

# **X274/13/02**

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NATIONAL  
QUALIFICATIONS  
2015

WEDNESDAY, 13 MAY  
1.00 PM – 3.30 PM

**BIOLOGY**  
**ADVANCED HIGHER**  
**(REVISED)**

## **SECTION A—Questions 1–25 (25 marks)**

Instructions for completion of Section A are given on *Page two*.

## **SECTION B (65 marks)**

The answer to each question should be written in ink in the answer book provided. Any additional paper (if used) should be placed inside the front cover of the answer book.

Rough work should be scored through.

All questions should be attempted. Candidates should note that Question 10 contains a choice.

Question 1 is on Pages 10, 11 and 12. Question 2 is on Page 13. Pages 12 and 13 are fold-out pages.



## **Read carefully**

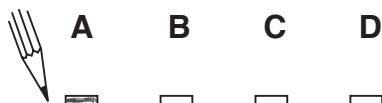
- 1 Check that the answer sheet provided is for **Biology Advanced Higher Revised (Section A)**.
- 2 For this section of the examination you must use an **HB pencil** and, where necessary, an eraser.
- 3 Check that the answer sheet you have been given has **your name, date of birth, SCN** (Scottish Candidate Number) and **Centre Name** printed on it.  
Do not change any of these details.
- 4 If any of this information is wrong, tell the Invigilator immediately.
- 5 If this information is correct, **print** your name and seat number in the boxes provided.
- 6 The answer to each question is **either A, B, C or D**. Decide what your answer is, then, using your pencil, put a horizontal line in the space provided (see sample question below).
- 7 There is **only one correct** answer to each question.
- 8 Any rough working should be done on the question paper or the rough working sheet, **not** on your answer sheet.
- 9 At the end of the examination, put the **answer sheet for Section A inside the front cover of the answer book**.

## **Sample Question**

Which of the following molecules contains six carbon atoms?

- A Glucose
- B Pyruvic acid
- C Ribulose bisphosphate
- D Acetyl coenzyme A

The correct answer is **A**—Glucose. The answer **A** has been clearly marked in **pencil** with a horizontal line (see below).



## **Changing an answer**

If you decide to change your answer, carefully erase your first answer and using your pencil, fill in the answer you want. The answer below has been changed to **D**.



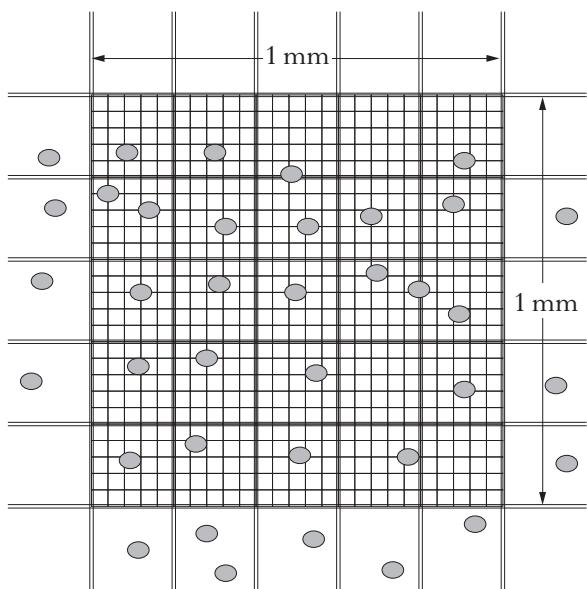
## SECTION A

**All questions in this section should be attempted.**

**Answers should be given on the separate answer sheet provided.**

- 1.** The diagram below represents red blood cells in a haemocytometer.

The grid is **0·1 mm** in depth.

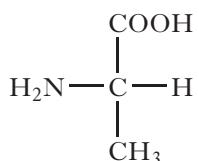


The number of red blood cells per **cm<sup>3</sup>** of blood sample is

- A  $2\cdot4 \times 10^3$
  - B  $2\cdot4 \times 10^4$
  - C  $2\cdot4 \times 10^5$
  - D  $2\cdot4 \times 10^6$ .
- 2.** Which of the following techniques can be used to count cells?

- A Immunoassay
- B Electrophoresis
- C Chromatography
- D Flow cytometry

- 3.** The diagram below represents the structure of the amino acid alanine.



In the diagram, the R group has the composition

- A —H
- B —NH<sub>2</sub>
- C —CH<sub>3</sub>
- D —COOH.

- 4.** An amino acid that has a hydrophobic R group is

- A polar
- B non-polar
- C positively charged
- D negatively charged.

- 5.** In the formation of nucleosomes, interacting positive and negative charges bind DNA in loops to

- A cyclins
- B histones
- C microtubules
- D transcription factors.

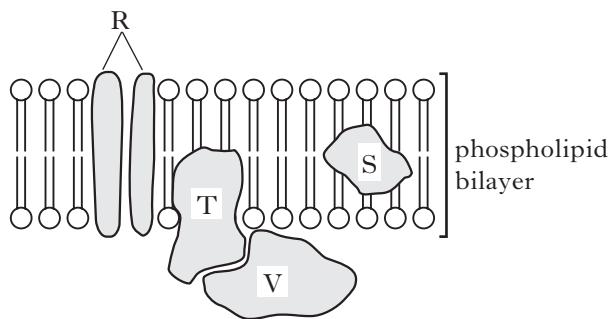
**[Turn over**

6. The catalytic power of an enzyme can be determined by measuring values called "Kcat" and "Km". If Kcat divided by Km gives a value between  $10^8$  and  $10^9$  units, the enzyme is said to have reached "catalytic perfection" where the rate it works at is limited only by the rate of diffusion of substrate.

The enzyme *acetylcholinesterase* has a Kcat of  $1.4 \times 10^4$  units and a Km of  $9 \times 10^{-5}$  units. Which line in the table below is correct for this enzyme?

