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**Pearson Edexcel
Level 3 GCE**

Centre Number

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Candidate Number

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Biology A (Salters Nuffield)

Advanced

Paper 2: Energy, Exercise and Coordination

Tuesday 20 June 2017 – Morning

Time: 2 hours

Paper Reference

9BN0/02

You must have:

Calculator, HB pencil, ruler

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.
- Show your working in any calculation questions and include units in your answer where appropriate.
- Answer the questions in the spaces provided
– *there may be more space than you need.*
- 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.

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.*

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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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 Serotonin is found in the brain and is important in health and wellbeing.

An imbalance of serotonin can lead to problems such as depression. An individual with symptoms of depression may have low serotonin levels in the brain.

- (a) Describe how low serotonin levels in an individual can affect the transmission of impulses in their brain.

(2)

Serotonin is a neurotransmitter, so low serotonin means less neurotransmitter is released into the synaptic cleft and less binds to receptors on the post-synaptic membrane. This results in fewer depolarisations of the post-synaptic membrane, so the threshold is not reached and there is less chance of an action potential being produced in the post-synaptic neurone.

- (b) The use of drugs such as MDMA (ecstasy) can cause an imbalance of chemicals in the brain.

- (i) Describe how the use of MDMA could affect the transmission of impulses in the brain.

(2)

MDMA increases the concentration of serotonin in the synapse by preventing the re-uptake of serotonin into the pre-synaptic neurone (and stimulating its release). Serotonin therefore keeps binding to the post-synaptic receptors, so nerve pathways using serotonin are more likely to be stimulated and more action potentials are produced.



(ii) Individuals who use MDMA may develop the symptoms of depression.

Explain how the use of MDMA could result in the development of these symptoms.

(2)

Repeated MDMA use results in depletion of serotonin, as it is released and not taken back up, so stores in the pre-synaptic neurone run low.

The post-synaptic membrane also becomes less responsive to serotonin due to a loss of receptors. Serotonin levels affect mood, and a lack of serotonin is associated with depression.

(Total for Question 1 = 6 marks)



2 As levels of activity increase, the heart can respond to the changing demand for oxygen.

(a) Which term describes the ability of heart muscle to contract without external stimulation?

(1)

- ☐ A autonomic
- ☐ B cardiac
- ☒ C myogenic
- ☐ D systolic

(b) Describe how the sinoatrial node (SAN) is involved in bringing about a change in heart rate as the level of activity increases.

(2)

As activity increases, the SAN receives more impulses (more stimulation from the sympathetic nervous system), so it depolarises more often.

The SAN sends out more frequent waves of depolarisation across the atria, leading to more frequent contraction of the atria and stimulation of the AVN, so the heart rate increases.

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(c) During the cardiac cycle there are pressure changes in the chambers of the heart.

Explain how pressure differences in the heart ensure efficient pumping of the blood into the arteries.

(3)

When the ventricles contract (ventricular systole) the pressure increases in the ventricles.

The pressure in the ventricles becomes greater than in the atria, causing the atrioventricular valves to close, which stops blood flowing back into the atria.

When the pressure in the ventricles becomes greater than in the arteries, the semilunar valves are forced open, forcing blood into the arteries (aorta and pulmonary artery).

When the ventricles relax, the higher pressure in the arteries closes the semilunar valves, preventing backflow.

(Total for Question 2 = 6 marks)



3 Cystic fibrosis is a condition that affects breathing.

(a) Explain why cystic fibrosis affects the rate of oxygen uptake in the lungs.

(3)

