Please check the examination details below before entering your candidate information

Candidate surname	Other names

Centre Number | Candidate Number

Pearson Edexcel International Advanced Level

Wednesday 17 January 2024

Morning (Time: 1 hour 45 minutes) | Paper reference **WBI15/01**

Biology

International Advanced Level
UNIT 5: Respiration, Internal Environment, Coordination and Gene Technology

You must have:
Scientific article (enclosed), scientific calculator, ruler, HB pencil

Total Marks

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.
- Answer the questions in the spaces provided – *there may be more space than you need*.

Information

- The total mark for this paper is 90.
- The marks for **each** question are shown in brackets – *use this as a guide as to how much time to spend on each question.*
- In questions labelled 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.

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Answer ALL questions.

Write your answers in the spaces provided.

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

1 Aerobic respiration is made up of several stages.

(a) Which is the correct order of the stages of respiration required for the complete oxidation of glucose?

(1)

☒	**A**	glycolysis	Krebs cycle	link reaction
☒	**B**	glycolysis	link reaction	Krebs cycle
☒	**C**	link reaction	Krebs cycle	glycolysis
☒	**D**	Krebs cycle	glycolysis	link reaction

(b) Write a **balanced** equation for the complete oxidation of glucose in aerobic respiration.

(2)

....

(c) The equation shows the aerobic respiration of a lipid.

$$2C_{18}H_{34}O_2 + 51O_2 \rightarrow 36CO_2 + 34H_2O$$

(i) Which is the respiratory quotient when this lipid is used in aerobic respiration?

(1)

☒ **A** 0.67

☒ **B** 0.71

☒ **C** 1.06

☒ **D** 1.42

(ii) The complete oxidation of one molecule of this lipid produces 122 molecules of ATP.

One molecule of this lipid contains 12 244 kJ of energy.

One molecule of ATP yields 30.51 kJ of the energy.

Calculate the percentage of energy in this lipid molecule that can be converted to energy in ATP.

Give your answer to **three** significant figures.

(2)

Answer .... %

(Total for Question 1 = 6 marks)

2 Impulses are transmitted along nerves as a series of action potentials.

An action potential can be split into four main stages:

- depolarisation
- repolarisation
- hyperpolarisation
- resting state.

(a) (i) Which row shows the events that happen during depolarisation of a neurone?

(1)

	Sodium channels	Membrane potential
☒ **A**	closed	decreasing
☒ **B**	closed	increasing
☒ **C**	open	decreasing
☒ **D**	open	increasing

(ii) Explain what happens during repolarisation in a neurone.

(3)

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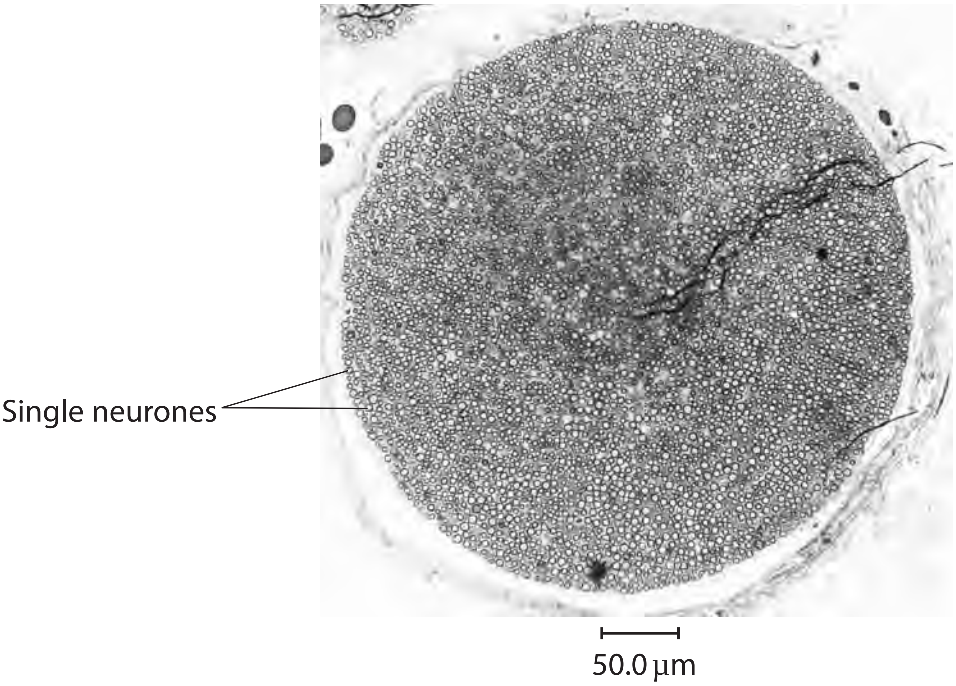
(b) The photograph is a cross-section of part of a sciatic nerve showing the neurones.



