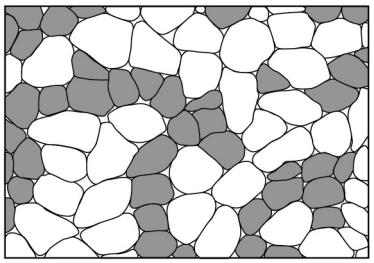
0 3 Scientists investigated the effect of regular exercise on skeletal muscle fibres in mice. The scientists compared the muscle fibres of mice after six weeks of regular exercise (trained mice) with those of mice that had not exercised (control mice). The scientists stained the muscle fibres from both sets of mice to show succinic acid dehydrogenase activity. The darker the stain the greater the succinic acid dehydrogenase activity.

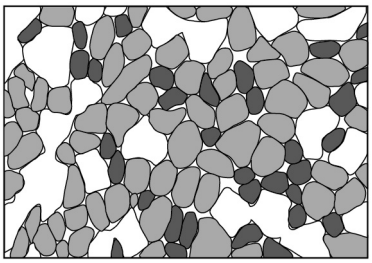
Figure 3 shows a typical set of results they obtained.

Figure 3

Control mice



Trained mice



0 3 . 1 Succinic acid dehydrogenase is an enzyme used in the Krebs cycle.

Suggest **one** reason for the difference in the staining between the muscle fibres of the control mice and the trained mice.

[1 mark]

0 3 . 2 The scientists then compared the length of time that the control mice and the trained mice could carry out prolonged exercise. The trained mice were able to exercise for a longer time period than control mice.

Explain why.

[3 marks]

0 3 . 3 The scientists determined the mean diameter of muscle fibres in trained mice using an optical microscope to examine sections of muscle tissue. The circular area (πr^2) of one field of view was 1.25 mm^2. The diameter of this area was equal to the diameter of 15 muscle fibres.

Using this information, calculate the mean diameter in μm (micrometres) of muscle fibres in this section of tissue.

[2 marks]

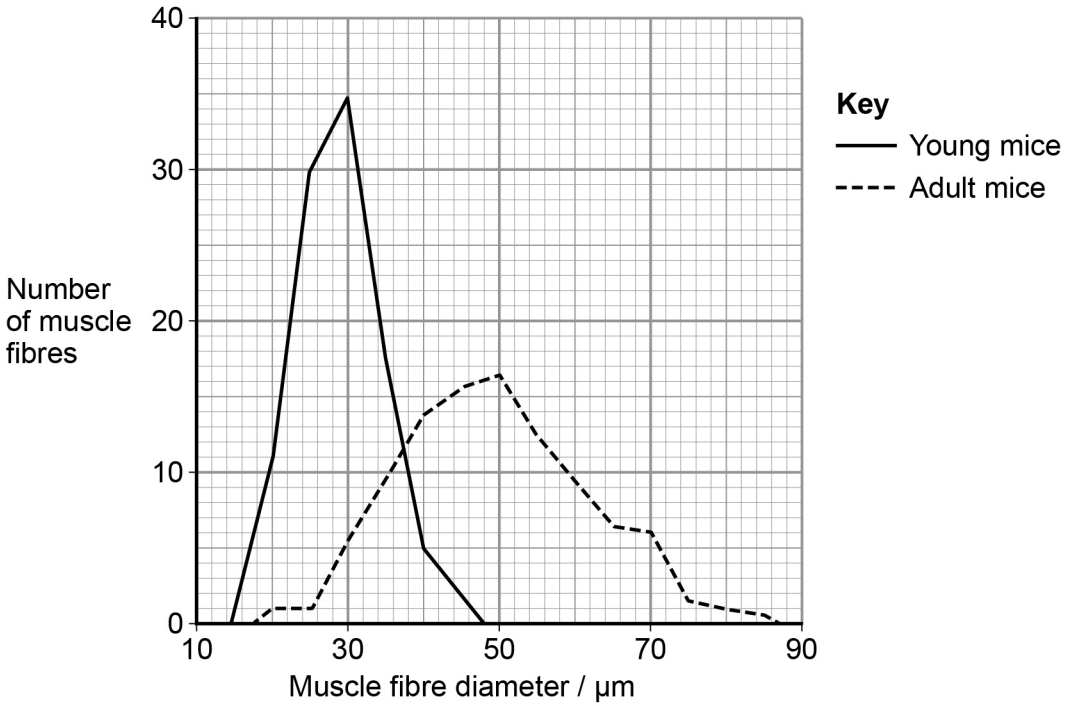
Answer = _____ μm

Question 3 continues on the next page

0 3 . 4 The scientists also compared the diameter of samples of muscle fibres taken from young mice and adult mice.

Some of their results are shown in **Figure 4**.

