OCR
Oxford Cambridge and RSA

Friday 16 October 2020 – Morning

A Level Biology B (Advancing Biology) H422/02

Scientific literacy in biology

Advance Notice

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 the Advance Notice.
- This document has **4** pages.

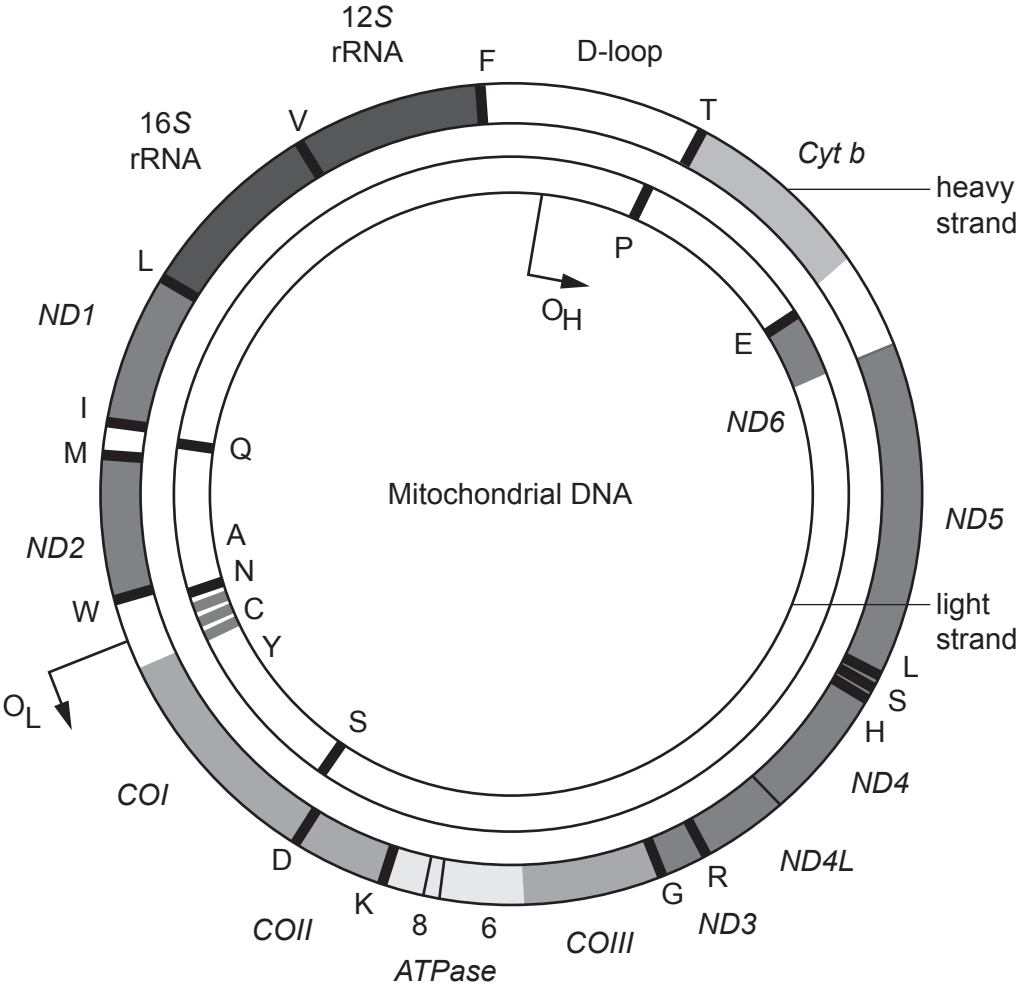
DC (ST/CT) 190611/4

Mitochondrial DNA and mitochondrial disease

Mitochondrial DNA (mtDNA) is much smaller than the DNA within chromosomes; it contains only 16 500 base pairs compared to over 3 billion pairs in nuclear DNA. The DNA within mitochondria is more similar to the DNA within bacteria than nuclear DNA. Each mitochondrion contains many copies of the mtDNA, and there are many mitochondria in each cell.