(i) Calculate the magnification of this photograph.

Give your answer in standard form.

(2)

Answer ....

(ii) Name a type of microscope that would be used to obtain this image.

(1)

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(iii) Explain how myelinated neurones enable a greater speed of transmission in a neurone.

(3)

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(Total for Question 2 = 10 marks)

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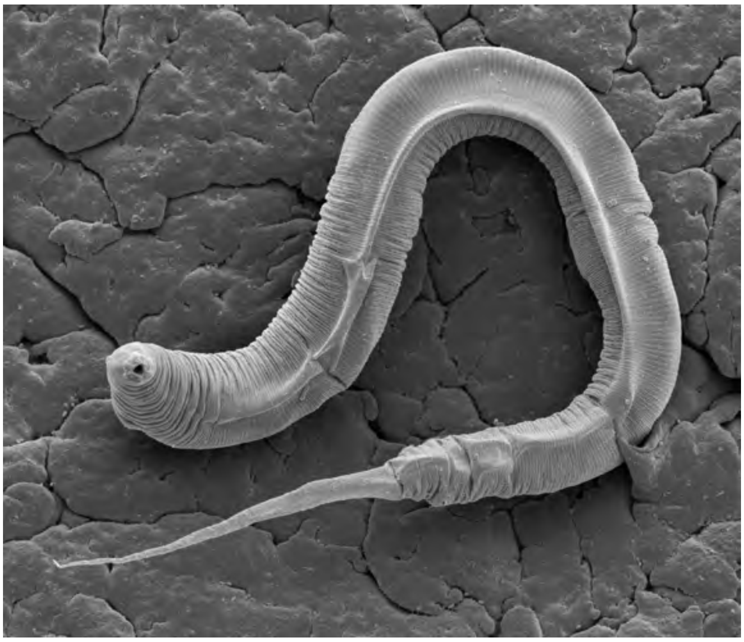
3 The photograph shows a roundworm, *C. elegans*.



Magnification × 200

(Source: © STEVE GSCHMEISSNER / SCIENCE PHOTO LIBRARY)

These roundworms are simple animals with a nervous system consisting of 302 neurones.

(a) The roundworm can respond to stimuli with reflex actions.

A reflex action is a rapid involuntary movement in response to a stimulus that involves receptors.

(i) Which receptors detect a change in light intensity and stimulate an action potential?

(1)

- ☒ **A** baroreceptors
- ☒ **B** chemoreceptors
- ☒ **C** osmoreceptors
- ☒ **D** photoreceptors

(ii) A reflex arc carries a nerve impulse from receptors in the skin to the central nervous system in a human.

Describe the structures that a nerve impulse passes through from the skin to the central nervous system.

(3)

(b) Roundworms respond to physical stimuli by changing the direction in which they swim.

The recovery time of roundworms following habituation was investigated.

