1. Aerobic respiration may be summarised by the following equation:

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$$

Although carbon dioxide and water are products of aerobic respiration, the equation is an over-simplification of the process.

State **and** explain **one** way in which this equation is an over-simplification.

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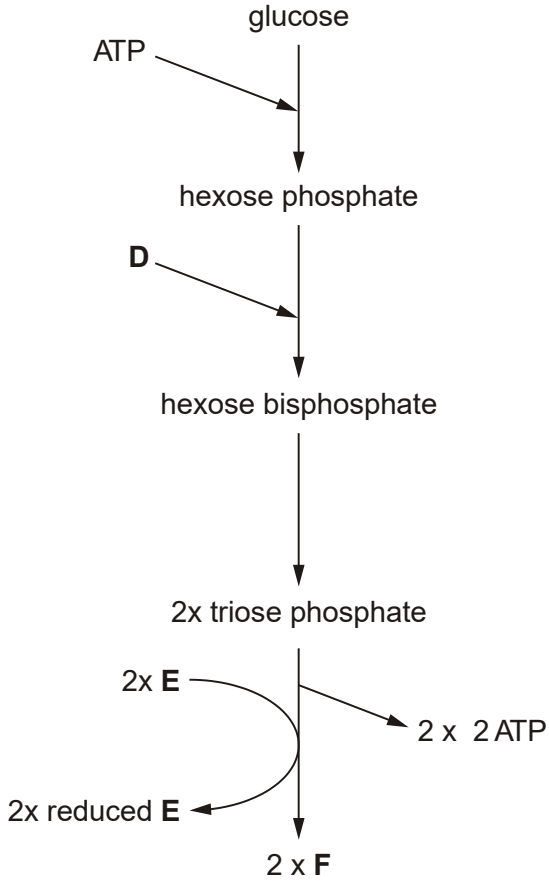
[Total 2 marks]

2. The figure below represents the first stage of respiration.



(i) Name the stage represented by the figure above.

.....

[1]

(ii) State precisely where in the cell this stage takes place.

.....

[1]

(iii) Identify the compounds **D**, **E** and **F**.

D .....

E .....

F .....

[3]

[Total 5 marks]

3. In **anaerobic** conditions, compound **F** does not proceed to the link reaction.

Describe the fate of compound **F** during anaerobic respiration in an animal cell **and** explain the importance of this reaction.

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[Total 5 marks]

4. Fig. 1 is a drawing of a common seal, *Phoca vitulina*, an aquatic mammal.

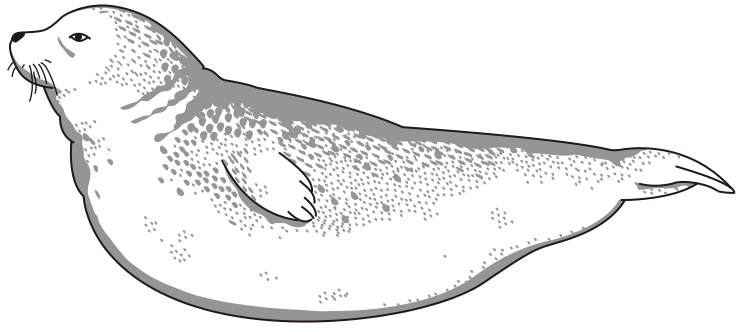

Fig. 1

The seal comes to the surface of the water to obtain air and it can then stay underwater for over 20 minutes.

Fig. 2 shows a seal at the surface of the water and Fig. 3 shows the same animal then submerging again.

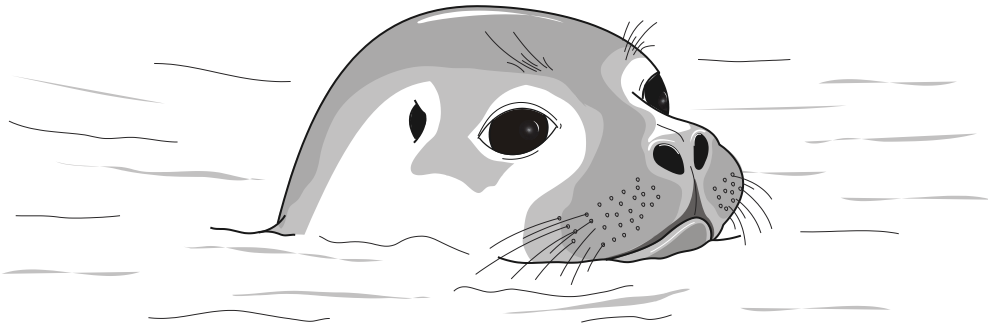

Fig. 2

Fig. 3

Suggest how the seal is adapted to respire for such a long time underwater.

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[Total 3 marks]

5. Herbicides (weedkillers) interfere with electron transport by accepting electrons.

Suggest how this causes plants to die.

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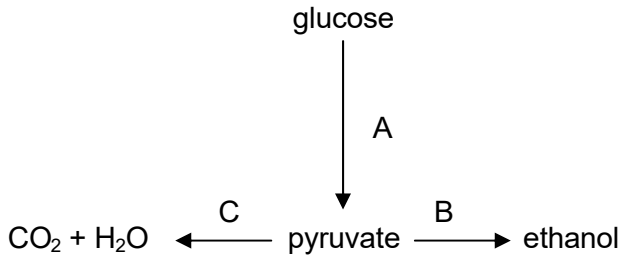
[Total 3 marks]

6. The figure below shows the relationship between various metabolic processes in yeast



(i) Identify the three metabolic processes.

