OCR
Oxford Cambridge and RSA

Friday 17 June 2022 – Morning

A Level Biology B (Advancing Biology)

H422/02 Scientific literacy in biology

Time allowed: 2 hours 15 minutes

You must have:
- the Insert (ns de th s document)
- a c ean copy of the Advance Not ce Art c e (ns de th s document)

You can use:
- a ru er (cm/mm)
- a sc ent f c or graph ca ca cu ator

Please write clearly in black ink. **Do not write in the barcodes.**

Centre number | | | | | | Candidate number | | | | |

First name(s) _____

Last name _____

INSTRUCTIONS
- Use black ink. You can use an HB pencil, but only for graphs and diagrams.
- Write your answer to each question in the space provided. If you need extra space use the lined pages at the end of this booklet. The question numbers must be clearly shown.
- Answer **all** the questions.
- Where appropriate, your answer should be supported with working. Marks might be given for using a correct method, even if your answer is wrong.

INFORMATION
- The total mark for this paper is **100**.
- The marks for each question are shown in brackets **[ ]**.
- Quality of extended response will be assessed in questions marked with an asterisk (*).
- This document has **24** pages.

ADVICE
- Read each question carefully before you start your answer.

Answer **all** the questions.

1 This question is based on the Advance Notice article **'Biochemistry of exercise-induced acidosis'**.

(a) The table shows several conversions that occur in carbohydrate metabolism.

Place **one** tick (✓) in the appropriate box in each row to indicate the type of reaction corresponding to each conversion. The first row has been completed for you.

Conversion	Hydrolysis	Condensation	Oxidation	Reduction
ATP $\longrightarrow$ ADP + P	✓			
glucose $\longrightarrow$ glycogen				
maltose $\longrightarrow$ glucose				
pyruvate $\longrightarrow$ lactate				
transfer of hydrogen atoms to NAD^+				

[3]

(b) Explain why the conversion of pyruvate to acetyl CoA is described as an oxidative decarboxylation reaction.

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(c) **(i)** Use the information in the Advance Notice article to calculate the net yield of protons (H^+) in glycolysis when glucose is used as a respiratory substrate and when glycogen is used as a respiratory substrate.

Net yield of H^+ from glucose = ...

Net yield of H^+ from glycogen = ...

[2]

(ii) Explain how metabolic acidosis leads to muscle fatigue during intense exercise.

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(d) The Advance Notice article describes how muscle fatigue may be caused by P produced from ATP hydrolysis.

(i) Describe the role of ATP in muscle contraction.

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(ii) Explain how formation of calcium phosphate would cause muscle fatigue.

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(e)* Muscles produce sufficient ATP by aerobic respiration during normal exercise.

Under these conditions, protons (H^+) generated in glycolysis are used by the mitochondria in oxidative phosphorylation.

Describe how protons generated in glycolysis are used to produce ATP in mitochondria **and** explain why these protons do not accumulate in mitochondria.

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Additional answer space if required.

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2 **(a)** The table lists structural features of DNA and transfer RNA (tRNA).

Put a tick (✓) in each box where that structural feature is present. The first row has been completed for you.

Feature	DNA	tRNA
Contains phosphodiester bonds	✓	✓
Contains deoxyribose		
Contains purines		
Always contains paired **and** unpaired bases		

[2]

(b) Complete the sentences using the most appropriate terms.

The first stage of protein synthesis is called ....., in which the enzyme DNA helicase unwinds the DNA so that RNA polymerase is able to bind. RNA nucleotides are activated by addition of phosphate groups from ..... . Activated RNA nucleotides align next to complementary bases on the template strands and then RNA polymerase forms ..... bonds between the nucleotides to form a strand of mRNA. The mRNA moves to the cytoplasm where it attaches to a ribosome. The first amino acid-tRNA complex with the correct complementary three base ..... then binds to the mRNA.

[4]

3 **(a)** Variable number tandem repeats (VNTRs) are patterns of repeated nucleotides in DNA sequences.

Variation in the length of VNTRs can be used to compare DNA samples from different people.

(i) Describe a procedure you could use to compare the lengths of the VNTRs in two samples of DNA.

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(ii) Explain why forensic analysis uses VNTRs from different chromosomes or from loci that are far apart on the same chromosome.

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(iii) More recent forensic methods use shorter tandem repeats, typically 3 – 5 bases long. These are called short tandem repeats (STRs).

STRs of different lengths at one locus represent alleles.

A sample of DNA from a crime scene was analysed at five different STR loci. **Table 3.1** lists the five alleles present in the crime scene DNA and the percentage of the population that shares each allele.

Allele	Percentage of population sharing the allele (%)
1	13.5
2	7.8
3	12.3
4	6.6
5	5.1

Table 3.1

A suspect's DNA matched all five alleles from the crime scene DNA.

Calculate the probability that the match was due to chance.

Give your answer in standard form and to **2** significant figures.

Probability = 1 in ..... **[2]**

(b) Hypothyroidism (underactive thyroid gland) has several causes.

