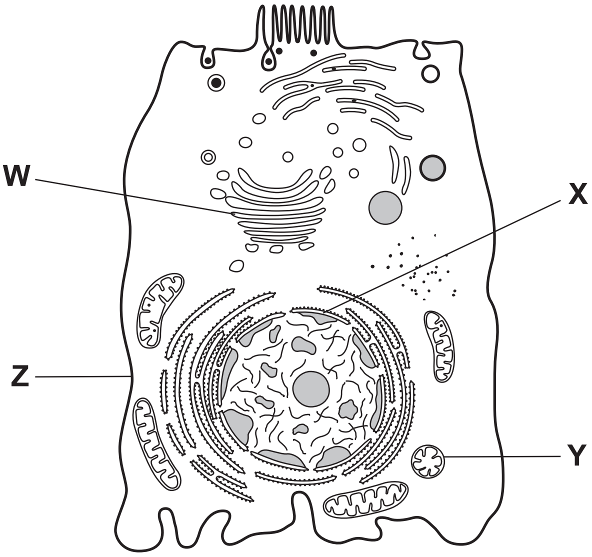
D potassium (K^+)

Your answer ☐

[1]

27 The diagram below shows the ultrastructure of an animal cell.

Four structures are labelled **W** to **Z**.



Which of the rows in the table below correctly identifies the structures that can (✓) and can **not** (×) be visualised under a light microscope?

Row	W	X	Y	Z
A	×	×	×	✓
B	×	✓	×	✓
C	✓	✓	✓	×
D	✓	×	×	✓

Your answer ☐

[1]

28 Brain atrophy is the loss of brain tissue as a result of neuronal cell death.

A study was conducted to investigate a possible relationship between brain atrophy and levels of β-amyloid in fifty patients with Alzheimer's disease.

Paired measurements of brain volume and β-amyloid were taken from each patient using an imaging technique.

Which of the statistical tests, **A** to **D**, is appropriate to analyse the correlation of the data obtained?

A chi squared (χ^2) test

B paired Student's *t*-test

C Spearman's rank

D unpaired Student's *t*-test

Your answer ☐

[1]

29 Alzheimer's disease is associated with several pathological changes in the brain.

Which of the options, **A** to **D**, is observed in the brain of an individual with Alzheimer's disease?

A β-amyloid protein in synaptic vesicles

B β-amyloid protein in the nuclei of neurones

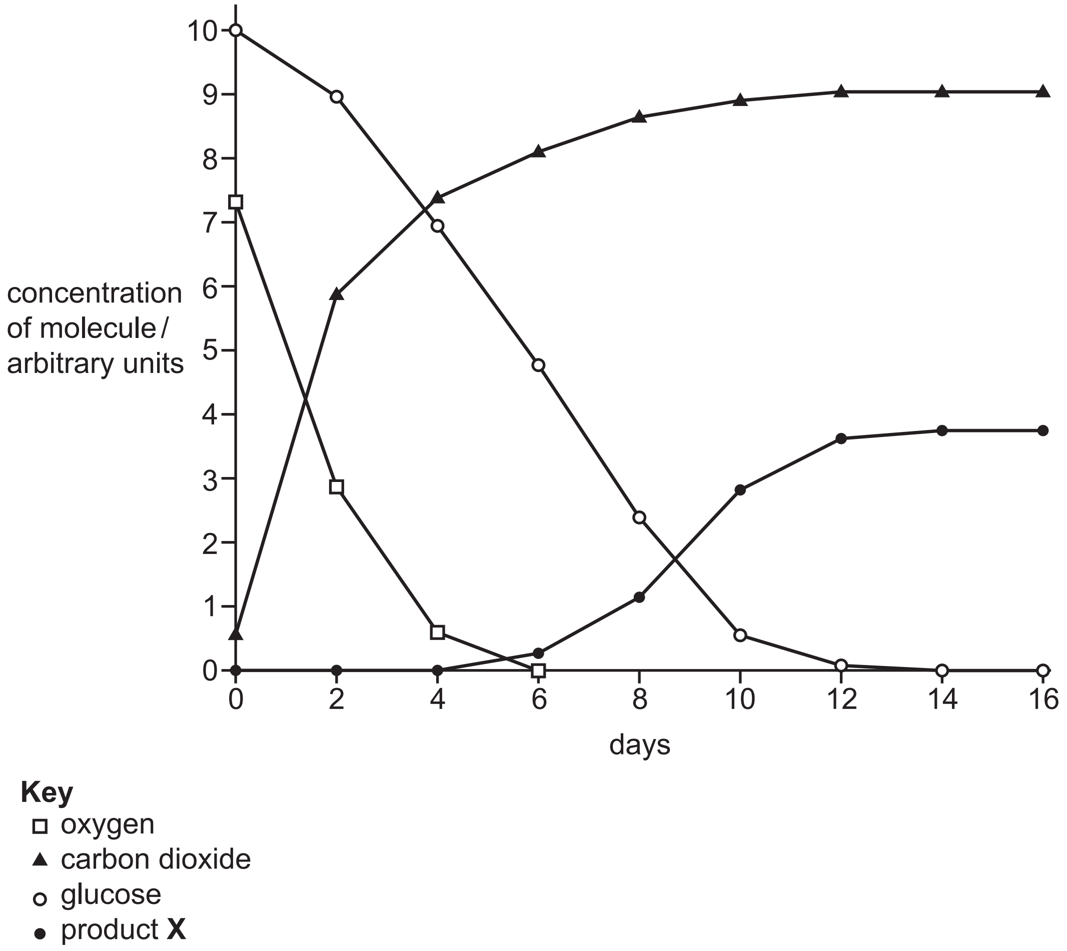
C neurofibrillary tangles in the cytoplasm of neurones