A .....

B .....

C .....

[3]

(ii) State the letter of the pathway in which acetyl coenzyme A is required.

.....

[1]

(iii) State the letter of the pathway in which ATP is utilised.

.....

[1]

[Total 5 marks]

7. In an investigation yeast cells were homogenised (broken up) and the resulting homogenate centrifuged. Portions containing only nuclei, ribosomes, mitochondria and cytosol (residual cytoplasm) were each isolated. Samples of each portion, and of the complete homogenate, were incubated in four ways:

1 With glucose.

2 With pyruvate.

3 With glucose and cyanide.

4 With pyruvate and cyanide.

Cyanide inhibits carriers in the electron transport chain, such as cytochromes.

After incubation, the presence or absence of carbon dioxide and lactate in each sample was determined.

The results are summarised in the table below.

✗ = absent ✓ = present ✓ = a little

	samples of homogenate									
	complete		nuclei only		ribosomes only		mitochondria only		cytosol	
	carbon dioxide	ethanol	carbon dioxide	ethanol	carbon dioxide	ethanol	carbon dioxide	ethanol	carbon dioxide	ethanol
1 glucose	✓	✓	✗	✗	✗	✗	✗	✗	✓	✓
2 pyruvate	✓	✓	✗	✗	✗	✗	✓	✗	✓	✓
3 glucose and cyanide	✓	✓	✗	✗	✗	✗	✗	✗	✓	✓
4 pyruvate and cyanide	✓	✓	✗	✗	✗	✗	✗	✗	✓	✓

(i) Explain why more carbon dioxide is produced when the complete homogenate is incubated with just glucose or pyruvate than when cyanide is present.

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[3]

(ii) Explain why carbon dioxide is produced when mitochondria are incubated with pyruvate but **not** when incubated with glucose.

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[3]

(iii) Explain why, in the presence of cyanide, ethanol production can still occur.

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[3]

[Total 9 marks]

8. (i) State what is meant by the term respiratory substrate.

.....

[1]

The equation below shows aerobic respiration of compound **A**.

$$C_{55}H_{100}O_6 + 77O_2 \rightarrow 55CO_2 + 50H_2O$$

compound **A**

The respiratory quotient (RQ) is defined as:

$$RQ = \frac{\text{volume of } CO_2 \text{ released}}{\text{volume of } O_2 \text{ absorbed}}$$

(ii) Calculate the RQ for this reaction. Show your working.

Answer = ...

[2]

(iii) Compound **A** is a fat.

Suggest what the RQ of a carbohydrate, such as glucose, might be.

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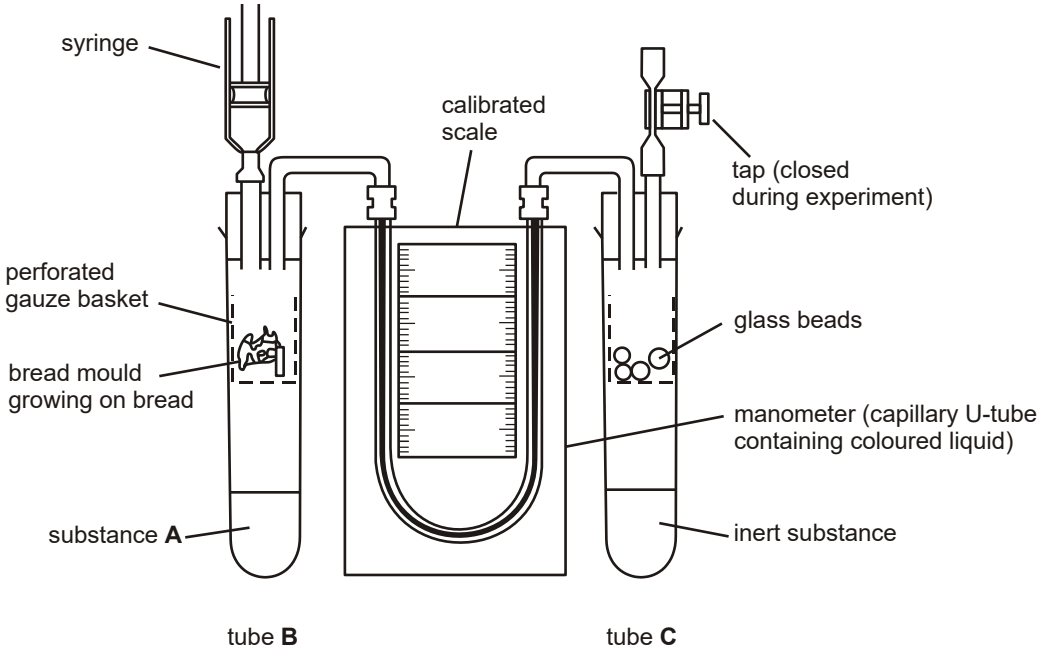
[1]

[Total 4 marks]

9. Below is a diagram of a respirometer. A respirometer can be used to measure the oxygen uptake of living organisms.



Describe how the apparatus shown in the diagram could be used to determine the **rate** of respiration of the bread mould, *Mucor*.