The mitochondrial genome contains 37 genes that encode 13 proteins (see diagram below). The 13 mitochondrial gene-encoded proteins are subunits of enzyme complexes in the oxidative phosphorylation system. The small mitochondrial genome is not able to independently produce all of the proteins needed for functionality; thus, mitochondria rely heavily on imported nuclear gene products.

The mitochondrial genome contains few non-coding DNA sequences. Three percent of the mitochondrial genome is non-coding DNA, whereas 93% of the nuclear genome is non-coding DNA.



A map of the human mitochondrial genome. The 37 genes include genes encoding for cytochrome c oxidase, cytochrome b and subunits of ATP synthase. The D-loop is a non-coding control region.

The DNA contained within your nucleus comes from both your parents; you inherit half your nuclear DNA from your mother and half from your father. However, the situation with mtDNA is different. Children inherit mtDNA from their mothers only. Sperm contain mitochondria, but they are broken down shortly after fertilisation. Since children inherit all of their mtDNA from the mother, only women can pass on mutations within this DNA.

The mitochondrial genome has a higher mutation rate (about 100-fold higher) than the nuclear genome. What explains the high mutation rate of mtDNA? Two nuclear genes, TWNK and POLG, encode enzymes for replicating the mitochondrial genome. TWNK encodes a helicase enzyme and POLG encodes DNA polymerase gamma. The POLG protein consists of two regions: a catalytic region that exhibits polymerase activity, and an exonuclease region that is involved in the recognition and removal of DNA base-pair mismatches that occur during DNA replication. A recent study suggests that mitochondria may have a nucleotide imbalance that leads to decreased POLG fidelity and higher mtDNA mutation rates.

What is mitochondrial disease?

When a person has mitochondrial disease, the mitochondria in the cells fail to produce enough energy. They are either inefficient or they do not work at all. There is huge variety in the symptoms and severity of mitochondrial disease. It depends on how many cells are affected and where they are in the body. Each person with mitochondrial disease will have a different combination of functional and non-functional mitochondria within each cell. However, there are times when particular body systems are affected in a recognisable pattern and these diseases have specific names. One example is Alper's disease.

Alper's disease

Alper's disease is a mitochondrial disease that affects the brain and liver. Symptoms of the disease include severe epilepsy, loss of developmental skills and liver failure.

Alper's disease is caused by mutations in the nuclear gene called POLG. The mutations are present in both the catalytic and exonuclease regions of POLG. The faulty product of POLG – the polymerase gamma enzyme – fails to produce sufficient amounts of functioning mtDNA in the liver and brain.

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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, Fig. 5.1 and Fig. 5.2.
- This document has **4** pages.