Study of family histories suggests that one cause is genetic.

Mutations in the thyroglobulin (*Tg*) gene are thought to cause hypothyroidism. An increasing number of patients with *Tg* mutations have been identified in Japan.

One study analysed *Tg* mutations using haplotype analysis.

(i) State the meaning of the term **haplotype**.

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..... **[1]**

(ii) In this study, DNA from patients with hypothyroidism was sequenced.

52 patients from 41 families had mutations in the *Tg* gene. **Table 3.2** shows the results of haplotype analysis for three of these mutations.

Patients with the R and T mutations were found only in specific locations.

The R mutation was found only in a single village surrounded by steep mountains and the sea.

Patients with the S mutation were found all over Japan.

Mutation	Number of patients	Number of families	Number of patients with same haplotype
R	8	5	8
S	12	11	9
T	7	5	7

Table 3.2

The researchers made these conclusions:

- The R, S and T mutations are three of many causes of hypothyroidism.
- The R and T mutations were caused by a founder effect.
- S is an old mutation that keeps reoccurring independently.

Explain how the researchers reached these conclusions.

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4 **(a)** **Fig. 4.1** and **Fig. 4.2** on the **Insert** are photomicrographs of sections of human lung.

(i) Identify the tissues labelled **A** and **B** in **Fig. 4.1**.

A .....

B .....

[2]

(ii) Identify the structure labelled **C** in **Fig. 4.2** and describe **one** visible way it is adapted for gas exchange.

Identity of **C** .....

Adaptation .....

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[2]

(iii) Identify the tissue labelled **D** in **Fig. 4.2** and describe its function.

Identity of **D** .....

Function .....

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[2]

(b) A section of lung tissue was prepared from a patient with emphysema.

Describe and explain how this would appear different to the lung tissue in **Fig. 4.2**.

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(c)* Asthma is a chronic condition, but an asthma attack involves severe acute symptoms.

Discuss the causes of asthma and how treatments target both the long-term condition and the acute symptoms.

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Additional answer space if required.

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5 **(a)** Ultrasound is used to screen for Down's syndrome in pregnancy. This is carried out between 11 and 14 weeks' gestational age.

If this screening indicates a high risk of Down's syndrome, fetal cells can be sampled for chromosome analysis.

(i) Give the name of **one** fetal sampling technique **and** state the exact source of cells used.

Name of technique .....

Source of cells .....

[2]

(ii) Give the name of the technique used in the chromosome analysis of the fetal cells.

..... **[1]**

(iii) Down's syndrome is described as trisomy 21.

Suggest what is meant by trisomy 21.

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..... **[1]**

(b) The gestational age of the fetus can be determined using one of two measurements:

- crown-rump length (CRL)
- head circumference (HC).

An accurate determination of gestational age is needed to ensure an accurate estimate of the risk of Down's syndrome.

(i) Suggest why biparietal diameter (the width of the fetus's head at its widest point) has been replaced by head circumference as a measure of gestational age.

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..... **[1]**

(ii) Current practice states that ultrasound screening for Down's syndrome risk should be used up to a gestational age of 14 weeks 1 day. From a gestational age of 14 weeks 2 days, screening should be done using a maternal blood sample.

A fetus was found to have a CRL of 61 mm.

The gestational age (in days) can be calculated using the formula:

$$\text{Gestational age} = 8.052 \times (\text{CRL} \times 1.037)^{0.5} + 23.73$$

Calculate the gestational age of the fetus in weeks and days, to the nearest day.

Gestational age = ... weeks ..... days **[2]**

(iii) Using your answer to part **(ii)**, state whether the screening for Down's syndrome risk of this fetus should be done by ultrasound or through a maternal blood sample.

..... **[1]**

(c) Fetal growth restriction (FGR) is a complication of pregnancy that results in a low birth weight. It affects up to 10% of all pregnancies and can lead to still-birth, poor growth in infancy and an increased risk of cardiovascular disease in later life. At present, there are no treatments for FGR.

FGR is diagnosed when fetal head circumference (HC) remains at or below the 5th percentile throughout gestation.

Table 5.1 shows HC data for three fetuses at 14, 22 and 30 weeks' gestational age.

Gestational age (weeks)	HC (mm)		
	Fetus A	**Fetus B**	**Fetus C**
14	71	75	92
22	185	172	195
30	272	252	293

Table 5.1

Fig. 5.1 is a fetal growth chart. The three lines represent the 5th, 50th and 95th percentiles.