	<i>Value of <math>\frac{K_{cat}}{K_m}</math></i>	<i>Is the enzyme "perfect"?</i>
A	$1.6 \times 10^8$	Yes
B	$6.4 \times 10^8$	Yes
C	$1.6 \times 10^8$	No
D	$6.4 \times 10^8$	No

7. The diagram below shows the arrangement of four proteins (R, S, T and V) and the phospholipid bilayer of a cell membrane.



Which of the proteins shown are integral membrane proteins?

- A S only
- B R only
- C S, R and T only
- D S, R, T and V

8. A hydrophobic signalling molecule diffuses into a cell through a

- A carrier protein
- B receptor protein
- C phospholipid bilayer
- D transmembrane channel.

9. Which line in the table below correctly describes features of cone cells in humans?

	<i>Function in low light intensity</i>	<i>Contain different forms of opsin</i>
A	no	yes
B	yes	yes
C	no	no
D	yes	no

10. Which line in the table below correctly matches checkpoint conditions with the stage of the cell cycle where they apply?

	<i>Success of DNA replication</i>	<i>Cell size</i>	<i>Chromosome alignment</i>
A	S	G <sub>1</sub>	M
B	G <sub>2</sub>	M	S
C	S	G <sub>1</sub>	G <sub>2</sub>
D	G <sub>2</sub>	G <sub>1</sub>	M

11. The role of cytokinesis is to

- A divide cytoplasm
- B move chromatids
- C form two nuclei
- D shorten spindle fibres.

12. Paclitaxel and cisplatin are chemotherapy drugs used in the treatment of some cancers. Paclitaxel inhibits spindle formation and cisplatin interferes with DNA replication.

Which line in the table below shows the phases of the cell cycle at which these drugs would act? (M = mitosis)

Chemotherapy drug		
	Paclitaxel	Cisplatin
A	G <sub>2</sub>	S
B	M	G <sub>1</sub>
C	S	M
D	M	S

13. Which line in the table below correctly identifies factors that trigger apoptosis?

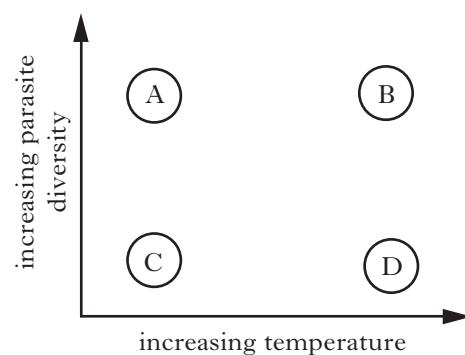
	p53 protein	Cell growth factors
A	absent	absent
B	present	present
C	present	absent
D	absent	present

14. Northern elephant seals, intensely hunted in the 19th century, have significantly less genetic variation than southern elephant seals that were hunted less in the same period.

This reduced genetic diversity is most likely a result of

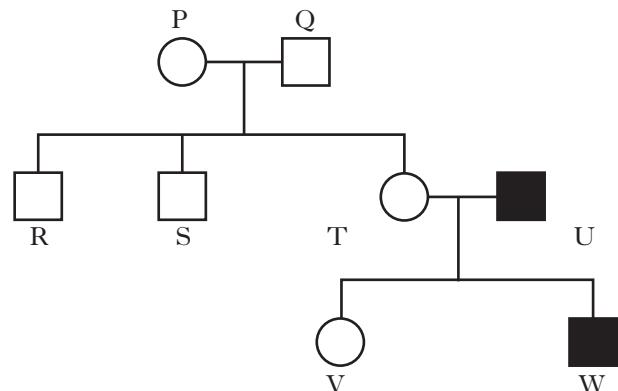
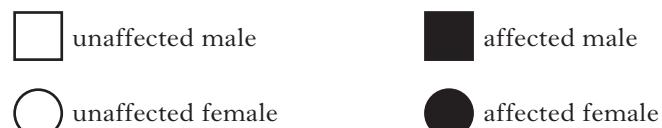
- A sexual selection
- B genetic drift
- C mutation
- D natural selection.

15. The diagram below gives information about conditions in four habitats.



In which habitat would parthenogenesis be most likely to occur?

16. Red-green colour deficiency is X-linked. The diagram below shows a family tree in which this condition occurs.



Which other individuals passed on the allele responsible for red-green colour deficiency in individual W?

- A T only
- B U only
- C T and U
- D T and P

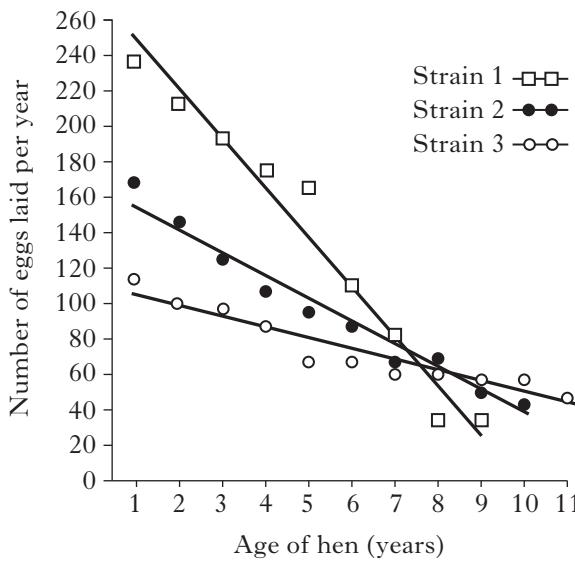
[Turn over]

17. The black belly stripe of great tit males (*Parus major*) is an important stimulus in territorial and courtship displays. Males with broader stripes make better parents and are more attractive to prospective mates. The width of the stripe is therefore correlated with male quality.

This stripe functions as

- A an honest signal
- B a sign stimulus
- C a fixed action pattern
- D an imprinting stimulus.

