Please check the examination details below before entering your candidate information

Candidate surname	Other names

Pearson Edexcel
International Advanced Level

Centre Number | | | | | |

Candidate Number | | | | |

Wednesday 20 January 2021

Afternoon (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.*
- **Show all your working in calculations and include units where appropriate.**

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 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.

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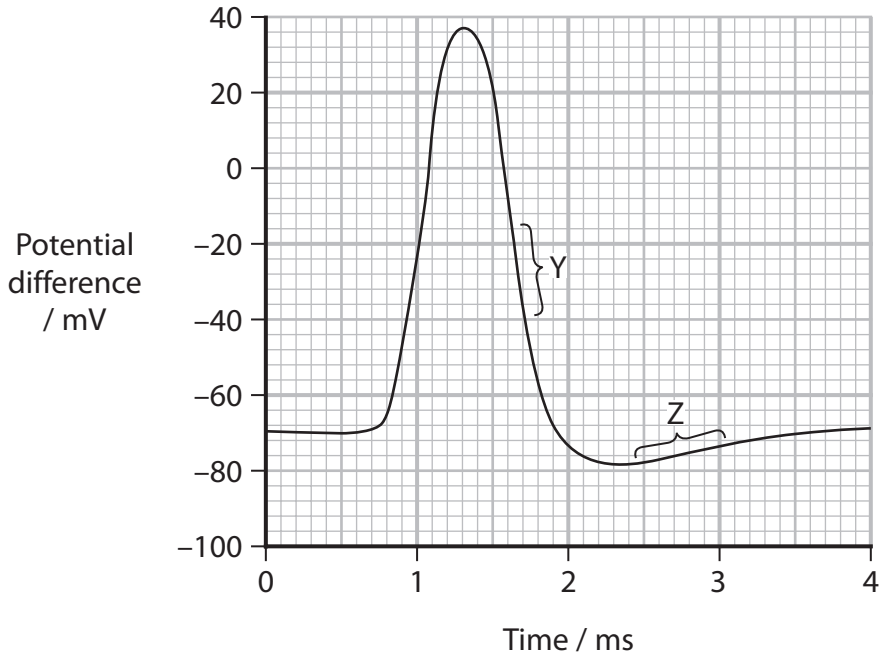
Answer ALL questions.

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 Nerve impulses travel along axons as action potentials.

(a) The graph shows an oscilloscope trace for an action potential in an axon.



(i) Which is the resting potential for this axon?

(1)

☒ **A** –70 mV

☒ **B** –78 mV

☒ **C** 38 mV

☒ **D** 108 mV

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(ii) Both voltage-gated sodium and voltage-gated potassium ion channels are involved in generating an action potential.

Which of these voltage-gated channels are open at Y?

(1)

- ☒ **A** no voltage-gated ion channels are open
- ☒ **B** voltage-gated sodium ion channels only
- ☒ **C** voltage-gated potassium ion channels only
- ☒ **D** both sodium and potassium voltage-gated ion channels

(iii) Which is the state of polarisation of the membrane at Z?

(1)

- ☒ **A** depolarised
- ☒ **B** hyperpolarised
- ☒ **C** hypopolarised
- ☒ **D** unpolarised

(iv) How many of the following statements are correct?

- the magnitude of the action potential is proportional to the strength of stimulus that generates the action potential
- action potentials spread out in both directions along the axon
- following an action potential, there is a refractory period during which it is not possible to generate a new action potential

(1)

- ☒ **A** none
- ☒ **B** one
- ☒ **C** two
- ☒ **D** three

(b) Explain why maintaining a resting potential requires ATP.

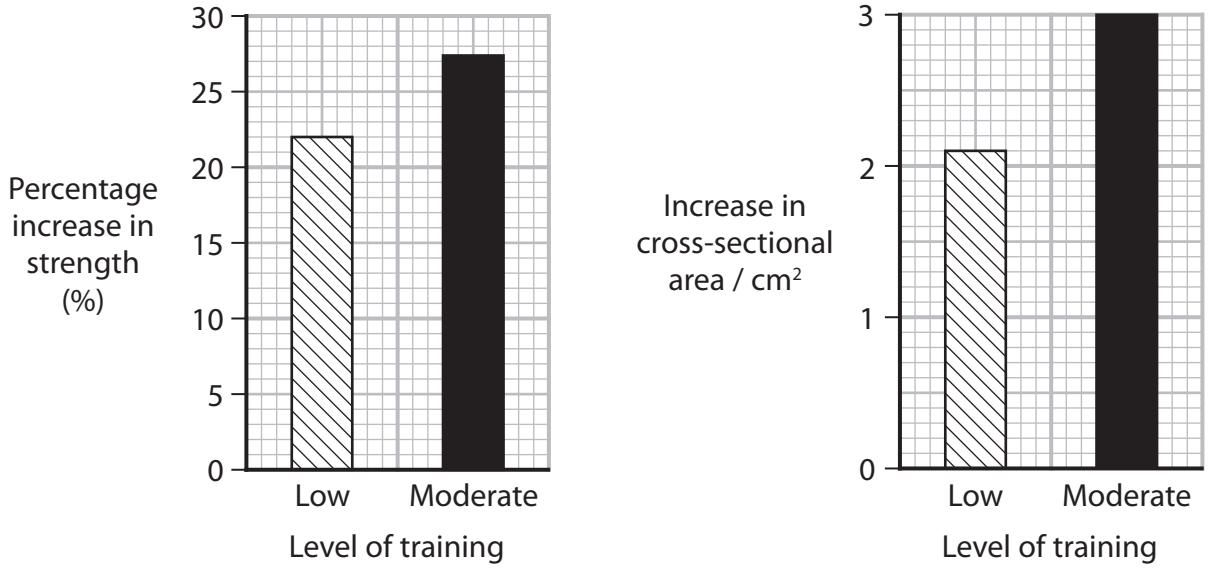
(3)