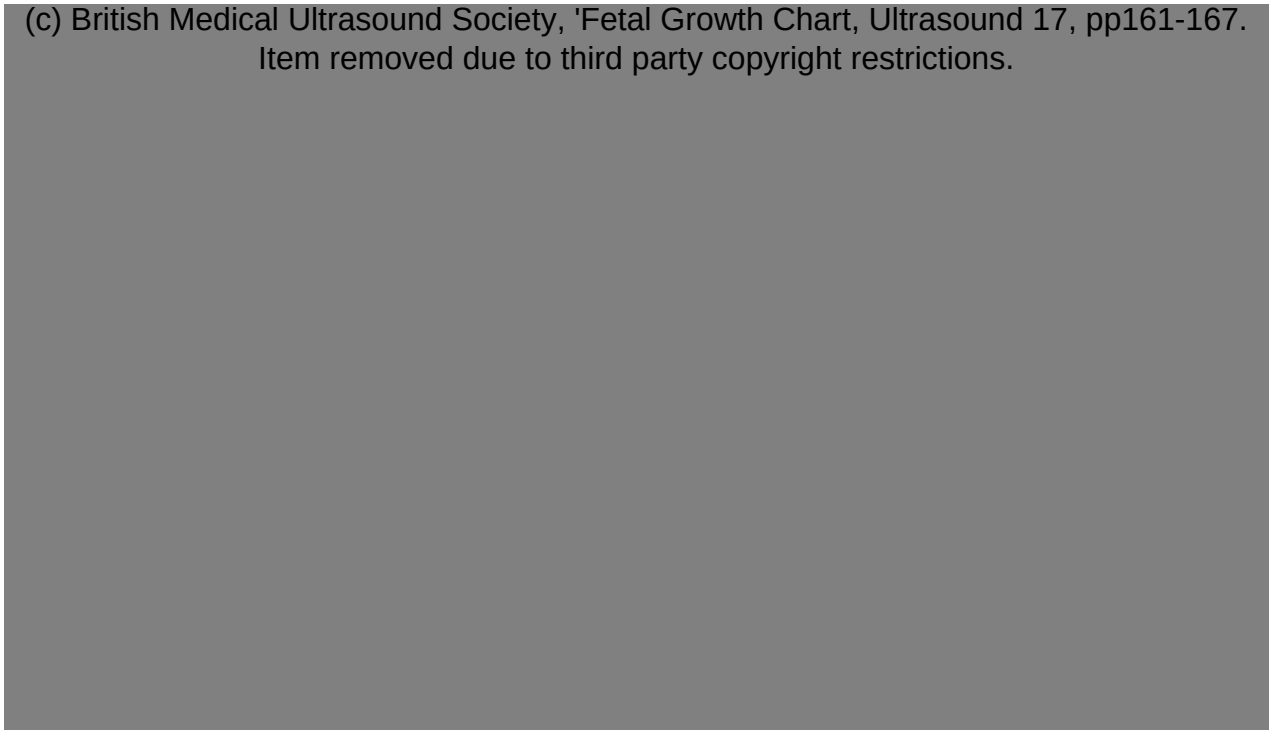

Fig. 5.1

Use the data in **Table 5.1** and the fetal growth chart in **Fig. 5.1** to explain which, if any, of the fetuses would be diagnosed with FGR.

Fetus(es) .....

Reason .....

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(d) FGR is associated with reduced levels of growth factors such as IGF-1 in both mother and fetus.

However, giving injections of IGF-1 to the mother has not been successful in treating FGR.

Gene therapy is now being investigated as a possible treatment for FGR.

Researchers tested gene therapy treatment on rabbits. The third fetus in a rabbit litter (the runt) has naturally reduced growth.

The researchers studied four groups of fetuses, as shown in **Table 5.2**. Each group consisted of five or six fetuses.

Group	Fetus type	Placenta injected with
A	normal	saline solution
B	runt	saline solution
C	runt	Ad-LacZ
D	runt	Ad-IGF-1

Table 5.2

Ad-LacZ used an adenovirus vector to deliver a gene that has no effect on the placenta.

Ad-IGF-1 used an adenovirus vector to deliver the *IGF-1* gene directly into the placenta.

(i) Suggest how the Ad-IGF-1 could safely deliver the *IGF-1* gene into cells in the placenta.

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..... **[2]**

(ii) Explain the purpose of Group **A** and Group **C** in the study.

Group **A** .....

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Group **C** .....

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[2]

(iii) The fetuses were allowed to grow and were weighed immediately after birth.

The results are shown in **Fig. 5.2**.

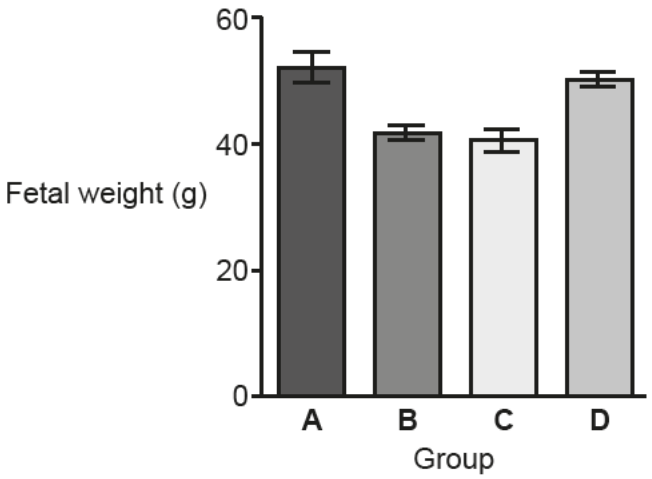

Fig. 5.2

Statistical analysis showed significant differences ($p < 0.01$) between these groups:

- groups **A** and **B**
- groups **B** and **D**
- groups **C** and **D**.

