Surname	Date	Tutor
First name(s)		

BioWelsh

GCE A LEVEL

BW-A2-3.1-W1

TOPIC WORKSHEET 1 – 3.1 IMPORTANCE OF ATP

BIOLOGY – A2 unit 3

Energy, Homeostasis and the Environment

Suggested time: 3 hours 25 minutes

For Tutor's use only

Question	Maximum Mark	Mark Awarded	Question	Maximum Mark	Mark Awarded
1.	10		9.	11	
2.	10		10.	10	
3.	10		11.	9	
4.	11		12.	12	
5.	10		13.	10	
6.	11		14.	9	
7.	11		15.	9	
8.	12		Total	155	

ADDITIONAL MATERIALS

In addition to this worksheet, you will require a calculator and a ruler.

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen. Do not use gel pen or correction fluid.

You may use a pencil for graphs and diagrams only.

Write your name and the date in the spaces at the top of this page.

Answer **all** questions.

Write your answers in the spaces provided in this booklet. If you are working on screen, write your answers on paper and number each one clearly.

INFORMATION FOR CANDIDATES

The number of marks is given in brackets at the end of each question or part-question. The worksheet is out of **155** marks.

The assessment of the quality of extended response (QER) will take place in question **15**.

The quality of written communication will affect the awarding of marks.

This worksheet is written by BioWelsh in the style of the WJEC A level Biology examination, following the WJEC specification (topic 3.1). It is not an official WJEC paper.

Tutor only

Answer **all** questions.

1. ATP is described as the universal energy currency of cells. **Image 1.1** shows how ATP is made and used in a cell. **R** and **S** are two reactions.

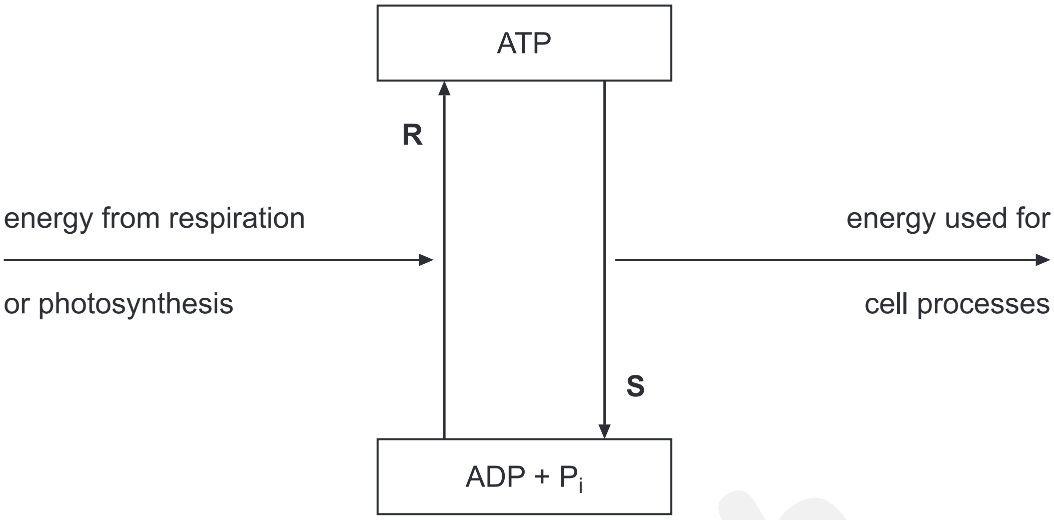

Image 1.1

(a) Name the type of reaction shown by **R** and by **S**. [2]

R ....

S ....

(b) Explain why ATP is described as the **universal** energy currency. [2]

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Tutor only

Table 1.2 shows the percentage of the ATP used by different processes in a model of a resting mammalian cell, based on published estimates.

Table 1.2

Process	Percentage of ATP used
protein synthesis	28
active transport of sodium and potassium ions	24
active transport of calcium ions	6
synthesis of RNA and DNA	4
other processes	38

(c) The cell hydrolyses 1.0×10^7 molecules of ATP every second. Calculate the number of molecules of ATP used for the active transport of sodium and potassium ions in **one minute**. **Give your answer in standard form.** [2]

Number of molecules = ...

(d) Glucose enters most mammalian cells by facilitated diffusion. Explain why this process does **not** appear in **Table 1.2**. [2]

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(e) Suggest why the percentage of ATP used for the active transport of sodium and potassium ions is much higher in a neurone than in the model cell. [2]

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Turn over.

Tutor only

2. **Image 2.1** shows the energy level of electrons as they pass along the electron transport chain in the inner mitochondrial membrane. The chain is made of proton pumps and electron carriers. **X** and **Y** are two coenzymes that deliver electrons to the chain. **Y** is produced only in the Krebs cycle. **Z** is the final electron acceptor.