D Tau protein around neurones

Your answer ☐

[1]

30 The graph below shows the concentration of several molecules over time in the medium of a cell culture.



Which of the following statements is/are correct?

1 The culture comprises mammalian cells, **not** yeast cells.

2 The graph shows evidence of aerobic and anaerobic respiration.

3 Product **X** is generated in the cell cytoplasm.

A 1, 2 and 3 are correct

B only 1 and 2 are correct

C only 2 and 3 are correct

D only 1 is correct

Your answer ☐

[1]

SECTION B

Answer **all** the questions.

31 The human immunodeficiency virus (HIV) is spread through direct contact with body fluids.

Untreated HIV infection causes progressive destruction of the immune system. This leads to acquired immunodeficiency syndrome (AIDS).

The graph in Fig. 31.1 summarises yearly epidemiological data relating to HIV infection and AIDS in the USA between 1981 and 2008.

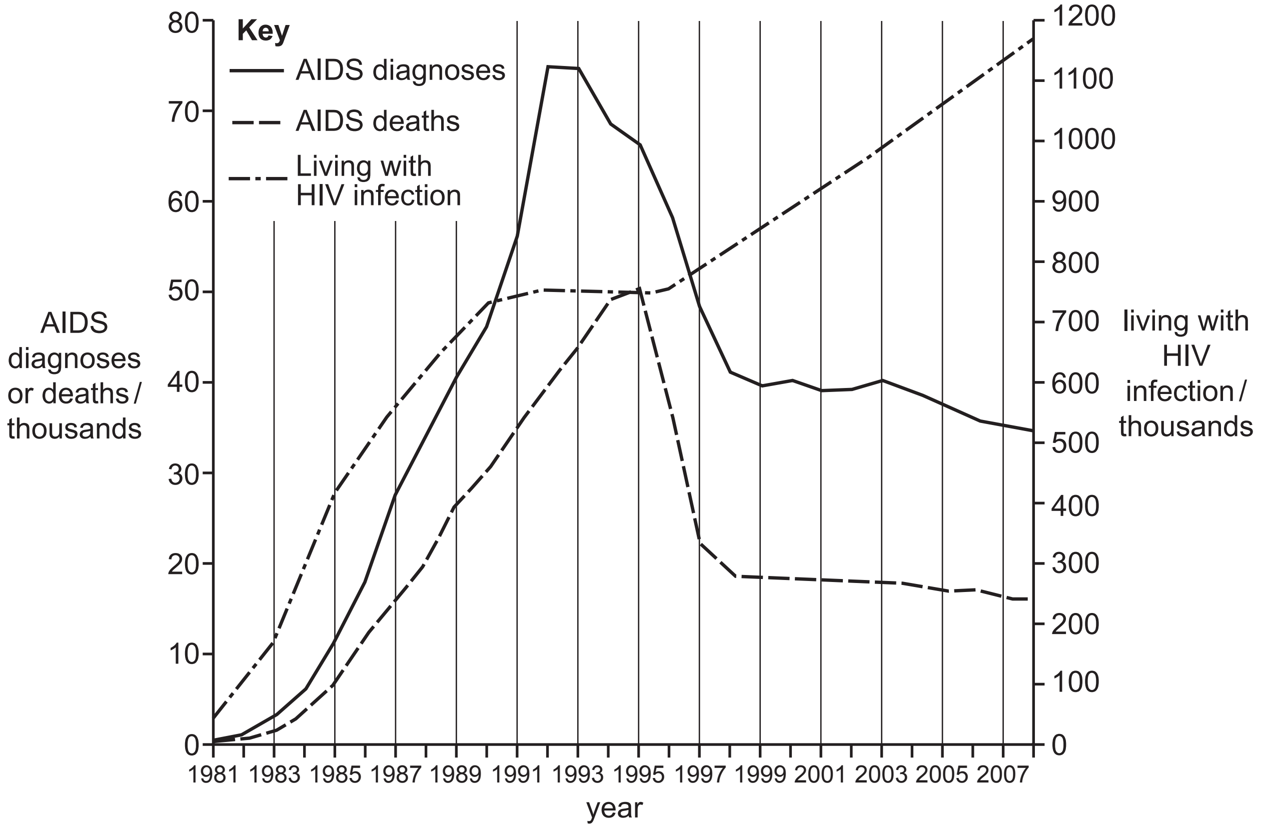


Fig. 31.1

(a) **(i)** The population of the USA in 1993 was 260 million.

Estimate the mortality rate of AIDS in the USA in 1993.

mortality rate = ... deaths per 100 000 population **[2]**

(ii) Patients with HIV/AIDS are managed with highly active antiretroviral therapy (HAART), which was introduced in 1996.

Discuss the effectiveness of HAART as a treatment for patients with HIV/AIDS. Use the data in Fig. 31.1 to support your answer.

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.... **[4]**

(b) HIV testing can prevent the spread of infection. In the UK, HIV testing must be carried out with consent from the patient. The results must be treated in a confidential manner.

Suggest **two** other ethical or social concerns associated with receiving an HIV positive test result.

1..

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2..

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[2]

(c) Vaccines against HIV are currently being developed:

- to protect individuals from contracting HIV
- to boost the immune response in HIV-positive individuals.

Explain why it is difficult to produce an effective vaccine for HIV.

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.... **[3]**

(d) HIV destroys the immune system by infecting and killing a type of T helper cell known as a CD4 cell. Therefore, blood levels of CD4 cells can indicate strength of the immune system in patients with HIV.

A clinical trial was conducted to evaluate the safety and effectiveness of a new HIV vaccine in patients with HIV receiving HAART.

(i) The vaccine contains a purified viral protein known as Tat, which is required for transcription of the HIV genome.

State **one** advantage of using purified Tat protein instead of a live, attenuated (weakened) virus.

....

.... **[1]**

(ii) Fig. 31.2 shows CD4 cell levels over time in patients immunised with 7.5 μg or 30 μg Tat protein.

