

Please check the examination details below before entering your candidate information

Candidate surname <i>StemUp Model Solution</i>		Other names
Centre Number	Candidate Number	

Pearson Edexcel Level 3 GCE

Time 2 hours	Paper reference	9BN0/02
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Biology A (Salters Nuffield)

Advanced

PAPER 2: Energy, Exercise and Co-ordination

You must have: Ruler, pencil and calculator	Total Marks
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Instructions

- Use **black** ink or ball-point pen.
- **Fill in the boxes** at the top of this page with your name, centre number and candidate number.
- Answer **all** questions.
- **Show all your working out** in calculations and **include units** where appropriate.
- Answer the questions in the spaces provided
– *there may be more space than you need.*

Information

- The total mark for this paper is 100.
- The marks for **each** question are shown in brackets
– *use this as a guide as to how much time to spend on each question.*
- You may use a scientific calculator.
- In questions marked with an **asterisk** (*), marks will be awarded for your ability to structure your answer logically, showing how the points that you make are related or follow on from each other where appropriate.

Advice

- Read each question carefully before you start to answer it.
- Try to answer every question.
- Check your answers if you have time at the end.

Turn over ►

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Q:1/1/1/1/1/



Answer ALL questions. Write your answers in the spaces provided.

Some questions must be answered with a cross ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

- 1 Blood from the lungs returns to the left side of the heart in the pulmonary vein. The pulmonary vein does not have valves.

(a) (i) Describe how the atrioventricular (AV) valves work during one cardiac cycle.

(2)

When the atria contract (atrial systole), blood pressure is greater in the atria than in the ventricles, so the AV valves are open and blood flows into the ventricles.

When the ventricles contract (ventricular systole), pressure in the ventricles becomes greater than in the atria, so the AV valves close. This prevents backflow of blood into the atria; the tendons stop the valves inverting.

- (ii) The structure of the pulmonary vein is different from the structure of the pulmonary artery.

Explain how this difference is related to the function of the pulmonary vein.

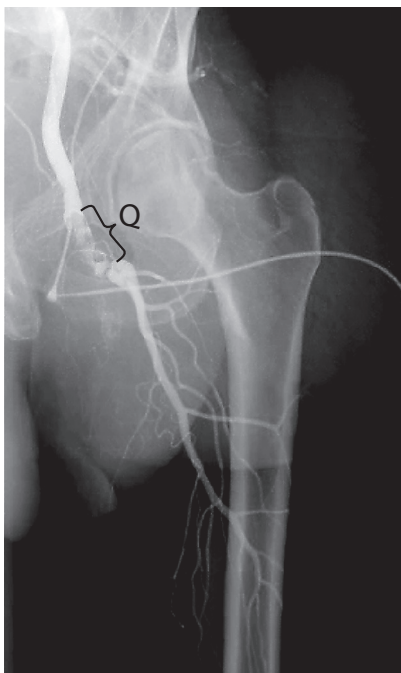
(2)

The pulmonary vein has a larger lumen and thinner walls, with less muscle, than the pulmonary artery. The larger lumen is because blood pressure in the vein is lower, so it reduces resistance to flow. Less muscle is needed because contraction of the wall is not needed to push blood back to the heart.



- (b) An angiogram is an X-ray image of a blood vessel. To produce an angiogram, a dye is added to the blood. The dye does not let X-rays through.

This angiogram shows the location of a blood clot (labelled Q) in a vein near the hip of a patient.



(Source: © ZEPHYR/SCIENCE PHOTO LIBRARY)

- (i) Which of the following is released by platelets at location Q?

(1)

- ☐ A fibrin
- ☐ B prothrombin
- ☐ C thrombin
- ☒ D thromboplastin

- (ii) Which of the following is an enzyme that converts a soluble plasma protein into an insoluble protein at location Q?

(1)

- ☐ A fibrinogen
- ☐ B prothrombin
- ☒ C thrombin
- ☐ D thromboplastin

(Total for Question 1 = 6 marks)

2 The human brain is an organ that has a range of functions.

(a) A student produced a table linking three descriptions of brain function to a labelled diagram of the brain.

Label	Description of function of labelled region in brain
1	Site where more synapses are formed during the critical window for vision
2	Required for the fine motor skills to draw a straight line
3	Area that sends impulses to the sinoatrial node (SAN) in response to a lowering of blood pH

Which diagram of the brain correctly matches the table?