(Total for Question 1 = 7 marks)

2 Many athletes train to improve muscle strength.

In an experiment, the effect on a muscle of 12 weeks of low or moderate training was investigated.

The graphs show the effect of 12 weeks of training on muscle strength and muscle cross-sectional area.



(a) The muscle strength of the athlete before moderate training was 12.5 a.u.

Calculate the muscle strength of the athlete after 12 weeks of moderate training.

Give your answer to 3 significant figures.

(3)

Answer .....

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(b) The types of muscle fibres present in samples taken before the training and after 12 weeks of low and moderate training were determined.

Fibre type	Percentage of fibres (%)		
	Before training	After 12 weeks of training	
		Low	Moderate
Slow twitch	44	44	44
Fast twitch	6	2	1
Intermediate	50	54	55

Intermediate fibres have structural properties between those of slow and fast twitch fibres.

(i) Describe how the structure of an intermediate fibre will differ from the structure of a slow twitch fibre.

(3)

(ii) Comment on the effect of exercise on this muscle.

Use the information in the graphs and the table to support your answer.

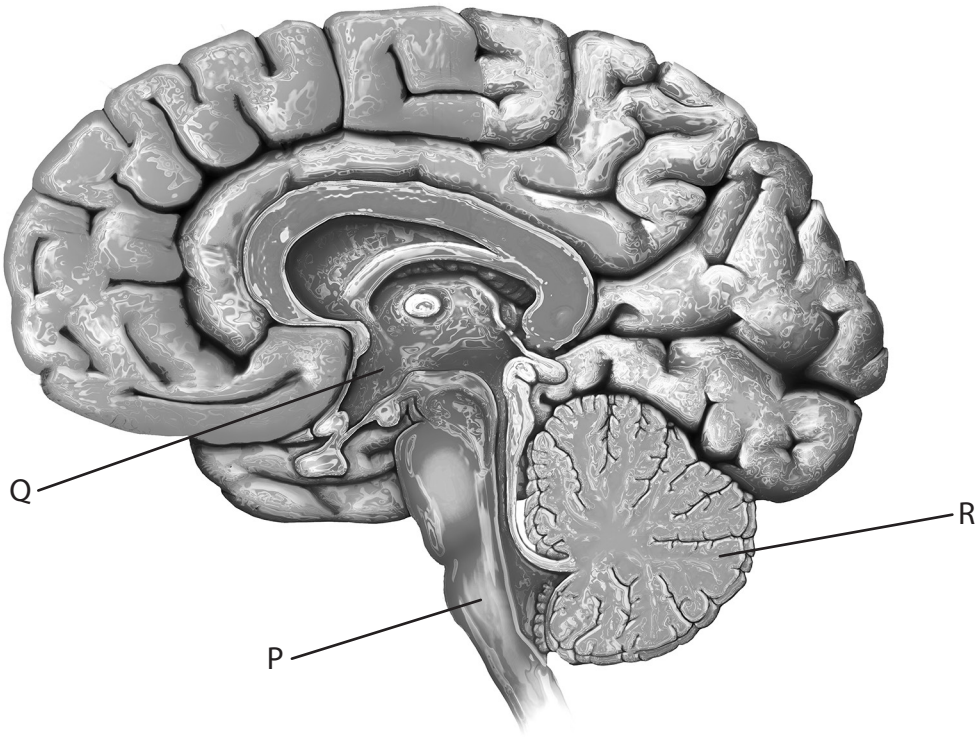
(3)

(Total for Question 2 = 9 marks)

3 The brain is responsible for processing information and coordinating responses.

(a) The diagram shows a human brain.

Three regions of the brain have been labelled.



(Source: © MARK GARLICK/SCIENCE PHOTO LIBRARY)

Complete the table with the name and function of each region.

(2)

Label	Name of the region	Function of the region
P	medulla oblongata	
Q		
R		balance and coordinating movement

(b) Seizures in the brain can be investigated using different imaging techniques.