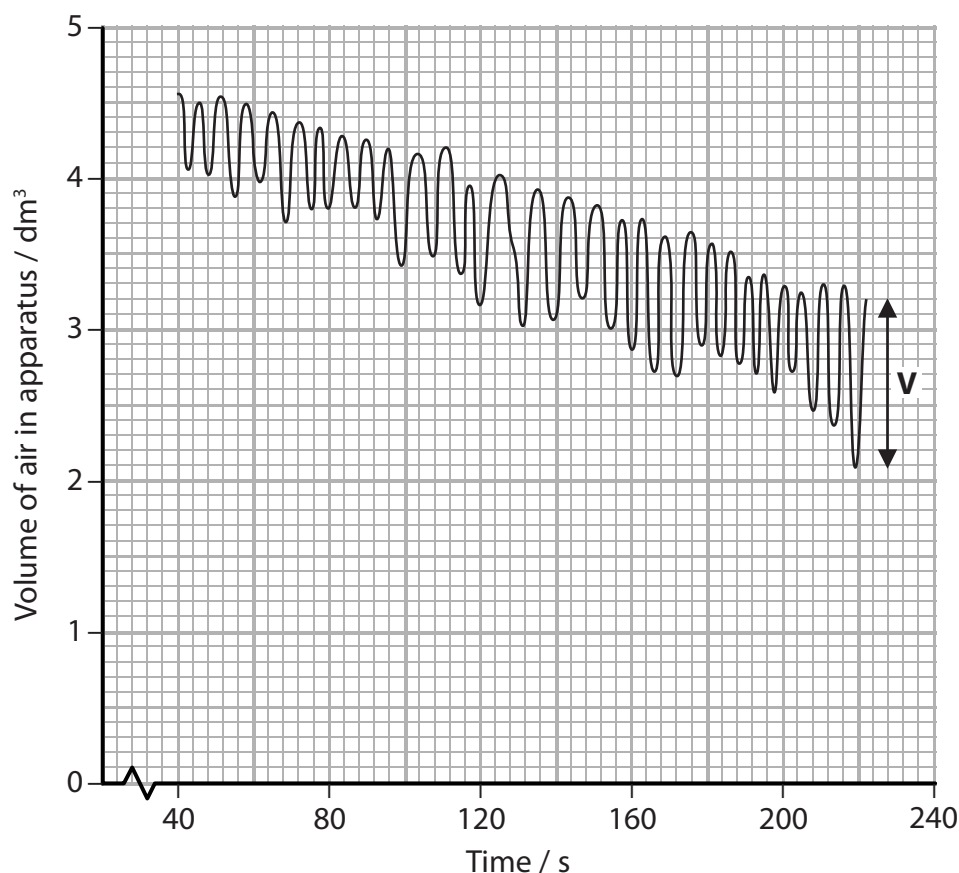
Cystic fibrosis causes thick, sticky (viscous) mucus to build up in the airways. This mucus cannot be moved by the cilia, so it accumulates.

The mucus restricts air flow through the bronchioles (narrowing of the bronchioles), so less air reaches the alveoli and the concentration gradient for oxygen is reduced.

Mucus in the alveoli increases the diffusion distance and reduces the surface area for gas exchange, so the rate of oxygen uptake is reduced.

(b) A person breathed air in and out of the air chamber of a piece of apparatus.

Measurements were made of changes in the volume of air in the chamber. The carbon dioxide produced was removed from the chamber. The changes in volume were recorded on the trace shown in the diagram.



(i) Which of the following is the name of this piece of apparatus?

(1)

- ☐ A colorimeter
- ☐ B potometer
- ☐ C respirometer
- ☒ D spirometer

(ii) Which of the following is shown by the label **V** on the trace?

(1)

- ☐ A alveolar volume
- ☒ B tidal volume
- ☐ C total lung volume
- ☐ D ventilation rate

(iii) Which of the following is the breathing rate in breaths per minute between 80 and 120 seconds?

(1)

- ☐ A 6 breaths min⁻¹
- ☒ B 9 breaths min⁻¹
- ☐ C 12 breaths min⁻¹
- ☐ D 16 breaths min⁻¹

(iv) Calculate the rate of oxygen uptake between 80 and 120 seconds.

(3)

$$\text{volume decrease from 80 s to 120 s} = 0.65 \text{ dm}^3$$

$$0.65 \times 1000 = 650 \text{ cm}^3$$

$$\text{rate} = 650 \div 40 = 16.25 \text{ cm}^3 \text{ s}^{-1}$$

$$16.25 \times 60 = 975 \text{ cm}^3 \text{ min}^{-1}$$

Answer **975** cm³ min⁻¹

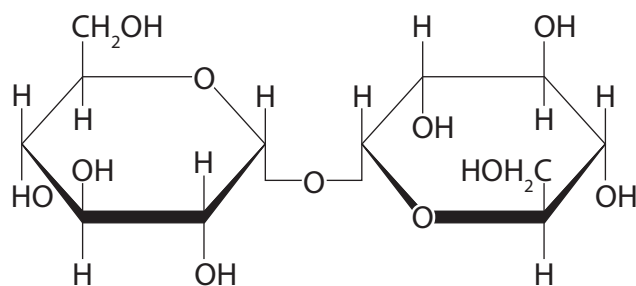
(Total for Question 3 = 9 marks)



P 4 8 1 7 6 A 0 7 3 2

- 4 Maltose and trehalose are disaccharides. Trehalose is formed from two molecules of α -glucose.