(1)

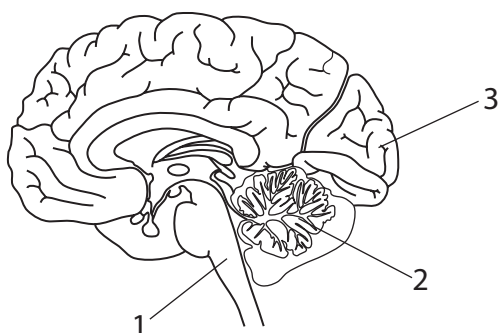


Diagram A

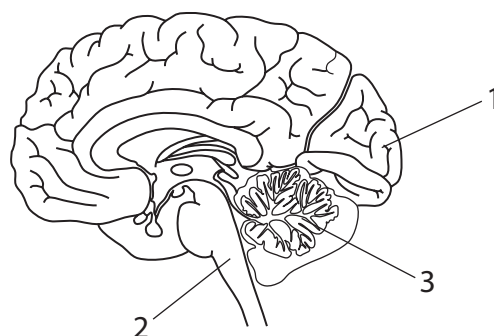


Diagram B

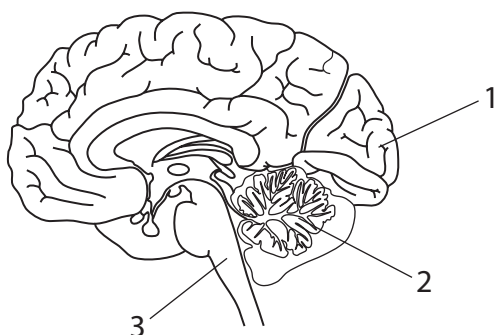


Diagram C

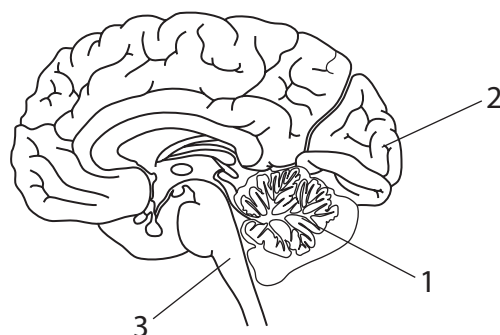


Diagram D



(b) There are various types of scan that can be used to study the brain.

- (i) Describe why a region of the brain might appear lighter in an image obtained by a functional magnetic resonance image (fMRI) scan.

(3)

The lighter region is more active, so its cells are carrying out more aerobic respiration.

This causes an increase in blood flow, so more oxygenated blood (oxyhaemoglobin) is delivered to this region.

The fMRI signals are reflected (not absorbed) by oxygenated blood, so areas with more oxyhaemoglobin appear lighter on the image.

- (ii) One scan combines positron emission tomography (PET) and computed tomography (CT). This scan can be used to show whether a person has cancer.

Describe why a combined PET and CT scan may be better for diagnosing cancer than a PET or CT scan on its own.

(3)

Using both scans gives information on function (from PET) and structure (from CT), and together they can produce 3D images.

The PET scan shows areas that are more metabolically active or dividing more, as tumour cells take up more of the radioactively labelled glucose.

The CT scan uses X-rays to give the location and size of the tumour. As each scan uses a different technique, an active area can be matched to a precise position.

(Total for Question 2 = 7 marks)



P 6 7 0 9 1 A 0 5 2 8

3 Some lipoproteins may reduce fertility in mammals.

(a) An investigation was carried out using mice of the same breed.

Female mice were divided into three groups, P, Q and R. Each group was given a different treatment.

The table shows the treatment given to the three groups of female mice.

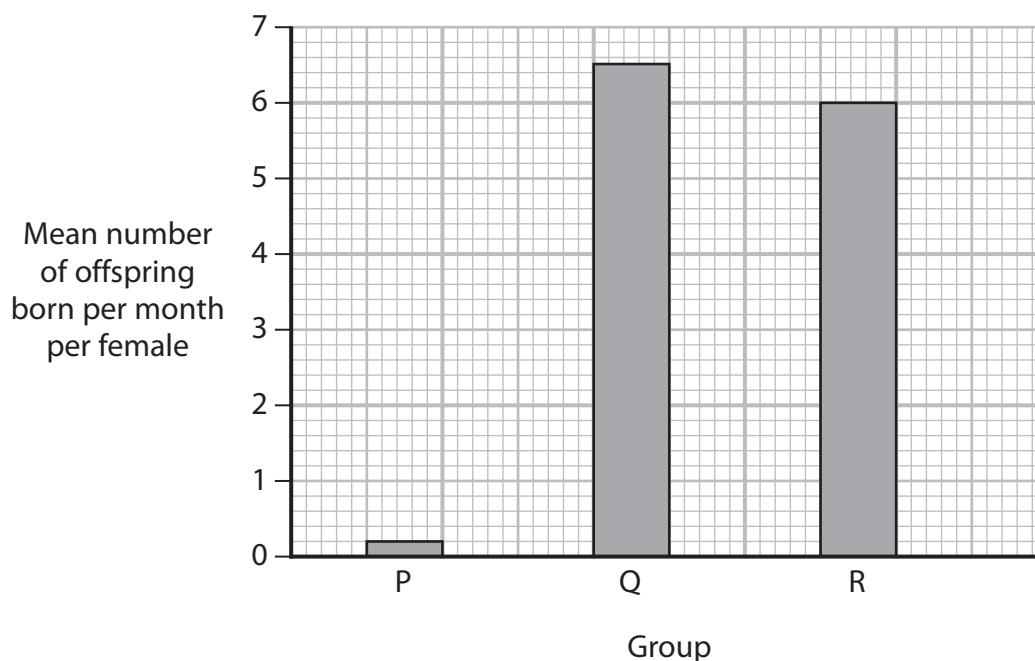
Group	Treatment
P	Genetically modified (GM) only
Q	Genetically modified and supplied with drug K
R	Supplied with drug K only

The GM mice have an increased concentration of high-density lipoproteins (HDLs) in their blood plasma.