The researchers concluded that Ad-IGF-1 gene therapy represents a suitable treatment strategy for FGR in humans.

Evaluate their conclusion.

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6 **Fig. 6.1** on the **Insert** shows a light micrograph of a transverse section through the root of a leguminous plant.

(a) **(i)** Identify the tissues labelled **E** and **F** on **Fig. 6.1**.

E .....

F .....

[2]

(ii) Suggest the function of the region marked **G** on **Fig. 6.1**.

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(b) *Vigna mungo* (black gram) is an important leguminous food crop in South Asia. The seeds are high in protein and are used to make dal, a staple of Indian food.

Formation of root nodules does not always lead to efficient nitrogen fixation. Some species of nitrogen-fixing bacteria will only induce nitrogen-fixing nodules on certain legumes.

Farmers sometimes inoculate seeds with nitrogen-fixing bacteria to try to improve yields.

An experiment investigated the effectiveness of this practice.

- A pure culture of a species of nitrogen-fixing bacteria was mixed with a charcoal carrier.
- The mixture was used to inoculate *V. mungo* seeds.
- 24 pots containing unfertilised soil were prepared.
- Half the pots were planted with 20 inoculated seeds each and half were planted with 20 untreated seeds (control group).
- The pots were moved to a greenhouse.
- After 45 days, 2 pots from each group were taken and measurements made of the plants.

The results are shown in **Table 6.1**.

Each set of measurements used 12 plants and the data are shown as mean ± 2 standard deviations.

	Height of plant (cm)	**Fresh weight (g)**	**Number of roots**	**Number of root nodules**
Inoculated seeds	45 ± 1.27	55 ± 1.03	25 ± 0.52	14 ± 0.46
Untreated seeds	23 ± 0.68	29 ± 0.82	12 ± 0.45	6 ± 0.26

Table 6.1

(i) State **one** variable that should be controlled during the 45 days to allow a valid comparison between the two groups of seeds.

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..... **[1]**

(ii) Explain why the seeds were grown in unfertilised soil.

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(iii) Suggest, with a reason, another control group that the researchers should have used.

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(iv) The researchers used a paired *t*-test to analyse their results.

Suggest whether this was an appropriate test to use.

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(v) State the number of degrees of freedom used for this paired *t*-test.

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(vi) The researchers concluded that farmers should use inoculated *V. mungo* seeds to maximise their yields.

Evaluate this conclusion.

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(c) Beef cattle can be fed on grass or cereal grains, such as maize.

It is common in some countries to raise beef cattle in two stages:

- the first 14 months the cattle are fed on grass
- the last 6 months they are fed on cereal grains.

Table 6.2 shows the average mass of a group of cattle at the end of each stage and the average mass of feed consumed during that stage.

Stage	Age at end of stage (months)	Average mass at end of stage (kg)	Average mass of feed consumed (kg)
Fed on grass	14	320	9600
Fed on grain	20	560	3120

Table 6.2

(i) Calculate the efficiency of biomass transfer in the period when the cattle are fed on grass and in the period when they are fed on grain.

Give your answer to **2** significant figures.

Fed on grass = ... %

Fed on grain = ... %

[2]

(ii) A student concluded that it would be more sustainable to raise beef cattle entirely on grass.

Evaluate this conclusion.

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(d) Alfalfa is a leguminous plant used as a food crop for livestock such as beef cattle.

Alfalfa grows in areas with a shortage of water.

Scientists investigated the drought resistance of two different varieties of alfalfa: Algonquin and Longdong.

Fig. 6.2 shows photomicrographs of the upper and lower epidermis of leaves taken from the two varieties.