(i) Which one of the following statements is correct?

(1)

☒ **A** CT scans are produced by the absorbance of magnetic fields

☒ **B** CT scans are produced by the absorbance of radio waves by deoxyhaemoglobin

☒ **C** CT scans produce a cross-sectional image of a thin slice through the body

☒ **D** CT scans can be used to study brain activity while a person is undertaking tasks

(ii) During a seizure, part of the brain will be overactive.

Describe how positron emission tomography (PET) could be used to identify the part of the brain involved.

(3)

(c) Some seizures can result in an increase in body temperature.

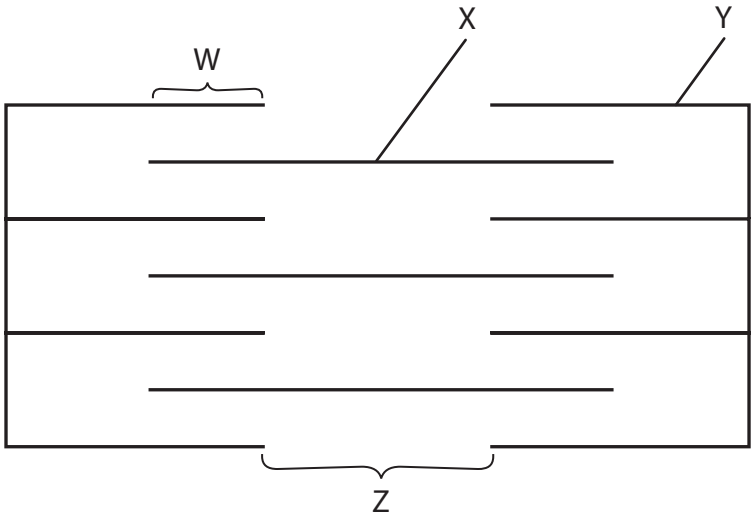
Suggest how a seizure in part of the brain could lead to an increase in body temperature.

(3)

(Total for Question 3 = 9 marks)

4 Skeletal muscles function to move the limbs of an organism.

(a) The diagram represents a sarcomere from skeletal muscle.



(i) Which protein forms the structure labelled X?

(1)

- ☒ **A** actin
- ☒ **B** myosin
- ☒ **C** tropomyosin
- ☒ **D** troponin

(ii) Which part becomes shorter when the muscle contracts?

(1)

- ☒ **A** W
- ☒ **B** X
- ☒ **C** Y
- ☒ **D** Z

(iii) How many of the following statements are correct when a sarcomere contracts?

- calcium ions bind to troponin
- calcium ions are released from the sarcoplasmic reticulum
- myosin changes shape

(1)

☒ **A** none

☒ **B** one

☒ **C** two

☒ **D** three

(iv) Which molecule contains an enzyme that hydrolyses ATP?

(1)

☒ **A** actin

☒ **B** myosin

☒ **C** tropomyosin

☒ **D** troponin

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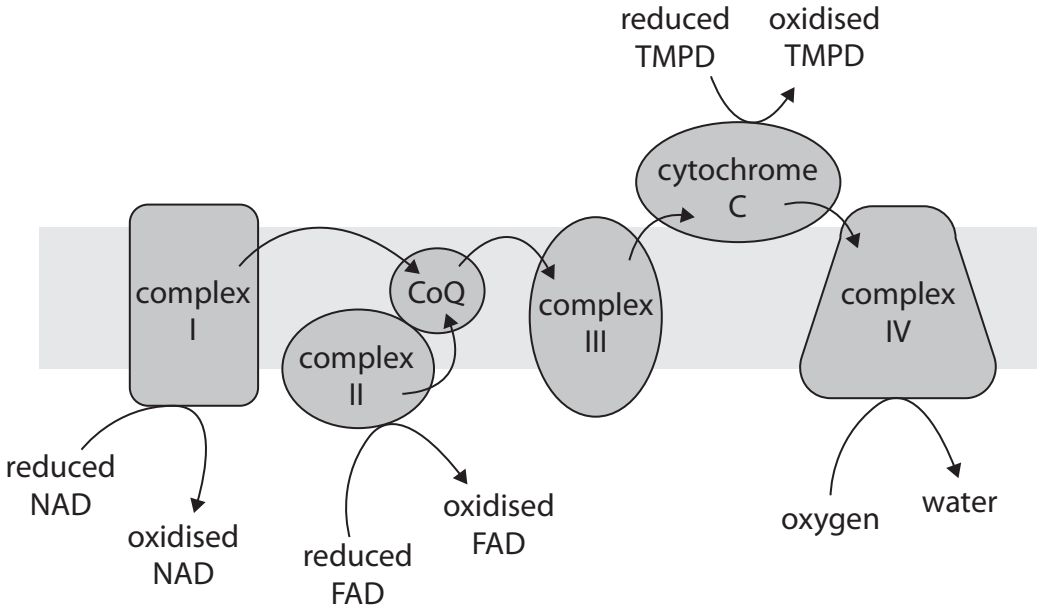
*(b) Inherited mitochondrial diseases affect muscle function.