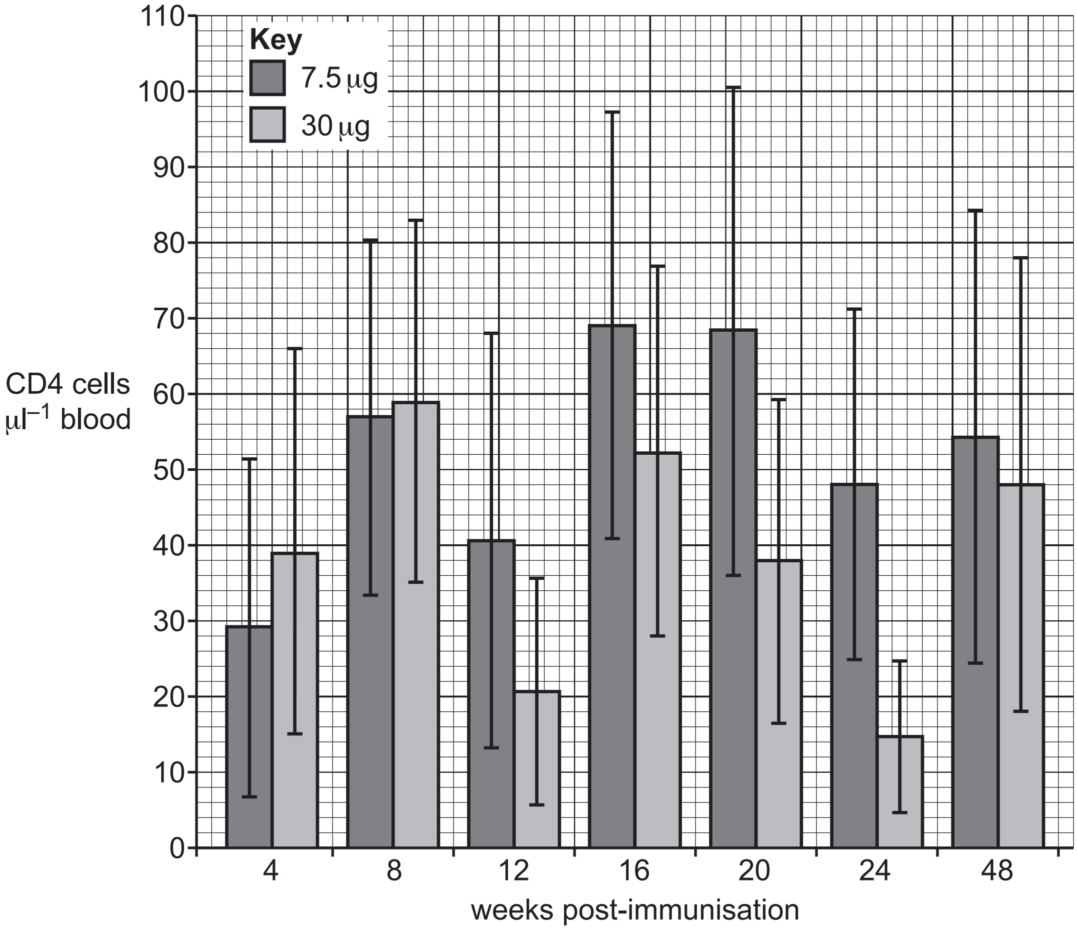

Fig. 31.2

Suggest **two** reasons why the effectiveness of the vaccine can **not** be determined from the data in Fig. 31.2.

1 ....

....

2 ....

.... **[2]**

(e) AIDS is an advanced stage of HIV infection that is defined by the occurrence of opportunistic infections, such as tuberculosis (TB) and hepatitis B and C. TB is the most common opportunistic infection in patients with HIV.

(i) In the UK, TB is a notifiable disease.

State **two** possible consequences of the reporting of a notifiable disease.

1 ....

....

2 ....

.... **[2]**

(ii) Active TB infection is treated with a combination of antibiotics.

The cell wall of the TB pathogen *Mycobacterium tuberculosis* is strengthened by complex lipid molecules.

What term is given to describe antibiotics that inhibit cell wall synthesis?

.... **[1]**

(iii) Multi-drug resistance is a major challenge in the treatment of patients with TB.

Outline how a population of *M. tuberculosis* may become resistant to antibiotics.

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.... **[3]**

Turn over

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32 Abscisic acid (ABA) is a plant hormone that plays a role in many physiological processes.

(a) **(i)** Most ABA is produced in root hair cells and is carried in xylem tissue to the leaves.

ABA is transported to the xylem tissue via the apoplast pathway. Describe this pathway.

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.... **[2]**

(ii) Some ABA is produced in leaves and is transported to the rest of the plant in phloem tissue.

The photomicrograph in Fig. 32.1, **on the insert**, is a transverse section through a stem.

State which letter, **R** to **U**, in Fig. 32.1, represents phloem tissue.

.... **[1]**

(iii) Describe and explain **three** ways in which phloem tissue is adapted for the transport of sugars and other small molecules.

1 ....

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2 ....

....

3 ....

....

[3]

(b) ABA is known to promote the closure of stomata.

Binding of ABA to receptors on the surface of guard cells results in the removal of ions.

Explain how a loss of ions in guard cells causes the stomata to close.

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.... **[2]**

(c) An experiment was conducted to investigate the effect of soil water potential on the production of ABA in leaves and the resistance to air flow through stomata.

The following parameters were measured daily in a maize plant:

- water potential of soil
- resistance to air flow through stomata
- ABA concentration in leaves.

Before the experiment, the plant was well-watered. The plant was not watered again until day 6 of the experiment.