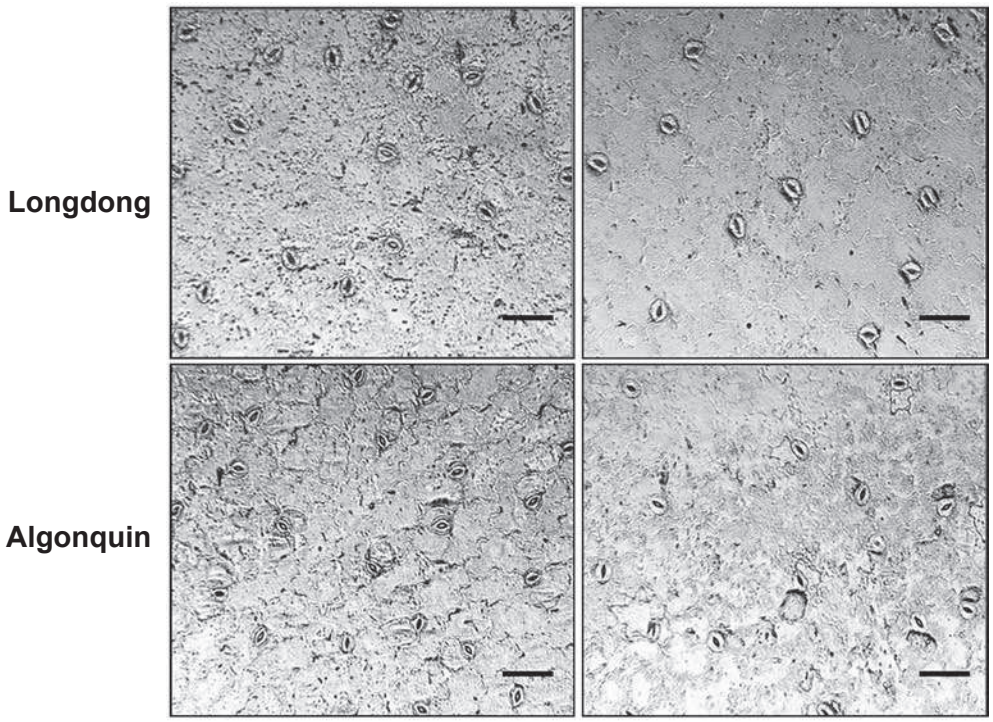


Fig. 6.2

Estimate the density of stomata on the lower epidermis of the two varieties.

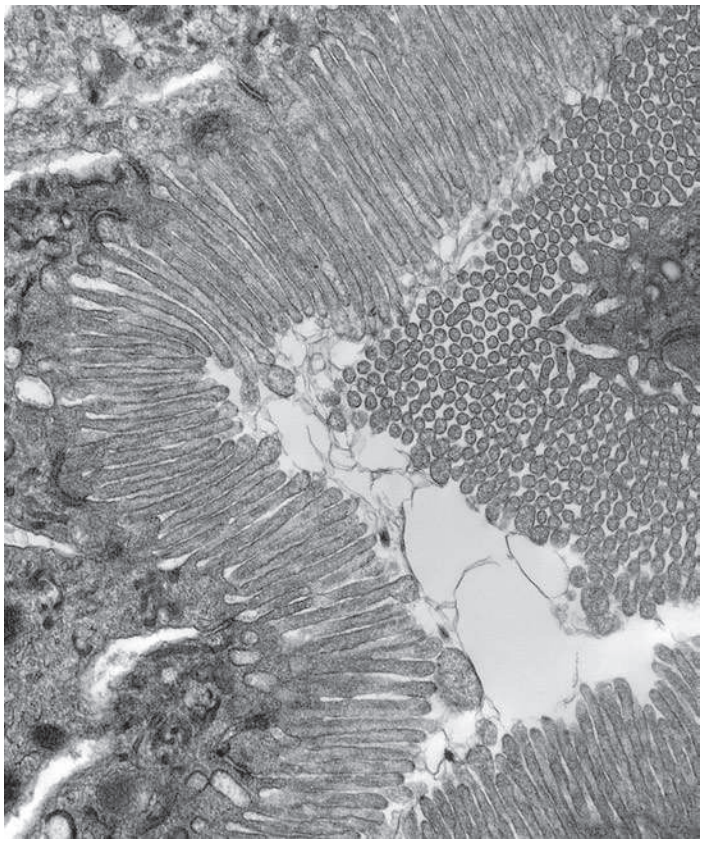
Give your answer as stomata mm ^{2}.

Longdong = ... stomata mm ^{2}

Algonquin = ... stomata mm ^{2}

[3]

7 **(a)** The image below is a transmission electron micrograph of a section through the proximal convoluted tubule (PCT) of a human kidney.



Identify **one** structural feature in the image and state how it is adapted to the function of the PCT.

Structural feature .....

Adaptation .....

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[2]

(b) Kidney failure can be treated by dialysis or transplant surgery.

(i) The table lists statements about two types of dialysis treatment.

Complete the table by writing 'true' or 'false' for each statement.

Statement	True or false
Both haemodialysis and peritoneal dialysis use a partially permeable membrane.	
The dialysis fluid for haemodialysis contains sugars and amino acids to match the composition of the patient's blood, but peritoneal dialysis uses saline solution.	
Haemodialysis must be performed several times per day.	

[2]

(ii) A student made the following statement about transplant surgery:

Dialysis is only a treatment for kidney failure, but transplant surgery is a permanent solution.

Evaluate the student's statement.

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END OF QUESTION PAPER

ADDITIONAL ANSWER SPACE

If additional space is required, you should use the following lined page(s). The question number(s) must be clearly shown in the margin(s).

OCR
Oxford Cambridge and RSA

Friday 17 June 2022 – Morning

A Level Biology B (Advancing Biology)

H422/02 Scientific literacy in biology

Insert

Time allowed: 2 hours 15 minutes

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INSTRUCTIONS
- Do **not** send this Insert for marking. Keep it in the centre or recycle it.