The diagram shows the electron transport chain in a mitochondrion.



In an investigation, samples of muscle tissue from healthy individuals and from four individuals with mitochondrial disease were collected.

The function of mitochondria, when these samples were treated with different substrates, was investigated.

Treating muscle tissue from healthy individuals with:

- pyruvate and malate increases the production of reduced NAD
- succinate increases the production of reduced FAD
- reduced TMPD increases the reduction of cytochrome c.

The oxygen consumption of the muscle tissue samples from healthy individuals and from four individuals with mitochondrial disease were recorded.
The results are shown in the table.

Sample taken from	Oxygen consumption in the presence of each treatment / pmol O_2 min^{-1} mg^{-1} of muscle tissue		
	pyruvate and malate	succinate	reduced TMPD
Individual 1	3.0	3.5	13.0
Individual 2	18.0	10.0	60.0
Individual 3	6.5	14.0	51.0
Individual 4	7.5	6.0	40.0
Healthy individuals	21.0 ± 5.0	13.5 ± 4.5	63.0 ± 20.0

The results of this investigation can be used to identify the defects in the electron transport chain of individuals with mitochondrial disease.

Comment on the defects in the electron transport chain in the individuals with mitochondrial disease.

(6)

(Total for Question 4 = 10 marks)

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5 One cause of blindness is a mutation in the DNA coding for the enzyme RPE65.

The enzyme RPE65 converts trans-retinal to cis-retinal.

(a) Explain why mutations in the RPE65 gene can result in blindness.

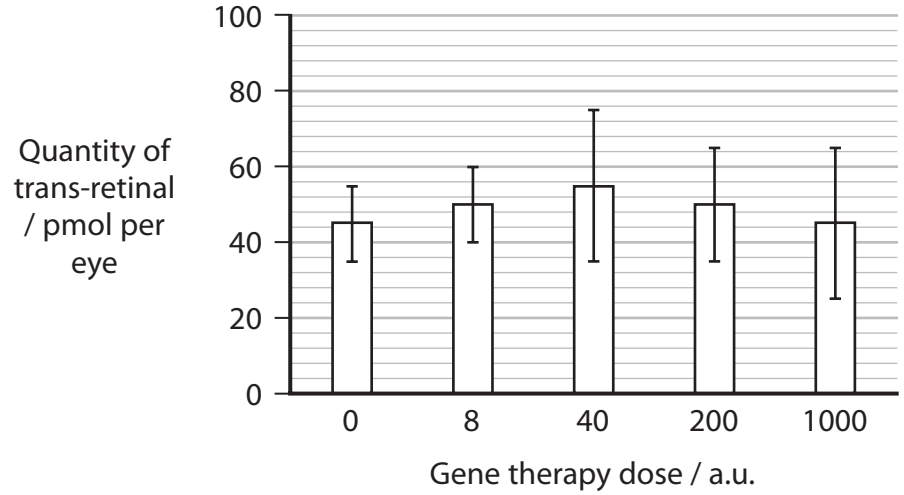
(3)

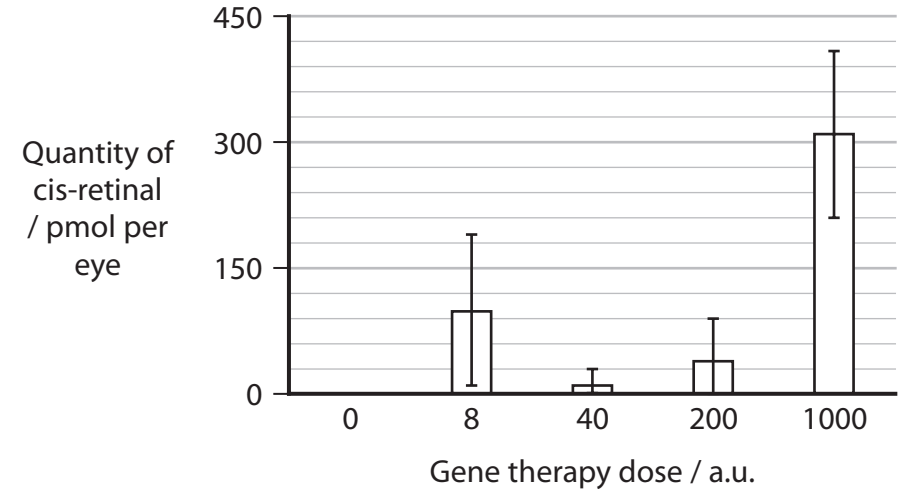
(b) Scientists are investigating the use of gene therapy to treat blindness caused by mutations in the RPE65 gene.