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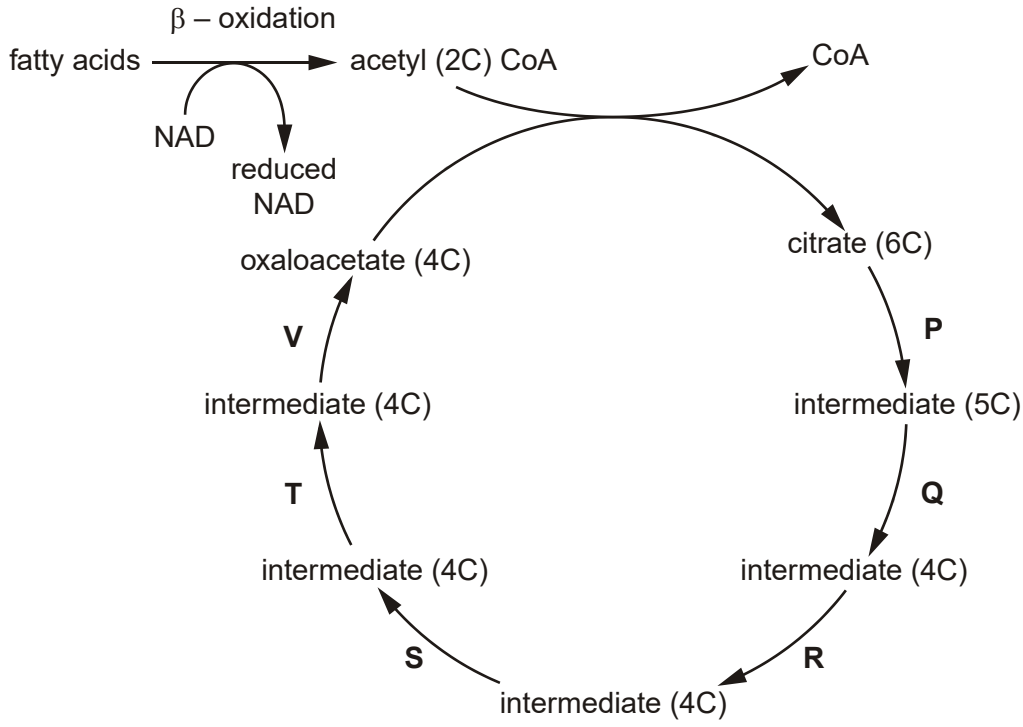
[Total 4 marks]

10. Below is an outline diagram of the Krebs cycle. A two carbon acetyl group enters the cycle by combining with a molecule of oxaloacetate. A molecule of citrate is formed which is decarboxylated and dehydrogenated to regenerate the oxaloacetate.



(a) (i) Explain the following terms:

decarboxylation .....

dehydrogenation .....

[2]

(ii) State the **letters** of the individual steps in the cycle where decarboxylation is taking place.

.....

[1]

(b) ATP is made directly by substrate level phosphorylation in the Krebs cycle.

State the number of ATP molecules that are made directly **per 'turn'** of the cycle.

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[1]

(c) The diagram also shows that fatty acids can be converted into acetyl CoA units by a process known as β-oxidation. Both this process and the Krebs cycle require NAD. The Krebs cycle also requires FAD. The hydrogen atoms released in β-oxidation and the breakdown of acetyl CoA in the Krebs cycle reduce the NAD and FAD molecules.

(i) State the number of reduced NAD and reduced FAD molecules that are formed in the Krebs cycle from **one** molecule of acetyl CoA.

reduced NAD .....

reduced FAD .....

[2]

(ii) State where the reduced NAD and reduced FAD molecules are reoxidised **and** describe what happens to the hydrogen atoms.

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[4]

(d) The liver is responsible for producing enzymes which detoxify alcohol by breaking it down into smaller units. This breakdown by enzymes uses NAD. This means that other reactions that use NAD are less likely to take place. The build up of fats in the liver is one of the first signs of liver damage due to excessive alcohol intake.

Using the information in the diagram above, explain why the build up of fats occurs in the liver of an individual who consumes large amounts of alcohol.

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[3]

[Total: 13 marks]

11. Many seeds contain food stores, including starch, proteins and lipids. A fully developed seed of *H. annuus* contains between 40% and 50% of unsaturated fatty acids, including oleic acid and linoleic acid. These fatty acids can be used as respiratory substrates for the production of ATP.

(i) Explain why seeds need ATP.

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[2]

(ii) Explain the **advantages** of storing lipid for use as a respiratory substrate in seeds.

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[2]

[Total 4 marks]

12. After chasing prey, a cheetah breathes rapidly (pants) for half an hour before it can run again.

Explain why panting is necessary.

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[Total 4 marks]

13. Hummingbirds are very small. Typically their mass is between 3 and 5 g. They are able to hover at a fixed point in the air by beating their wings very rapidly. The rufous hummingbird, *Selasphorus rufus*, is a migratory species. It breeds in Canada and Alaska in the summer, migrates south to Mexico in the autumn and returns to high latitudes in spring after completing its annual moult (loss of feathers, which are then re-grown).