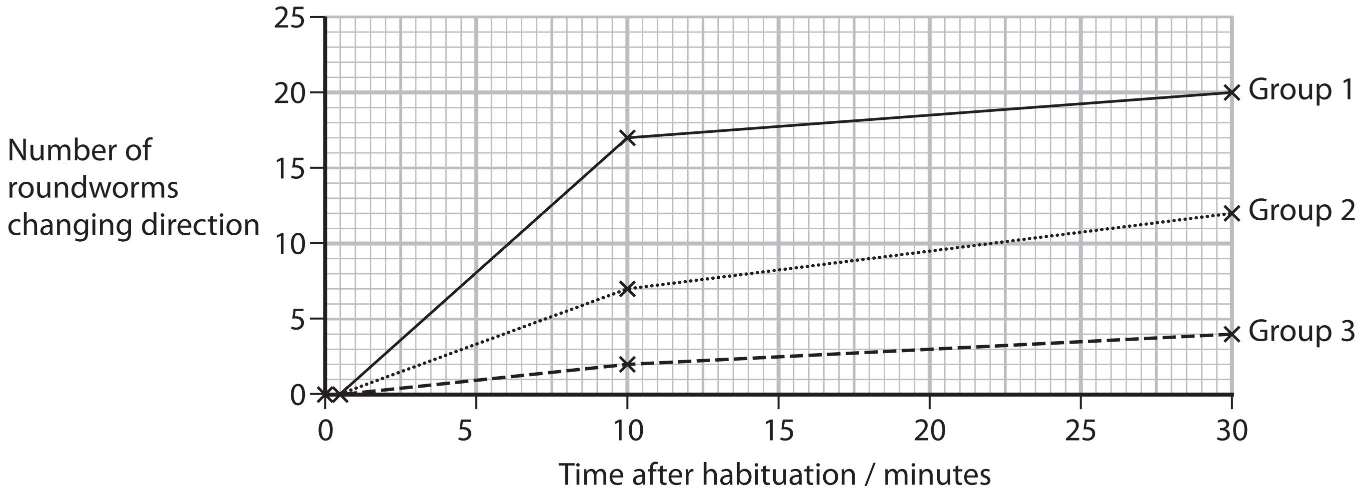
Three groups of 25 roundworms were kept in separate Petri dishes.

The roundworms were habituated to a physical stimulus by tapping the side of the Petri dish at different time intervals.

- Group 1 were habituated with 60 taps at 2-second intervals.
- Group 2 were habituated with 60 taps at 10-second intervals.
- Group 3 were habituated with 60 taps at 60-second intervals.

At 0, 0.5, 10 and 30 minutes after this habituation, each Petri dish was tapped once and the number of roundworms whose swimming direction changed was recorded.

The graph shows the results of this investigation.



(i) Calculate the percentage difference between the number of roundworms in group 1 and group 2 that changed direction 30 minutes after habituation.

Use the equation:

$$\text{percentage difference} = \frac{\text{difference between two values}}{\text{mean of the two values}} \times 100$$

(2)

Answer .... %

(ii) Describe **three** conclusions about recovery times after habituation.

(3)

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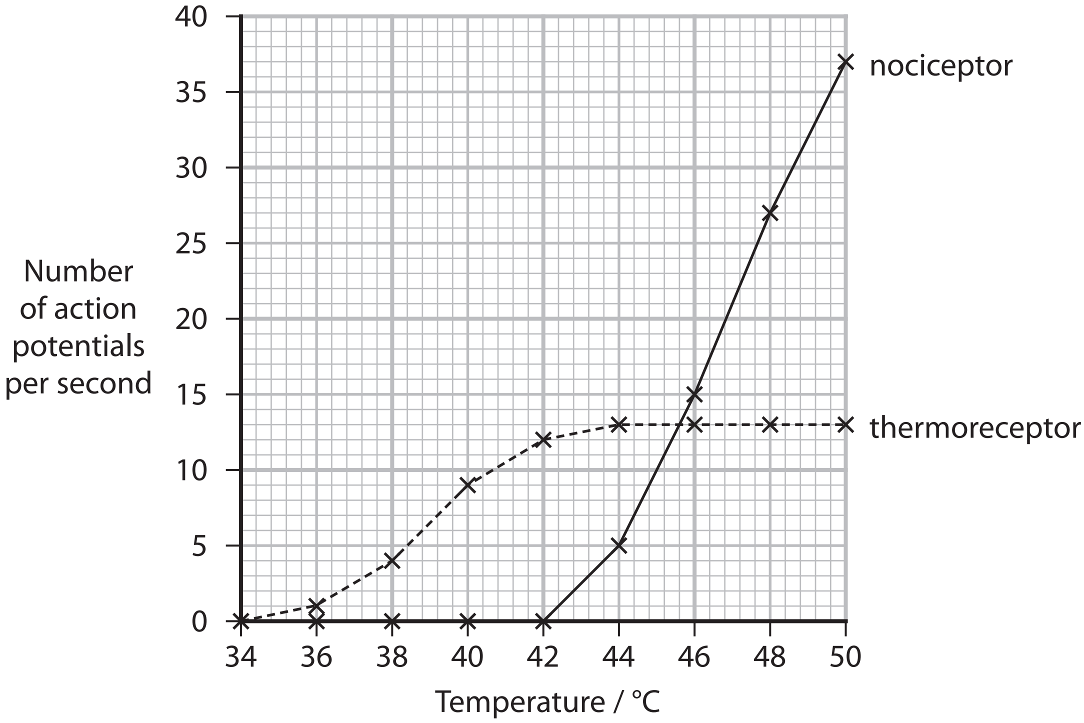
(Total for Question 3 = 9 marks)