The diagram shows a molecule of trehalose.



- (a) (i) Describe the reaction that joins two α -glucose molecules to form a disaccharide.

(2)

A condensation reaction: the OH groups on the two α -glucose molecules react and a molecule of water is formed (removed).

This forms a glycosidic bond between the two glucose molecules.

- (ii) Compare and contrast the structures of trehalose and maltose.

(2)

Similarity: both are disaccharides formed from two molecules of α -glucose joined by a glycosidic bond.

Difference: maltose has an α -1,4 glycosidic linkage, but trehalose has an α -1,1 glycosidic linkage, so in trehalose one of the glucose monomers is inverted.



(b) Some flying insects store trehalose and glycogen in their wing muscles.

(i) Trehalose is broken down to glucose by the enzyme trehalase.

Which of the following describes how glucose is produced from trehalose?

(1)

- ☐ A anabolism
- ☐ B catalysis
- ☐ C glycolysis
- ☒ D hydrolysis

(ii) Insect flight uses a lot of energy. Explain the advantage of insects storing both trehalose and glycogen.

(4)

Glucose is used in respiration to provide energy as ATP, which is needed for contraction of the flight muscles.

Glycogen is a polymer of glucose, so it stores lots of glucose molecules in a compact, insoluble form that does not affect water potential.

Glycogen has lots of branches with many terminal ends, so enzymes can hydrolyse it quickly to release glucose rapidly when needed.

Breakdown of trehalose by trehalase makes two molecules of glucose available in a single hydrolysis reaction, so it provides a more immediate source of glucose. Storing both means glucose is always available for respiration during long flights.

(Total for Question 4 = 9 marks)



5 The sex of a mammal is determined by a pair of sex chromosomes. There are two types of sex chromosome known as X and Y.

- (a) (i) Which row in the table correctly shows the sex chromosomes found in the male and female gametes of mammals?

(1)

	Present in egg	Present in sperm
☐ A	Y	either X or Y
☐ B	either X or Y	X
☐ C	either X or Y	Y
☒ D	X	either X or Y

- (ii) Explain why genes found on the sex chromosome pair have a pattern of inheritance that is different from genes found on other chromosome pairs.

(2)

The X chromosome carries genes (loci) that are not present on the Y chromosome, so males have only one copy (allele) of these genes.

If only one allele is inherited, it will be expressed even if it is recessive, so males show these sex-linked characteristics more often than females.



(b) Inheritance of sex in birds is also determined by a pair of sex chromosomes.

A breeding experiment was carried out to investigate the inheritance of sex in birds.

A gene found on the sex chromosomes in pigeons determines the colour of their feathers. The dominant allele, B, produces blue feathers and the recessive allele, b, produces red feathers.

Male pigeons with red feathers were crossed with females that had alleles for blue feathers only.

- (i) Use a genetic diagram to explain the expected results of this cross if birds inherit sex in the same way as mammals.

(3)

Parents: red male X^bY × blue female X^BX^B

Gametes: X^b and Y X^B

gametes	X^b	Y
X^B	X^BX^b	X^BY

Offspring: X^BX^b = blue female, X^BY = blue male

The allele is carried on the X chromosome: the red male is X^bY and the blue female is X^BX^B .

Every offspring inherits X^B from the mother, so females are X^BX^b and males are X^BY .

All offspring, male and female, are expected to have blue feathers.



P 4 8 1 7 6 A 0 1 1 3 2

- (ii) The cross between male pigeons with red feathers and female pigeons with alleles for blue feathers only was carried out.

The offspring produced suggested that sex chromosomes in birds have a different effect on sex compared with the sex chromosomes in mammals.

All the male offspring had blue feathers and all the female offspring had red feathers.

Deduce how the inheritance of sex in birds differs from that in mammals.

(3)

The female offspring are red, so they must have inherited the recessive allele b from their father, as the mother has only B alleles.

The female offspring must only inherit one allele of this gene (from the father), otherwise they would also receive B from the mother and be blue. Males are blue, so they inherit two alleles, B from the mother and b from the father.