Drug K was used to lower the blood plasma HDL levels.

The mice in each group were allowed to breed with non-genetically modified male mice and the number of offspring born was recorded.

The graph shows the results.



(i) The mice were all of one breed to improve data

(1)

- ☐ A accuracy
- ☐ B precision
- ☐ C quantity
- ☒ D validity

(ii) State a null hypothesis for this investigation.

(1)

There is no difference in the mean number of offspring born per month per female between the groups, whether genetically modified or not, or supplied with drug K or not.

(iii) Comment on the effect of blood plasma HDL levels on the fertility of these female mice.

(4)

The GM mice in group P, with high HDL levels, had very few offspring (about 0.2 per month), the fewest of any group. Therefore raised plasma HDL levels lead to reduced fertility.

When GM mice were given drug K to lower HDL (group Q), the mean rose to about 6.5 offspring, so lowering HDL restores fertility.

However the non-GM mice given drug K (group R) had fewer offspring (about 6.0) than group Q, suggesting that HDL levels below a certain concentration also reduce fertility, so some HDL is required for fertility.

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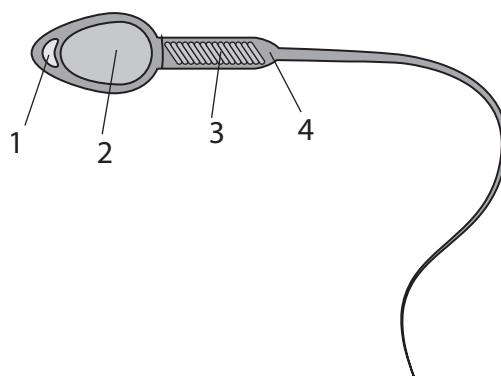
(b) Which of the following are always the same for both mammalian sperm and egg cells of the same species?

1. The total mass of nuclear DNA
2. They both release enzymes by exocytosis

(1)

- ☐ **A** Neither of them
- ☐ **B** 1 only
- ☒ **C** 2 only
- ☐ **D** 1 and 2

(c) The diagram shows a mammalian sperm cell.



Which of the labelled parts contains enzymes that phosphorylate glucose during respiration?

(1)

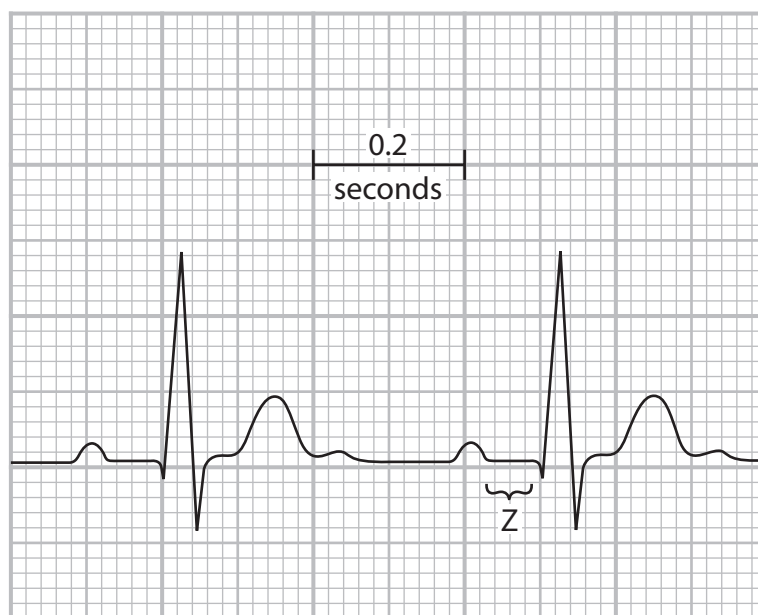
- ☐ **A** 1
- ☐ **B** 2
- ☐ **C** 3
- ☒ **D** 4

(Total for Question 3 = 8 marks)

4 A person arrived at hospital having eaten some poisonous berries.

(a) An electrocardiogram (ECG) was recorded for this person.

The diagram shows part of the ECG obtained.



(i) Tachycardia for an adult is defined as a heart rate above 100 beats per minute.

Calculate the percentage increase above 100 beats per minute for the heart rate of this person.