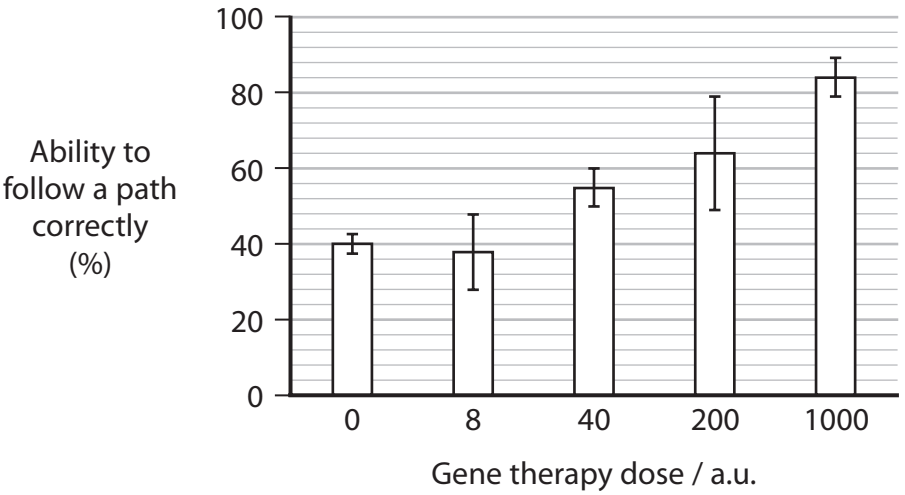
In one investigation, different gene therapy doses containing functioning RPE65 genes were compared.

Two months after treatment, the trans-retinal and cis-retinal in each eye and the ability to follow a path were measured.

The graphs show the results of this investigation.







Describe the conclusions that can be made from this investigation.

Use the information in the graphs to support your answer.

(4)

(c) Mutations in other genes can result in blindness.

Describe how these genes could be identified.

(3)

(Total for Question 5 = 10 marks)

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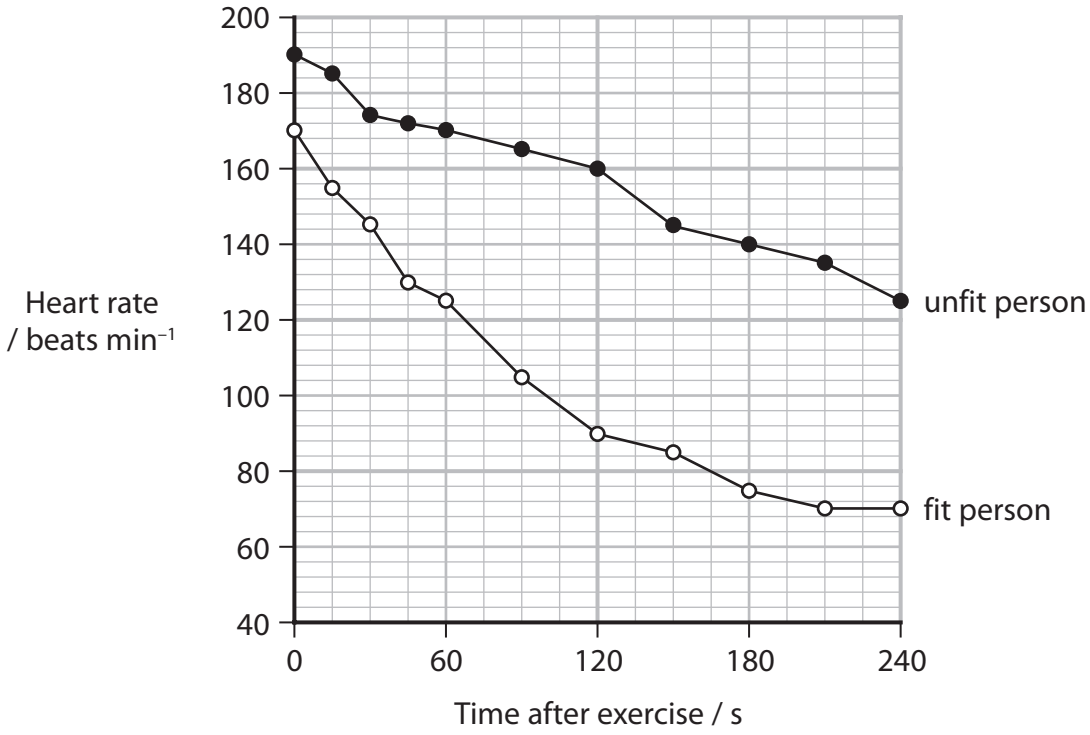
6 Exercise affects the cardiac output of a person.

The graph shows the change in heart rate following exercise for an unfit person and for a fit person.



(a) The heart rate of the unfit person decreased by 16%, 120 seconds after exercise.

Calculate the difference in percentage decrease in heart rate of these two people, 120 seconds after exercise.

Give your answer to an appropriate number of decimal places.

(3)

Answer .....