So in birds it is the opposite of mammals: females have two different sex chromosomes (the gene is not on the one from the mother) and males have two of the same sex chromosome.

(Total for Question 5 = 9 marks)



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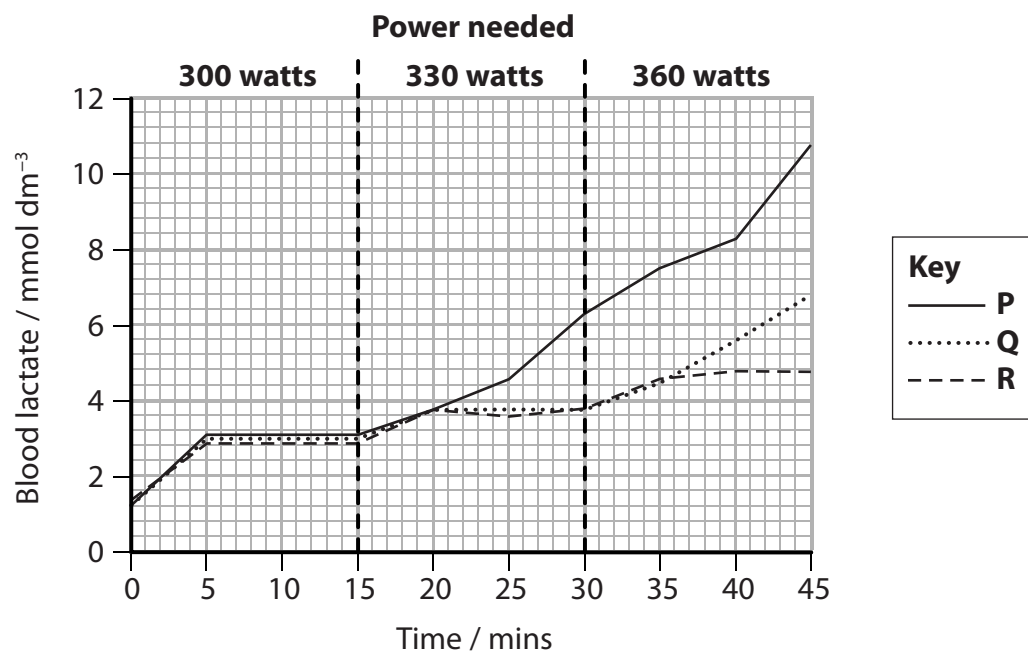
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- 6 Athletes monitor the effect of different levels of exercise on their blood lactate concentration. This helps them to train effectively.

In a study, three athletes, **P**, **Q** and **R**, used an exercise bicycle for 45 minutes. The power needed to maintain a constant speed was increased every 15 minutes. Their blood lactate concentration was measured at 5-minute intervals.

The results are shown in the graph.



- (a) Explain the increase in blood lactate concentration observed between 0 and 5 minutes.

(2)

At the start of exercise there is insufficient oxygen for aerobic respiration to meet the demand for energy, so muscle cells carry out anaerobic respiration and release lactate into the blood.



- (b) Give reasons why blood lactate concentration remains constant between 5 and 15 minutes.

(3)

There is an increased, sufficient oxygen supply to the muscles because heart rate and breathing rate have increased.

So most of the energy is now supplied by aerobic respiration, and little extra lactate is made.

Lactate is broken down by the liver, so the rate of lactate production is balanced by the rate of lactate breakdown.

- (c) The most effective training involves the greatest power requirement over longer periods of time. Therefore, it is important to avoid high concentrations of blood lactate, which causes muscle fatigue, for as long as possible.

Analyse the data to deduce how each of these three athletes should plan their training.

(4)

Athlete P should train at an intensity of 300 watts, as P's blood lactate increases sharply once the power rises to 330 watts (after 15 minutes).

Athlete Q should train at an intensity of 330 watts, as Q's lactate stays fairly constant at 330 watts but increases at 360 watts (after 30 minutes).

Athlete R should train at an intensity of 360 watts, as R's lactate levels off at about 4.8 mmol dm^{-3} at 360 watts.