(2)

$$\text{Time for one beat (R to R)} = 0.5 \text{ s}$$

$$\text{Heart rate} = 60 \div 0.5 = 120 \text{ beats per minute}$$

$$\% \text{ increase} = (120 - 100) \div 100 \times 100 = 20\%$$

Answer 20 %

(ii) The length of time labelled Z on the ECG was shorter than for a person with a normal heart rate.

Which of the following is shown by label Z on the diagram?

(1)

- ☐ A the time that the atria are contracting
- ☐ B the time for the atrioventricular (AV) valves to open
- ☒ C the time that the atrioventricular node (AVN) delays depolarisation
- ☐ D the time that the ventricles are contracting

- (b) One of the poisons in the berries can bind to acetylcholine receptors on the surface membrane of cells in the SAN. This prevents acetylcholine binding to the receptors if it is in low concentration.

This person was treated with a drug that stopped acetylcholinesterase from being released into the synaptic gap.

Explain how this drug lowered the heart rate of this person.

(3)

The drug means acetylcholine is not broken down (as quickly), so the concentration of acetylcholine in the synaptic gap is maintained and increased.

This higher concentration of acetylcholine is able to compete with the poison, so more acetylcholine binds to the receptors on the cell surface membrane of the SAN cells.

Acetylcholine slows the rate at which the SAN depolarises, so fewer impulses are sent and the heart rate falls.

- (c) The poison also caused the pupils of this person to dilate.

Describe the interaction of the muscles in the eye that led to this dilation of the pupils.

(3)

The iris contains circular muscles and radial muscles, which act antagonistically (an antagonistic interaction).

To dilate the pupil, the radial muscles in the iris contract while the circular muscles in the iris relax.

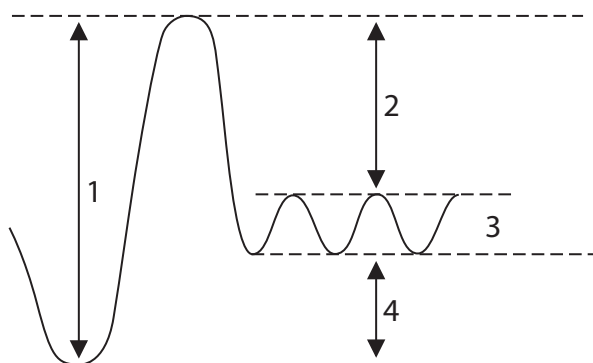
This pulls the iris outwards so the pupil becomes wider and lets more light in.

(Total for Question 4 = 9 marks)



5 A spirometer can be used to study aspects of the human respiratory system.

(a) The diagram shows a trace produced using a spirometer.



Which of the following parts of the spirometer trace could be used to determine the maximum volume of air that can be exhaled?

(1)

- ☒ **A** 1 only
- ☐ **B** 2 and 3 combined
- ☐ **C** 3 only
- ☐ **D** 3 and 4 combined

- (b) The availability of oxygen in the air is lower at high altitudes because of the lower air pressure.

Populations of humans that have lived at high altitude for many generations have adapted to these conditions.

One adaptation these people have is a larger thorax than people living at lower altitudes.

A student made the following hypothesis:

People with this adaptation will have a lower breathing rate as their tidal volume will be greater than those without the adaptation.

- (i) Devise a valid investigation, using a spirometer, to test this hypothesis.

(4)

Select people with different thorax sizes: one group with the adaptation (whose families have lived at high altitude) and one group without it from low altitude, about 20 in each.

Select people who are similar in other respects, e.g. the same age, sex and fitness level.

Control variables: measure all subjects at rest, at the same temperature and after the same level of previous activity.

Each person breathes into the spirometer for 1 minute. Measure tidal volume as the difference in volume from peak to trough on the trace, and breathing rate by counting the number of peaks in a set time. Repeat, calculate means and use a statistical test to compare the groups.



- (ii) Another adaptation to living at high altitude is to have more red blood cells circulating in their blood.

Explain how a bone marrow stem cell can give rise to red blood cells.

(4)

The stem cell is exposed to certain stimuli (e.g. the hormone erythropoietin).

This causes some genes, such as the gene for haemoglobin, to be activated and other genes to be deactivated.

Only the activated genes are transcribed, so mRNA is produced from them and translated into proteins such as haemoglobin.