Figure 4



Describe **two** differences between these samples of muscle fibres.

[2 marks]

1 _____

_____

_____

2 _____

_____

_____

8

Do not write outside the box

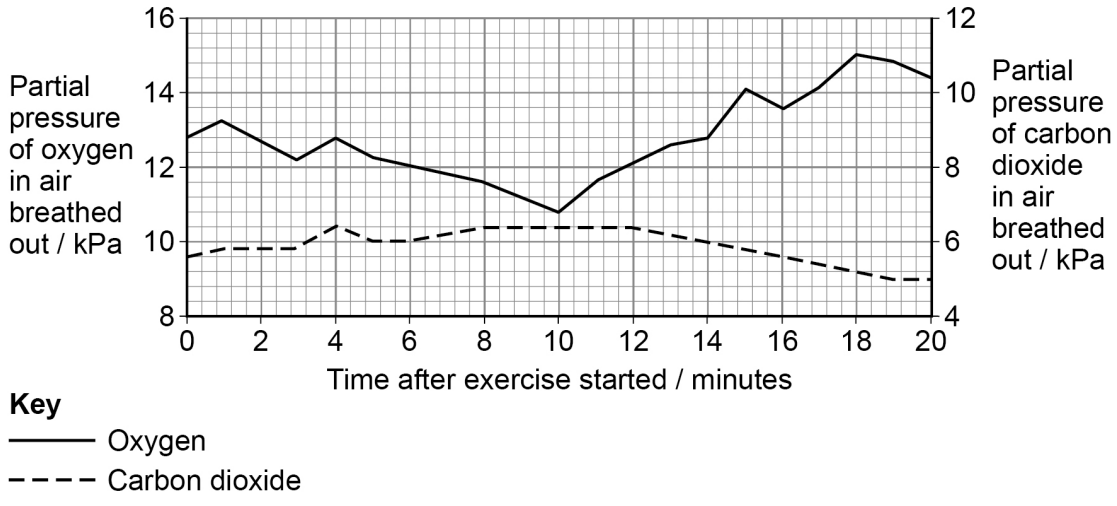
0 6 . 1 Describe the advantage of the Bohr effect during intense exercise.

[2 marks]

A cyclist completed a fitness test on an exercise bike. The intensity of the exercise was increased every 10 seconds. The test finished when he was unable to cycle any further. The partial pressure of oxygen (pO_2) and of carbon dioxide (pCO_2) in air breathed out was measured.

Figure 3 shows the results of the cyclist's fitness test.

Figure 3



Ventilatory threshold (VT) is a measure of the point when anaerobic respiration increases because aerobic respiration alone can no longer maintain muscle contraction.

Do not write outside the box

0 6 . 2 VT can be identified as the **first** point when there is an increase in pO_2 breathed out, without an equivalent increase in pCO_2 breathed out.

Use **Figure 3** to determine the **time** after the exercise started when the cyclist reached VT.

Calculate the **ratio** of pO_2 to pCO_2 in breathed-out air at this time.

Show your working.

[2 marks]

Time when the cyclist reached VT = _____ min

Ratio of pO_2 to pCO_2 at VT = _____:1

0 6 . 3 An increase in the intensity of exercise produces an increase in the volume of carbon dioxide produced.

However, **Figure 3** shows that the pCO_2 in air breathed out did **not** show a large increase during the exercise.

Suggest **one** physiological change that would cause this result. Explain how the physiological change would allow for the removal of the increase in the volume of carbon dioxide produced.

[2 marks]