(a) Suggest why the rufous hummingbird has a very high requirement for energy.

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[4]

In order to save energy, rufous hummingbirds can enter a state called torpor during the night. This is when their metabolic rate and body temperature both drop to a very low level. An investigation into how rufous hummingbirds use, save and store energy at different times of year was carried out. Key findings of the study are given in Figs. 1, 2 and 3 below.

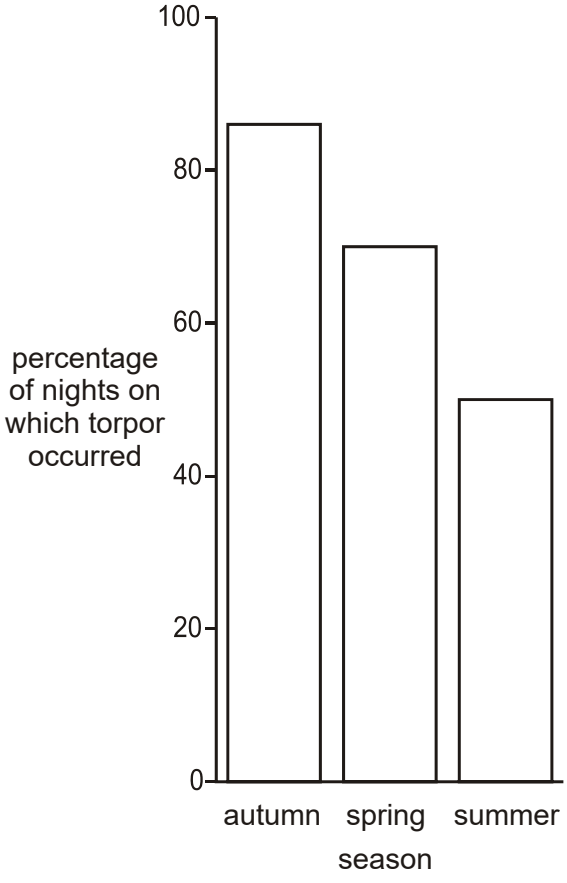

Fig. 1

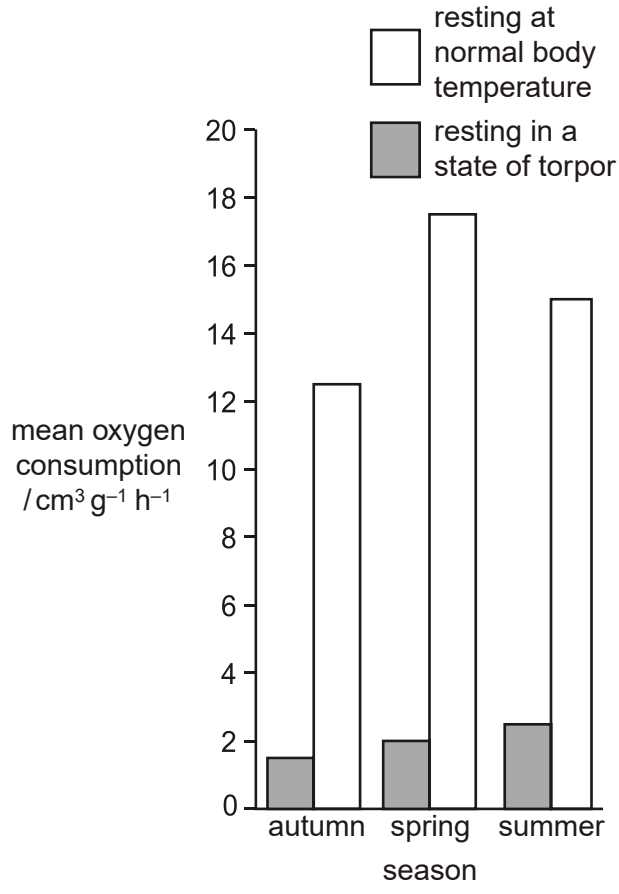

Fig. 2

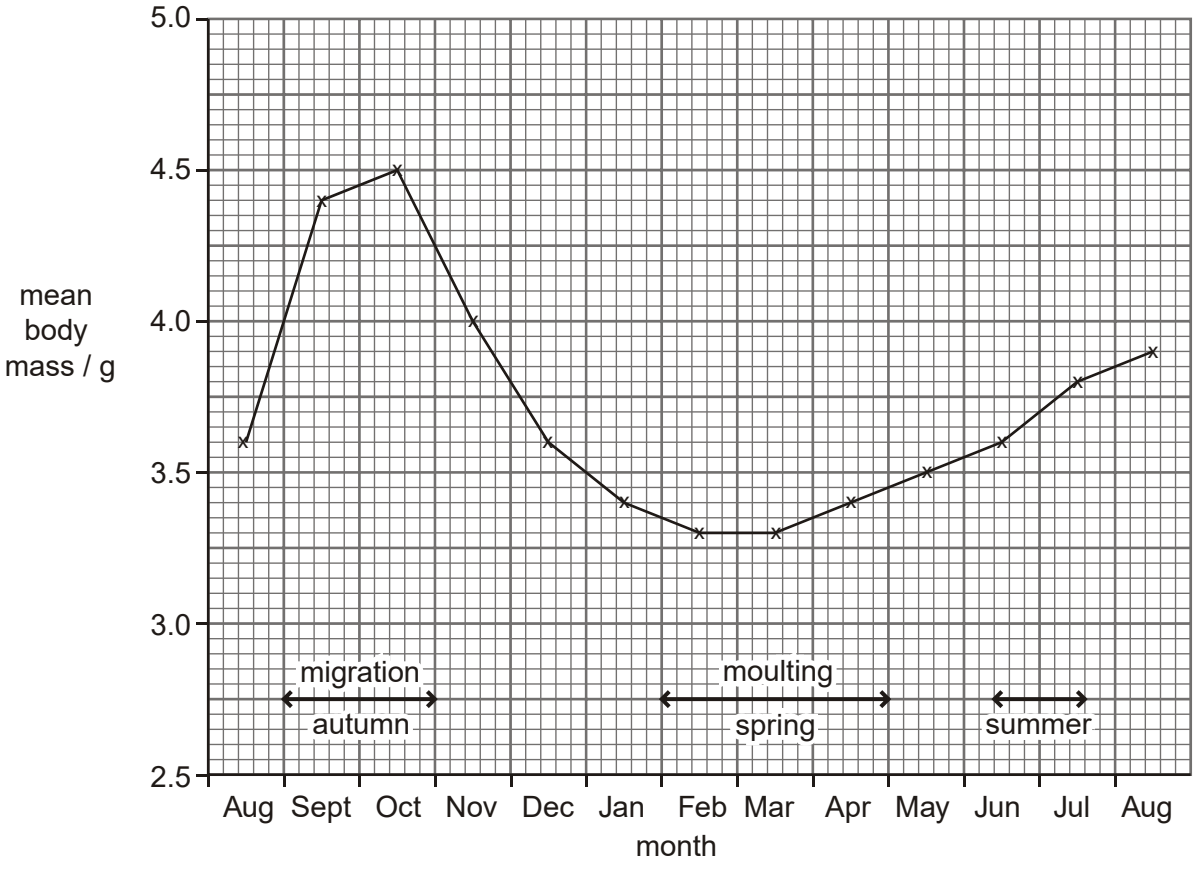

Fig. 3

- Fig. 1 shows how use of torpor by the birds varies according to season.
- Fig. 2 compares the oxygen consumption of birds resting at normal body temperature with that of birds resting in a state of torpor.
- Fig. 3 shows how body mass of the birds changes over the course of a year.

(b) Use Figs. 1, 2 and 3 to describe and explain the results for the birds in the September-October (autumn) period.

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[4]

(c) Suggest how the low body mass of the birds in spring may be related to enhancing the birds' survival during the moulting period, when the feathers are lost and regrown.

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[2]

(d) It is suggested that **smaller** birds, which have a larger surface area to volume ratio when compared to larger birds, require **more** oxygen per gram of their body mass.

Discuss whether the data given in Figs. 3.1, 3.2 and 3.3 support this hypothesis.

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[3]

[Total: 13 marks]

14. The bulb of the onion plant, *Allium cepa*, is widely used in food preparation. It has a strong smell and flavour when raw due to sulphur-containing chemicals that are released when an onion is cut. The precursor of these flavour molecules is in the cytoplasm of the onion bulb cells. This precursor is acted on by an enzyme called alliinase, which is stored in the cell vacuole. Alliinase breaks the precursor molecule into two volatile flavour molecules, which enter the air, and into a third product, pyruvate, which remains dissolved in the onion tissue.