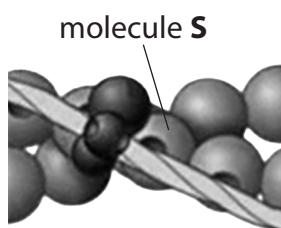
Each athlete should train at the highest power before the next level, because there would be an increase in lactate at the next level of intensity, causing earlier muscle fatigue.

(Total for Question 6 = 9 marks)

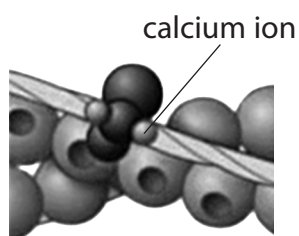


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- 7 Muscle cells contain myofibrils. The diagrams show the arrangement of some of the molecules present in a myofibril when calcium ions are absent and when they are present.



calcium ions absent



calcium ions present

- (a) Which of the following is molecule **S**?

(1)

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

- (b) (i) Describe the changes caused when calcium ions bind to the molecules shown in the diagram.

(2)

Calcium ions bind to troponin, which changes shape and moves tropomyosin away from the actin.

This exposes the myosin binding sites on the actin filament.



(ii) Explain how these changes cause muscles to contract.

(4)

The myosin heads can now bind to the binding sites on actin, forming actin-myosin cross bridges.

The bound myosin head changes shape (bends forward, the power stroke), pulling the actin filaments to slide over the myosin towards the M line.

ATP binds to the myosin head, which detaches; calcium ions activate ATPase, so ATP is hydrolysed to ADP and inorganic phosphate (Pi), and the energy released re-cocks the head so it can bind again further along.

Therefore the sarcomeres shorten, so the myofibrils and muscle fibres shorten and the muscle contracts.

(c) Describe how the concentration of calcium ions around the myofibrils is controlled.

(3)

A nerve impulse (action potential) arrives at the neuromuscular junction and causes depolarisation of the sarcolemma, which spreads down the T-tubules.

This causes calcium channels in the sarcoplasmic reticulum to open, so calcium ions are released from the sarcoplasmic reticulum into the sarcoplasm around the myofibrils.

When stimulation stops, calcium ions are taken back up into the sarcoplasmic reticulum by active transport, using ATP.

(Total for Question 7 = 10 marks)



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8 The muscles of the earthworm (*Lumbricus terrestris*) contract when it is touched. This is known as the withdrawal response.

(a) Which of the following terms describes a change in response as a result of repeated stimulation?

(1)

- ☐ A co-ordination
- ☒ B habituation
- ☐ C inhibition
- ☐ D reduction

(b) Contraction of the muscle in the withdrawal response is stimulated by nerve impulses. These nerve impulses can be detected using electrodes.

Explain the electrical changes in an axon that allow these nerve impulses to be detected.

(4)

The potential difference across the axon membrane changes, from a resting potential of about -70 mV to about $+40\text{ mV}$ (depolarisation) and back again (repolarisation); this change is detected by the electrodes.

Depolarisation is due to increased permeability to sodium ions, as voltage-gated sodium channels open and sodium ions move into the axon.

This is followed by an increased permeability to potassium ions, as potassium channels open and potassium ions move out of the axon, causing repolarisation of the membrane.

This action potential passes along the axon as a wave of depolarisation.



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(c) Studies were carried out to investigate the withdrawal response in earthworms.

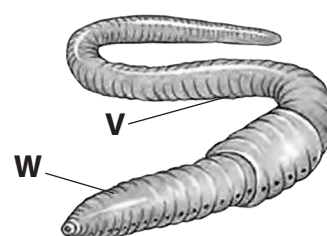
The duration of the withdrawal response is the length of time that the muscles remain contracted. If the stimulus is repeated, the withdrawal response is either reduced in duration or lost.

In one study, an earthworm was touched 20 times in one minute at point **V** as shown in the diagram. The shortening of the earthworm's body was measured after 20 stimuli.

The effect of touching point **W** in the same way was recorded and also the effect of alternating touches between points **V** and **W**.