Physiological change _____

_____

Explanation _____

_____

_____

_____

Question 6 continues on the next page

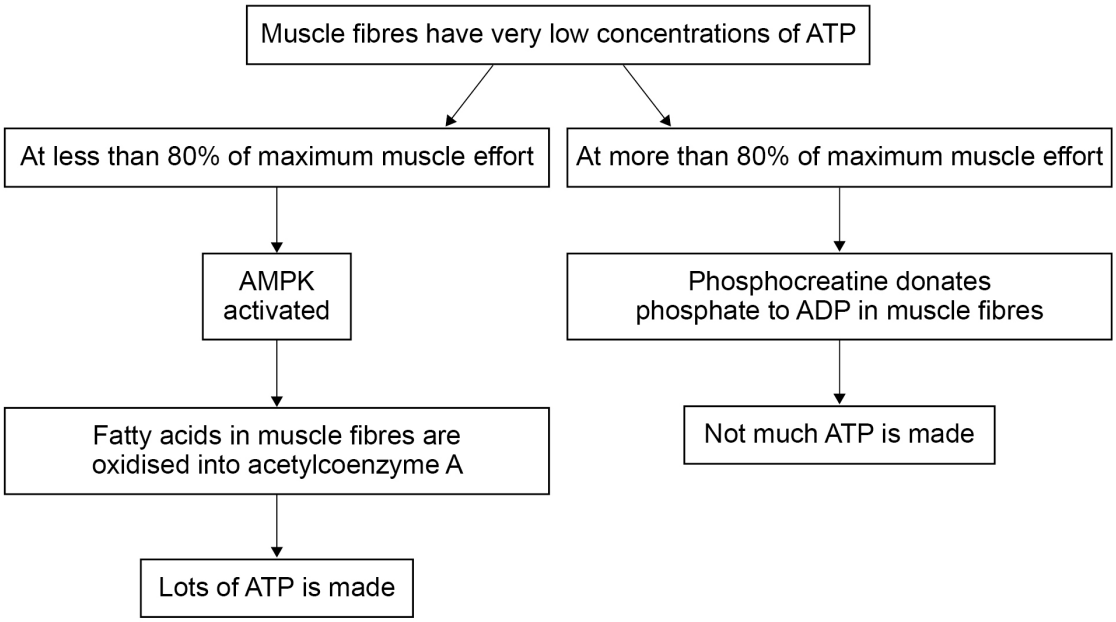
Do not write outside the box

When muscle fibres have very low concentrations of ATP, they may get ATP in the following ways.

- AMPK (an enzyme) oxidises fatty acids.
- Phosphocreatine donates phosphate to ADP in anaerobic conditions.

Figure 4 shows how these chemicals work.

Figure 4



0 6 . 4 At more than 80% of maximum muscle effort, ATP can only be made for a limited time.

Use **Figure 4** to suggest **one** reason why.

Tick (✓) the correct box.

[1 mark]

ATP cannot move into muscle fibres at a fast-enough rate. ☐

Muscle fibres have a limited amount of phosphocreatine. ☐

Muscle fibres produce too much lactate. ☐

Muscle fibres quickly run out of ADP. ☐

Do not write outside the box

0 6 . 5 GW1516 is a performance-enhancing drug. GW1516 activates AMPK **and** develops slow muscle fibres at rest.

Use **Figure 4** to justify why professional athletes are **not** allowed to take GW1516.

Do **not** include details of chemiosmotic theory in your answer.

[4 marks]

Question 6 continues on the next page

Do not write outside the box

EPO is another performance-enhancing drug. It can increase the haematocrit (the percentage of red blood cells in blood).

0 6 . 6 A heart attack is caused by a lack of glucose and oxygen being delivered to cardiac muscle via the coronary arteries. The overuse of EPO can increase the risk of a heart attack.

Suggest how.

[2 marks]

0 6 . 7 The normal haematocrit for human males is 47(±5)%. For professional male cyclists, the maximum haematocrit allowed is 50%.

A student suggested that professional male cyclists should be allowed to use EPO until their haematocrit is 50%.

Give **two** reasons why this suggestion is **not** valid.

[2 marks]

1

2

15

Do not write outside the box

1 0 Read the following passage.

North American black bears can hibernate for up to 7 months without food or water. The bears survive using the fat stores in their bodies. The bears build up the fat stores during the summer. During hibernation, the heart rate of black bears decreases from a summer mean of 55 beats per minute to 14 beats per minute. Their metabolic rate falls by 75%.

In many mammals, 'uncoupling proteins' help to maintain a constant body temperature during hibernation. Uncoupling proteins are found in the inner mitochondrial membrane and act as proton channels during chemiosmosis. However, these proton channels do not generate ATP.

In the mountains of North America, when winter changes into spring, the coat colour of snowshoe hares changes from white to brown. Climatic changes have caused the snow to melt earlier. This has reduced the survival rate of snowshoe hares in these habitats. The change in coat colour occurs when new fur replaces old fur. This is called moulting. Recent research has shown that snowshoe hares within a population moult at different times. Moulting at different times could be a major factor in ensuring the survival of snowshoe hare populations.

Use the information in the passage and your own knowledge to answer the following questions.

1 0 . 1 Black bears can hibernate for up to 7 months without food or water (lines 1–2).

Suggest and explain how.

[3 marks]

Do not write outside the box

1 0 . 2 During hibernation, the heart rate and the metabolic rate of black bears decrease (lines 3–5).

Use your knowledge of the nervous control of heart rate to describe how these are linked.

[4 marks]

1 0 . 3 In many mammals, 'uncoupling proteins' help to maintain a constant body temperature during hibernation (lines 6–7).

Suggest and explain how.

[2 marks]

Question 10 continues on the next page

Do not write outside the box

1 0 . 4 Climatic change has reduced the survival rate of snowshoe hares in mountain habitats (lines 11–13).

Suggest and explain how.

[2 marks]

1 0 . 5 Snowshoe hares within a population moult at different times (line 15).