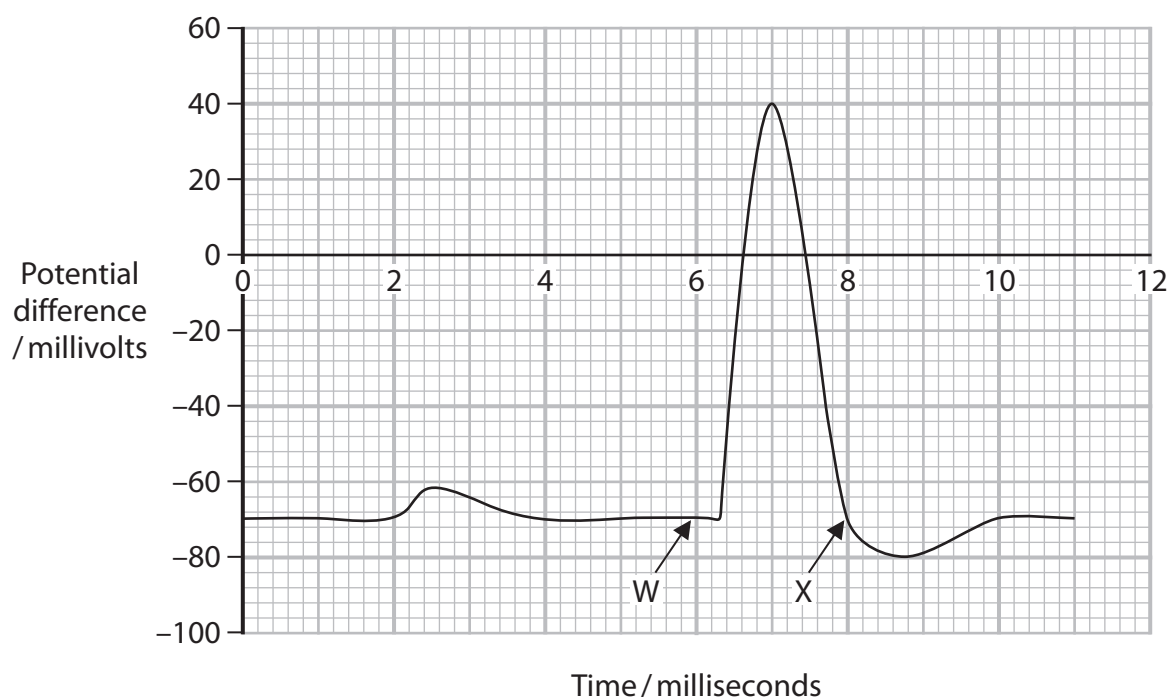
The stem cell therefore becomes specialised by differentiation into a red blood cell. During this the nucleus is removed and the cell develops a biconcave shape.

(Total for Question 5 = 9 marks)



6 The nervous system is one of the features found only in animals.

- (a) The graph shows the change in potential difference across the cell surface membrane of a neurone when it is stimulated at point W.



- (i) The threshold intensity is the minimum electrical stimulus that will cause a neurone to form an action potential.

Which potential difference could be the threshold potential for this neurone?

(1)

- ☐ A -80 millivolts
- ☐ B -70 millivolts
- ☒ C -60 millivolts
- ☐ D 40 millivolts

- (ii) Explain the changes in the sodium and potassium ion concentrations in the cytoplasm of the neurone from point W to point X on the graph.

(4)

At W the stimulus causes voltage-gated sodium ion channels to open, so sodium ions diffuse into the neurone from outside the cell. This causes an increase in the sodium ion concentration in the cytoplasm and the membrane depolarises to +40 mV.

At about 7 milliseconds (+40 mV) the sodium ion channels close and voltage-gated potassium ion channels open, so potassium ions diffuse out of the neurone from the inside. This causes a decrease in the potassium ion concentration in the cytoplasm as the membrane repolarises.

- (iii) Explain why the neurone becomes hyperpolarised after point X on the graph.

(3)

After X the voltage-gated potassium ion channels remain open, so potassium ions continue leaving the axon cytoplasm, making the inside more negative than the resting potential.

This is the refractory period, which prevents another depolarisation occurring and allows time for the neurone to reset to the resting potential.

This ensures that nerve impulses travel in one direction only.

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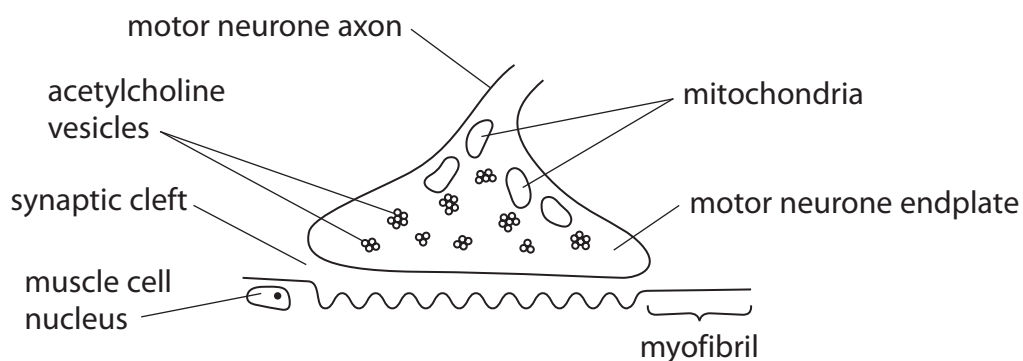
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- (b) The junction between the end of a motor neurone and a muscle myofibril is a modified synapse.