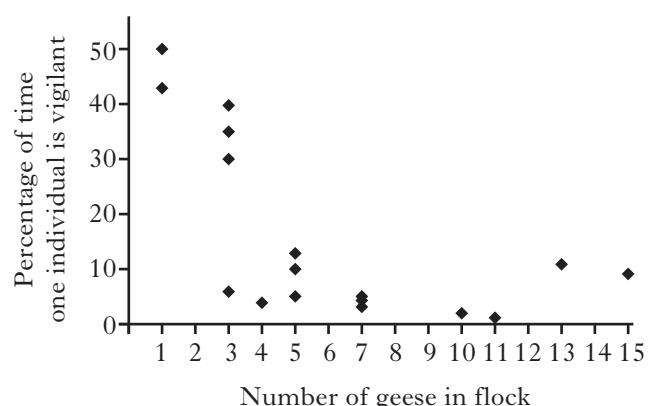
18. The graph below shows the fecundity (reproductive output) of three different strains of white Leghorn domestic hens in relation to age.



Which of the following conclusions can be supported from the information shown?

- A Young hens lay more eggs during their lifetime than older hens.
- B Fecundity decreases faster with age in birds that lay more eggs early in life.
- C The lifelong reproductive output of all three strains is approximately equal.
- D Fecundity in later life is independent of fecundity in earlier years.

19. The Arctic fox is a predator of barnacle geese. To avoid predation, geese periodically look up from grazing to scan for foxes. In a study of this *vigilance* behaviour, different flock sizes of geese were monitored for ten minutes when a cardboard model of an Arctic fox was placed 100 m away. The percentage of the time per individual spent on vigilance behaviour was recorded for different flock sizes, as shown in the graph below.



Which of the following would also have to be done to test the hypothesis that vigilance behaviour in response to the Arctic fox decreases as flock size increases? Repeat the work

- A and calculate the average results
- B using a recording time of 20 minutes
- C to get data for the missing flock sizes
- D with no model fox present.

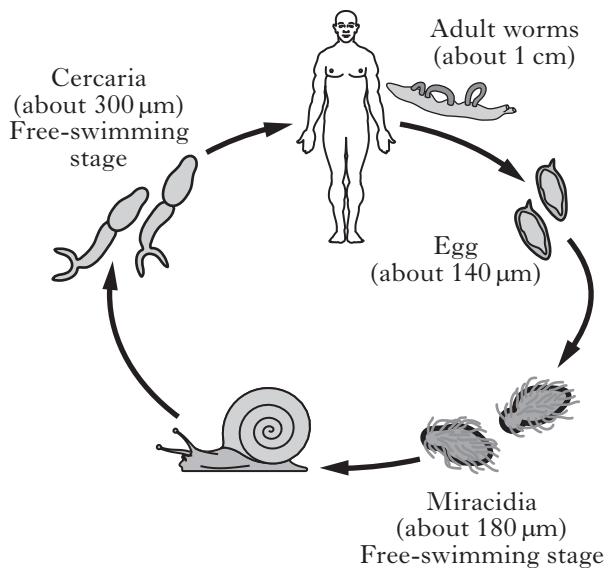
20. The fundamental niche of a species

- A includes the set of resources available in the absence of competitors
- B includes the set of resources available in the presence of competitors
- C permits coexistence in a community
- D permits sharing of resources with other species.

21. Which of the following human diseases is caused by a macroparasite?

- A schistosomiasis
- B HIV
- C tuberculosis
- D influenza

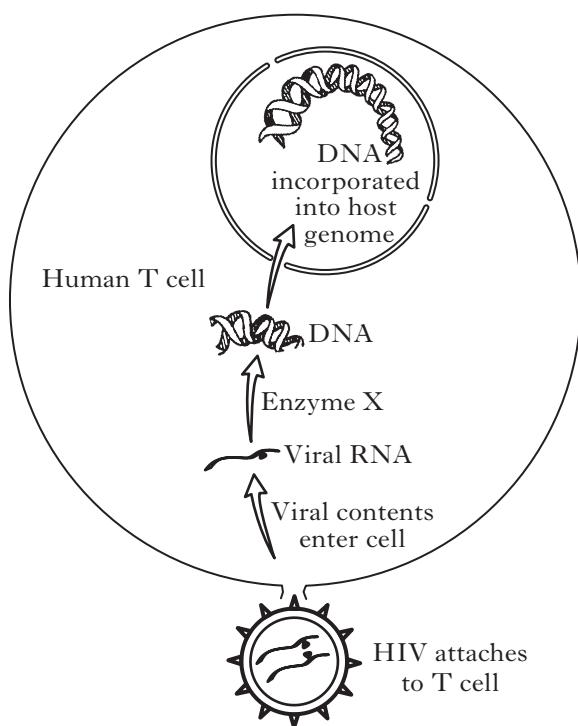
22. The diagram below shows the life cycle of a parasitic worm that causes a disease in humans.



Which line in the table below correctly describes the roles of the other species in this parasite's life cycle?

	<i>Definitive host</i>	<i>Intermediate host</i>	<i>Snail is a vector</i>
A	snail	human	no
B	human	snail	no
C	snail	human	yes
D	human	snail	yes

23. The diagram below shows part of the infection cycle of a human T cell by the retrovirus HIV.



Enzyme X is

- A DNAase
- B DNA polymerase
- C RNA polymerase
- D reverse transcriptase.

24. Which of the following is a non-specific immune response to a parasite?

- A Apoptosis induced by T lymphocytes
- B Presentation of antigens by phagocytes
- C Apoptosis induced by natural killer cells
- D Production of antibody by B lymphocyte clone

**[Turn over**

25. *Neutrophils*, the most abundant white cell in mammals, are phagocytes that have to be replaced in large numbers every day. The half-life of neutrophils is only 6 hours; that is, their population decreases by half in this period.