4 The nervous system of an organism enables it to respond to a stimulus.

(a) Nociceptors and thermoreceptors are receptors that are sensitive to changes in temperature.

An investigation compared the effects of temperature on the activity of thermoreceptors and nociceptors in the skin of volunteers.

The graph shows the number of action potentials produced when each type of receptor was stimulated at different temperatures.



(i) Which is the ratio of the action potentials produced at 48 °C by nociceptors compared with thermoreceptors?

(1)

☒ **A** 0.40 : 1

☒ **B** 2.0 : 1

☒ **C** 2.07 : 1

☒ **D** 2.1 : 1

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(ii) Nociceptors are better than thermoreceptors at preventing serious damage to tissues at high temperatures.

Comment on the extent to which the results of this investigation support this statement.

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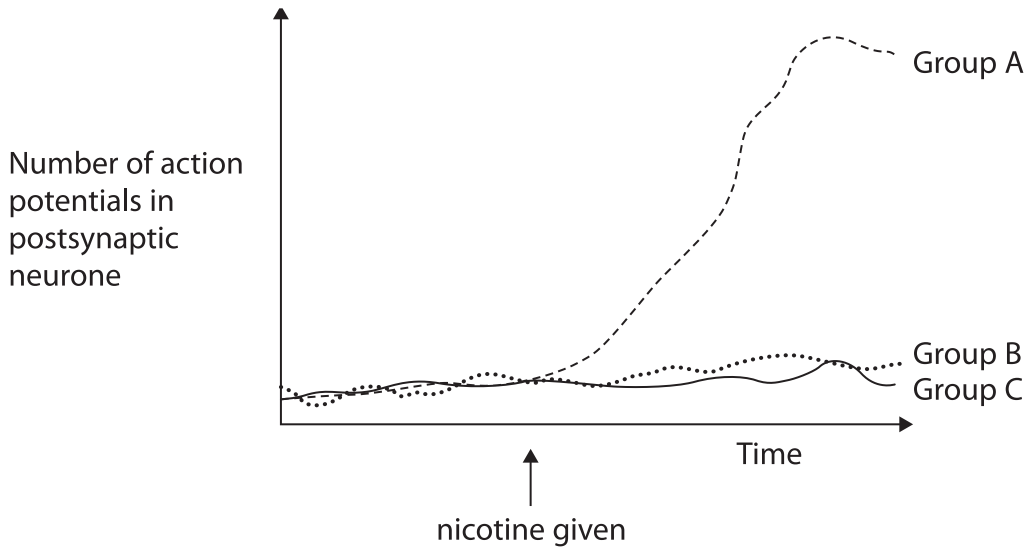
(b) Scientists used three groups of mice (A, B and C) to investigate the effect of nicotine on the transmission of nerve impulses.

- Group A were given nicotine
- Group B were not given nicotine
- Group C were given nicotine but were deficient in the gene that produces the acetylcholine receptor on the postsynaptic membrane.

The mice in groups A and C were given the same dose of nicotine (0.5 mg / kg) over the same time period.

The results are shown in the graph.



Explain the results of this investigation.

Use your own knowledge and the results in the graph to support your answer.

(4)

(Total for Question 4 = 9 marks)

5 Small variations in DNA sequences and activation of genes can explain why individuals respond differently to diseases and the drugs used to treat them.

(a) Describe how active genes could be identified.

(2)

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(b) Epigenetic modification can have an effect on the activity of genes in a cell.

(i) Which is the role of histones in the cell?

(1)

☒ **A** act as a transcription factor

☒ **B** form pores in the nuclear membrane

☒ **C** give structural support for DNA molecules

☒ **D** produce RNA polymerase

(ii) Which is the process that regulates gene expression?