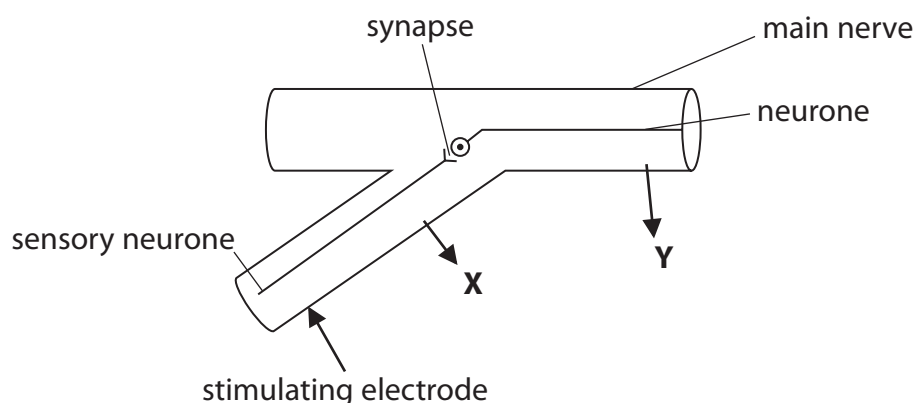
The results of this study are shown in the table.

Nature of stimulus	Change in body length after 20 stimuli / mm
All stimuli at point V	0
Stimuli alternating between points V and W	17
All stimuli at point W	0

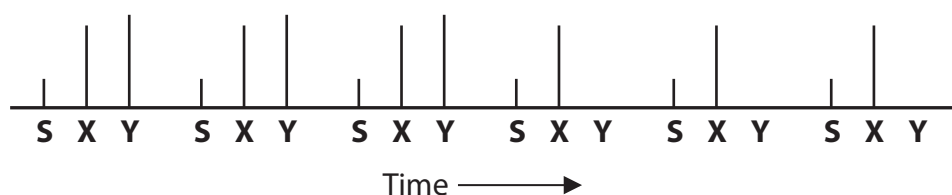


In another study, sensory neurones of an earthworm were stimulated by an electrode six times.

Nerve impulses were recorded at positions **X** and **Y** as shown in the diagram.



Nerve impulses recorded at **X** and **Y** are shown in the diagram below. The presence of a line indicates that an impulse was detected. **S** shows the stimulus.



- * (i) Analyse the data from these two studies to evaluate the most likely cause of the loss of the withdrawal response.

(6)

In the first study, when all 20 stimuli were at point V, or all at point W, there was no change in body length (0 mm), so the withdrawal response was lost after repeated stimulation. When stimuli alternated between V and W the body still shortened by 17 mm, so there was no habituation. V and W stimulate different sensory neurones, so the loss is not due to muscle fatigue but to repeated use of the same nerve pathway.

In the second study an impulse was recorded at X after all six stimuli, so the sensory neurone conducts an impulse every time it is stimulated. Electrode X is close to where the stimulus is applied, before the synapse. At Y, further from the stimulus and beyond the synapse, impulses were recorded after the first three stimuli, but after repeated stimulation no impulse was detected.

This shows the impulse is lost at the synapse between the sensory neurone and the neurone monitored at Y. The most likely cause of loss of the withdrawal response is habituation at the synapse: with repeated impulses fewer calcium ion channels open in the pre-synaptic membrane, so fewer vesicles fuse and less neurotransmitter is released, and there is not enough time to produce more neurotransmitter. So the threshold is not reached on the post-synaptic neurone, no action potential is produced and the muscles do not contract.



P 4 8 1 7 6 A 0 2 1 3 2

- (ii) Devise an experiment to show that the frequency of the stimulation used in the first study should be 20 stimuli per minute.

(4)

Use earthworms of the same species and similar size. Touch each worm at the same point (point V) with a cotton bud, using the same pressure each time.

Use a range of at least five frequencies above and below 20 per minute, e.g. 5, 10, 15, 20, 25 and 30 stimuli per minute, each for one minute.

Give a 2 minute recovery time between tests (or use a fresh worm for each frequency) so earlier habituation does not affect results.

Check for habituation by observing whether there is no response to touch, i.e. no change in length of the earthworm after the stimuli.

Repeat with at least five earthworms at each frequency and find the frequency at which habituation reliably occurs.

(Total for Question 8 = 15 marks)

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9 Emphysema is a condition that causes changes to the tissues in the lungs.

In an investigation, the surface area for gas exchange and the volume of the lungs of three groups of individuals were determined. The results are shown in the table.