The diagram shows this neuromuscular junction.



Describe how the neurotransmitter crosses this synapse.

(2)

Vesicles fuse with the presynaptic membrane, releasing acetylcholine into the synaptic cleft by exocytosis.

The acetylcholine then crosses the synapse by diffusion, down its concentration gradient, to receptors on the motor endplate.

(Total for Question 6 = 10 marks)

7 Athletes compete in a range of environmental conditions.

(a) An investigation studied the effects of environmental conditions on athletes.

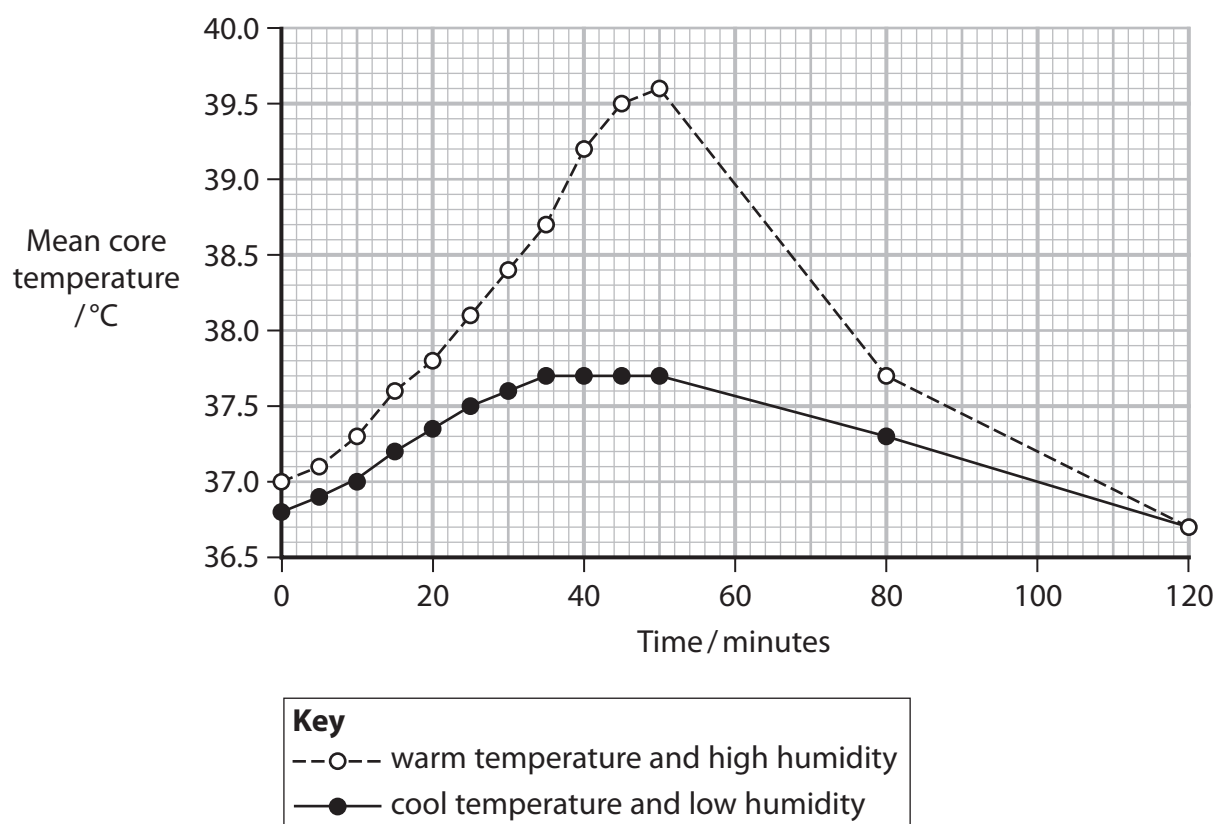
A group of nine athletes ran for 50 minutes in two sets of environmental conditions:

- warm temperature and high humidity
- cool temperature and low humidity.

All other variables were kept constant including the level of exercise.

The core temperature of each athlete was recorded during the exercise and for 70 minutes following the exercise.

The results are shown in the graph.



(i) Explain why there was a change in core temperature during the first 20 minutes of exercise.

(2)

During exercise there is increased respiration in the muscles to release energy for contraction.

Respiration is inefficient, so heat (thermal energy) is released faster than it can be lost, and core temperature rises.

(ii) Using the results of this investigation, a student concluded that during exercise:

- the human thermoregulatory system only works in cool environmental temperatures when the humidity is low.

Comment on this conclusion.

(4)

Core temperature increased more when humidity was high during exercise (to 39.6°C compared with 37.7°C), so body temperature is not as well controlled at higher humidity, as sweat evaporates less easily.

In low humidity there was no rise in body temperature after 35 minutes (it stayed at 37.7°C), showing thermoregulation was working.