Explain how this could ensure the survival of snowshoe hare populations in these mountain habitats.

[4 marks]

15

END OF QUESTIONS

Do not write outside the box

0 4 Scientists investigated the effect of a decrease in pH on muscle contraction. The scientists did the investigation with four different preparations of isolated muscle tissue: **A**, **B**, **C** and **D**.

A - mouse muscle fibres at typical pH of mouse muscle tissue (control 1).

B - mouse muscle fibres at 0.5 pH units below typical pH.

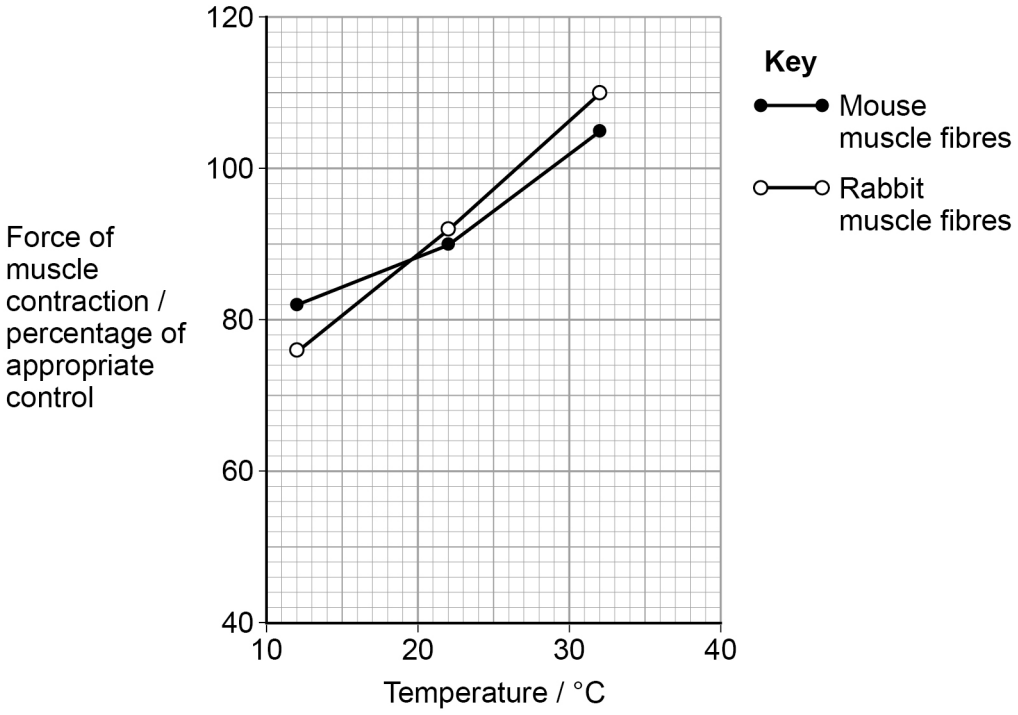
C - rabbit muscle fibres at typical pH of rabbit muscle tissue (control 2).

D - rabbit muscle fibres at 0.5 pH units below typical pH.

They measured the force of muscle contraction of the muscle fibres at 12 °C, 22 °C and 32 °C

Figure 3 shows the results the scientists obtained for **B** and **D** compared with the appropriate control.

Figure 3



Do not write outside the box

0 4 . 1 A student looked at the results and concluded that a decrease in pH does cause a decrease in the force of muscle contraction.

Use **Figure 3** to evaluate this conclusion.

[4 marks]

[Extra space]

Question 4 continues on the next page

Do not write outside the box

0 4 . 2 Another group of scientists suggested that a decrease in the force of muscle contraction is caused by an increase in the concentration of inorganic phosphate, Pi, in muscle tissues.

Their hypothesis is that an increase in the concentration of Pi prevents the release of calcium ions within muscle tissues.

Explain how a decrease in the concentration of calcium ions within muscle tissues could cause a decrease in the force of muscle contraction.

[3 marks]

0 4 . 3 In muscles, pyruvate is converted to lactate during prolonged exercise.

Explain why converting pyruvate to lactate allows the continued production of ATP by anaerobic respiration.

[2 marks]

9

Answer **all** questions in the spaces provided.

0 1 . 1 Exercise causes an increase in heart rate.