If there were 100 billion ( $100 \times 10^9$ ) present at the start of a day and there was no replacement, approximately what percentage would remain 24 hours later?

- A 0%
- B 6%
- C 13%
- D 25%

[END OF SECTION A]

**Candidates are reminded that the answer sheet MUST be returned INSIDE the front cover of the answer book.**

[Turn over for SECTION B on *Page ten*

**DO NOT WRITE ON THIS PAGE**

## SECTION B

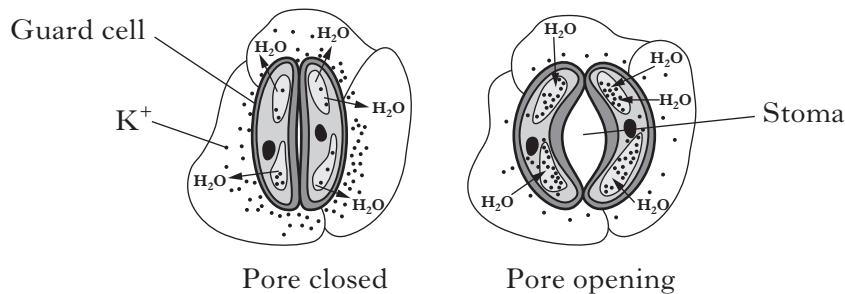
**All questions in this section should be attempted.**

**All answers must be written clearly and legibly in ink.**

- Photosynthesis and transpiration in plants are both affected by the size of the pores (stomata) in leaf epidermis. As stomatal diameter increases, more CO<sub>2</sub> diffuses into leaves for photosynthesis but at the same time more water is lost by transpiration. The mechanism for controlling stomatal diameter ensures that the whole plant can both make food and avoid dehydration.

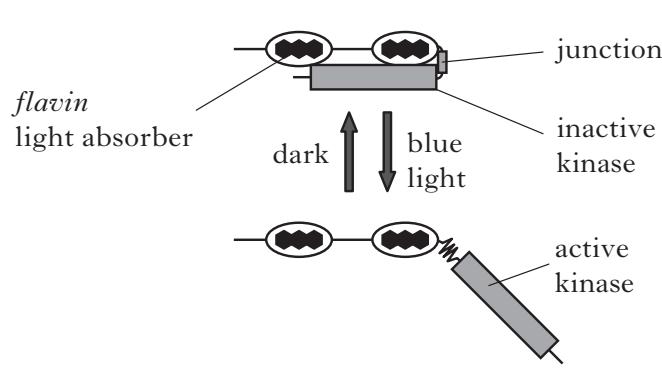
Pores form between pairs of guard cells. The cells are arranged in pairs so that, when they take in water by osmosis, they swell and the pore forms. They swell because water molecules diffuse in following the inward diffusion of ions, mainly potassium (K<sup>+</sup>) (Figure 1).

**Figure 1: Water movement in guard cells**

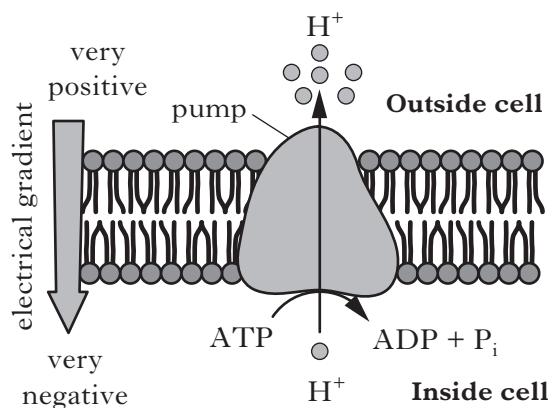


It has been known for some time that, in most plants, pores open in response to blue light and that the mechanism triggering K<sup>+</sup> influx lies in guard cell plasma membranes. The mechanism now appears to be a sequence of events involving different types of membrane proteins. The first are *phototropins*, photoreceptor proteins activated by blue light (Figure 2A). The second are H<sup>+</sup>-ATPases, transmembrane proteins that use energy from ATP to pump H<sup>+</sup> out of cells (Figure 2B). Thirdly there are channel proteins specific for K<sup>+</sup> ions. Finally, there are aquaporins that are responsible for up to 95% of the plasma membrane's permeability to water.

**Figure 2A: Activation of phototropin protein by blue light**



**Figure 2B: Active transport by H<sup>+</sup>-ATPase**

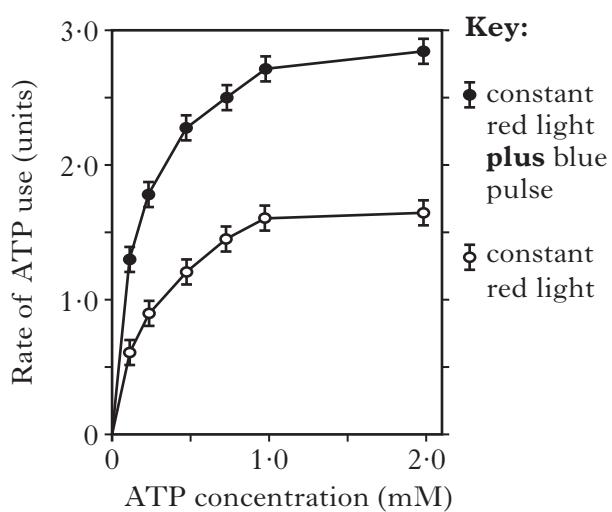


Protoplasts were produced from isolated guard cells by removing their cell walls. The protoplasts were then used in experiments to investigate the link between light and the operation of H<sup>+</sup>-ATPase. For all the results shown, the red light was on continuously and the blue light input was given as a **30 second pulse** at the start of the monitoring. "RL" shown on graphs indicates results when only the background red light was applied and blue light was absent.