(b) Calculate the heart rate of the unfit person at 5 minutes.

The change in heart rate of the unfit person is a linear relationship.
Use the equation for a straight line $y = mx + c$.

(3)

Answer .....

(c) Explain the difference in the time it would take for these two individuals to recover from the exercise.

(3)

(d) Describe how heart rate is controlled in response to changes in the blood, following exercise.

(4)

(Total for Question 6 = 13 marks)

7 Parkinson's disease is a nervous system disorder that affects movement.

(a) In people with Parkinson's disease, some neurones in the brain die.

Many of the symptoms of Parkinson's disease are due to a loss of neurones that produce a neurotransmitter called dopamine.

(i) Describe how a neurotransmitter transmits a nerve impulse across a synapse.

(4)

(ii) One treatment for Parkinson's disease is a drug called L-DOPA.

Describe how L-DOPA reduces some of the symptoms of Parkinson's disease.

(3)

(b) Scientists can induce pluripotent stem cells to produce transcription factors involved in the synthesis of dopamine.

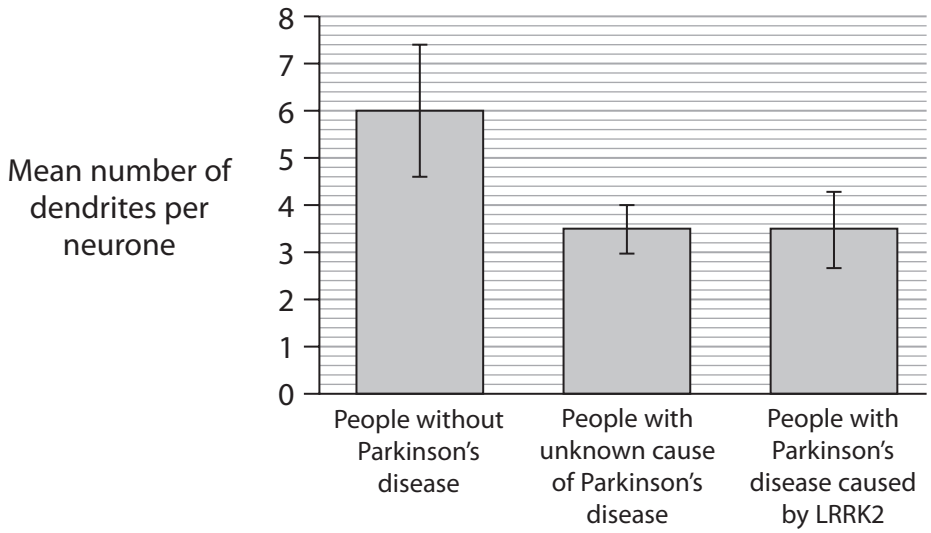
(i) Explain how transcription factors are involved in the synthesis of dopamine.

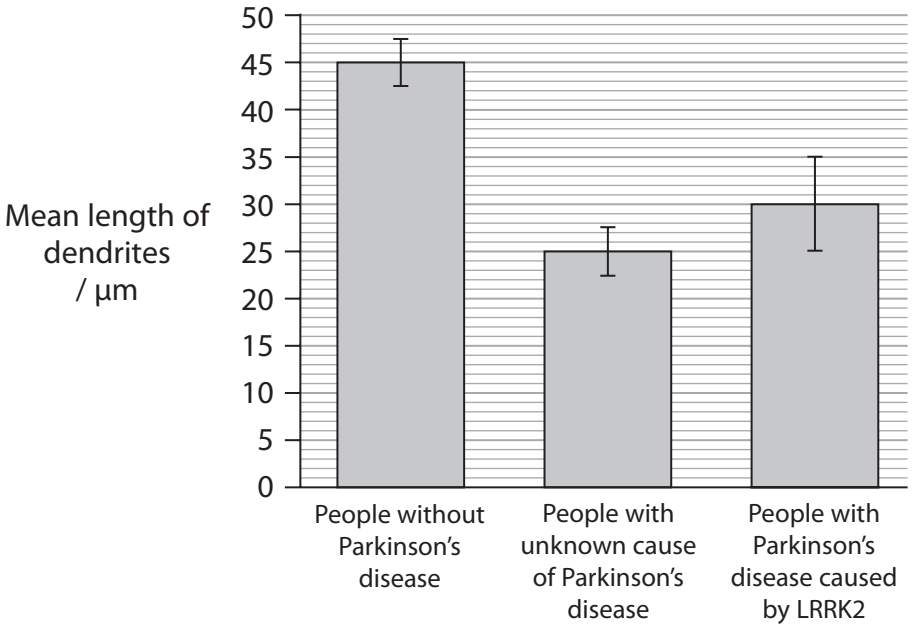
(2)

(ii) Some people with Parkinson's disease have a DNA mutation called LRRK2.

Scientists studied the effect of this mutation on the dendrites of dopamine neurones produced from the stem cells of three groups of people.

The graphs show some of the results of their study.