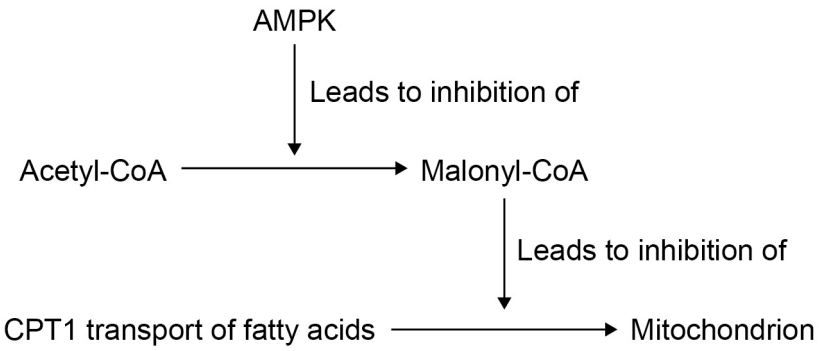
Describe the role of receptors and of the nervous system in this process.

[4 marks]

0 1 . 2 AMP-activated protein kinase (AMPK) is an enzyme that regulates a number of cellular processes. Exercise leads to activation of AMPK.

Figure 1 shows one effect of activation of AMPK during exercise.

Figure 1



CPT1 is a channel protein that transports fatty acids into mitochondria.

Using **Figure 1**, explain the benefit of activation of AMPK during exercise.

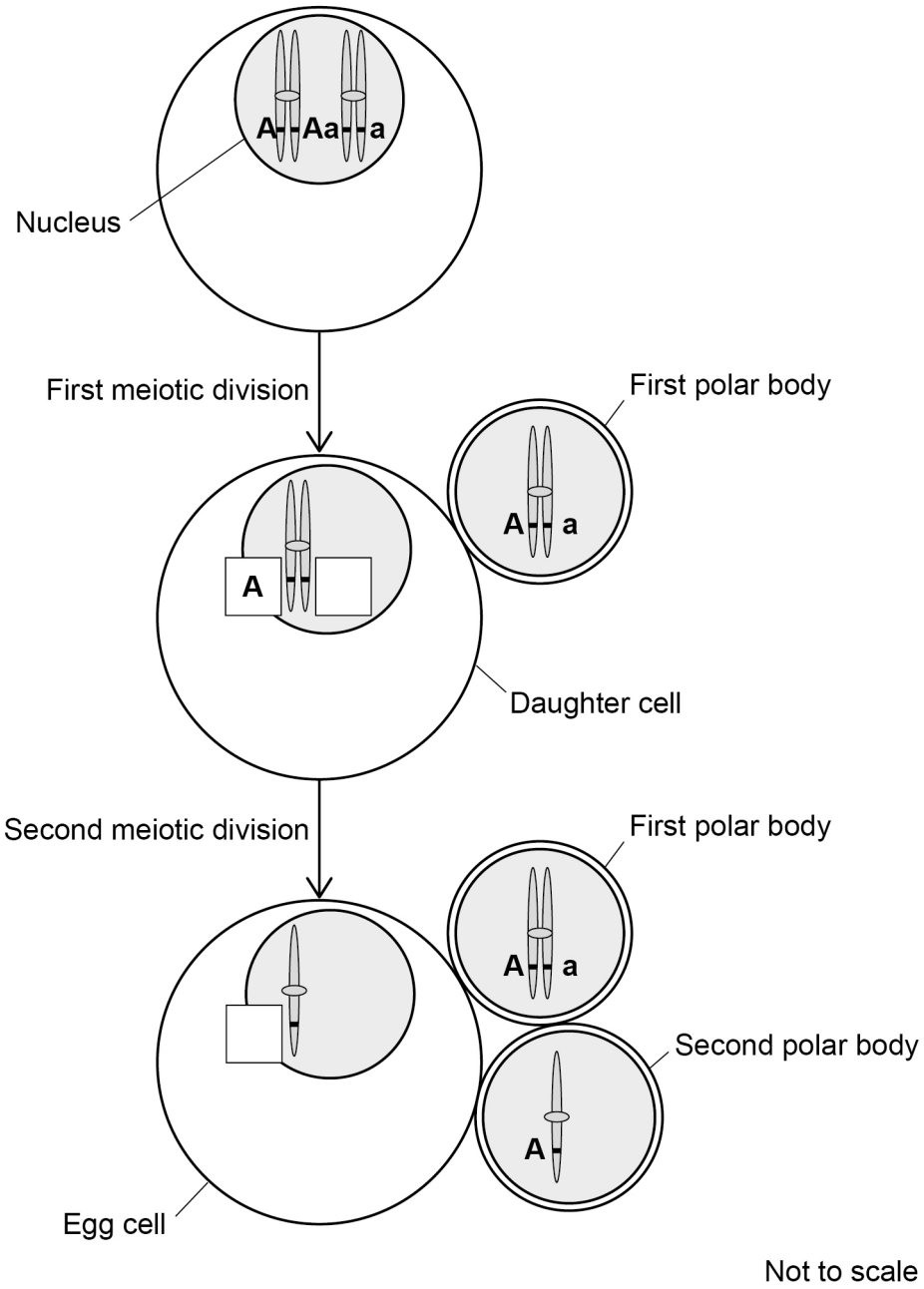
[3 marks]

7

0 3 In women, the first division of meiosis produces one daughter cell that has almost all of the cytoplasm. The other daughter cell consists of a nucleus surrounded by a very small amount of cytoplasm and a cell-surface membrane. This very small daughter cell is called a polar body. Polar bodies do not usually divide. The same process occurs in the second division of meiosis, resulting in one egg cell and two polar bodies.