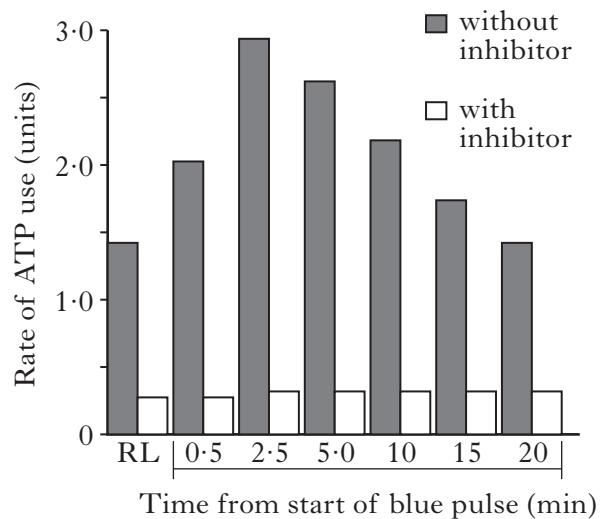
### Question 1 (continued)

Figure 3 below shows how light treatments affect the response of  $H^+$ -ATPase to increasing substrate concentration, as measured by ATP use. Figure 4 tracks the activity of the pump for 20 minutes following a **single** blue light pulse, with and without a pump inhibitor. Figures 5A and 5B show the effects of blue light intensity on the role of the pump.

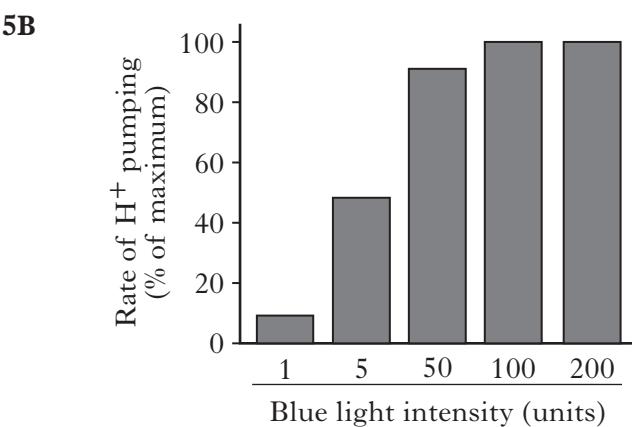
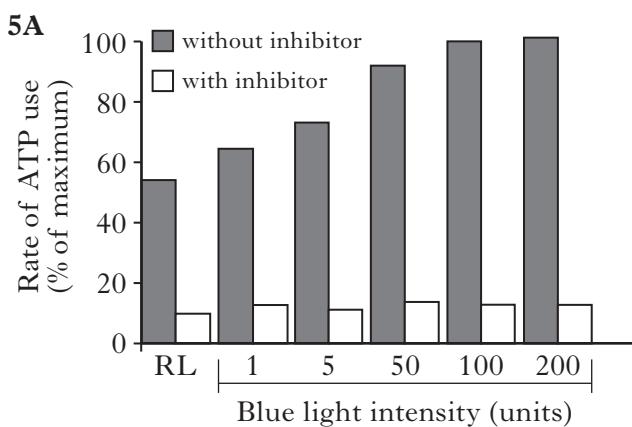
**Figure 3: Effect of light on activity  
 $H^+$ -ATPase pump**



**Figure 4: Response of  $H^+$ -ATPase pump to red light (RL) and pulse of blue light, with and without pump inhibitor**



**Figure 5: Effect of blue light intensity on the activity of  $H^+$ -ATPase pump**



[Question 1 continues on Page twelve]

**Question 1 (continued)**

- (a) Refer to Figure 2A.

Flavin is a non-protein component of phototropin; it becomes covalently bonded on absorbing blue light.

- (i) State the term used to describe a non-protein component in the structure of a protein. 1

- (ii) What new activity can the phototropin carry out on exposure to light? 1

- (b) Refer to Figure 3.

- (i) Describe the results for the red light treatment in the absence of blue light. 1

- (ii) What do the error bars confirm about the effect of a blue light pulse on ATP use? 1

- (c) (i) What is the role of a control in an experimental context? 1

- (ii) Explain how results from Figure 4 show that most of the energy consumed by protoplasts is by H<sup>+</sup>-ATPase activity. 1

- (d) One aim of the experiment for Figure 4 was to determine, for the other experiments, when it would be best to measure ATP use following the pulse of blue light.

- (i) State the term used for an experiment with this type of aim. 1

- (ii) From the Figure, select the best time to measure ATP use after the pulse. Justify your choice. 1

- (e) What conclusion can be reached by considering the correlation between Figures 5A and 5B? 1

- (f) In guard cells, channels for K<sup>+</sup> influx are *voltage-gated*.

- (i) Explain what “voltage-gated” refers to when describing ion transport channels. 1

- (ii) Plants do not have sodium-potassium pumps; H<sup>+</sup>-ATPase is their equivalent. From the information provided, explain how a pulse of blue light can facilitate the movement of K<sup>+</sup> ions into guard cells. 2

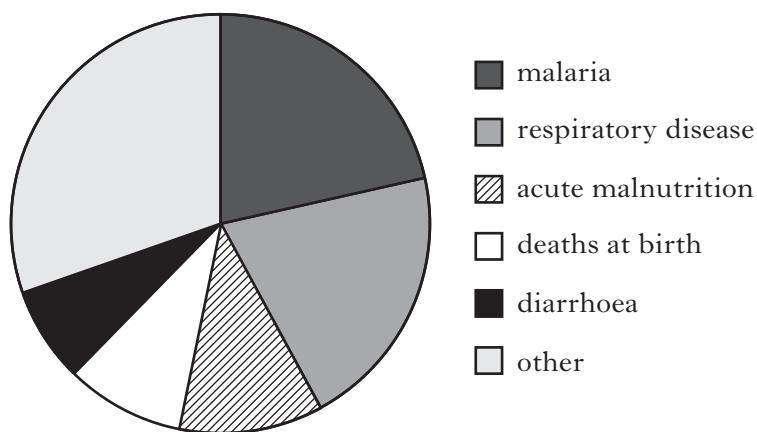
- (iii) Explain why experiments using guard cell protoplasts cannot show that K<sup>+</sup> ion influx will cause stomata to open. 1