(a) Explain why the strong smell of an onion is only released when the onion is cut or damaged.

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[3]

The strength of an onion's flavour can be estimated by measuring the concentration of pyruvate in cut onions. The table below shows the pyruvate concentration of fresh onions, onions from the previous season that have overwintered, and onions of a new variety called Supasweet.

type of onion	pyruvate concentration / μmol g^{-1}
fresh	7
overwintered	4
Supasweet	3

(b) Suggest why the concentration of pyruvate is lower in an overwintered onion.

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[2]

(c) The mild Supasweet onions were produced by a process of artificial selection. The growing environment also needs to be manipulated to decrease the concentration of flavour molecules.

(i) Explain how artificial selection was used to produce the mild Supasweet onions.

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[3]

(ii) Use the information given about the biochemistry of the onion smell and flavour to suggest an environmental change that would enable a milder onion to be grown.

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[1]

(d) It is claimed that strong onions, with a more pungent smell and flavour, are able to resist rotting over the winter better than milder onions.

Describe how you would test this claim.

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[3]

[Total: 12 marks]

15. All organisms require energy in order to remain alive. Plants use solar energy to combine water and carbon dioxide into complex organic molecules. Both plants and animals then break down organic molecules in respiration. Energy released in this process is used in the formation of ATP.

Describe the structure of ATP.

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[Total: 4 marks]

16. In this question, one mark is available for the quality of use and organisation of scientific terms.

There are a number of organic molecules in cells whose role is to transfer hydrogen atoms from one compound to another. Examples include NAD, FAD and NADP.