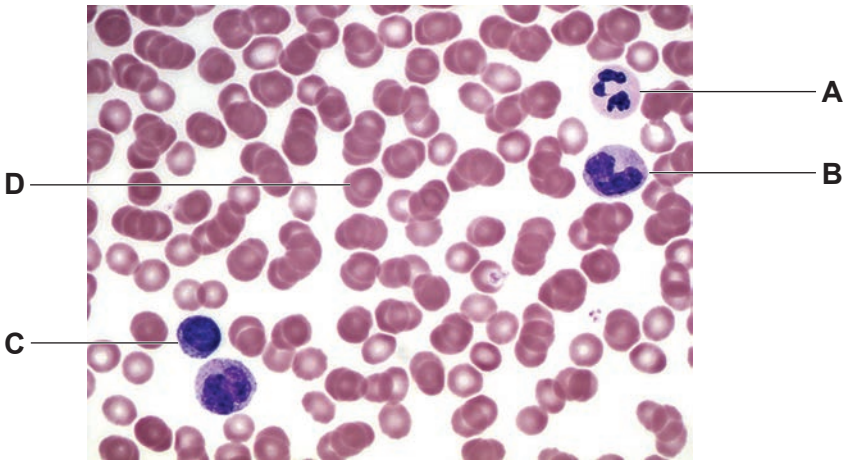

Fig. 4

Fig. 5.1

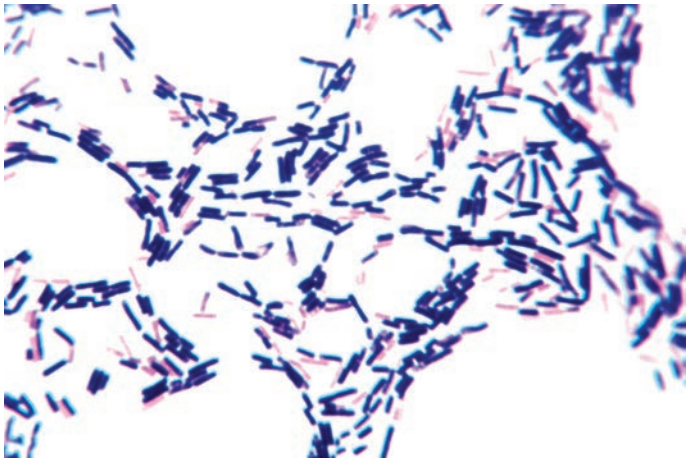

Fig. 5.2

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A Level Biology B (Advancing Biology)

H422/02 Scientific literacy in biology

Time allowed: 2 hours 15 minutes

You must have:
- the Insert
- a clean copy of the Advance Notice (inside this document)

You can use:
- a scientific or graphical calculator
- a ruler (cm/mm)

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H 4 2 2 0 2

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 may use an HB pencil 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 **20** 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 **'Mitochondrial DNA and Mitochondrial Disease'**, on the **Insert**.

(a) Mitochondrial DNA (mtDNA) is much smaller than nuclear DNA and is similar to prokaryotic DNA.

(i) Give **two** ways, apart from size, in which mtDNA differs from nuclear DNA.

1. .....

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2. .....

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[2]

(ii) Complete the following table of comparisons between mtDNA, RNA and ATP. Put a tick (✓) in each box where that component is present.

The first line has been completed for you.

Component	mtDNA	RNA	ATP
adenine	✓	✓	✓
ribose			
uracil			
pyrimidine			

[3]

(iii) The mitochondrial genome contains 37 genes. Of these, only 13 code for proteins.

Suggest what the remaining genes encode.

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

(b) Like replication of nuclear DNA, replication of mtDNA is semi-conservative.

(i) Explain what is meant by the term semi-conservative replication.

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

(ii) Explain how mutations in the catalytic and exonuclease regions of the *POLG* gene could have different effects on the replication of mtDNA.

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

(c) Sequencing the mitochondrial genome has helped our understanding of the function of mitochondria and the basis of mitochondrial disease.

PCR is used to amplify the mtDNA in a sample before sequencing.

(i) In PCR, the DNA is placed in a buffered solution in a thermocycler.

State the **three** other components that are placed in the buffered solution in PCR.

1. .....

2. .....

3. .....

[3]

(ii) A sample contained 1500 molecules of mtDNA.

Calculate the number of mtDNA molecules you would expect after 15 cycles of PCR.

Express your answer as a $\log_{10}$ value.

number of molecules = ... **[2]**

(iii) Place the events, **A** to **G**, in the correct order in the boxes below to describe the process of gel electrophoresis. The first one is done for you.

A DNA fragments are placed in wells by the cathode

B when the current is stopped, shorter fragments will finish nearer the anode

C UV light can be used to visualise banding patterns

D a current is applied

E the gel plate is covered in buffer solution

F DNA fragments can be extracted for further analysis

G the DNA fragments begin moving towards the anode

E						

[4]

(d) The Advance Notice article describes the causes and symptoms of mitochondrial disease.

Explain why raised concentrations of lactate confirm diagnosis of mitochondrial disease.

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

2 **(a)** Type 1 and type 2 diabetes have different treatments.

(i) Compare the treatments for type 1 and type 2 diabetes.

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..... **[3]**

(ii) Explain why measurement of the concentration of glycosylated haemoglobin is used to evaluate how well a patient's blood glucose concentration has been controlled.

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

(b) Diabetes can lead to the development of a disease called retinopathy, which involves damage to the retina.

Some doctors have suggested that hypertension increases the risk of retinopathy in patients with type 1 diabetes.

A clinical trial was carried out to investigate the effect of blood pressure on the risk of developing retinopathy.

Two groups of patients with type 1 diabetes were selected and treated as follows:

- the test group of 231 patients received lisinopril, a drug that reduces hypertension
- the control group of 228 patients received a placebo

Both groups were monitored for a period of 24 months. Their blood pressure and glycosylated haemoglobin concentrations were measured regularly.