(13)

[Question 2 is on fold-out Page thirteen]

2. Conflict and natural disasters can have major consequences for the health of human populations. Frequently, people affected in these ways have to be accommodated in refugee camps. The Figure below shows the major causes of death (mortality) in children younger than five years of age in African refugee camps operated by the UN between 2006 and 2010.

**Figure: Mortality in under-fives in Africa**



- (a) In refugee camps, diarrhoea is frequently caused by intestinal parasites, such as *Cryptosporidium* and *Giardia*.

Give **two** factors associated with camp conditions that may increase the transmission rates of these organisms. 2

- (b) In African refugee camps, children under five develop diarrhoea at the rate of 35·5 cases/1000 children under five/month.

Calculate how many new cases of diarrhoea will develop in one year in a refugee camp with a population of 20 000 children under five. 1

**(3)**

3. Coat colour in cats is determined by several genes. One of these is an X-linked gene that has two alleles. One allele ( $X^G$ ) determines orange coat colour; when only the other allele ( $X^g$ ) is present, coat colour is black. Although the orange allele is dominant, female cats inheriting both alleles are not orange. Instead, the coat is a patchwork of orange and black, a condition known as tortoiseshell.



orange



black



tortoiseshell

- (a) A female tortoiseshell cat mates with a stray male and gives birth to the following kittens: two males, one orange and one black; three females, two tortoiseshell and one orange.

(i) State the genotype and phenotype of the stray male. 1

(ii) State the genotypes of the orange kittens. 2

- (b) X inactivation occurs in the cells of female embryos.

(i) Why is X inactivation necessary? 1

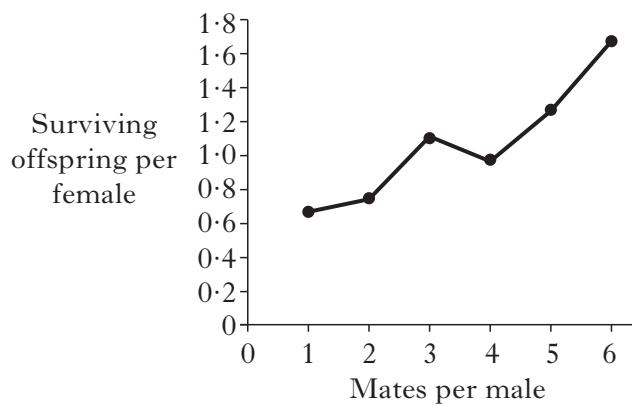
(ii) Explain how "patchiness" arises during development of tortoiseshell cats. 2

- (c) State the term used to describe an individual able to produce gametes that differ in their sex chromosomes. 1

**(7)**

4. The red-winged blackbird (*Agelaius phoeniceus*) is widely distributed in large areas of North and Central America. It prefers grassland habitats, particularly in marshy or wetland areas.

Territorial males show a form of polygamy called *polygyny* and may mate with and defend up to ten females in the territory, depending on the food resources available. The graph below shows the relative reproductive success of females mating with males that have from one to six mates.



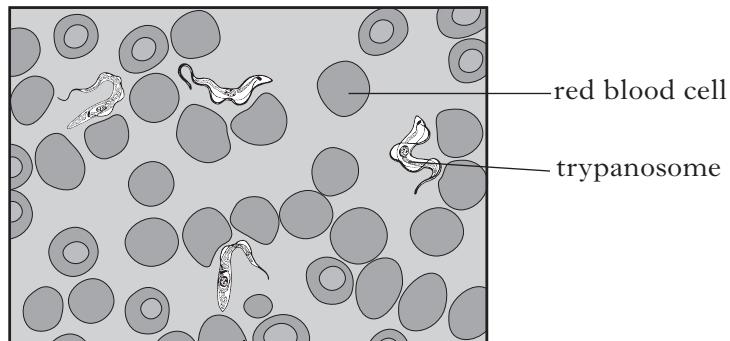
- (a) Describe the trend shown in the graph. 1
- (b) How do the data justify the conclusion that it benefits females to mate with males that have the best territories? 1
- (c) Natural selection is concerned with “survival of the fittest”.  
Using the idea of *optimal reproduction*, explain why a male bird should favour polygyny over mating with a single female. 1
- (d) In this species, investment in the young by the female is greater than by the male.  
Suggest **one** way in which this greater investment is demonstrated. 1

(4)

[Turn over

5. Human African trypanosomiasis, also known as sleeping sickness, threatens the lives of millions of people living in 36 countries of sub-Saharan Africa. The disease is caused by a unicellular parasite called *Trypanosoma brucei*. The parasite is transmitted to humans by bites from infected tsetse flies (*Glossina spp.*), belonging to the phylum Arthropoda. Marks