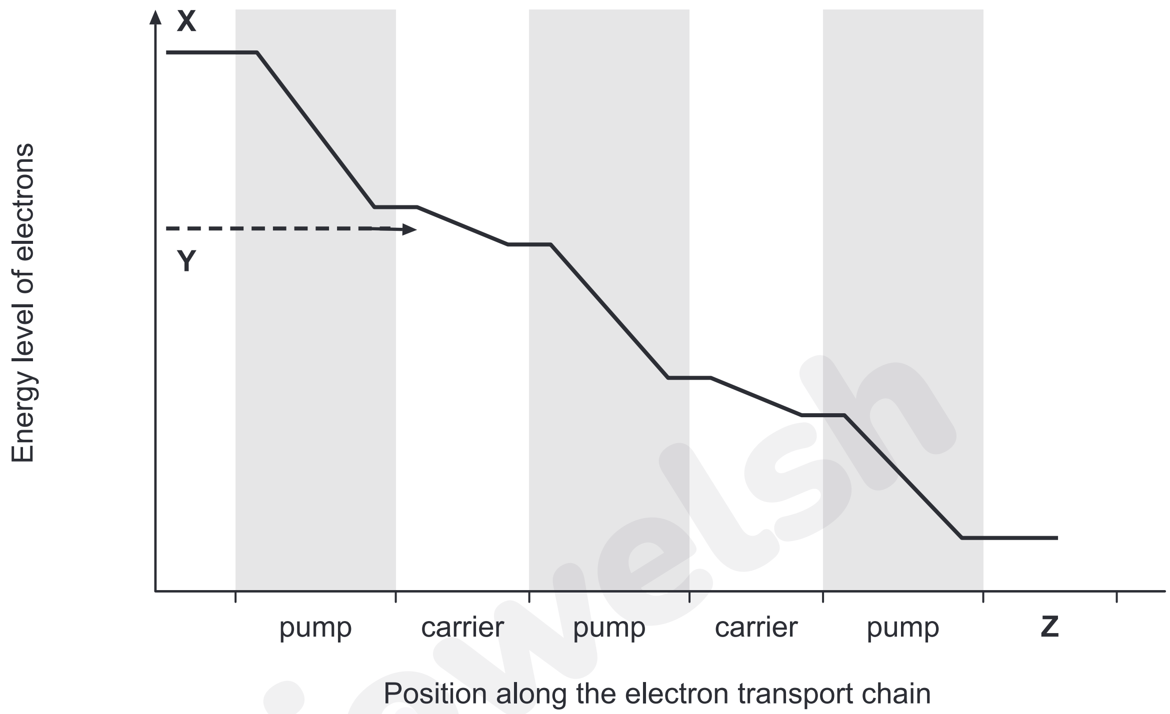

Image 2.1

(a) Name the reduced coenzymes **X** and **Y**. [2]

X ....

Y ....

(b) Describe what happens to the electrons as they pass along the chain and how their energy is used. [3]

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Tutor only

(c) Explain why it is an advantage that the energy of the electrons is released in several small steps rather than in one step. [2]

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(d) Using **Image 2.1**, explain why each reduced **Y** produces two molecules of ATP but each reduced **X** produces three. [2]

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(e) Name **Z** and the product formed when it accepts electrons. [1]

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Turn over.

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3. **Image 3.1** is a transmission electron micrograph of part of a mitochondrion from a mammalian lung cell.

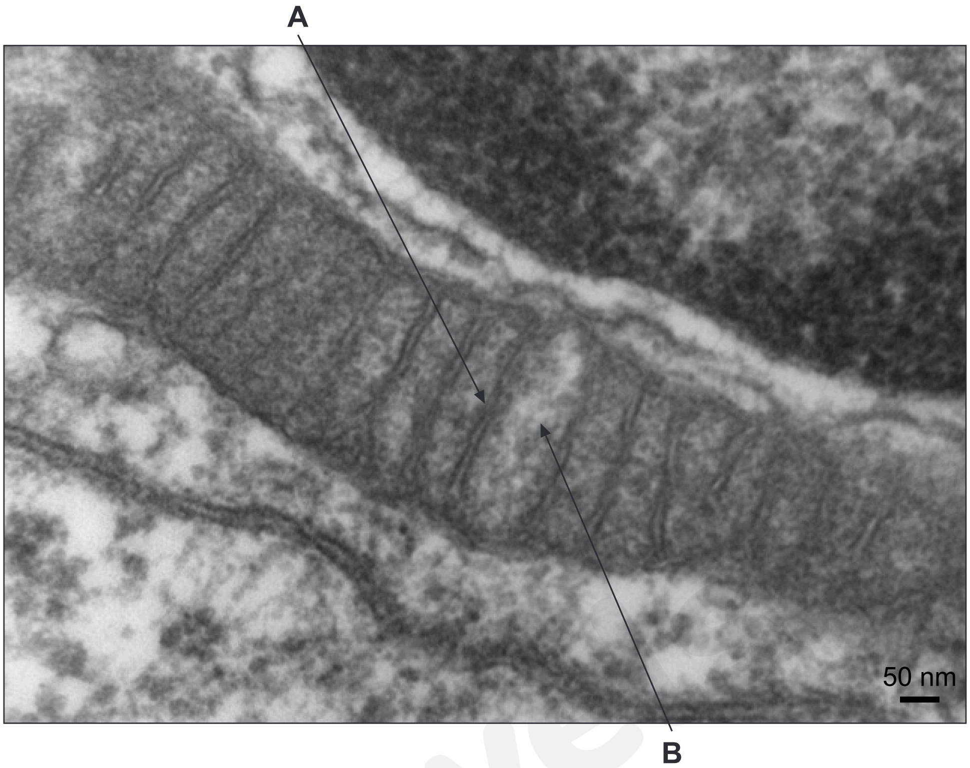

Image 3.1

(a) Identify the structures labelled **A** and **B**. [2]

A ....

B ....

(b) State **precisely** where ATP synthetase is found in a mitochondrion. [1]

....

(c) Use the scale bar to calculate the magnification of **Image 3.1**. Give your answer to **2 significant figures**. Show your working. [2]

Magnification = × ....

Tutor only

Table 3.2 shows the percentage of the cell volume occupied by mitochondria, and the area of inner mitochondrial membrane in each μm^3 of mitochondrion, in liver cells and in two types of muscle cell. The values are based on published measurements.