The results of the trial are shown in the table.

	Number of patients who developed retinopathy or whose retinopathy worsened	**Number of patients whose retinopathy improved**	**Mean blood pressure at start of trial**	**Mean blood pressure at end of trial**
Test group (lisinopril)	21	33	$\frac{123}{81}$	$\frac{120}{80}$
Control group (placebo)	39	28	$\frac{123}{81}$	$\frac{123}{81}$

(i) Name an instrument used to measure blood pressure.

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

(ii) Calculate the percentage decrease in the systolic blood pressure in the test group over the course of the trial.

percentage decrease = ... % **[2]**

(iii)* The doctors running the clinical trial concluded that lisinopril had beneficial effects on retinopathy caused by type 1 diabetes.

Evaluate this conclusion.

In your answer, suggest what additional information the doctors would need to be more confident in their conclusion.

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..... **[6]**

Additional answer space if required.

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(c) One factor that contributes to damage to the retina is macular oedema, which is swelling in the eye.

Use your knowledge of tissue fluid formation to explain how hypertension could increase the incidence of oedema.

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..... **[3]**

(d) A researcher collected data for the incidence of hypertension and type 2 diabetes in a population.

(i) Describe how the researcher could test for correlation between hypertension and type 2 diabetes.

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

(ii) The researcher found that there was a positive correlation between hypertension and type 2 diabetes.

As a result, they concluded that type 2 diabetes was caused by hypertension.

Explain why the researcher's conclusion may not have been correct.

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

3 **(a)** Fig. 3.1 outlines the two stages of photosynthesis.

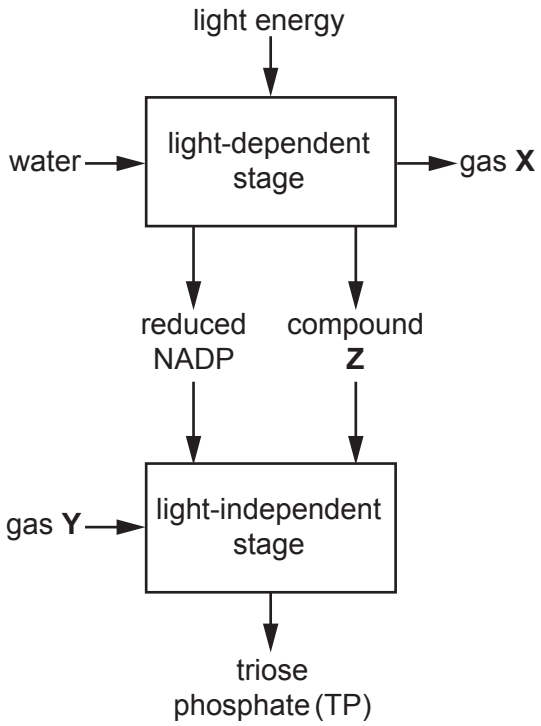

Fig. 3.1

(i) Identify the following from Fig. 3.1:

gas **X** .....

gas **Y** .....

compound **Z** .....

[2]

(ii) Name the structure in the chloroplast in which the light-dependent stage of photosynthesis takes place.

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

(iii) Describe **two** ways in which the structure you named in **(ii)** is adapted to its function.

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

(b) A student used paper chromatography to analyse a mixture of photosynthetic pigments.

Fig. 3.2 shows the chromatogram produced. The student numbered each spot and marked the position of the centre of each spot with a pencil mark to help with measurement.