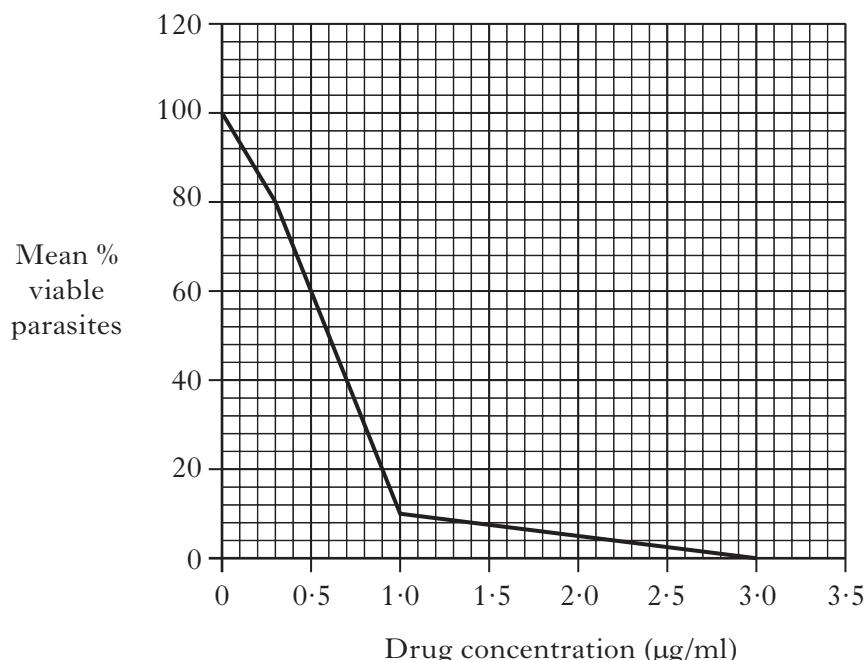
**Figure 1: Trypanosome parasites among red blood cells of an infected individual**



- (a) State **one** feature of tsetse flies that allows them to be classified as arthropods. 1
- (b) During the course of infection, *Trypanosoma* changes its antigenic surface. Explain how this helps it to avoid destruction by the host's immune system. 1
- (c) Many internal parasites lack organs associated with feeding and gas exchange. State the term that applies to organisms adapted in this way. 1
- (d) The development of effective drug treatment for sleeping sickness has proved to be very difficult. *Fexinidazole*, the first new drug in 30 years targeting the advanced and fatal stage of the disease, is currently being tested.

Figure 2 below shows some of the *in vitro* results obtained for fexinidazole; parasite viability was measured after a 72-hour drug exposure.

**Figure 2: Effect of fexinidazole in *Trypanosoma brucei***



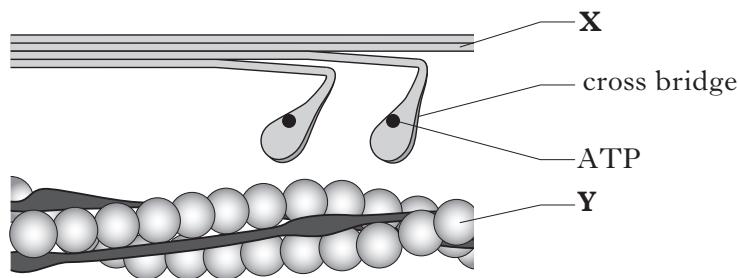
**Question 5 (d) (continued)**

- |  |   |
|--|---|
| (i) Suggest <b>one</b> reason why controlling this parasitic disease with drug treatment has proved to be so difficult.  | 1 |
| (ii) $IC_{50}$ is the concentration of a drug or other substance needed to inhibit a given biological process by half. What is the $IC_{50}$ for fexinidazole?   | 1 |
| (iii) Some of the pre-clinical trials were carried out <i>in vivo</i> , using animals. Explain how harm to animals could be minimised in research.   | 1 |
| (iv) Clinical trials involving healthy human subjects were carried out to determine the safety of fexinidazole. These trials were <i>double-blind</i> , that is neither researchers nor subjects were allowed to know until the trial was over who had received the drug and who had received an inert alternative, a placebo.<br>Suggest why these trials have a double-blind design. | 1 |

(7)

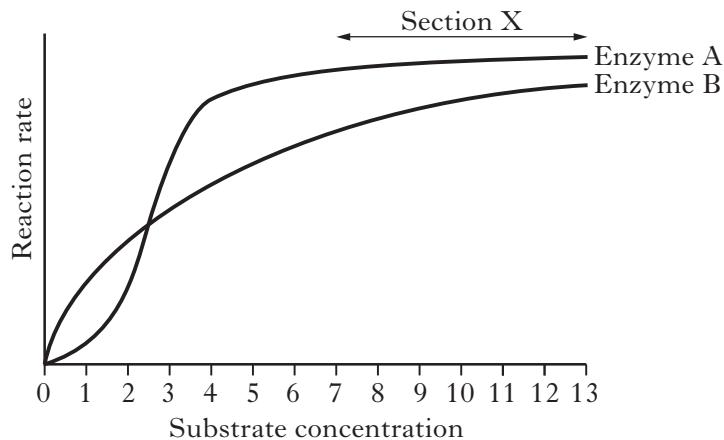
**[Turn over**

6. The diagram below represents protein molecules in muscle tissue as it contracts. The cross bridge is part way through the “power stroke” having just detached from molecule Y.



- (a) Name the proteins **X** and **Y**. 1
  - (b) What type of enzyme activity do the cross bridges possess? 1
  - (c) Describe the sequence of events that results in muscle contraction following the binding of ATP shown in the diagram. 2
  - (d) Explain the significance of the reversible nature of phosphate binding in this example. 1
- (5)**