Table 3.2

Type of cell	Percentage of cell volume that is mitochondria	Area of inner membrane / μm^2 per μm^3 of mitochondrion
rat liver	20	20
rat heart muscle	28	40
hummingbird flight muscle	35	58

(d) (i) Calculate the area of inner mitochondrial membrane in 1 μm^3 of hummingbird flight muscle cell. [2]

Area = ... μm^2

(ii) Explain how a large area of inner membrane allows a high rate of ATP production. [2]

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(iii) Suggest why hummingbird flight muscle has the highest values in **Table 3.2**. [1]

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4. Protons are hydrogen ions. The pH of a solution depends on its concentration of protons. **Table 4.1** shows the pH on each side of the inner membrane in actively respiring mitochondria.

Table 4.1

Compartment	pH
intermembrane space	7.0
matrix	7.8

(a) Explain why the pH of the intermembrane space is lower than the pH of the matrix. [2]

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The concentration of protons, in mol dm^{-3}, can be calculated using the formula:

$$\text{concentration of protons} = 10^{-pH}$$

(b) (i) Calculate the concentration of protons in the matrix. **Give your answer in standard form.** [2]

Concentration = ... mol dm^{-3}

(ii) Calculate how many times greater the concentration of protons is in the intermembrane space than in the matrix. [1]

Number of times = ...

(c) The gradient across the inner membrane is described as an electrochemical gradient. Explain why. [2]

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Tutor only

(d) Gramicidin is an antibiotic that forms channels through which protons can cross membranes. When gramicidin was added to the mitochondria, the pH of both compartments became 7.4. Explain why ATP production by the mitochondria stopped. [2]

(e) Without gramicidin, suggest what would happen to the pH of the intermembrane space if the mitochondria were deprived of oxygen. Explain your answer. [2]

11

Tutor only

5. **Image 5.1** is a simplified drawing of the enzyme ATP synthetase in the inner membrane of a mitochondrion. **R**, **S** and **T** are parts of the enzyme. **P** and **Q** are the regions on either side of the membrane.

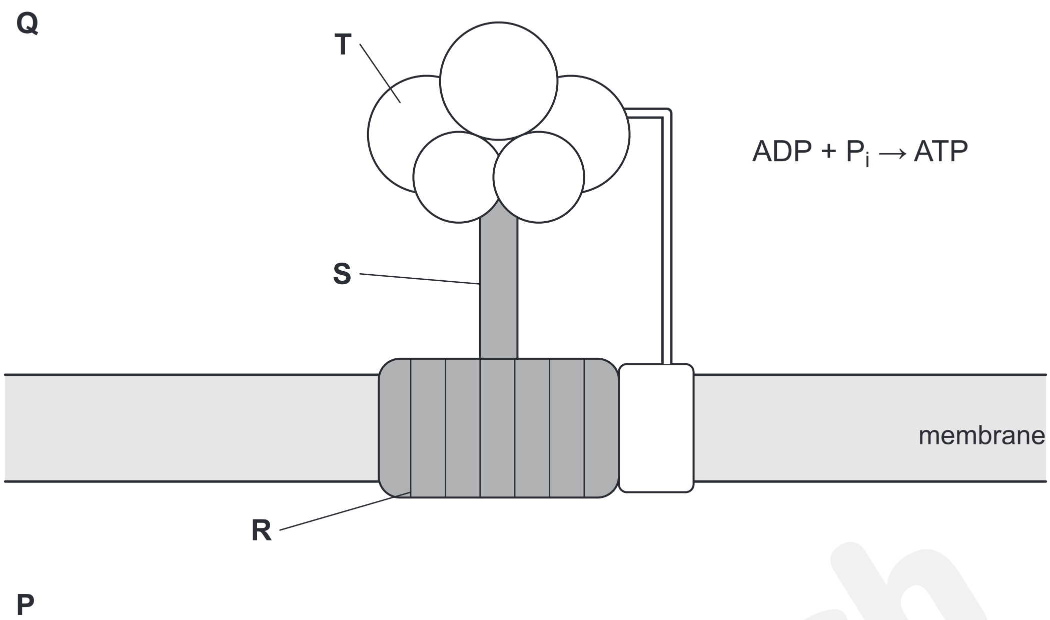

Image 5.1

(a) Identify regions **P** and **Q**. Give a reason for your answer. [2]

P ....

Q ....

Reason ....

....

(b) On **Image 5.1**, draw an arrow labelled **H** to show the path taken by protons through the enzyme. [1]

(c) Describe how the movement of protons through ATP synthetase leads to the synthesis of ATP. [3]

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Tutor only

In cow mitochondria the rotor **R** is made of 8 subunits. Each proton that passes through the enzyme turns the rotor by one subunit. One complete turn of the rotor produces 3 molecules of ATP.

(d) (i) Calculate the number of protons needed to make one molecule of ATP. Give your answer to **1 decimal place**. [1]

Number of protons = ...

(ii) In yeast mitochondria the rotor is made of 10 subunits. Calculate the percentage increase in the number of protons needed to make one molecule of ATP in yeast compared with cows. [2]

Percentage increase = ... %

(e) Suggest **one** advantage to a mammal of needing fewer protons to make each molecule of ATP. [1]

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Tutor only

6. In 1974, scientists tested the chemiosmotic theory using artificial vesicles made of phospholipid. Bacteriorhodopsin is a protein from a microorganism that lives in salt lakes. It pumps protons across a membrane when it absorbs light. It is not part of an electron transport chain.

The scientists placed bacteriorhodopsin and ATP synthetase from cow mitochondria in the membranes of the vesicles, as shown in **Image 6.1**. ADP and inorganic phosphate were added to the solution outside the vesicles.