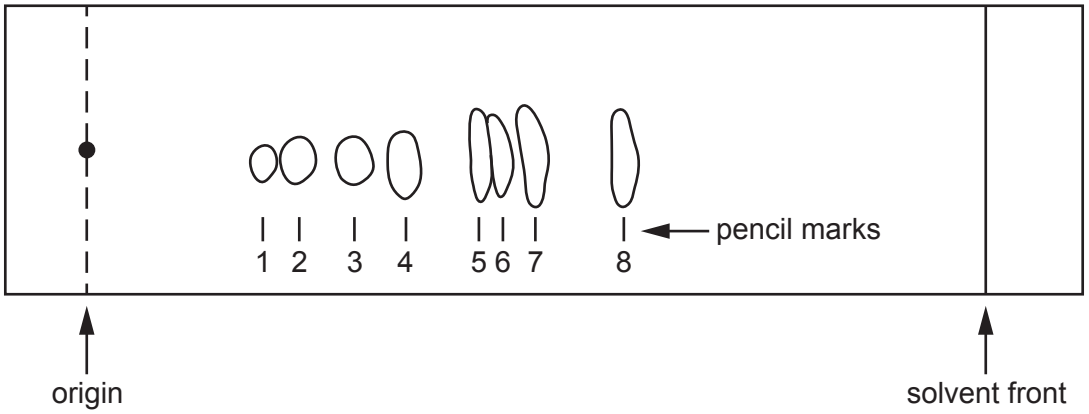

Fig. 3.2

(i) Explain why the student did not allow the solvent to reach the end of the paper.

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

(ii) Calculate the R_f value for spot 5.

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

R_f = ... **[2]**

(iii) The student had a table of R_f values. However, these values were determined using a different solvent mixture than the one used by the student.

Explain why using this table of values might lead to incorrect identification of the pigments.

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

(c) When light energy is absorbed by photosynthetic pigments it causes electrons to be excited to a higher energy level.

(i) Explain how energy from the excited electrons is transferred to ATP.

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..... **[4]**

(ii) Suggest **two** reasons why the transfer of energy from excited electrons to ATP is not 100% efficient.

1. .....

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2. .....

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[2]

4 **(a)** Fig. 4, **on the Insert**, shows a photomicrograph of a blood smear.

(i) Identify the three different types of leucocytes labelled **A**, **B** and **C** on Fig. 4.

A .....

B .....

C .....

[3]

(ii) State one structural feature of the cell labelled **D** in Fig. 4 that is different to other eukaryotic cells.

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

(b) A sample of blood was diluted by taking 0.001 cm^3 of blood and making up to a total volume of 1.5 cm^3.

The number of erythrocytes in the diluted sample was counted using a haemocytometer of depth 0.1 mm.

There were 15 cells in a 0.2 mm square.

(i) Suggest **one** thing you would do when diluting the blood sample to ensure that the number of erythrocytes is calculated accurately.

.....

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

(ii) Calculate the total concentration of erythrocytes in the undiluted blood sample.

Give your answer as cells cm^{-3} in standard form.

concentration = ... cells cm^{-3} **[4]**

5 **(a)** Fig. 5.1, **on the Insert**, shows an image of a culture of bacteria growing on agar in a petri dish.

(i) A student concluded that there were two different species of bacteria in the culture.

Evaluate the student's conclusion.

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..... **[3]**

(ii)* Outline a practical procedure to obtain pure cultures of the bacterial species growing on the plate in Fig. 5.1.

In your answer you should include the steps you would take to avoid contamination and confirm the purity of the cultures produced.

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..... **[6]**

Additional answer space if required.

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(b) Fig. 5.2, **on the Insert**, shows a photomicrograph of bacteria that have been stained with Gram stain.

(i) Explain what can be concluded about the types of bacteria present in this culture.

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

(ii) Describe how Gram stain changes the colour of bacterial cells.

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

(c) A student investigated the effect of different antibiotics on the growth of bacteria.

They prepared two agar plates:

- Plate 1 was inoculated with a non-pathogenic strain of *E. coli* (a Gram-negative bacterium).
- Plate 2 was inoculated with a non-pathogenic strain of *S. aureus* (a Gram-positive bacterium).

Discs of filter paper were soaked in either an antibiotic solution or distilled water. The discs were then placed on the surface of each plate.

The plates were incubated for 48 hours and the zone of inhibition around each disc was measured.

The results are shown in the table.

Solution on filter paper	**Zone of inhibition (mm)**	
	Plate 1 (*E. coli*)	**Plate 2 (*S. aureus*)**
Water	0	0
Penicillin	2	16
Polymyxin B	15	1
Tetracycline	15	14

The student made the following conclusions:

1. Penicillin and Polymyxin B are both narrow-spectrum antibiotics.
2. Tetracycline is a broad-spectrum antibiotic.
3. Penicillin is active only against Gram-positive bacteria.
4. Polymyxin B is active only against Gram-negative bacteria.
5. Tetracycline is a bacteriostatic antibiotic whereas penicillin and polymyxin B are both bactericidal antibiotics.