Measurement	Individuals without emphysema	Individuals with mild emphysema	Individuals with severe emphysema
Mean surface area for gas exchange / m ²	118 ± 11	97 ± 8	30 ± 5
Mean total lung volume / cm ³	4772 ± 223	6232 ± 410	6725 ± 384
Mean surface area for gas exchange : volume ratio	247.3 : 1		44.6 : 1

- (a) (i) Calculate the mean surface area for gas exchange : volume ratio for individuals with mild emphysema.

(2)

$$97 \text{ m}^2 = 97 \times 10\,000 = 970\,000 \text{ cm}^2$$

$$970\,000 \div 6232 = 155.6$$

Answer 155.6 : 1

- (ii) There appears to be a difference in the lung volume of individuals with mild emphysema and those with severe emphysema.

Which of the following would be a relevant statistical test to determine whether this difference is significant?

(1)

- ☐ A chi-squared
- ☐ B correlation coefficient
- ☐ C standard deviation
- ☒ D Student's t-test



(iii) Give reasons for the variation in the lung volumes of healthy individuals.

(2)

Healthy individuals have different heights and body masses, so larger people have larger lungs.

They differ in sex (men have larger lungs than women) and in age.

(iv) Give a reason for calculating the surface area for gas exchange to volume ratio in this investigation.

(1)

To allow a valid comparison between the groups, as total lung volume differs between the groups.



- (b) Fick's law of diffusion can be used to calculate a value for the effectiveness of the uptake of oxygen by the lungs.

This value can be calculated using the equation

$$\text{value} = \frac{\text{surface area} \times \text{concentration difference}}{\text{diffusion distance}}$$

The diffusion distance in alveoli is $0.5 \mu\text{m}$.

The mean oxygen concentration in alveoli is 14 kPa and in the capillaries is 5 kPa.

The calculated value for healthy individuals is 2124.

- (i) Calculate the value for individuals with severe emphysema.

(2)

$$\begin{aligned} \text{value} &= (30 \times (14 - 5)) \div 0.5 \\ &= (30 \times 9) \div 0.5 = 540 \end{aligned}$$

Answer 540

- (ii) Calculate the percentage difference between the value for individuals with severe emphysema and the value for individuals without emphysema.

(2)

$$\begin{aligned} 2124 - 540 &= 1584 \\ (1584 \div 2124) \times 100 &= 74.6\% \end{aligned}$$

Answer 74.6%



(c) Explain why individuals with severe emphysema will tire more easily than healthy individuals. (3)

In severe emphysema there is a smaller surface area for gas exchange (30 m² compared with 118 m²) and a smaller surface area : volume ratio, and an increased diffusion distance.

Therefore there is a reduction in the rate of oxygen uptake into the blood, so less oxygen reaches the muscles.

Therefore there is less oxygen for aerobic respiration, so less ATP is produced.

This leads to more anaerobic respiration, and the build-up of lactate causes fatigue.

(Total for Question 9 = 13 marks)



- 10 The modern bread wheat plant (*Triticum aestivum*) has been developed from other plant species that have different genomes.

Three species of plant and their genomes are shown in the images.