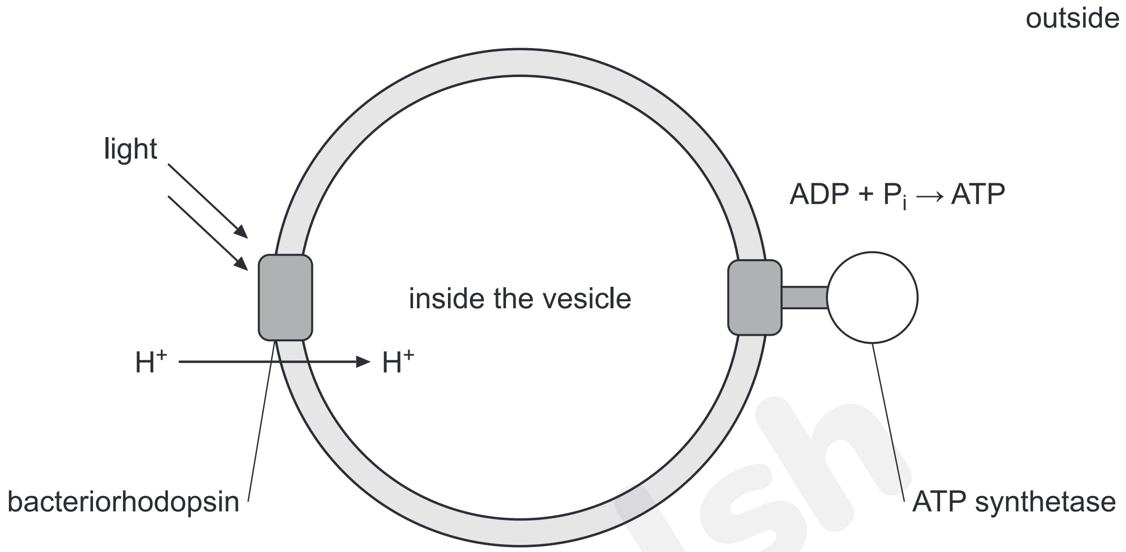

Image 6.1

Table 6.2 shows the results.

Table 6.2

Vesicle	Proteins in the membrane	Conditions	ATP produced / au
1	bacteriorhodopsin and ATP synthetase	light	100
2	bacteriorhodopsin and ATP synthetase	dark	2
3	ATP synthetase only	light	1
4	bacteriorhodopsin only	light	0
5	bacteriorhodopsin and ATP synthetase, with gramicidin, which lets protons cross the membrane	light	3

(a) State whether the concentration of protons became higher inside or outside vesicle 1 in the light. Explain your answer. [2]

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Tutor only

(b) Explain why vesicle 1 produced ATP. [3]

(c) Explain the results for vesicles 2, 3 and 5. [3]

(d) Explain how these results support the chemiosmotic theory. [2]

(e) Suggest the purpose of vesicle 4. [1]

11

Tutor only

7. Newborn babies and hibernating mammals have brown fat, a tissue whose cells contain very large numbers of mitochondria. The inner mitochondrial membrane of these cells contains thermogenin, a channel protein that lets protons pass through it. **Image 7.1** shows part of this membrane. **J** and **K** are two other membrane proteins.

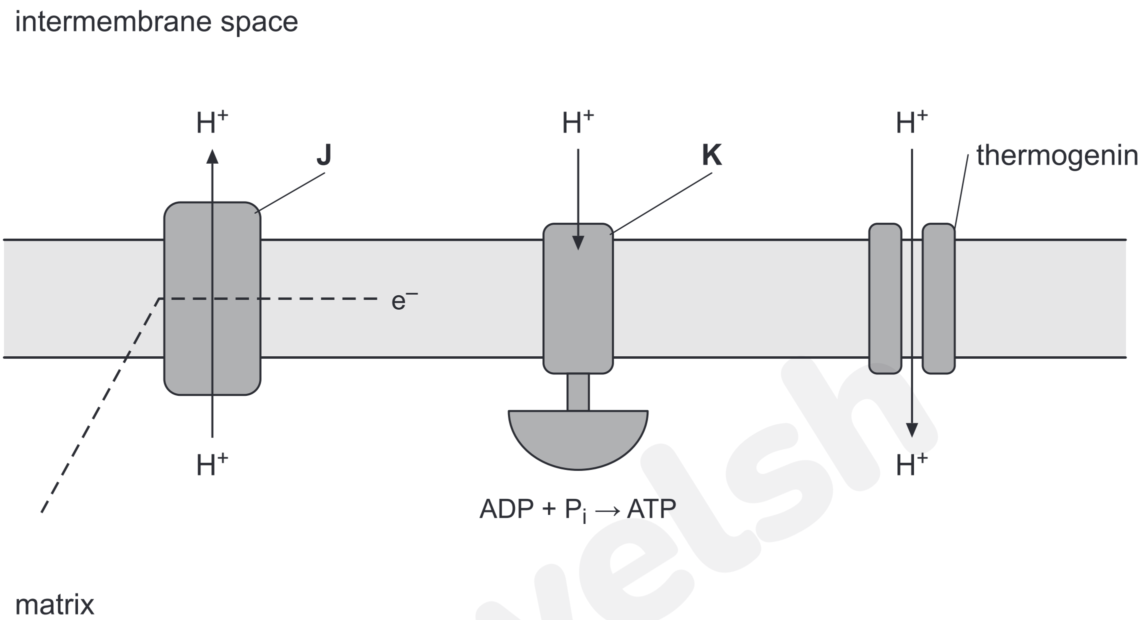

Image 7.1

(a) Identify proteins **J** and **K**. [2]

J ....

K ....

Mitochondria were isolated from liver cells and from brown fat cells of the same mammal. **Table 7.2** shows their oxygen uptake and ATP production.