(i) Evaluate the student's conclusions.

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..... **[3]**

(ii) Describe **two** improvements that could be made to the student's method to increase the accuracy of their results.

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2. .....

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[2]

(iii) Suggest the mechanism of action of penicillin.

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

(iv) Suggest how the mechanism of action of polymyxin B differs from that of penicillin.

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

(v) Outline an experiment to distinguish between a bactericidal antibiotic and a bacteriostatic antibiotic.

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..... **[3]**

6 **(a)** Fig. 6 shows the reactions of one stage of respiration.

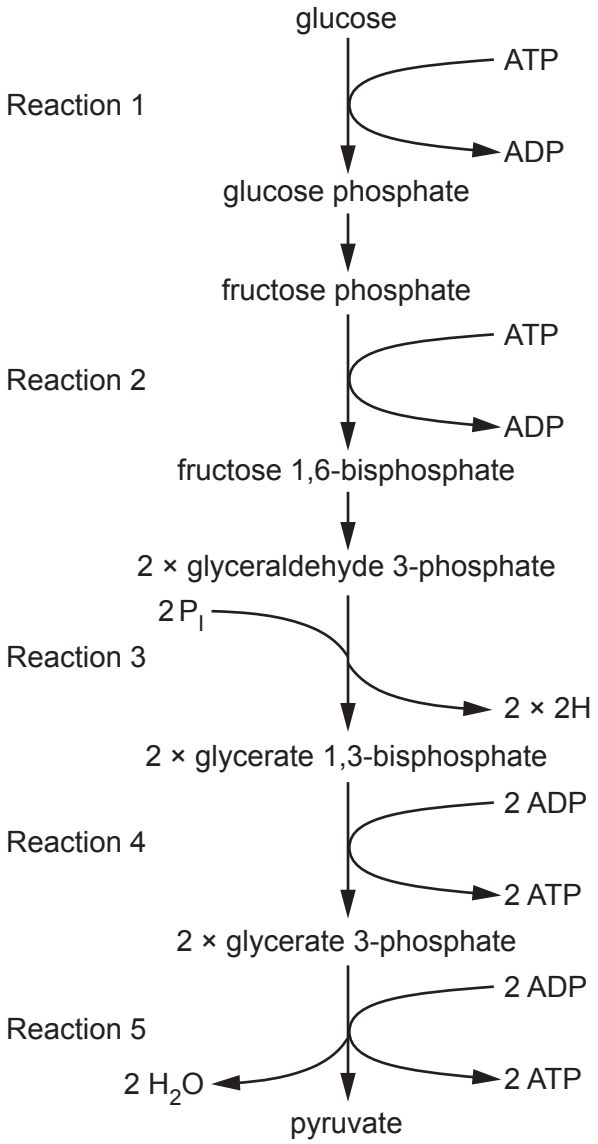

Fig. 6

(i) Name the stage of respiration shown in Fig. 6.

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

(ii) State the location in the cell where the reactions in Fig. 6 occur.

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

(iii) Complete the following table by placing a tick (✓) in the appropriate boxes to show which reactions include substrate level phosphorylation, hydrolysis or a dehydrogenase enzyme.

Reaction	Substrate level phosphorylation occurs	Hydrolysis reaction occurs	Dehydrogenase enzyme is used
1			
2			
3			
4			
5			

[3]

(iv) Reactions 1 and 2 in Fig. 6 illustrate how ATP is used to phosphorylate molecules.

Phosphorylation of glucose prevents it from being able to diffuse out of the cell.

Suggest **one** other effect of glucose phosphorylation that is important in the process shown in Fig. 6.

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

(b) Complete the following passage using the correct words or terms.

In the link reaction, coenzyme A accepts two carbons from .....

to form acetyl coenzyme A. At the same time ..... and

..... are formed. This is an example of oxidative

decarboxylation. Acetyl coenzyme A enters the Krebs cycle and reacts with oxaloacetate to

form ..... which is then converted back to oxaloacetate.

[4]

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).