The diagram in **Figure 3** shows the formation of an egg cell and two polar bodies during meiosis. It also shows what happens to one pair of homologous chromosomes. This pair carries two alleles of gene A.

Figure 3



0 3 . 1 Complete **Figure 3** by putting **A** or **a** in the boxes. One box has been completed for you with **A**.

[1 mark]

0 3 . 2 Put a tick (✓) in the box next to the name of the process that produced the combination of alleles on the chromosome in the first polar body in **Figure 3**.

[1 mark]

Anaphase ☐

Crossing over ☐

Independent assortment ☐

Semi-conservative replication ☐

0 3 . 3 A scientist measured the diameter of a polar body and the diameter of the nucleus inside it. The diameter of the polar body was 10.4 μm and the diameter of the nucleus was 7.0 μm. The density of mitochondria in the cytoplasm of the polar body (outside of the nucleus) was 0.08 mitochondria per μm^3.

Calculate the number of mitochondria in the polar body. You should assume polar bodies and nuclei are spherical.

The formula for the volume of a sphere is $\frac{4}{3}\pi r^3$ where $\pi = 3.14$

Show your working.

[2 marks]

Number of mitochondria = _____

0 3 . 4 Mitochondrial diseases are caused by faulty mitochondria. All of a person's mitochondria are inherited from their mother via the egg cell. An egg cell contains approximately 3×10^5 mitochondria.

One proposed treatment to prevent passing on faulty mitochondria involves

- removing the nucleus from an egg cell donated by a woman with healthy mitochondria
- replacing this nucleus with the contents of the polar body from a woman whose egg cells are affected by mitochondrial disease.

Suggest how this treatment prevents inheritance of mitochondrial diseases.

[2 marks]

0 3 . 5 If most of the mitochondria in a cell are faulty, this prevents many important enzyme-catalysed reactions taking place or slows them down.

Suggest and explain **one** reason why.

[2 marks]

8

Turn over for the next question

Question	Marking Guidance	Mark	Comments
03.1	Increase in aerobic respiration OR Increase in/more mitochondria OR Increase in/more slow muscle fibres;	1 max	Ignore: reference to Krebs cycle as this in the stem of the question.
03.2	1. (More aerobic respiration) produces more ATP; 2. Anaerobic respiration delayed; 3. Less or no lactate;	3	1. Accept: produces ATP faster. 2. Accept: aerobic respiration can continue. 2. Accept : no anaerobic respiration. 3. Accept: lactic acid.
03.3	1. Correct answer in range 84 to 84.2 = 2 marks;; 2. For one mark accept incorrect answer but shows r (radius) = 0.63 (mm) OR d (diameter) = 1.26 (mm);	2	2. Ignore: numbers after 0.63 and 1.26.
03.4	1. A numerical comparison of range = **2 marks** i.e. Young (fibres) range 14/15 – 47/48 (μm) **and** adult (fibres) 17/18 - 86/87/88 (μm) OR Young (fibres) range 32/33/34 **and** adult (fibres) range 68/69/70/71; 2. Comparison of range without numbers = one mark i.e. Adult (fibres) greater range/spread/variation (of diameters) OR Young (fibres) smaller range/spread (of diameters);	2 max	1. Accept: **one** mark for comparison of minimum values i.e. 14/15 compared to 17/18 Allow **one** mark for comparison of maximum values i.e. 47/48 compared to 86/87/88. 1. Note: comparison of both maximum and minimum values = **2 marks.**

Question	Marking Guidance	Mark	Comments
06.1	1. Increases dissociation of oxygen; 2. For aerobic respiration at the tissues/muscles/cells **OR** Anaerobic respiration delayed at the tissues/muscles/cells **OR** Less lactate at the tissues/muscles/cells;	2	1. Accept unloading/ release/reduced affinity for dissociation
06.2	1. (Time) 10 minutes; 2. (Ratio) 1.6875(:1); Allow 1 mark for correct ratio calculated from wrong time	2	For the ratio accept any correct rounding
06.3	1. Increase in breathing (rate); 2. Similar/same pCO_2 per breath, but more breaths; **OR** 3. Increase in tidal volume; 4. Similar/same pCO_2 per breath, but increased volume per breath;	2	Award mark points 1 and 2 **OR** 3 and 4 1. Allow more breaths per minute 1. Reject more BPM 3. Accept each breath is deeper
06.4	Second box ticked (Muscle fibres have a limited amount of phosphocreatine.)	1	