The results are shown in Fig. 32.2.

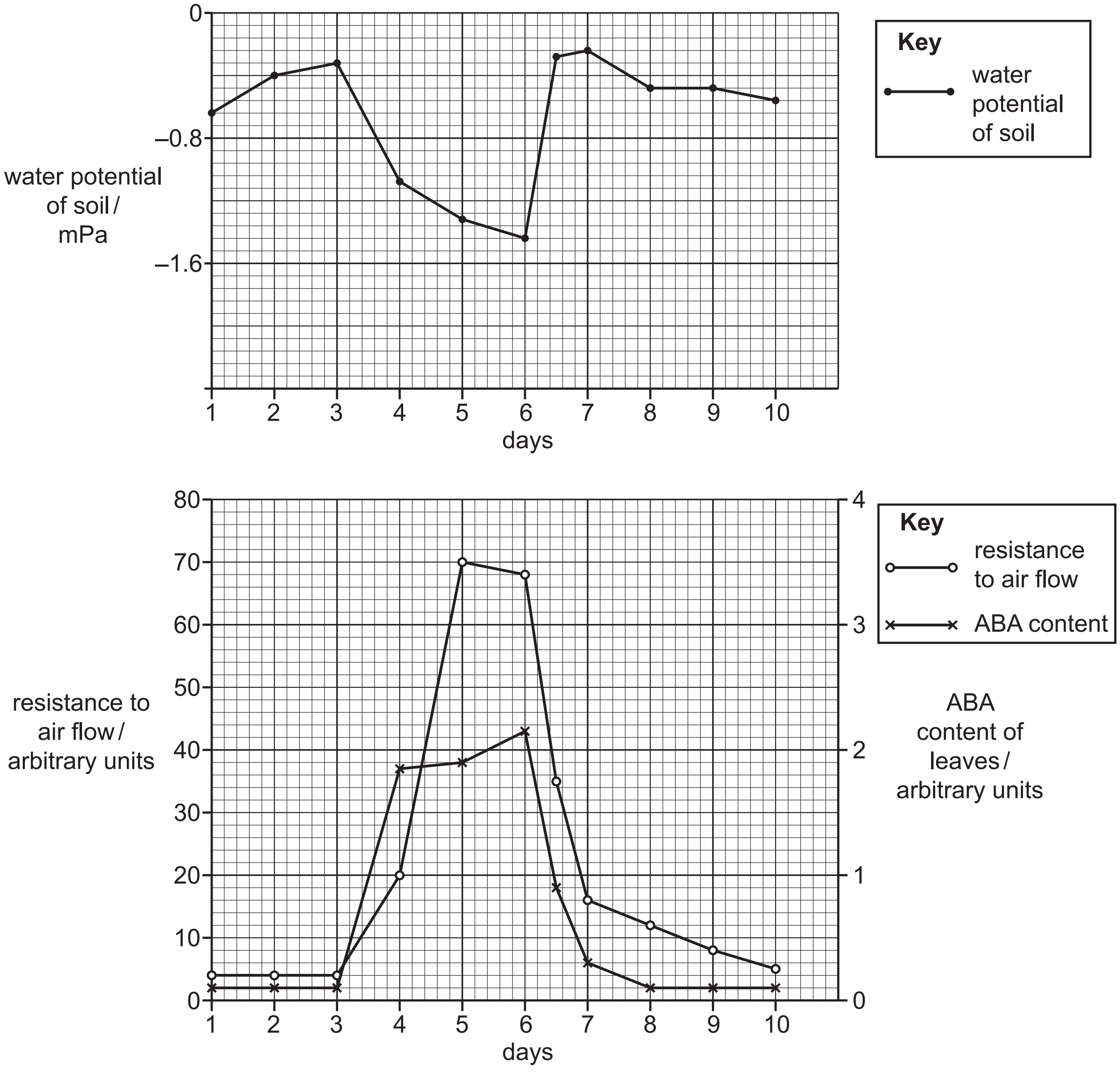

Fig. 32.2

The investigator made the following claim:

The data show that dry soil conditions promote the synthesis of ABA in maize plants, causing stomata to close.

Discuss the validity of this claim using **only** the data shown in Fig. 32.2.

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.... **[3]**

Turn over for the next question

33 An experiment was carried out to investigate osmosis in potato cells.

Six beakers were filled with distilled water and dissolved sucrose to produce six solutions ranging from 0.0 to 1.0 mol dm^{-3} sucrose concentration.