INFORMATION
- This Insert contains Fig. 4.1, Fig. 4.2 and Fig. 6.1.
- This document has **4** pages.

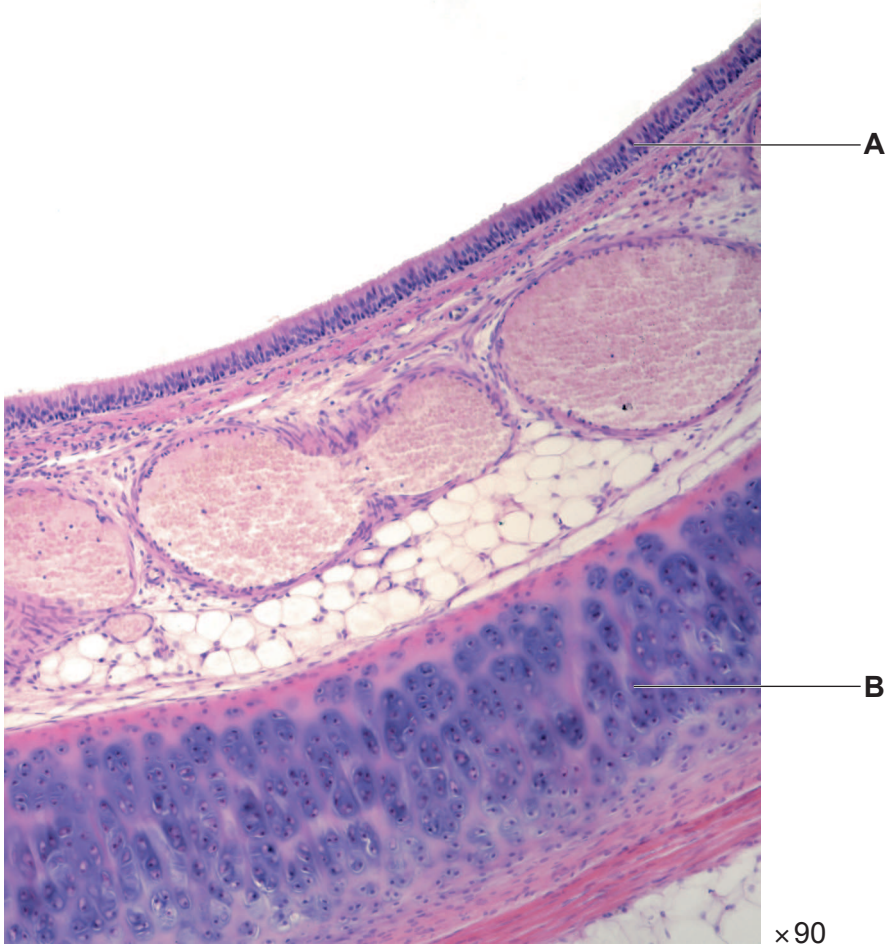

Fig. 4.1

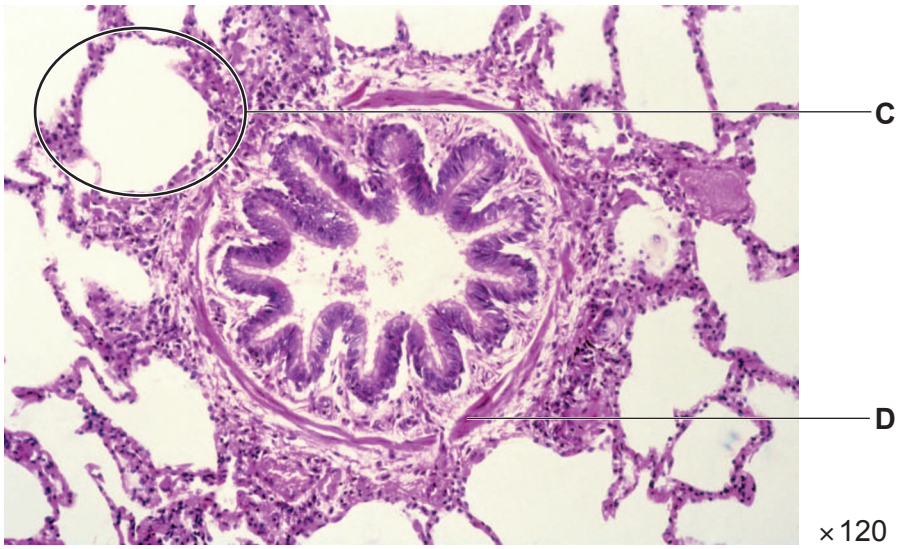

Fig. 4.2

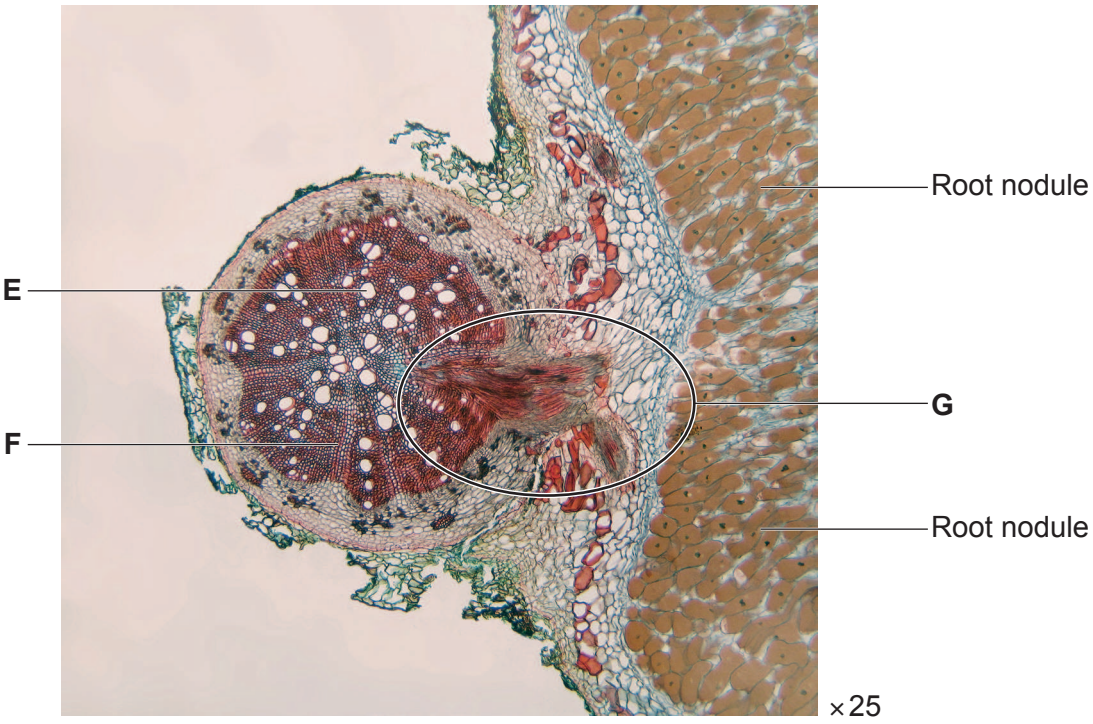

Fig. 6.1

Oxford Cambridge and RSA

Friday 17 June 2022 – Morning

A Level Biology B (Advancing Biology)

H422/02 Scientific literacy in biology

Advance Notice Article

Time allowed: 2 hours 15 minutes

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INSTRUCTIONS
- Do **not** send this Advance Notice Article for marking. Keep it in the centre or recycle it.

INFORMATION
- This is a clean copy of the Advance Notice Article you have already seen.
- This document has **4** pages.

Biochemistry of exercise-induced acidosis

The development of acidosis during intense exercise has a traditional explanation: an increase in lactic acid production. Each lactic acid molecule can release a proton and form the acid salt sodium lactate. Based on this explanation, if the rate of lactate production is high enough, the cellular proton buffering capacity will be exceeded, which results in a decrease in cellular pH. These biochemical events have been termed lactic acidosis. An increase in lactate production has long been considered one of several causes of muscle fatigue during intense exercise.

However, many scientists think there is no biochemical evidence that lactate production causes acidosis. In fact, lactate production reduces acidosis rather than causing it. There is a wealth of research evidence to show that acidosis is caused by reactions other than lactate production.