However, temperature and humidity were changed together: no investigation was carried out on low temperature with high humidity, so the effect of humidity cannot be separated.

Also only nine athletes were used, on one occasion per condition, and exercise lasted only 50 minutes, so the conclusion is not valid.

(iii) Compare and contrast the changes in core body temperature, in the two environments, after the exercise was completed.

(3)

Both decrease after exercise, and both reach the same temperature (about 36.7°C) by 70 minutes after running (120 minutes).

There is a greater decrease in the warm, high humidity conditions (39.6 to 36.7°C) than in the cool, low humidity conditions (37.7 to 36.7°C).

There is a greater rate of cooling in warm humid conditions, which is non-linear, whereas cooling in cool, low humidity is almost linear.



- (b) In another investigation, samples of blood were taken from athletes during exercise and after exercise.

The concentration and activity of neutrophils, a type of phagocyte, in the blood were measured.

The table shows the results.

Measurements	During exercise	Immediately after exercise
Mean concentration of neutrophils in blood / 10^6 cells cm^{-3}	3.57	3.42
Mean activity of neutrophils / a.u.	28.4	22.0

- (i) The mean body mass of the athletes was 70 kg and the mean volume of blood per athlete was 5 dm^3 .

Calculate how many fewer neutrophils there are in the blood per kilogram of body mass immediately after exercise.

(3)

$$3.57 - 3.42 = 0.15 \times 10^6 = 150\,000 \text{ cells cm}^{-3}$$

$$5 \text{ dm}^3 = 5000 \text{ cm}^3$$

$$150\,000 \times 5000 = 750\,000\,000 \text{ per athlete}$$

$$750\,000\,000 \div 70 = 10\,714\,286$$

$$10\,714\,286 \text{ kg}^{-1}$$

- (ii) State how these results support the statement that exercise increases the risk of infection.

(1)

After exercise there are fewer neutrophils and the activity of the neutrophils is reduced, so fewer pathogens are destroyed by phagocytosis.

(Total for Question 7 = 13 marks)

8 Cells can be classified as either prokaryotic or eukaryotic.

(a) Which row identifies the type of DNA found in prokaryotic cells?

(1)

	Plasmid DNA is	Chromosomal DNA is
☒ A	double-stranded	double-stranded
☐ B	double-stranded	single-stranded
☐ C	single-stranded	double-stranded
☐ D	single-stranded	single-stranded

(b) Eukaryotic cells contain a range of membrane-bound organelles including the Golgi apparatus and the rough endoplasmic reticulum (rER).

(i) Name two other organelles that are bound by a single membrane.

(1)

Lysosomes and smooth endoplasmic reticulum (SER).

- (ii) The table shows the percentage of cell membranes that make up Golgi apparatus and rER in the cells from two organs.

Organ	Percentage of cell membranes (%)	
	Golgi apparatus	rER
Liver	7	35
Pancreas	10	60

Explain the differences in the percentage of membranes that comprise the two organelles in these cells.

(5)

Pancreatic cells have more rER (60% compared with 35% in liver cells). This is for the synthesis of protein, such as digestive enzymes and the hormone insulin; ribosomes on the rER make the protein, which is then folded in the rER.

Pancreatic cells also have more Golgi apparatus (10% compared with 7%). This is for the modification of protein, e.g. adding carbohydrate to produce glycoprotein, and packaging it.

More vesicles are produced by the Golgi apparatus in pancreatic cells, because the pancreas secretes more protein (enzymes and insulin) by exocytosis, whereas liver cells secrete less protein.

(c) In one study, measurements were taken of a single Golgi apparatus.

The measurements were:

- total number of cisternae = 6
- height of each cisterna = 15 nm
- distance between adjacent cisterna = 25 nm

Calculate the total height of the stack of cisternae in this Golgi apparatus.

Give your answer in micrometres.

(2)

$$\text{Cisternae: } 6 \times 15 = 90 \text{ nm}$$

$$\text{Gaps: } 5 \times 25 = 125 \text{ nm}$$

$$\text{Total} = 90 + 125 = 215 \text{ nm}$$

$$215 \div 1000 = 0.215 \text{ } \mu\text{m}$$

0.215

..... μm

(d) Beetroot cells contain the pigment betalain.

When beetroot cells are placed in alcohol, the concentration of betalain in the cells changes.

Explain why alcohol affects the concentration of betalain in these cells.

(3)

The concentration of betalain in the cells decreases.

This is because the membrane lipids (phospholipids) dissolve in alcohol, which increases membrane permeability.

So betalain diffuses out of the cells, down its concentration gradient.

(Total for Question 8 = 12 marks)



9 The inheritance of coat colour in mice has been investigated.

Some scientists crossed mice that had yellow coats. The offspring had either yellow coats or non-yellow coats.

- (a) (i) Explain how the scientists knew which allele for coat colour was recessive.

(2)

Yellow parents produced some non-yellow offspring, so the parents must have been heterozygous (a dominant and a recessive allele).