Table 7.2

Source of mitochondria	Oxygen uptake / nmol O_2 min^{-1} mg^{-1} protein	ATP produced / nmol min^{-1} mg^{-1} protein
liver	80	400
brown fat	120	60

(b) Calculate the number of molecules of ATP produced for each molecule of oxygen used by each type of mitochondrion. [2]

Liver ....

Brown fat ....

Tutor only

(c) Using **Image 7.1**, explain why brown fat mitochondria produce much less ATP for each molecule of oxygen used. [3]

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(d) Suggest why the oxygen uptake of brown fat mitochondria is higher than that of liver mitochondria. [2]

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(e) Suggest why brown fat is important for the survival of newborn babies. [2]

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Tutor only

8. *Chlamydomonas* is a single-celled green alga. **Image 8.1** is a transmission electron micrograph of part of a *Chlamydomonas* cell.

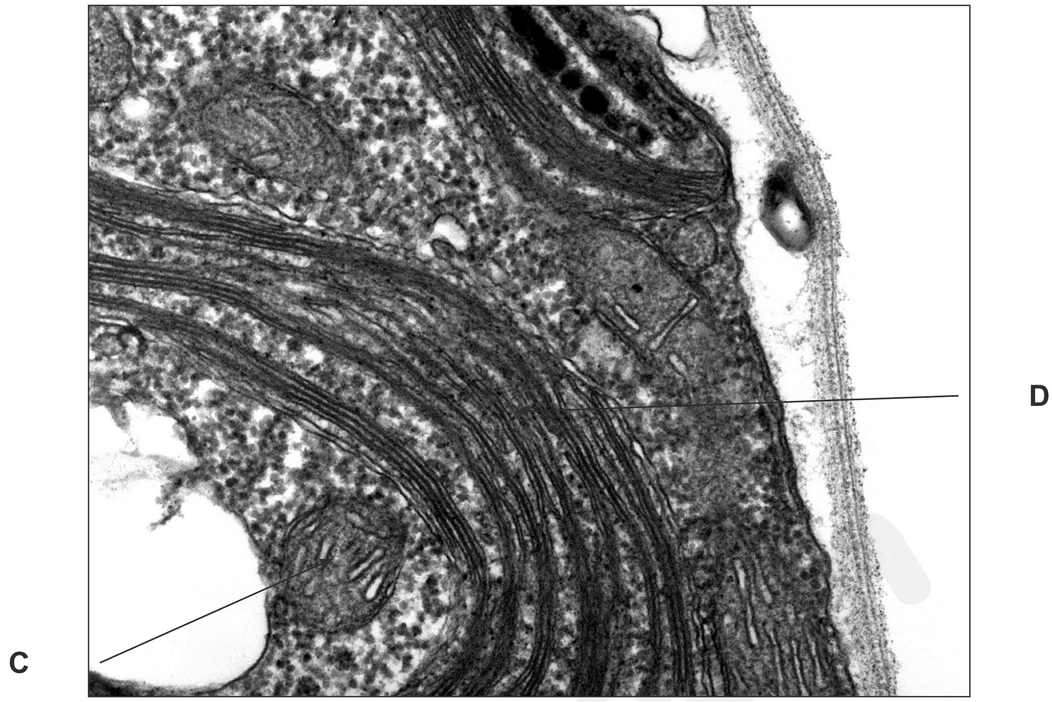

Image 8.1

(a) Identify organelle **C** and structure **D**. [2]

C ....

D ....

(b) Mitochondria and chloroplasts both make ATP by chemiosmosis. Complete **Table 8.2** to compare the two organelles. [4]

Table 8.2

Feature	Mitochondrion	Chloroplast
membrane containing the electron transport chain	....	....
compartment into which protons are pumped	....	....
final electron acceptor	....	....
region where ATP is produced	....	....

(c) State how water provides electrons for the chloroplast electron transport chain and explain how this also helps to form the proton gradient. [2]

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Tutor only

(d) Explain how the reduction of NADP helps to maintain the proton gradient. [2]

(e) Suggest why *Chlamydomonas* cells need mitochondria as well as a chloroplast. [2]

12

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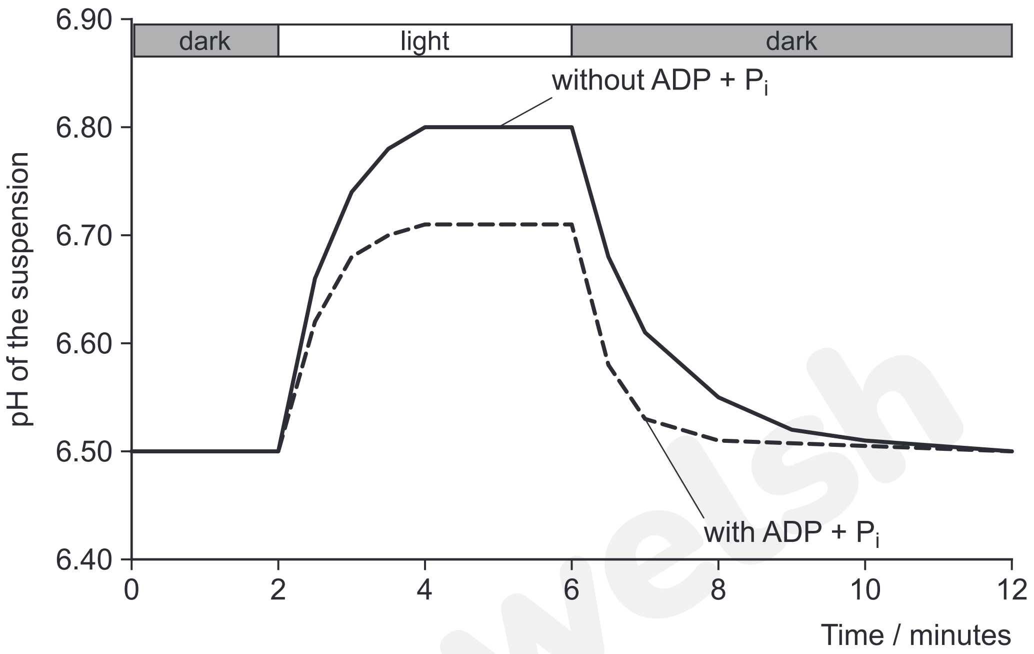
9. Thylakoids were isolated from spinach leaves and suspended in a weakly buffered solution containing a substance that accepts electrons from the electron transport chain. A pH electrode recorded the pH of the solution around the thylakoids. The thylakoids were kept in the dark, then lit for 4 minutes, then returned to the dark. The experiment was repeated with ADP and inorganic phosphate added. **Graph 9.1** shows the results.