A potato was peeled and cut into slices of exactly 2.50 g mass. Five slices were soaked in each sucrose solution for 30 minutes. The slices were then removed, briefly dried with tissue and weighed.

The final mass of each potato slice is shown in Table 33.

Sucrose concentration / mol dm^{-3}	**Final mass of potato slice / g**						
	1	**2**	**3**	**4**	**5**	**Mean**	**Standard deviation**
0.0	2.78	2.74	2.79	2.80	2.89	2.80	0.06
0.2	2.66	2.58	2.61	2.64	2.66	2.63	0.03
0.4	2.44	2.47	2.45	2.50	2.43	2.46	0.03
0.6	2.38	2.29	2.36	2.34	2.29	2.33	▨
0.8	2.32	2.31	2.20	2.26	2.28	2.27	0.05
1.0	2.25	2.23	2.19	2.16	2.26	2.22	0.04

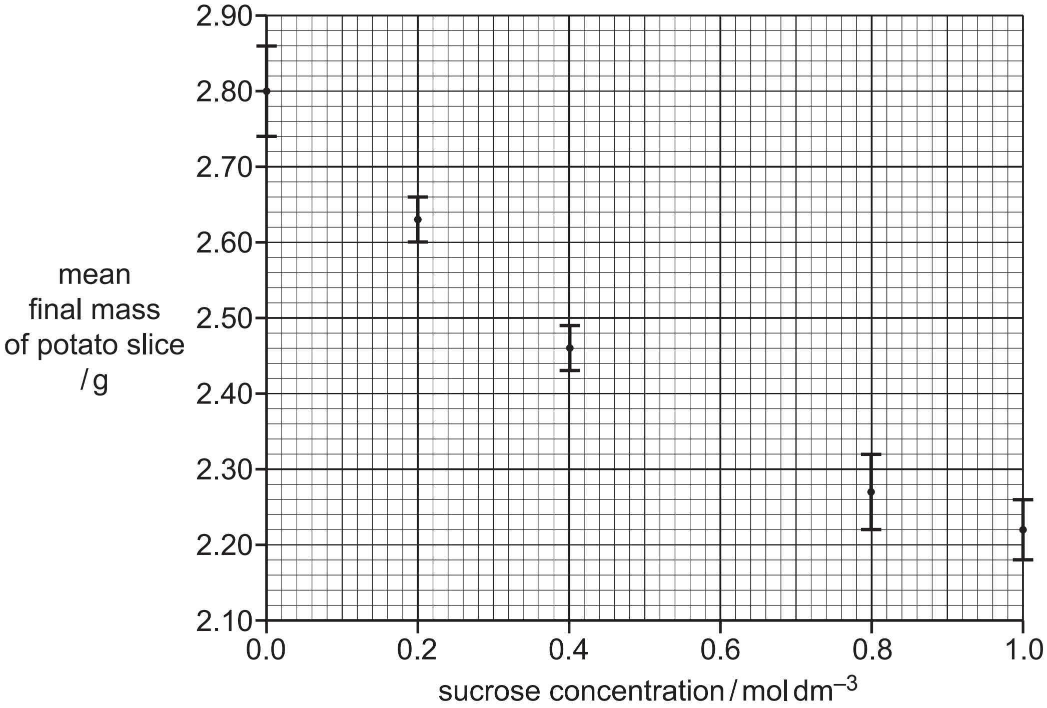
Table 33

(a) (i) Calculate the standard deviation for the final mass of potato slices soaked in 0.6 mol dm^{-3} sucrose concentration.

Use the formula: $s = \sqrt{\frac{\sum(x - \bar{x})^2}{n - 1}}$

standard deviation = ... **[2]**

(ii) The graph below represents the data in Table 33.



Complete the graph by plotting the data for the potato slices soaked in 0.6 mol dm^{-3} sucrose using the data in Table 33 **and** the standard deviation calculated in **(a)(i)**.

[2]

(iii) With reference to the data in Table 33, explain how the sucrose concentration of the solution determines the final mass of potato.

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.... **[3]**

(iv) Suggest **two** factors in the method that could have contributed error to the data, as shown by the error bars in the graph in **(a)(ii)** on page 25.

1 ....

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2 ....

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[2]

(b) Osmosis can also be investigated on a single-cell scale with microscopy by measuring cell size.