Protons do not accumulate in cells when the ATP demand of muscle contraction is met by mitochondrial respiration. Instead, protons are used by the mitochondria for oxidative phosphorylation, maintaining the proton gradient across the inner mitochondrial membrane. It is only when exercise intensity increases that there is a greater reliance on ATP regeneration from non-mitochondrial sources: glycolysis and the creatine phosphate system.

Creatine phosphate is used as a source of ATP during vigorous exercise. Production of ATP in this way consumes protons.

creatine phosphate + ADP + H^+ $\rightleftharpoons$ creatine + ATP

Glycolysis is usually considered to start with glucose. However, in muscle cells, glycogen is an important respiratory substrate. Glycogen is converted to glucose phosphate, not glucose, as shown in **Fig. 1**.

There are proton transport systems between the cytosol and the mitochondria. These transport systems reveal the power of mitochondrial respiration in helping to control the balance of protons within the cell. Mitochondrial metabolism releases electrons and protons from substrates and uses these electrons and protons to eventually produce ATP. Protons, ADP and P_i are transported into the mitochondria from the cytoplasm. The protons are required for the reduction of molecular oxygen; ADP and P_i are required to generate more ATP for muscle contraction.

A proton is released every time ATP is broken down to ADP and P_i. Metabolic acidosis occurs when the rate of ATP hydrolysis, and therefore the rate of ATP demand, exceeds the rate at which ATP is produced in the mitochondria.