Graph 9.1

(a) Describe the change in pH of the suspension without ADP and P_i when the light was switched on. [2]

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(b) Explain why the pH of the suspension rose in the light. [3]

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Tutor only

(c) Calculate the percentage decrease in the concentration of protons in the suspension when the pH rose from 6.50 to 6.80. Give your answer to the **nearest whole number**. [2]

Percentage decrease = ... %

(d) Explain why the pH fell after the light was switched off. [2]

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(e) Using your knowledge of chemiosmosis, explain the differences between the results with and without ADP and P_i. [2]

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Tutor only

10. Bacteria have no mitochondria. They make ATP by chemiosmosis using an electron transport chain that pumps protons out of the cytoplasm. Alkaliphilic bacteria live in very alkaline lakes. **Table 10.1** shows the pH outside and inside the cells of two species of bacteria.

Table 10.1

Species	pH outside the cell	pH of the cytoplasm
Escherichia coli	7.0	7.7
Bacillus pseudofirmus (alkaliphilic)	10.5	8.3

(a) State where the electron transport chain is found in a bacterial cell. [1]

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(b) Describe **one** similarity and **one** difference between chemiosmosis in a bacterium and in a mitochondrion. [2]

Similarity ....

....

Difference ....

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(c) Using **Table 10.1**, explain why protons flow into the cytoplasm of *E. coli* through ATP synthetase. [2]

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(d) The concentration of protons is 10 times greater for each fall of 1 pH unit. Calculate how many times greater the concentration of protons is in the cytoplasm of *B. pseudofirmus* than outside the cell. [2]

Number of times = ...

Tutor only

(e) *B. pseudofirmus* still makes ATP by chemiosmosis, with protons moving into the cell through ATP synthetase. Using your knowledge of the electrochemical gradient, suggest how this is possible. [2]

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(f) Suggest why *B. pseudofirmus* keeps the pH of its cytoplasm much lower than the pH outside. [1]

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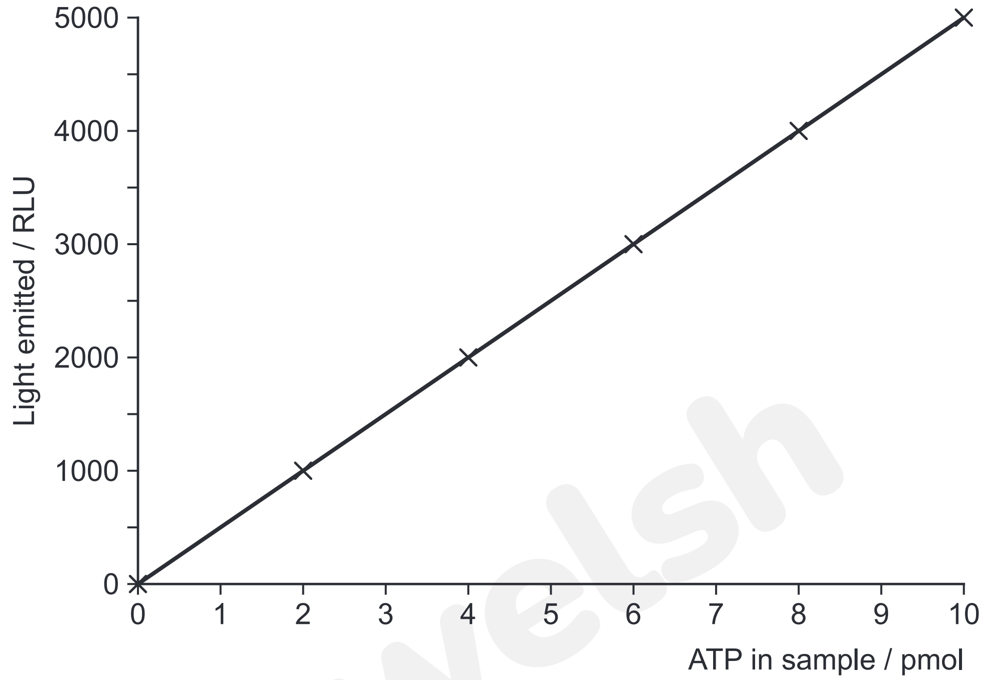
Turn over.

Tutor only

11. Fireflies produce light using the enzyme luciferase:

luciferin + ATP + oxygen → oxyluciferin + AMP + pyrophosphate + light

Food factories use this reaction to check that surfaces are clean. A surface is wiped with a swab, which is then placed in a reagent containing luciferin and luciferase. A luminometer measures the light emitted in relative light units (RLU). **Graph 11.1** is a calibration curve made using known amounts of ATP.



Graph 11.1

(a) Explain why no light is produced by the reagent unless ATP is present. [2]

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(b) A swab from a chopping board gave a reading of 2600 RLU. Use **Graph 11.1** to find the amount of ATP in the sample. [1]

ATP = ... pmol

Tutor only

(c) One mole contains 6.02×10^{23} molecules and 1 pmol = 10^{-12} mol. Calculate the number of molecules of ATP in the sample. **Give your answer in standard form.** [2]

Number of molecules = ...