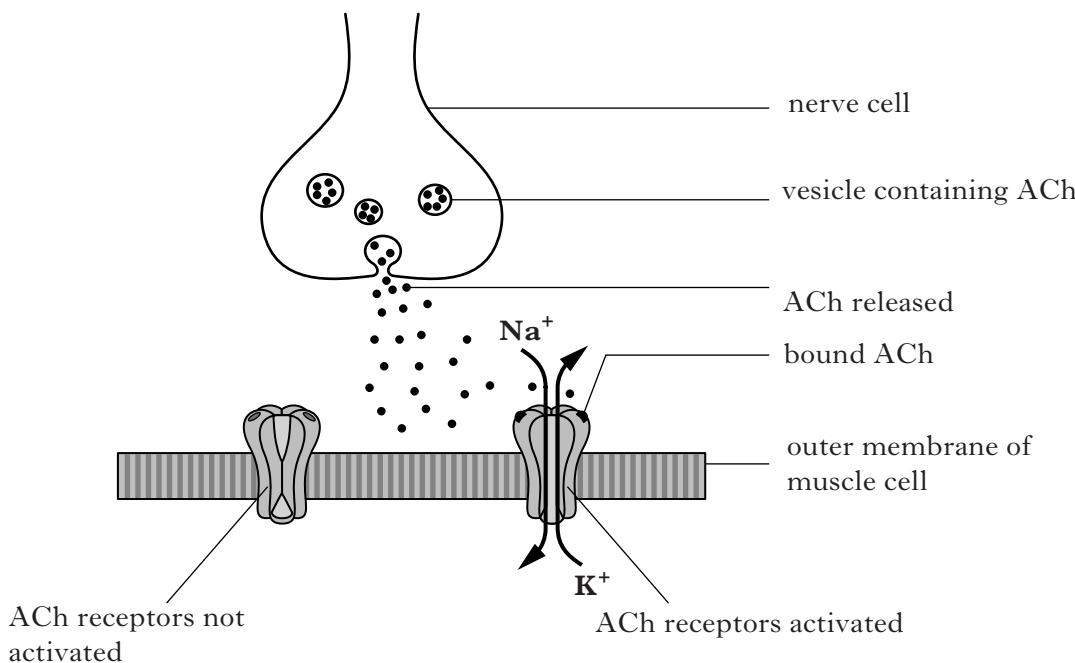
7. When a substance binds to a protein's binding site, for example a substrate to an enzyme, the protein changes shape. The change in shape has an effect that allows the protein to perform its function. The Figure below compares the response of two types of enzyme to increasing substrate concentration.



- (a) Describe how the complementary shape and chemistry of an enzyme and its substrate are essential to an enzyme's function. 2
  - (b) Explain why substrate concentration is not limiting the rate of reaction in section X on the graph. 1
  - (c) State which enzyme shows evidence of cooperativity. Use data to justify your answer. 1
- (4)**

8. Acetylcholine (ACh) works at the junction between nerve and muscle cells (neuromuscular junction) where it stimulates muscle contraction by binding to receptors in the outer membrane of muscle cells.

Binding of ACh to its receptor opens an ion channel as illustrated below.  
 $(Na^+ =$  sodium ions;  $K^+ =$  potassium ions.)



The released ACh is broken down by an enzyme called *acetylcholinesterase* attached to the muscle cells. Breakdown is very fast, so the muscle cells are quickly able to respond again.



- (a) Two types of drug used by anaesthetists affect signalling by ACh at the neuromuscular junction:

*vecuronium*: competitively blocks the ACh receptor  
*neostigmine*: inhibits acetylcholinesterase.

When vecuronium blocks the binding of ACh to its receptor, muscle contraction stops. Explain how neostigmine would reverse the effects of vecuronium. 2

- (b) Acetylcholine is also widely distributed in the central nervous system.

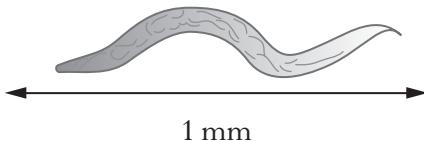
(i) Describe the events during nerve transmission that follow binding of a neurotransmitter such as ACh to its receptor. 2

(ii) How is resting potential re-established in the nerve cells? 1

**(5)**

[Turn over]

9. *Caenorhabditis elegans* (*C. elegans*) is a small free-living soil nematode. In this worm the position and number of cells is constant. Only 1090 cells are generated during development and, of these, 131 undergo apoptosis leaving 959 surviving cells, which is the normal phenotype of an adult. The worm's fixed sequence of development has made it a very useful model organism for studying the genes controlling apoptosis.



- (a) *C. elegans* is a widely used “model” organism.

Explain how humans benefit from the use of model organisms.

1

- (b) Explain the importance of apoptosis in the development of a multicellular organism.

1

- (c) Describe the role of caspases in apoptosis.

1

- (d) Studies of *C. elegans* have identified genes that encode key proteins controlling cell death. The diagram below shows how the proteins encoded by these genes are organised in a sequence.

CED-3 protein activates caspases when CED-4 is free to bind to it. In the absence of a cell death signal, CED-9 is bound to CED-4. In the presence of a cell death signal, CED-9 releases CED-4.



The table gives information about the phenotypes of four mutant strains of *C. elegans* in which mutated genes lead to abnormal patterns of apoptosis.

Mutated gene(s)	Adult phenotype (Number of surviving cells during development)
<i>ced-4</i>	1090
<i>ced-3</i>	1090
<i>ced-9</i>	0
<i>ced-3 and ced-9</i>	1090

- (i) Explain the adult phenotype of the *ced-4* mutant strain.

2

- (ii) What evidence is there that all cells in *C. elegans* contain this control mechanism?

1

- (iii) Studies of mutant worms allowed the proteins to be ordered into the sequence shown in the figure.

How does the result for the *ced-3/ced-9* double mutant support this sequence?

1

(7)

**10.** Answer **either A or B.**

**A.** Discuss meiosis under the following headings:

- |  |   |
|--|---|
| (i) the sequence of events;                      | 7 |
| (ii) the origin of genetically variable gametes. | 3 |

**OR**

**B.** Discuss the process of evolution under the following headings:

- |   |   |
|---|---|
| (i) importance of mutation in enabling evolution; | 6 |
| (ii) factors increasing the rate of evolution.    | 4 |
- (10)**

[*END OF SECTION B*]

[*END OF QUESTION PAPER*]

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