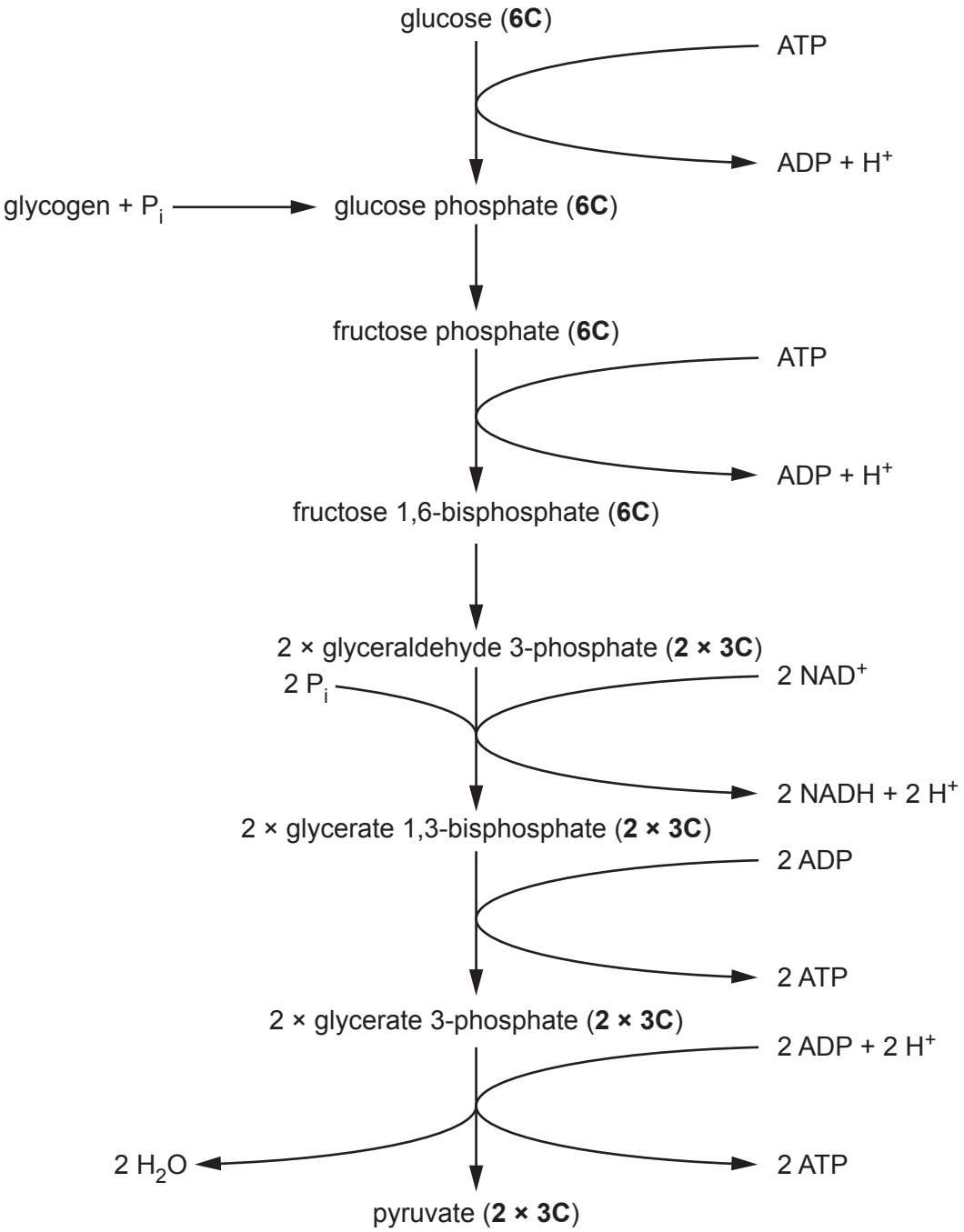

Fig. 1 The reactions of glycolysis using glucose or glycogen as the respiratory substrate

In muscle cells, the ATP that is supplied from non-mitochondrial sources is eventually used to fuel muscle contraction. This increases proton release and is responsible for the acidosis of intense exercise. Lactate production increases under these cellular conditions to prevent pyruvate accumulation and supply the NAD^+ needed for glycolysis. Increased lactate production therefore coincides with cellular acidosis, but it does not **cause** it. Nonetheless, lactate production remains a good indirect marker for the metabolic conditions that induce metabolic acidosis in cells. If muscles did not produce lactate, acidosis and muscle fatigue would occur more quickly and exercise performance would be severely impaired.

Any factor that reduces the ability of muscles to contract is likely to cause muscle fatigue. Another explanation for muscle fatigue does not involve acidosis. During intense exercise, ATP is hydrolysed to ADP and P_i. Scientists have suggested that the P_i combines with calcium ions in the sarcoplasmic reticulum to form insoluble calcium phosphate. This reaction is thought to represent another cause of muscle fatigue during exercise.