(1)

☒ **A** crossing over

☒ **B** epigenetic changes

☒ **C** post-transcriptional changes

☒ **D** post-translational changes

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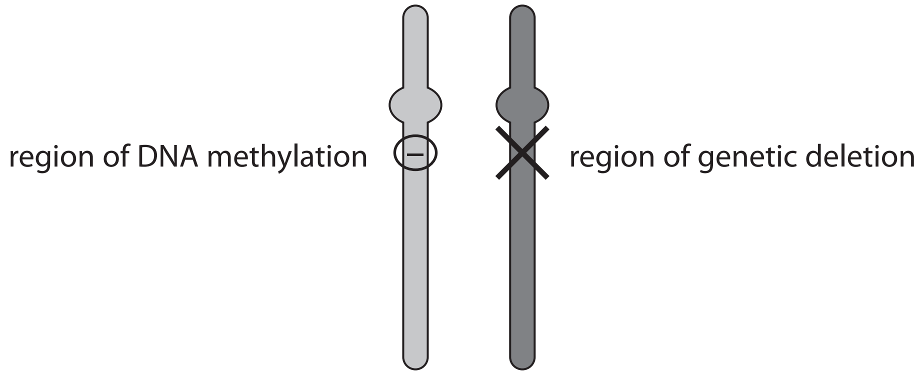
(c) Prader–Willi syndrome is an inherited genetic disorder that involves changes on chromosome 15.

The chromosome inherited from the father has genetic deletions.

The chromosome inherited from the mother has DNA methylated bases.

The diagram shows these chromosomes for an individual with Prader–Willi syndrome.



(i) Explain why these changes in the chromosome of this individual would cause Prader–Willi syndrome.

(3)

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(ii) The symptoms of Prader–Willi syndrome can be treated using human growth hormone (HGH).

This hormone is a protein produced by the pituitary gland.

Describe how *Escherichia coli* bacteria can be used to produce human growth hormone.

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(Total for Question 5 = 11 marks)

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6 The fastest recorded speed by a human was set by Usain Bolt sprinting in 2009. He achieved a speed of 12.3 metres per second.

(a) (i) Name the main type of muscle fibre that is being used in the leg muscles of a sprinter.

(1)

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(ii) During a sprint race, leg muscles produce lactate.

Describe what happens to the lactate at the end of the race.

(3)

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(iii) Which of the following statements are features of muscle fibres in a long-distance runner?

(1)

1. have reduced blood capillary network

2. have larger number of mitochondria

3. contain a low concentration of myoglobin

☒ **A** 1 only

☒ **B** 2 only

☒ **C** 1 and 3 only

☒ **D** 2 and 3 only

(iv) Which of the following explains how muscles contract?

(1)

☒ **A** Fick's law

☒ **B** fluid mosaic model

☒ **C** lock and key hypothesis

☒ **D** sliding filament model

*(b) Exercise has many benefits for the health and wellbeing of an individual.

An investigation was carried out on non-athletes and athletes.