Comment on these results.

(3)

(Total for Question 7 = 12 marks)

8 The scientific document you have studied is adapted from an article in Education in Chemistry: Developing vaccines, Self-defence classes for our immune system.

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

(a) The Ebola virus can infect endothelial cells.

Describe how this virus can cause internal bleeding (paragraph 1).

(2)

(b) Explain how 'our immune systems learn to make another type of protein, called an antibody' (paragraph 4).

(4)

(c) One method of slowing the degradation of vaccine proteins is to dry a mixture of sugars and vaccine on a filter.

Explain why flushing with water releases the vaccine from the filter (paragraphs 8 and 9).

(2)

(d) During the production of some vaccines, the virus is allowed to replicate in eggs (paragraph 13).

Explain how a vaccine produced in this way may become less effective.

(3)

(e) Scientists are using genetically modified bacteria and insect cells to produce the antigens for Ebola vaccines (paragraph 13).

(i) Describe how insect cells could be genetically modified to produce the antigens for an Ebola vaccine.

(4)

(ii) Suggest **three** benefits of using an insect cell to produce the Ebola virus antigen.

(3)

(f) Suggest why the stems of the different versions of haemagglutinin molecules are the same but the heads can be different (paragraph 15).

(2)

(Total for Question 8 = 20 marks)

TOTAL FOR PAPER = 90 MARKS

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Pearson Edexcel International Advanced Level

Wednesday 20 January 2021

Afternoon (Time: 1 hour 45 minutes) | Paper Reference **WBI15/01**

Biology

Advanced

Unit 5: Respiration, Internal Environment, Coordination and Gene Technology

Scientific article for use with Question 8

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Pearson

Scientific article for use with Question 8.

Self-defence classes for our immune system

Andy Extance finds out how vaccines help people fight off germs without getting ill

1. If you've ever been off sick with a cold, you probably felt too lousy to realise that infections can be much, much worse. Usually people tend to fight off germs like bacteria and viruses quickly enough – but there are plenty of deadly germs. Perhaps the scariest is Ebola, which has affected many West African countries several times in recent years. On average, it kills around half of infected people, following internal and external bleeding. Even the familiar flu virus killed around 100 million people in 1918. But what if you could get protection against these diseases without needing to feel ill?

2. You've hopefully already had this magical-sounding treatment, better known as a vaccine. Vaccines protect us by teaching blood cells how to fight infection, explains Katie Ewer, senior immunologist at the Jenner Institute in Oxford, UK. The idea is to copy what happens when our bodies react to infections, for example when we catch colds. 'When we use a vaccine it's the same process, but we're telling cells in your blood how to respond to that infection without you having to get sick,' Katie says. And chemistry is central to efforts to design and make better vaccines and stop them breaking down before they're used.

3. Every vaccine works against a specific germ. They do this by targeting chemical building blocks that both viruses and bacteria contain. In such germs, genes made of DNA or similar RNA molecules act similarly to how a computer program might control a robot. They encode instructions on how to assemble small amino acid molecules into larger proteins that make up germs' bodies.

(Source: © dra_schwartz/Getty Images)

A scientist extracts a virus from an egg.

Inject a virus into a chicken egg and it will multiply, then scientists can take it out for use in vaccines.

4. Bacteria, which are much larger than viruses, can travel through our blood and multiply on their own, copying themselves many times. Eventually, our immune systems learn to make another type of protein, called an antibody, which can recognise bacterial protein shapes. Antibodies stick to bacteria using intermolecular forces like hydrogen bonding. The antibodies can then signal for white blood cells to come and kill the unwelcome invaders. Most vaccines train our immune system to make antibodies needed for bad germs before they infect us, Katie explains.

5. Vaccines are often made from germs that have already been killed or tamed. Exposing our immune system to such inactive germs lets antibodies learn to recognise them. For example most flu vaccines use weakened, but live, flu viruses. During the manufacturing process, the viruses are injected into chicken eggs, where they multiply. Companies can then take the virus back out through a needle for use in vaccines. In most cases the vaccine itself is combined with another component, called an adjuvant, just before it's given to people. Aluminium phosphate and aluminium hydroxide are among the most common adjuvants used.

6. Using adjuvants is tricky, because 'we don't know completely how they work', Katie admits. 'They amplify the immune response to whichever protein you're trying to use in your vaccine,' she says. 'Adjuvants are really important for vaccinating young children and the elderly; where we know that responses to vaccines are not as good as in adults. But if you give too much of an adjuvant, you get a very sore arm, and so on. It's usually the adjuvant that gives you any side effects.'