Fig. 33 shows the view down a microscope fitted with a stage micrometer.

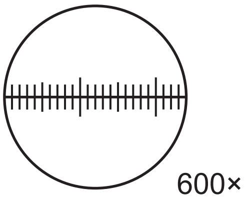

Fig. 33

Calculate the **area** of the field of view of the microscope set up as shown in Fig. 33.

Give your answer to the nearest whole number.

area = ... μm^2 **[2]**

34 VO_2 max is an indicator of cardiovascular fitness and a predictor of mortality risk.

(a) **(i)** Describe what is meant by the term VO_2 max.

....

.... **[1]**

(ii) VO_2 max can be estimated from measurements of heart rate.

Suggest **one** advantage of **estimating** VO_2 max over taking a direct measurement.

....

.... **[1]**

Question 34(b) begins on page 28

(b)* A study published in 2004 demonstrated that VO_2 max can be estimated from an individual's maximum heart rate (HR_{max}) and resting heart rate (HR_{rest}), as follows:

$VO_2 \text{ max} = 15 \times (HR_{max} \div HR_{rest})$

Outline a method to investigate the effect of a fitness training programme on estimated VO_2 max in a group of school students.

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.... **[6]**

Additional answer space if required

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(c) Some athletes train at high altitude prior to participation in a sporting event. High altitude is defined as an elevation greater than 2000 m above sea level.

At high altitude, atmospheric air pressure is lower than at sea level, but the proportion of oxygen in the air remains the same.

(i) VO_2 max is **immediately** decreased at high altitude. Suggest why.

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.... **[2]**

(ii) Air temperature changes at higher altitudes.

Suggest why air temperature can affect VO_2 max.

....

.... **[1]**

(d) Excess post-exercise oxygen consumption (EPOC) is required for the regeneration of ATP and the replenishment of muscle glycogen stores.

Give **two** other reasons why excess oxygen is required after exercise.

1..

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2..

....

[2]

(e) The objective of training, particularly at high altitudes, is to increase the efficiency of oxygen delivery to muscle fibres.

The photomicrographs in Fig. 34, **a** and **b**, show sarcomeres in the relaxed and contracted state.

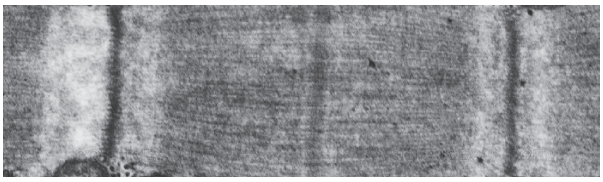

Fig. 34a

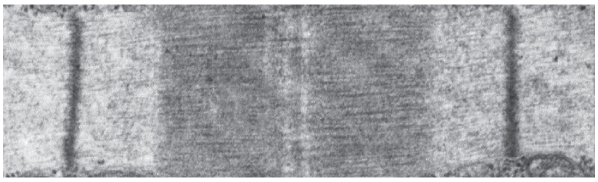

Fig. 34b

State which photomicrograph, **a** or **b**, shows a sarcomere in the relaxed state. Give **two** pieces of evidence to justify your answer.

photomicrograph ....

evidence 1 ....

....

evidence 2 ....

.... **[2]**

(f) Table 34 shows some of the events of the sliding filament mechanism of muscle contraction. The events are lettered **A** to **E**.

A	ATP is hydrolysed to ADP and inorganic phosphate by the ATPase activity on the myosin head.
B	The myosin head binds to another myosin binding site on the actin filament.
C	ATP binds to the myosin head, causing the head to detach from the myosin binding site on the actin filament.
D	ADP and inorganic phosphate are released. The myosin head pushes the actin filament towards the centre of the sarcomere.
E	The angle of the myosin head changes into a new (cocked) position.

Table 34

Write the letters, **A** to **E**, in the correct order in the spaces below. The first space has been done for you.

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

35 CRISPR is an adaptive system in bacteria that protects against invading viruses by destroying viral DNA upon entry into cells.

CRISPR is an acronym for **c**lustered **r**egularly **i**nterspaced **s**hort **p**alindromic **r**epeats.

(a) Define the term palindrome in the context of DNA.

....

.... **[1]**

(b) The actions of CRISPR are mediated by an enzyme-RNA complex. The enzyme, Cas9, is attached to a guide RNA molecule, as shown in Fig. 35.