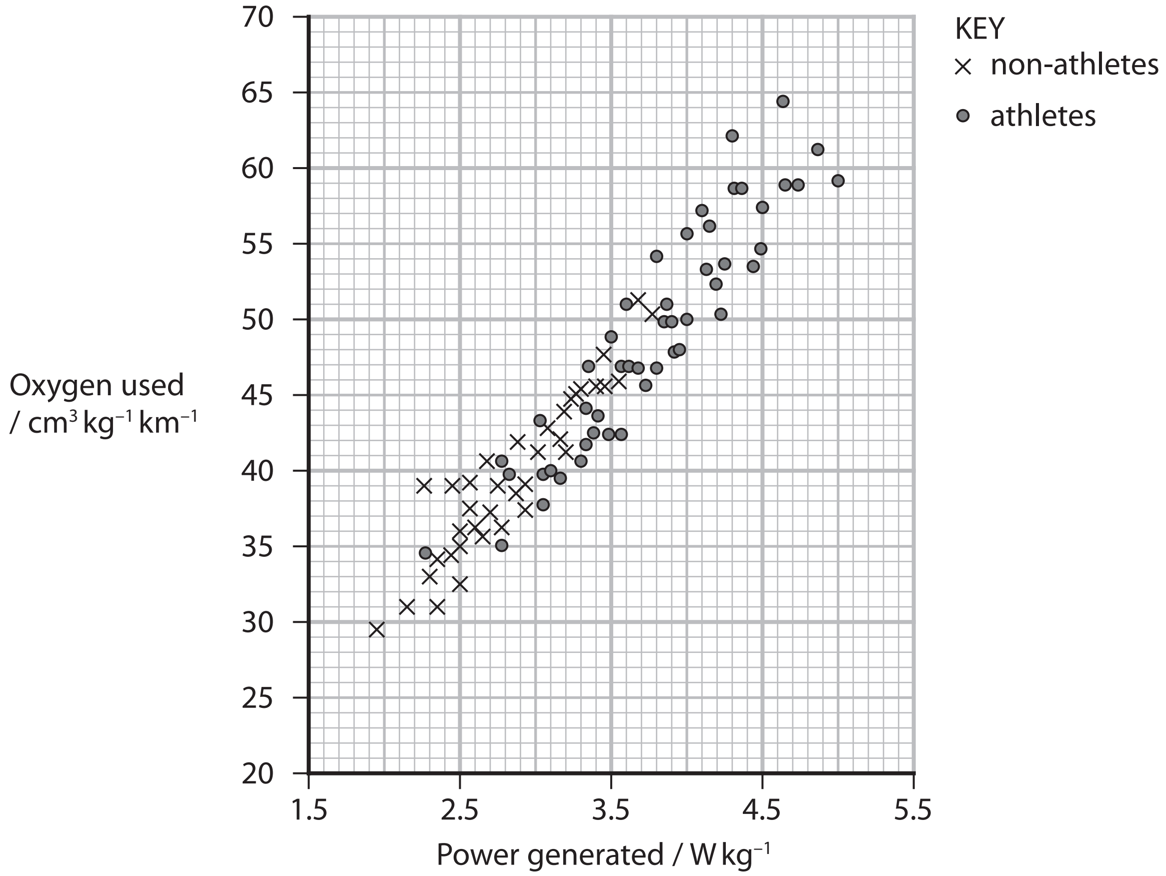
All participants did a series of physical exercises and several measurements were taken.

The means of the measurements are given in the table.

Mean measurement	Non-athletes (n=11)	Athletes (n=10)
Resting heart rate / bpm	71	66
Peak heart rate / bpm	196	190
Maximum volume of oxygen used under anaerobic conditions / $cm^3 kg^{-1} minute^{-1}$	20	35
Maximum volume of oxygen used under aerobic conditions / $cm^3 kg^{-1} minute^{-1}$	39	57

In a different investigation the relationship between power generated and oxygen used was studied in athletes and non-athletes.

The results are shown in the graph.



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Discuss the differences in the results for the athletes and non-athletes in these two investigations.

Use your knowledge and information in the table and graph to support and explain your answer.

(6)

(Total for Question 6 = 12 marks)

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7 The kangaroo rat is a mammal adapted to living in a warm dry habitat.

(a) The resting body temperature of a kangaroo rat is 37 °C.

During exercise the body temperature is maintained between 38.5 °C and 40 °C.

Explain how the body temperature can be regulated to stay between 38.5 °C and 40 °C.

(4)

(b) In mammals, urine is produced by ultrafiltration and the selective reabsorption of solutes and water.

Kangaroo rats are adapted to survive on a diet of dry seeds and little or no drinking water.

Suggest how kangaroo rats are adapted to survive in areas with little drinking water and dry seeds.

(3)

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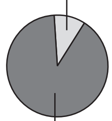
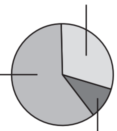
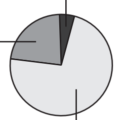
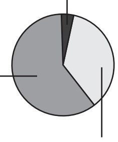
(c) The diagram compares the daily water balance between a kangaroo rat and a human.

	Water balance in a kangaroo rat ($2\,cm^3$ / day)	Water balance in a human ($2500\,cm^3$ / day)
Water gain / cm^3	food (0.2)  metabolism (1.8)	food (750) liquid (1500)  metabolism (250)
Water loss / cm^3	faeces (0.09) urine (0.45)  evaporation (1.46)	faeces (100) urine (1500)  evaporation (900)

(i) Calculate the difference in urine produced over seven days by the kangaroo rat and by the human.