06.5	1. More acetylcoenzyme A would enter the Krebs cycle; 2. (So) the Krebs cycle generates (more) reduced coenzymes **OR** (So more) reduced coenzymes pass their electrons to the electron transfer chain; 3. (So more) ATP would be produced; 4. Athletes could build (slow) muscle (fibres) without exercising; 5. (Having more) slow muscle (fibres) would increase endurance;	4 max	1. 2. and 3. idea for more is required once 2. Accept examples of reduced coenzymes 2. Reject production of reduced NADP or NADPH$_2$ 4. Ignore 'develop (slow) muscle (fibres) at rest' as in stem of question 4. Accept description of not exercising, eg without training 5. Accept descriptions of endurance in terms of delayed onset of anaerobic respiration

06.6	1. (EPO) causes blood to thicken; 2. (The thickened blood) could block the coronary arteries **OR** (The thickened blood) slows blood flow **OR** (The thicker blood) could cause clots;	2	1. Accept descriptions of thickening, eg more viscous 2. Reject atheroma/plaque (forms) 2. Accept could cause thrombus/embolus

06.7	1. Some cyclists will gain a bigger advantage/increase **OR** Cyclists with a haematocrit of 50% would not be able to gain an advantage; 2. There are health risks (associated with) taking EPO;	2	1. Accept use of the data, or suitable calculations, eg some may have an 8% increase, others 0% 1. Some cyclists might naturally have a haematocrit over 50% (and so not be allowed to compete) 2. Accept dangerous side-effects of taking EPO, or examples of health risks

Question	Marking Guidance	Mark	Comments
10.1	1. Fat (store) used in respiration/metabolism; 2. Less energy/food (store) is required due to low respiration/metabolism **OR** Less energy/food (store) is required due less movement; 3. Gluconeogenesis; 4.Low surface area to volume reduces heat loss **OR** Fat (layer/insulation) reduces heat loss; 5. Long loop of Henle so less water lost; 6. Water provided from respiration; 7. Reduced/no urination; 8. Less evaporation;	3 max	**Mark points 1 to 4 = 2 max**. **Mark points 5 to 8 = 2 max**. 1 and 2. Reject respiration 'uses energy' or 'produces energy'. 3. Accept description in terms of using glycerol, fatty acids or amino acids. 5. Accept thick medulla (in kidney) for long loop of Henle. 8. Accept less sweating.
10.2	1. (Lower metabolism so) less/low CO_2 (in blood); 2. (Detected by) chemoreceptors; 3. (Chemoreceptors) located in aorta/medulla **OR** (Chemoreceptors) located in carotid artery; 4. Fewer impulses to cardiac centre; **OR** Fewer impulses to medulla (oblongata); 5. (More) impulses along parasympathetic/vagus pathway/neurones/nerve **OR** Fewer impulses along sympathetic pathway/neurones/nerve; 6. (To) SAN;	4 max	**If neither mark point 1 or 2 credited = 3 max.** 1. Accept increase in pH or decrease in H ions/acidity for less CO_2. Ignore baroreceptors. 2. Ignore detects oxygen, (concentration). 3. Accept carotid body or aortic body. 4 and 5. Reject (once only) reference to 'an/one impulse'. 4 and 5. Reject 'signals', 'messages' (once only) for 'impulses' 4 and 5. Accept 'action potential/s' for impulses.

10.3	1. Allow passage of protons/H^+; 2. (Energy) released as heat;	2	1. Ignore direction of movement/diffusion/active transport. 2. Accept 'produces heat' but reject 'produces 'heat energy'.
10.4	1. Less snow **so** less camouflage; 2. More hares seen/eaten/killed by predators;	2	1. Accept 'snow melts' 1. Accept description of less camouflage, e.g. more hares seen. 2. Accept description of predation.
10.5	1. Hares which moult earlier (more likely to) survive; 2. Hares which moult earlier (more likely to) reproduce; 3. Pass on (advantageous) <u>allele</u>; 4. Frequency of <u>allele</u> increases (in future populations);	4	1. Accept less likely to be killed for 'survive'. 1. Accept description of survival e.g. not killed/eaten. 1. Accept moult quicker/faster for earlier. 1 and 2. Answers must be in the context of moulting earlier/quicker/faster. Accept rabbits for hares. 2 and 3. Accept 'pass on allele to offspring' or 'to next generation' = 2 marks. 4. 'More alleles' is not enough for a mark.