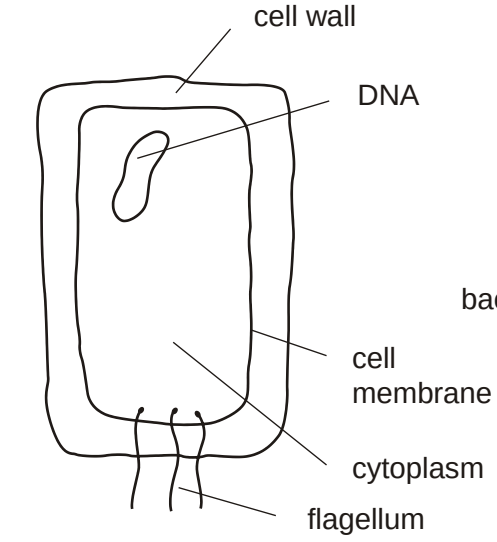
NAD, FAD and NADP are important molecules in plant cells. Describe, in detail, the role of these molecules within a **palisade mesophyll cell**.

[7]

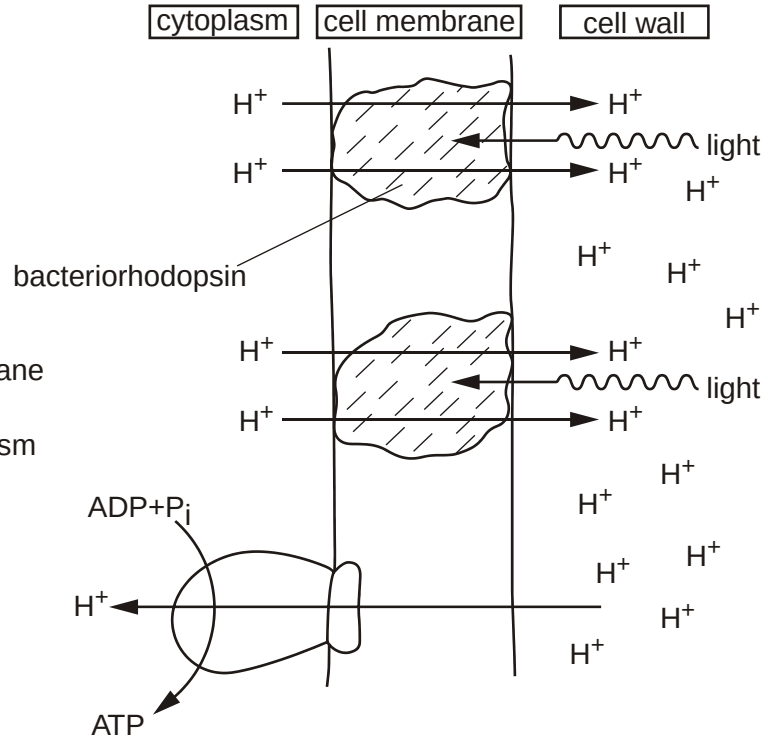
Quality of Written Communication [1]

[Total 8 marks]

17. Some bacteria can survive in anaerobic conditions by utilising light energy to drive the production of ATP in the cell membrane. In such conditions, *Halobacterium salinarium* makes the protein bacteriorhodopsin. When this protein absorbs light, protons (H^+) are pumped outwards across the cell membrane. This is shown in the figure below.



Halobacterium salinarium
(general structure)



Using the information above together with your knowledge of photophosphorylation and oxidative phosphorylation, explain how *H. salinarium* makes ATP in anaerobic conditions.

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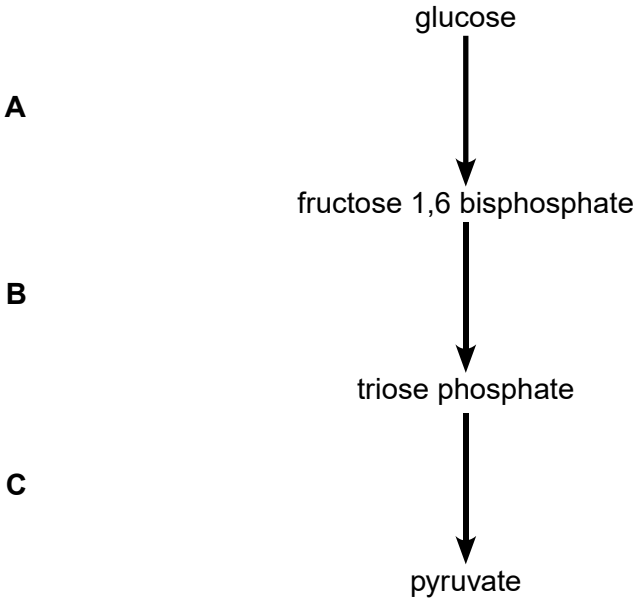
[Total 4 marks]

18. The following figure is an outline of the glycolytic pathway.



With reference to the figure, state the letter, **A**, **B** or **C**, in the glycolytic pathway where the following processes occur.

phosphorylation using ATP ……..

dehydrogenation ……..

formation of ATP ……..

splitting of a hexose ……..

[Total 4 marks]

19. Explain why, under **aerobic** conditions, lipids have a greater energy value per unit mass than carbohydrates or proteins.