A boost for poor countries

7. Another problem is that vaccines can break down, explains Manjari Lal, who researches vaccine formulation at PATH, an international non-profit organisation focused on health innovation. 'The most common degradation is protein denaturation, which involves unfolding of the three-dimensional structure,' she says. This could be caused by heat, physical force or chemical breakdown. Chemical breakdown can be especially important when vaccines are converted from liquid to powder through freeze-drying. In this approach, PATH's workers freeze solutions containing sugar stabilisers and remove ice by putting the vessel they're in under vacuum. The vaccine's pH has to stay stable during this process to avoid chemical damage. Manjari and her colleagues have to add the right combination and type of salts to ensure this.

8. Similarly, heat breakdown is a problem when vaccines need to go to poor, hot countries where fridges are scarce. Katie's Jenner Institute colleagues have found a way to make mixtures survive heat using common table sugar, sucrose and a different form of sugar, trehalose. The scientists leave a mixture of these sugars and the vaccine and adjuvant to dry slowly on a filter or membrane, where they solidify into a thin, sugary film. Alcohol functional groups on the sugars hold vaccine proteins' shape steady using intermolecular interactions, again including hydrogen bonding.

9. Manjari and her PATH co-workers also use a similar approach, and she emphasises the importance of stopping proteins moving. Because there's little water, it's also hard for other substances to get into the film to break the protein down. Degradation reaction rates slow down enormously. In the Jenner Institute method, vaccine makers then put the membrane into a simple plastic cartridge that can sit on the end of a syringe. When the vaccine is needed, medical staff can just flush it with water, releasing the vaccine and injecting it into a patient.

10. For many widely-used vaccines, researchers found the right trigger to form antibodies from because they 'got lucky early in the process', Katie says. With limited scientific knowledge, vaccines for other diseases have been out of reach. These diseases are often caused by viruses, and sometimes antibodies don't work against these. That's because viruses can recognise and grab proteins on the surface of our cells. Viruses force their way inside these cells and hijack their protein machinery to churn out copies of themselves.

11. 'Then, the job is much more difficult because you've got to clear the virus from inside those infected cells, and antibodies can't do that.' Katie notes. One option Katie and her team have used to develop an Ebola vaccine is to block viruses from getting into cells. This is possible because over the last decade it's become much cheaper to read the genes encoding how germs are built. She can work out which genes relate to proteins that Ebola uses to grab onto our cells.

12. 'We can then generate a vaccine that produces antibodies against those proteins,' Katie says. 'That's very straightforward, because there are only seven proteins encoded within the Ebola genome.' Making an Ebola vaccine is surprisingly easy – none that have been tested in people have been unsuccessful, she notes. They mainly hadn't existed because no one had prioritised developing them.

Hatching different ideas

13. Another problem arises during production when companies cultivate viruses in eggs. At this point, the viruses can change slightly and become less effective in vaccines. Instead, Katie and her fellow Jenner Institute scientists produce proteins for use in vaccines by genetically modifying bacteria, yeast or insect cells to make them. They can then blast the cells open, and separate out the proteins they need using chemical purification techniques like chromatography.

14. Such advances are part of a general improvement in vaccine production that also opens up opportunities to make them more powerful than ever before. Katie specialises in making 'sub-unit' vaccines that can train a type of white blood cell called a T-cell to kill off virus-infected cells. 'You take a common cold virus and delete about half of its genome,' she explains. 'It can't reproduce inside a human, but can express a gene and show a protein to the immune system.' This 'is much more difficult' than making antibody-training vaccines, she says, but it could help deal with an important problem: flu vaccines sometimes don't work.

15. This problem occurs because there are many different strains of flu, which are given names like H1N1 or H5N1. The H refers to a protein called haemagglutinin, which is what antibodies arising from conventional vaccines target. Currently, if a vaccine doesn't cover the strain that infects us, our immune systems aren't trained to fight it off. Haemagglutinin has a head and a stem, with antibodies from vaccines normally targeting the head part. However, that part varies between different versions of haemagglutinin. The stem is more uniform and stable, but usually ignored by the immune system. Using the gene for this stem to make a sub-unit vaccine could protect against every form of flu.

16. The Jenner Institute is using this approach on other illnesses where vaccines are urgently needed, including HIV, tuberculosis and, especially, malaria. 'The big Ebola outbreak in West Africa two years ago killed around 11,000 people,' Katie observes. 'Malaria kills that number every two weeks!' Malaria is caused by parasites that are much larger and more genetically complex than bacteria or viruses. It is therefore hard to decide which protein a vaccine should target.

(Source: © AMOS GUMULIRA/Contributor/Getty Images)

Malaria is a big killer; every two weeks, it kills around 11,000 people. But hope is in sight. A vaccine that has been in development for 30 years has entered large-scale human trials, thanks to improvements in vaccine production.

17. Katie highlights a vaccine for malaria that entered large-scale human trials in April 2019, having been in development for 30 years. Now we understand the science much better, malaria could be one of the first diseases to benefit from improved ways of delivering immune self-defence, she suggests. 'We can make the vaccine cheaper and easier to manufacture, potentially safer – making it into the 21st century version, hopefully.'

Andy Extance & Jenny Koenig © Royal Society of Chemistry 2020

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