Question	Marking Guidance	Mark	Comments
04.1	1. Lower (force of contraction) in mouse/**B** (than control/100%) below 29 °C **OR** Lower (force of contraction) in rabbit/**D** (than control/100%) below 26.5 °C; 2. Higher (force of contraction) in mouse/**B** (than control/100%) above 29 °C **OR** Higher (force of contraction) in rabbit/**D** (than control/100%) above 26.5 °C; 3. Only (used) mouse **and** rabbit **OR** No other organism/species used; 4. Body temperature of mouse/rabbit higher (than temperatures investigated); 5. Only used one/0.5 pH (below typical pH) **OR** (Should) use more pH values; 6. (Used) isolated muscle tissue; 7. No stats test to see if (difference is) significant;	4 max	1. Accept any temperature below 29 °C for mouse/**B** or any specified temperature below 26.5 °C for rabbit/**D.** 2. Accept any temperature above 29 °C for mouse/**B** or any temperature above 26.5 °C for rabbit/**D.** 1. and 2. Accept 27 °C for 26.5 °C and accept 28.5 °C for 29 °C. 3. Accept only two animals/species used. 4. Accept body temperature of mouse/rabbit not known 7. Ignore SD.
04.2	1. (Less/No) tropomyosin moved from binding site **OR** Shape of tropomyosin not changed so binding site not exposed/available; 2. (Fewer/No) actinomyosin bridges formed; 3. Myosin head does not move **OR** Myosin does not pull actin (filaments) **OR** (Less/No) ATP (hydrol)ase (activation);	3	1 and 2. Reject active site only once. 1. Ignore troponin. 2. Accept actin and myosin do not bind. 3. Reject ATP synthase. Do not penalise reference to calcium rather than calcium ions. Credit all mark points even if context relates to what happens when calcium ions are present.

04.3	1. Regenerates/produces NAD **OR** oxidises reduced NAD; 2. (So) glycolysis continues;	2	1. Reject NADP and any reference to FAD. 1. Accept descriptions of oxidation e.g. loss of hydrogen. 2. Accept description of glycolysis e.g. glucose to pyruvate. 2. Accept 'for oxidising/converting triose phosphate to pyruvate'.

Question	Marking Guidance	Mark	Comments
01.1	1. Chemoreceptors detect rise in CO_2/H^+/acidity/carbonic acid/fall in pH OR Baro/pressure receptors detect rise in blood pressure; 2. Send impulses to cardiac centre/medulla; 3. More impulses to SAN; 4. By sympathetic (nervous system for chemoreceptors/CO_2) OR By parasympathetic (nervous system for baro/pressure receptors/blood pressure);	4	1. Ignore: location of receptors. 1. Ignore: chemoreceptors detect oxygen. 2 and 3. Accept: action potentials. 2. Reject: 'messages', 'signals', 'an impulse' or an 'action potential'. 3. Ignore: messages', 'signals', 'an impulse' or an 'action potential' as emphasis here is on increase in frequency.
01.2	1. Less/no malonyl-CoA; 2. (More) fatty acids transported/moved into mitochondria; 3. Respiration/oxidation of fatty acids provides <u>ATP</u>;	3	1. 'Inhibition of malonyl-CoA' on its own is not enough but accept production of malonyl-CoA is inhibited. 2. Accept: 'transport of fatty acids into mitochondria is not inhibited'. 2. Ignore: method of entry. 3. Accept: for respiration any stage of aerobic respiration e.g. Krebs (cycle), link (reaction) etc. 3. Reject: production of energy, **but** accept production of energy in the form of <u>ATP</u>. 3. Accept: acetyl CoA can enter Krebs cycle/mitochondria to provide ATP.

Question	Marking Guidance	Mark	Comments
03.1	Lowercase **a** in both boxes	1	
03.2	Tick in box next to 'Crossing over';	1	
03.3	32.73 / 32.7 / 32 / 33;; Award 1 max for **either** 409 (409.2) for difference in volume (but incorrect number of mitochondria); **OR** Answer of 262 (261.9) (using diameter, rather than radius);	2	
03.4	1. Egg (created) has nucleus / DNA / genes of (affected) woman / mother; 2. It has mostly / many / lots of normal mitochondria (of unaffected woman) **OR** There are few faulty mitochondria;	2	1. Accept ref. to zygote / embryo / child for egg 1. Accept genetic information 1. Ignore references to alleles 1. Reject if nucleus from wrong egg / woman 2. Reject ref. to **production** of healthy mitochondria as result of treatment
03.5	1. Not enough / little ATP produced; 2. ATP provides **energy** for (enzyme) reactions **OR** ATP phosphorylates substrates / enzymes, **so** making them (more) reactive;	2 max	**One** reason asked for, so list rule applies 1. Ignore ref. to no ATP produced 2. Accept (leads to) lower activation energy for reaction 2. Reject if mention energy produced