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[Total 2 marks]

20. Many chemicals will 'uncouple' oxidation from phosphorylation. In this situation, the energy released by oxidation of food materials is converted into heat instead of being used to form ATP. One such compound is dinitrophenol, which was used in munition factories for the manufacture of explosives during the First World War. People working in these factories were exposed to high levels of dinitrophenol.

Suggest **and** explain why people working in munitions factories during the First World War became very thin regardless of how much they ate.

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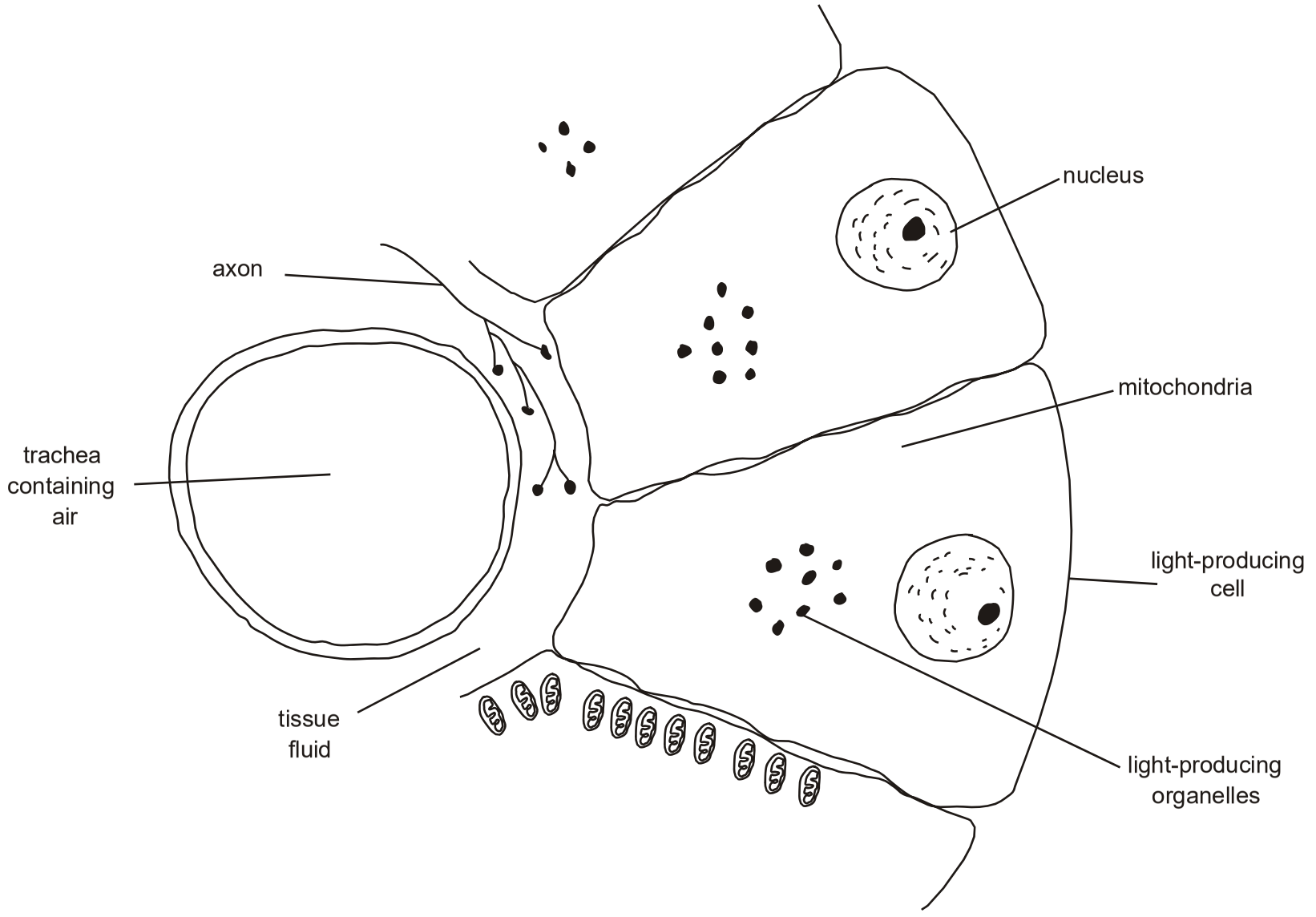
[Total 3 marks]

ø Ô**21.** Read the passage below and answer the questions that follow, which relate to this passage.

How fireflies light up

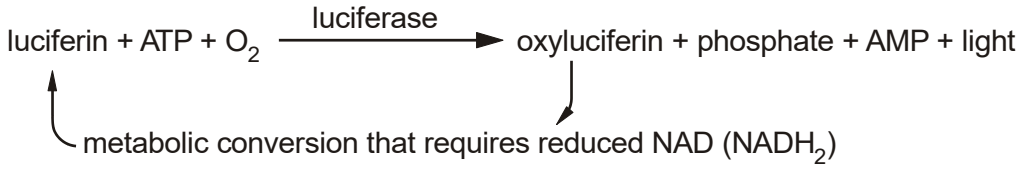
Fireflies are insects which have organs producing flashes of light. Fireflies are active at night and the light flashes are an important part of their sexual behaviour.