Because the parents had yellow coats, yellow is dominant, so the recessive allele is for non-yellow coat.

- (ii) The crosses led to a total of 1599 offspring being produced.

Predict the number of yellow and non-yellow offspring produced.

(2)

Offspring with a yellow coat	Offspring with a non-yellow coat
1199	400

(iii) The table shows the actual number of offspring with each coat colour.

Offspring with a yellow coat	Offspring with a non-yellow coat
1064	535

Explain why there are differences between the predicted and actual numbers of these mice.

(3)

The actual ratio is 2 : 1 (1064 : 535) rather than the predicted 3 : 1.

This is because no homozygous dominant individuals survive: the homozygous dominant genotype is lethal, so 2/3 of surviving offspring are heterozygous yellow ($1599 \times 2/3 = 1066$).

Also fertilisation is random, so actual numbers vary by chance from the predicted ones.



*(b) There is a gene in humans similar to the mouse coat colour gene.

This human gene comprises 74 775 base pairs. The mRNA produced from this gene codes for a protein made up of 132 amino acids.

Explain the differences in the gene coding for this protein and the mRNA produced from it.

(6)

The gene is much larger than the mRNA. 132 amino acids need only 132 codons, so a minimum of 396 bases in the mRNA, whereas the gene has 74 775 base pairs.

This is because the gene contains introns (non-coding sequences) as well as exons. After transcription the pre-mRNA undergoes post-transcriptional modification: the introns are removed, so the mRNA contains far fewer bases.

The gene also includes a promoter, a site where RNA polymerase and transcription factors bind, which is not copied into the mRNA.

The DNA is double stranded, so it is more stable for storing information, and one strand acts as a template strand. The mRNA is single stranded, so its bases (codons) are exposed and can bind to tRNAs with complementary anticodons, so amino acids are brought and joined in the correct sequence.

The mRNA contains ribose rather than deoxyribose and uracil rather than thymine. As it is smaller and not bound to other genes, it can exit the nucleus through the nuclear pores to the ribosomes.

(Total for Question 9 = 13 marks)



10 All mammals have an internal skeleton that includes bone and cartilage. Bones contain calcium ions.

- (a) Explain one way in which cartilage at the ends of the bones in the knee joint reduces wear and tear.

(2)

The cartilage is smooth and slippery, which reduces friction and prevents the bones rubbing together.

It is also compressible, acting as a cushion to absorb shocks.

- (b) In humans, calcium ions are important for structure as part of bone material. These ions are also involved in physiological processes in soft tissue. Soft tissue is non-bony material.

The table shows some data relating to humans.

mean mass of an adult	80 kg
mean percentage of body mass that is bone	4%
mean mass of calcium ions per adult	1000 g
mean percentage of calcium ions present in soft tissue	1%

- (i) Calculate the calcium ion concentration in the soft tissue of a human.

(3)

$$Ca^{2+} \text{ in soft tissue} = 1\% \text{ of } 1000 \text{ g} = 10 \text{ g} = 10\,000\,000 \mu\text{g}$$

$$\text{Soft tissue} = 96\% \text{ of } 80 \text{ kg} = 76.8 \text{ kg} = 76\,800 \text{ g}$$

$$10\,000\,000 \div 76\,800 = 130.2 \mu\text{g g}^{-1}$$

$$130.2 \mu\text{g g}^{-1}$$



* (ii) Calcium ions are also found in the tissue of plants.

The calcium ion concentration in one species of plant has been measured.

It was found to be $170 \mu\text{g g}^{-1}$ of plant tissue.

A student made the conclusion that:

Calcium ions are more important in the tissue of plants than in animals.

Evaluate this conclusion.

(6)

The plant tissue has a higher concentration of calcium ions ($170 \mu\text{g g}^{-1}$) than human soft tissue ($130.2 \mu\text{g g}^{-1}$), which appears to support the conclusion.

However, concentration is not the same as importance. Also the human value is for soft tissue only and does not include bones, where 99% of the calcium is; including bone, humans have about $12\,500 \mu\text{g g}^{-1}$, far more than the plant.

Only one plant species was measured, which may not be representative of all plants, and humans are not necessarily representative of all animals.

Calcium ions are important in both. In plants they form calcium pectate in the middle lamella, holding cell walls together. In humans they are needed for bone tissue, blood clotting (prothrombin to thrombin), muscle contraction (binding to troponin so tropomyosin moves and exposes binding sites on actin) and at synapses (calcium ions entering cause vesicles to fuse with the presynaptic membrane).

So the conclusion is not supported by the data.

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(c) Milk from humans contains both calcium ions and lactose.

Lactose is a disaccharide.

Describe how lactose is formed from two monosaccharides.

(2)

Glucose and galactose are joined by a glycosidic bond, formed in a condensation reaction with the removal of a water molecule.

(Total for Question 10 = 13 marks)

TOTAL FOR PAPER = 100 MARKS