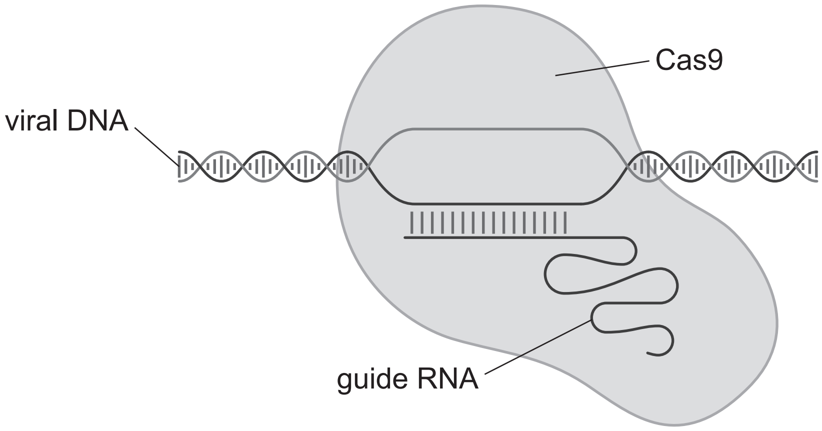

Fig. 35

The guide RNA molecule is complementary to the viral DNA molecule. Upon binding of the guide RNA to viral DNA, Cas9 cuts straight through both strands of the DNA at a precise position. The gene encoded by the DNA is inactivated. This prevents the virus from replicating inside the bacterial cell.

(i) Cas9 is an endonuclease enzyme because it cuts within a nucleotide sequence.

Name another type of bacterial endonuclease enzyme.

.... **[1]**

(ii) State **one** similarity and **one** difference between Cas9 and the type of enzyme in **(b)(i)**.

similarity ....

....

difference...

....

[2]

(c) CRISPR has been adapted into a laboratory tool for genetic modification in eukaryotic cells. Using purified Cas9 protein and artificially-synthesised guide RNA molecules, scientists can target genes of interest.

In eukaryotic cells, DNA breaks induced by Cas9 are repaired by the cell's own (imperfect) DNA repair mechanisms. This leads to the generation of mutations at the site of the DNA break, and the gene function is lost.

RNA interference (RNAi) is another laboratory tool that scientists can use to target genes of interest.

Using the information provided, and your knowledge of RNAi, discuss the advantages **and** disadvantages of CRISPR and RNAi for the study of gene function.

CRISPR ....

....

....

....

RNAi ....

....

....

....

[4]

(d) Using the most appropriate word(s), complete the sentences below about the production of mature mRNA.

A molecule of pre-mRNA contains sequences that code for amino acids, known as .... , and sequences that are non-coding, known as .... The process of .... removes non-coding regions and joins coding regions to produce a molecule of mature mRNA. In this way, a gene may code for several different proteins.

[3]

36 The photomicrograph in Fig. 36, **on the insert**, shows a section of pancreatic tissue.

An endocrine structure is labelled **X**.

(a) **(i)** Identify structure **X**.

.... **[1]**

(ii)* In a healthy individual, the concentration of blood glucose is maintained at around 80 to 90 mg per 100 cm^3.

Discuss the mechanisms that control blood glucose concentration.

Your answer should include **named** cell types and biochemical pathways.

....

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....

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....

....

.... **[6]**

Additional answer space if required

....

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....

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....

(b) Impaired regulation of blood glucose concentration is a feature of diabetes.

Scientists are investigating new treatments for diabetes using mouse models. Diabetes can be induced in healthy mice by administering a compound called streptozotocin (STZ) and feeding the mice with a normal or high-fat diet.

STZ is toxic to pancreatic islet cells.

(i) Two strategies for inducing diabetes in healthy mice are described below. For each strategy, suggest which **type** of diabetes would be induced **and** provide an explanation.

High dose of STZ and a normal diet.

....

....

Low dose of STZ and a high-fat diet.

....

....

[2]

(ii) Both strategies are carried out over a period of five weeks. After this time, the mice are tested for diabetes.

Name **one** test that can be used to confirm that the mice are diabetic.

.... **[1]**

END OF QUESTION PAPER

ADDITIONAL ANSWER SPACE

If additional space is required, you should use the following lined page(s). The question number(s) must be clearly shown in the margin(s).