(d) Explain why detecting ATP shows that living cells or food residues are present on a surface. [2]

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(e) Suggest **one** limitation of using this test to detect bacteria on a surface. [1]

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(f) Suggest **one** variable that should be controlled when swabbing surfaces so that readings can be compared. [1]

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9

Tutor only

12. Methylene blue is an artificial hydrogen acceptor. It is blue when oxidised and colourless when reduced. A student investigated the effect of temperature on the activity of dehydrogenase enzymes in yeast. **Image 12.1** shows the apparatus used. The time taken for the blue colour to disappear was recorded.

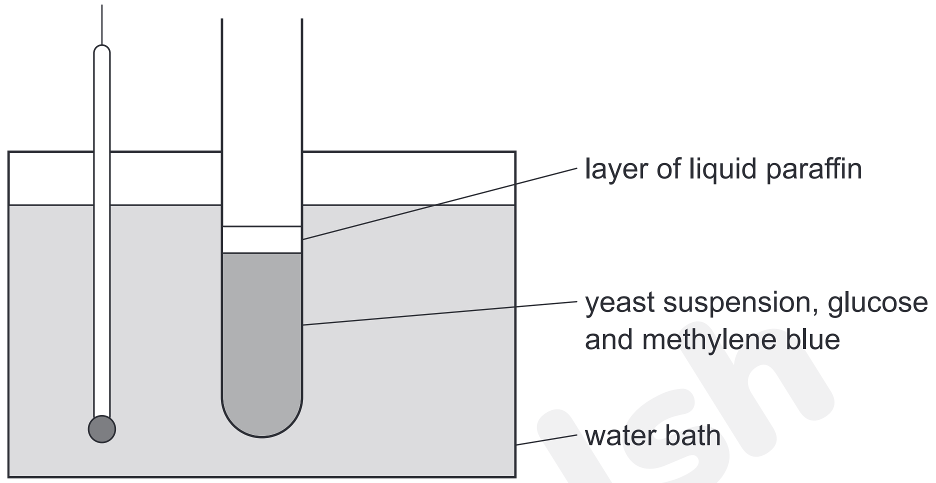

Image 12.1

(a) Explain why the methylene blue lost its colour. [2]

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Table 12.2 shows the results.

Table 12.2

Temperature / °C	Trial 1 / s	Trial 2 / s	Trial 3 / s	Mean time / s	Rate / 1000 ÷ mean time
20	612	598	605	605	1.7
30	290	302	296	296	....
40	148	152	212	....	....
50	205	198	201	201	5.0
60	> 1200	> 1200	> 1200	–	0.0

(b) (i) Identify the anomalous result in **Table 12.2**. [1]

....

Tutor only

(ii) Complete **Table 12.2**. Do **not** include the anomalous result. Give rates to **1 decimal place**. [2]

(c) Plot a graph of rate against temperature on the grid below. Join the points with straight lines. [4]

(d) Explain why a layer of liquid paraffin was placed on top of the suspension. [1]

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(e) Describe a suitable control for this investigation and explain why it is needed. [2]

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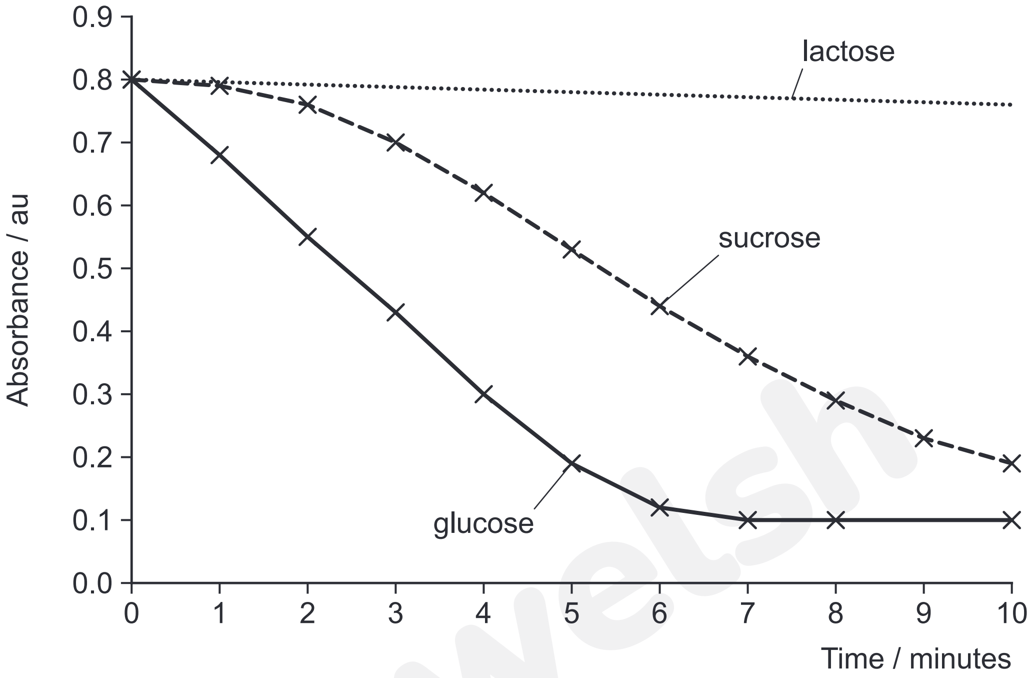
Tutor only

13. DCPIP is another artificial hydrogen acceptor. It is blue when oxidised and colourless when reduced. A student kept a yeast suspension without any sugar for 24 hours. The yeast was then mixed with DCPIP and one of three sugars at the same concentration. A colorimeter measured the absorbance of the mixture every minute. The more blue DCPIP present, the higher the absorbance. **Graph 13.1** shows the results. A tube with water in place of sugar gave the same results as lactose.