Triticum aestivum
Genomes A, B and D

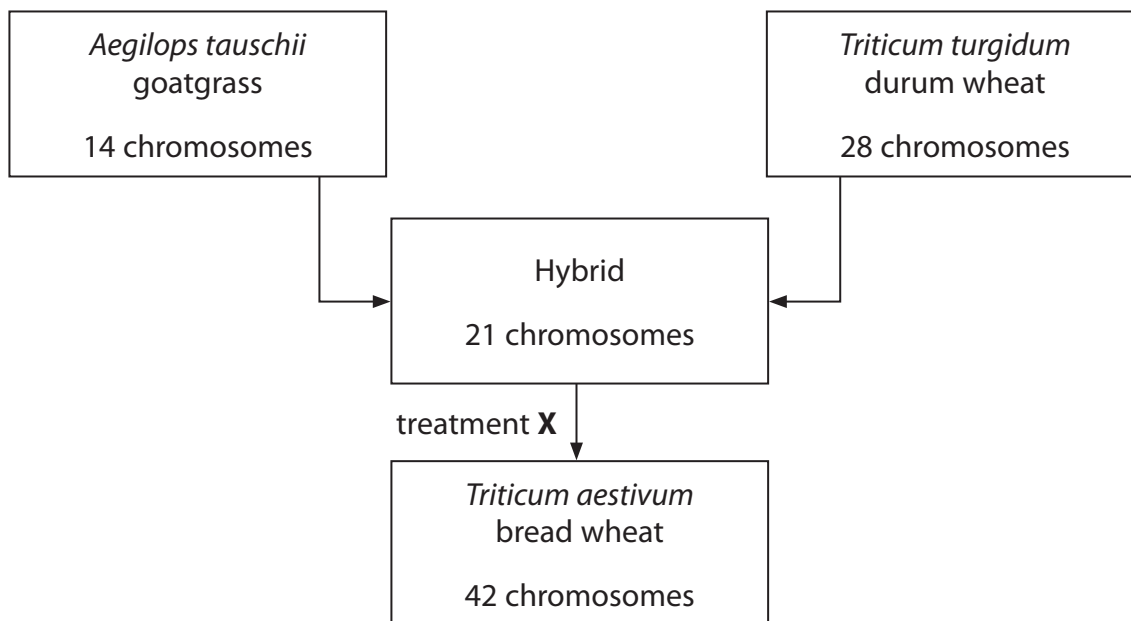


Triticum turgidum
Genomes A and B



Aegilops tauschii
Genome D

The diagram shows how chromosomes from different species have combined to produce the bread wheat species used to produce flour.



- (a) Explain why each cell of the hybrid plant has 21 chromosomes in its nucleus.

(2)

Aegilops tauschii (goatgrass) has 14 chromosomes, so its gamete contributes 7 chromosomes.

Triticum turgidum (durum wheat) has 28 chromosomes, so its gamete contributes 14; 7 + 14 = 21.



- (b) Which row in the table shows the number of chromosomes in cells from these different plant species?

(1)

	<i>A. tauschii</i> gamete	<i>T. turgidum</i> leaf cell	<i>T. aestivum</i> gamete
☐ A	7	14	42
☒ B	7	28	21
☐ C	14	28	42
☐ D	14	14	21

- (c) Explain why the hybrid plant cannot produce haploid gametes.

(2)

There is an odd number of chromosomes (21), so the chromosomes do not form homologous pairs.

Therefore meiosis cannot take place, as it requires chromosome pairs to separate.

- (d) Treatment X in the diagram uses the chemical colchicine.

Colchicine breaks down spindle fibres in dividing cells.

Explain how treatment of cells of the hybrid plant with colchicine could result in the development of fertile *Triticum aestivum* plants.

(3)

Before mitosis, during interphase, the DNA replicates so each chromosome is copied.

Colchicine breaks down the spindle fibres, so the chromatids are not separated and both copies of the chromosomes remain in the same cell.

This produces cells with double the chromosome number (42), so every chromosome has a homologous pair.

*So meiosis can occur, allowing production of haploid gametes (21 chromosomes), giving fertile adult *Triticum aestivum* plants.*



P 4 8 1 7 6 A 0 2 9 3 2

- *(e) New varieties of plants with desirable combinations of characteristics can be produced using the methods shown in the table.

Method	Example
Formation of hybrids	In wheat, genome D includes genes for a tolerance of harsh conditions and genome A promotes large starch stores in seeds.
Genetic modification	Production of specific molecules in plant cells.
Selective breeding	Plants with desired characteristics can be used for breeding to produce plants with combinations of desired characteristics.

Evaluate the risks and benefits of producing varieties of plants using these methods.

(6)

Benefits: forming hybrids could combine the genes for tolerance of harsh conditions from genome D with large starch stores from genome A, so crops can be grown in a wider range of conditions, such as drought, with an increased yield. Genetic modification can give pest or disease resistance, increasing yield and reducing the need to use pesticides; herbicide resistant crops can be sprayed with herbicide without being harmed. GM crops can also produce useful molecules, such as higher nutrient content or pharmaceutical products.

Risks: hybridisation could allow genes for tolerance of harsh conditions from genome D to enter pest (weed) species, producing pests able to grow in a wide range of conditions. In GM, genes may transfer into wild relatives or pest species, making control difficult, or enter food chains, and antibiotic resistance marker genes could pass to other species. Selective breeding reduces genetic diversity (gene pool size), so useful alleles are lost and crops are less able to adapt to environmental change.

Overall, the benefits for food production are large, but gene transfer (hybrids, GM) and loss of diversity (selective breeding) must be controlled, e.g. with seed banks.

(Total for Question 10 = 14 marks)

TOTAL FOR PAPER = 100 MARKS



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