Give your answer in standard form.

(2)

Answer ....

(ii) Comment on the differences in water gain and water loss between the kangaroo rat and the human.

Use your knowledge and information in the diagram to support and explain your answer.

(4)

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(Total for Question 7 = 13 marks)

8 The scientific article you have studied is adapted from an article in Clinical Nutrition entitled *Muscle tissue changes with aging* (July 2004).

Use the information from the scientific article and your own knowledge to answer the following questions.

(a) Give a definition for the term **sarcopenia** (paragraph 1).

(1)

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(b) Satellite cells are stem cells (paragraph 2).

Explain how a specialised cell such as a muscle cell is produced from a stem cell.

(3)

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(c) Testosterone is a steroid hormone.

Describe how reduced production of testosterone in the male testes can result in reduced muscle protein (paragraph 5).

(4)

(d) Insulin control of blood glucose is an example of a negative feedback loop (paragraph 7).

Explain how negative feedback can maintain a system within a narrow limit.

(2)

(e) Suggest how insulin increases the uptake of glucose by muscle cells (paragraph 7).

(2)

(f) Aerobic exercise may increase muscle size (hypertrophy) in older individuals.

Describe how computed tomography (CT) scans can be used to measure these increases in muscle size in older individuals (paragraph 9).

(2)

(g) Explain why aerobic exercise increases mitochondrial density and activity (paragraph 9).

(3)

(h) Whey and egg protein are often used to supplement protein-poor diets.

Explain why diets rich in these proteins may not be ideal for the prolonged treatment of sarcopenia (paragraph 11).

(3)

(Total for Question 8 = 20 marks)

TOTAL FOR PAPER = 90 MARKS

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Pearson Edexcel International Advanced Level

Wednesday 17 January 2024

Morning (Time: 1 hour 45 minutes)

Paper reference **WBI15/01**

Biology

International Advanced Level
UNIT 5: Respiration, Internal Environment, Coordination and Gene Technology

Scientific article for use with Question 8
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Scientific article for use with Question 8

1. One of the most striking effects of age is the involuntary loss of muscle mass, strength, and function, termed sarcopenia. Muscle mass decreases approximately 3–8% per decade after the age of 30 and this rate of decline is even higher after the age of 60. This involuntary loss of muscle mass, strength, and function is a fundamental cause of and contributor to disability in older people. A decrease in muscle mass is also accompanied by a progressive increase in fat mass and consequently changes in body composition, and is associated with an increased incidence of insulin resistance in the elderly. Furthermore, bone density decreases, joint stiffness increases, and there is a small reduction in stature (kyphosis). All these changes have probable implications for several conditions, including type 2 diabetes, obesity, heart disease, and osteoporosis.

Potential causes of sarcopenia

2. The etiology of sarcopenia is not clearly understood, but several mechanisms have been proposed. At the cellular level, specific age-related alterations include a reduction in muscle cell number, muscle twitch time and twitch force, sarcoplasmic reticulum volume and calcium pumping capacity. Sarcomere spacing becomes disorganized, muscle nuclei become centralized along the muscle fibre, the plasma membrane of muscle becomes less excitable, and there is a significant increase in fat accumulation within and around the muscle cells. Neuromuscular alterations include a decrease in the nervous firing rate to muscle, the number of motor neurons, and the regenerative abilities of the nervous tissue. Motor unit size also increases. Further, aging is associated with changes in satellite cell number and recruitment, an indication and potential cause of reduced muscle growth.

3. Besides the muscle-specific alterations highlighted, other age-related changes in endocrine function or responsiveness to hormonal stimuli, nutrition or responsiveness to nutrients, and physical activity may be responsible for the development and worsening of sarcopenia. Most likely, sarcopenia is a multifactorial problem. Among all its potential causes, however, a reduction in endocrine function, physical activity and appropriate nutrition are potentially treatable with behavioural interventions or pharmacological agents, and for this reason will be discussed in this review.

Endocrine changes relevant to sarcopenia

4. A variety of hormonal changes are seen during the aging process that may contribute to muscle loss with aging. We have selected the most important changes in relation to their effect on skeletal muscle.