Graph 13.1

(a) Explain why the absorbance fell when glucose was present. [2]

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(b) Calculate the mean rate of change in absorbance with glucose during the first 4 minutes. Give the units. [2]

Rate = ...

Tutor only

(c) Suggest why the rate was lower with sucrose than with glucose during the first 3 minutes. [2]

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(d) Using **Graph 13.1**, explain what the results show about the ability of this yeast to respire lactose. [2]

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(e) Explain why the yeast was kept without sugar for 24 hours before the experiment. [1]

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(f) Explain **one** advantage of using a colorimeter rather than judging the colour change by eye. [1]

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Tutor only

14. Seed banks store seeds of wild plants for many years. The viability of stored seeds can be checked with a solution of a tetrazolium compound (TTC). TTC is colourless, but it turns red when it is reduced by dehydrogenase enzymes in living tissue.

Seeds were soaked in water for 18 hours and cut lengthways through the embryo. They were then placed in TTC solution in the dark at 30 °C for 3 hours. Only seeds with a fully red embryo were counted as viable. **Table 14.1** shows the results for one species of wildflower after different storage times.

Table 14.1

Storage time / years	Seeds tested	Embryo fully red	Embryo partly red	Embryo not stained	Percentage viable
0	50	48	1	1	96
10	50	45	3	2	90
20	50	38	6	6	....
30	50	21	14	15	....

(a) Explain why the embryos of living seeds turned red. [2]

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(b) Complete **Table 14.1**. [2]

(c) Explain why the seeds were cut to expose the embryo. [1]

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(d) Suggest why the seeds were soaked in water before the test. [1]

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(e) Suggest why the seeds were kept in the dark while in the TTC solution. [1]

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Tutor only

(f) Suggest why seeds with a partly red embryo make the results less certain, and how the viability of the seeds could be checked in another way. [2]

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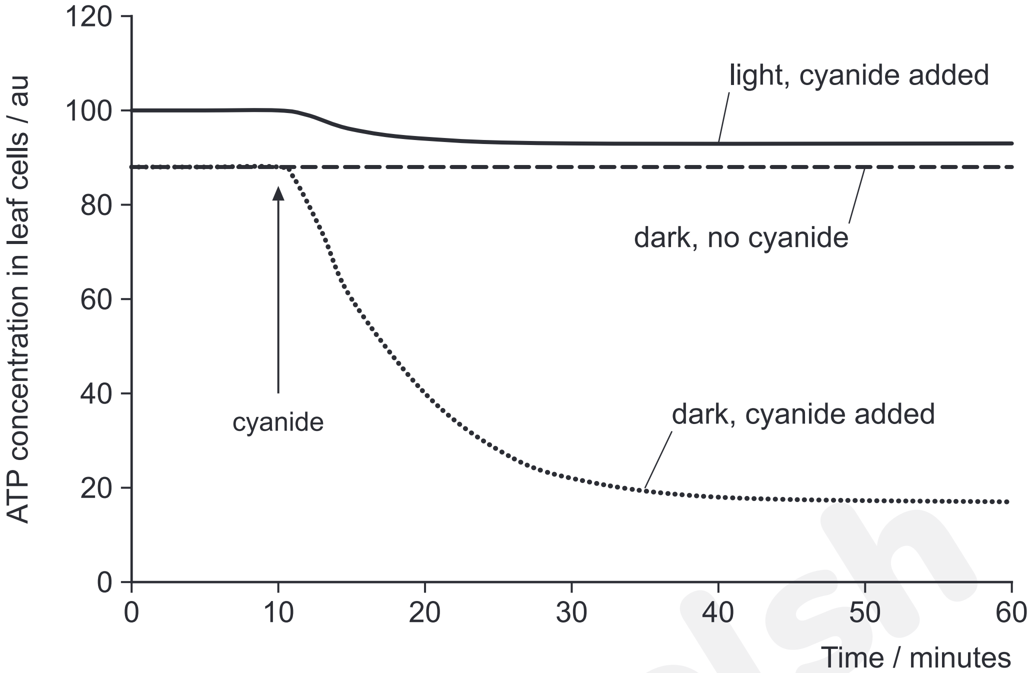
Tutor only

15. Leaf mesophyll cells contain both mitochondria and chloroplasts. Leaf discs were kept in the light or in the dark. At 10 minutes, some discs were given cyanide at a concentration that blocks only the final carrier of the mitochondrial electron transport chain. **Graph 15.1** shows the concentration of ATP in the leaf cells.



Graph 15.1

Describe how electron transport chains in mitochondria and in chloroplasts produce proton gradients, including the source of the excited electrons in each organelle. Explain how a proton gradient is used to synthesise ATP. Use **Graph 15.1** to explain the effect of cyanide on the concentration of ATP in leaf cells in the dark and in the light. [9 QER]

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END OF WORKSHEET

9

Turn over.

A Tutor Meets Tutee project

BioWelsh worksheets are written and checked by Tutor Meets Tutee tutors for WJEC A level Biology students.

Mark this worksheet with the BioWelsh mark scheme **BW-A2-3.1-W1** (MS).

Acknowledgements

Image 3.1: Photo: Louisa Howard, public domain (Wikimedia Commons). Cropped; letters and scale bar redrawn.

Image 8.1: Photo: Dartmouth Electron Microscope Facility, Dartmouth College, public domain (Wikimedia Commons). Cropped; letters added.