5. The primary and most potent anabolic steroid is testosterone. In about 60% of men over the age of 65, testosterone levels decrease to below the normal youthful values, in a process termed andropause. Unlike the rapid decrease in oestradiol seen with menopause, testosterone concentrations gradually decrease throughout the aging process. Since testosterone increases muscle protein synthesis, muscle mass and strength, it has been proposed that the decrease in testosterone may cause a decrease in muscle protein synthesis and result in a loss of muscle mass.

6. In women, oestradiol levels abruptly decrease during menopause. Very little information is available regarding the role of menopause in sarcopenia. It appears that muscle mass is not affected by the decrease in oestrogens. Cross-sectional studies evaluating the effects of age on lean body mass and appendicular muscle mass have shown that the rate of decline of muscle mass in women does not increase after menopause, suggesting a marginal role, if any, of this event in the development of sarcopenia in women.

7. The ability of muscle tissue to respond to insulin is an important aspect of overall insulin sensitivity. The incidences of insulin resistance and type 2 diabetes increase with aging and sarcopenia may play an important role. Most studies have reported that the prevalence of insulin resistance and glucose intolerance is higher in older individuals when the data are reported per unit of body mass, but these differences disappear if the data are corrected by lean body mass. This suggests that the changes in body composition may drive the increase in insulin resistance with age. Although insulin is usually considered in the context of its ability to increase glucose uptake into cells, there is emerging evidence that insulin resistance of muscle and whole body protein metabolism in the elderly may be an important contributor to sarcopenia.

Physical activity and sarcopenia

8. Another important contributor to sarcopenia is inactivity. Although it is difficult to causally determine the relative importance of a sedentary lifestyle in the development of sarcopenia, it is very well known that short-term muscle inactivity severely reduces muscle mass and strength even in young individuals. Typical examples are bed rest and weightlessness. It is also recognized that these muscle changes can be counteracted by exercise, typically resistance exercise.

9. Aerobic exercise has been shown in several studies to improve VO_2max, mitochondrial density and activity, insulin sensitivity and energy expenditure in young and older individuals. Two studies have also shown that prolonged and intense aerobic exercise can increase muscle protein synthesis in young active individuals. Recent preliminary data suggest that aerobic exercise (40% VO_2max) can also acutely increase muscle protein synthesis in healthy, independent older people. Although aerobic exercise does not induce obvious muscle hypertrophy, some studies have shown that intense aerobic exercise training can induce some degree of hypertrophy, as indicated by increased calf circumference, muscle fibre area, and satellite cell activation.

Nutrition and sarcopenia

10. Malnutrition leads to muscle wasting. It has been shown that aging is associated with a progressive reduction in food intake, which predisposes to energy-protein malnutrition. Further, older people may voluntarily reduce their protein intake in order to comply with reduced fat and cholesterol diets. Recent studies suggest that the protein requirements of older individuals may be higher (~1 g / kg / day) than the level currently recommended by the Institute of Medicine (0.8 g / kg / day). Thus, nutritional interventions are appealing potential means for the prevention and treatment of sarcopenia of the elderly due to the easy applicability and safety.

11. Nonessential amino acids comprise a significant portion of dietary proteins, including the high-quality proteins (e.g. whey, egg) that are typically used to supplement protein-poor diets. Since nonessential amino acids do not appear to be necessary for the acute stimulation of muscle protein anabolism in older people, high-quality proteins may still be inadequate for a dose-effective prolonged treatment of sarcopenia, given the excessive amount of calories that they provide in the form of nonessential amino acids.

Conclusion

12. Sarcopenia is a multifactorial process. A reduction in endocrine function, physical activity and inadequate nutrition all play an important role in the reduction of muscle mass with normal aging. Testosterone replacement therapy could be a useful intervention in hypogonadal older men for increasing muscle mass and strength, although it is not currently recommended. Hormone replacement therapy for menopause, adrenopause or somatopause appears to have a marginal or no positive effect on muscle mass and strength. Exercise training and proper nutrition can have dramatic effects on muscle mass and strength. An optimal intervention program may include an exercise-training schedule that incorporates both resistance and aerobic exercise with adequate intake of total calories and protein. This would not only improve muscle mass and strength, but it would also reduce insulin resistance, which is more prevalent in the elderly. Providing a nutritional supplement of only amino acids or protein might also be beneficial to promote muscle growth by stimulating muscle protein synthesis and increasing the total daily caloric intake, but further investigations are needed.