Within their light-producing organs are tubes, filled with air, called tracheae. These tracheae supply oxygen to light-producing cells. The figure below shows the arrangement of light-producing cells around a trachea.


nucleus
axon
mitochondria
trachea
containing
air
light-producing
cell
tissue
fluid
light-producing
organelles

Light is produced by organelles situated well away from the surfaces of the cells nearest the trachea.

The reaction that produces light requires **both** oxygen **and** ATP.



When the organ is not producing any light, the numerous mitochondria use oxygen very fast. These mitochondria lie between the tracheae and the light-producing organelles, just under the cell membrane, so that no oxygen is available for the oxidation of luciferin.

A flash of light is produced when nerve impulses stimulate the walls of the tracheae and the cytoplasm of the light-producing cells, to produce nitrous oxide. Nitrous oxide diffuses rapidly through the cells. It enters mitochondria and inhibits oxidative phosphorylation, so the oxygen concentration increases in the cytoplasm of the light-producing cells.

Nitrous oxide is very unstable and breaks down quickly, so its effects are temporary.

An extract of crushed fireflies was found to be an extremely sensitive test for the presence of ATP in foods, such as milk and meat. The more bacteria there are in the food, the more light is produced, provided the mixture of food and firefly extract is well oxygenated.

Fortunately for fireflies, luciferin can be synthesised artificially and luciferase has been produced by gene technology, using methods similar to those for producing human insulin.

(a) Different species of firefly often live in the same habitat. The frequency with which a firefly flashes its light organ on and off, is a characteristic of a species.

Suggest an advantage, for fireflies, of flashing at a characteristic frequency.

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.....

[1]

(b) (i) State the process by which oxygen reaches the light-producing organelles.

.....

[1]

(ii) Explain why the light-producing organelles are located well away from the plasma (cell surface) membrane.

.....

[1]

(c) Suggest why it is important for the effects of nitrous oxide to be temporary.

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[2]

(d) Light-producing cells in fireflies do not divide. State **three** ways in which these cells might use ATP **other** than in the production of light.

1 .....

2 .....

3 .....

[3]

(e) If a firefly is suddenly crushed, for example by hitting a car windscreen, it produces a prolonged and unusually bright flash of light after which all light production ceases.

Suggest an explanation for these observations.

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[3]

(f) A solution containing luciferin, luciferase and oxygen glows when painted onto the surface of meat contaminated by live bacteria, but not if the meat is contaminated by dead bacteria.

Explain this observation.

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[1]

(g) What substance would be extracted and purified from light-producing cells of fireflies in order to produce luciferase by gene technology?

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[1]

[Total 13 marks]

22. An investigation was carried out into photosynthesis and respiration in a leaf. The net uptake of carbon dioxide by the leaf in bright light, and the mass of carbon dioxide released in the dark were determined at different temperatures. The results are shown in the following table.

temperature / °C	5	10	15	20	25	30
net uptake of CO_2 in bright light / mg g^{-1} dry mass h^{-1}	1.3	2.4	3.0	3.3	3.0	2.2
release of CO_2 in dark / mg g^{-1} dry mass h^{-1}	0.4	.07	1.0	1.4	1.9	2.8
true rate of photosynthesis / mg CO_2 g^{-1} dry mass h^{-1}						

(i) State **two** types of tissue in a leaf where there is a net uptake of carbon dioxide in bright light.

1 .....

2 .....

[2]

(ii) Assuming the rate of respiration in the light is equal to the rate of respiration in the dark, calculate the true rate of carbon dioxide uptake in photosynthesis at each temperature and **add the figures to the table above**.

[1]

(iii) The term temperature coefficient (Q_{10}) is used to express the effect of a 10 °C rise in temperature on the rate of a chemical reaction. It is calculated in the following way:

$$Q10 = \frac{\text{rate of reaction at } \mathbf{t} + 10\ °C}{\text{rate of reaction at } \mathbf{t}\ °C}$$

where **t** = any given temperature.

Between 5 °C and the optimum temperature for enzyme-catalysed reactions, the Q_{10} is approximately 2.

Discuss whether the data in the table above supports this statement for both respiration and photosynthesis.

respiration .....

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photosynthesis .....

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[4]

(iv) When plants are grown in glasshouses during autumn and winter, when the natural light intensities are low, it is important that temperatures are kept relatively low.

With reference to respiration **and** photosynthesis, explain why it is essential to do this.

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[3]

[Total 10 marks]

23. After a lawn had been cut using a mower, the grass cuttings were piled up in a corner of the garden.

Ten days later, the heap of grass cuttings had steam rising from it.

A tube was pushed into the heap and an air sample was obtained from near its centre. This air sample was dried and then analysed to find the percentages of oxygen and carbon dioxide present. These concentrations could be measured to an accuracy of ±1 %.

A thermometer was also inserted into the centre of the heap and the temperature was recorded.

The results of the investigation are shown in the table below, which also shows data for the air above the ground near the heap.

sampling point	oxygen concentration / %	carbon dioxide concentration / %	temperature / °C
near the centre of the heap of grass	13	8	42
above the ground near the heap	21	0	16

As the heap of grass was in the shade for several hours before the readings were taken, it could **not** have become warm by absorbing solar radiation.

Explain the results shown in the table.

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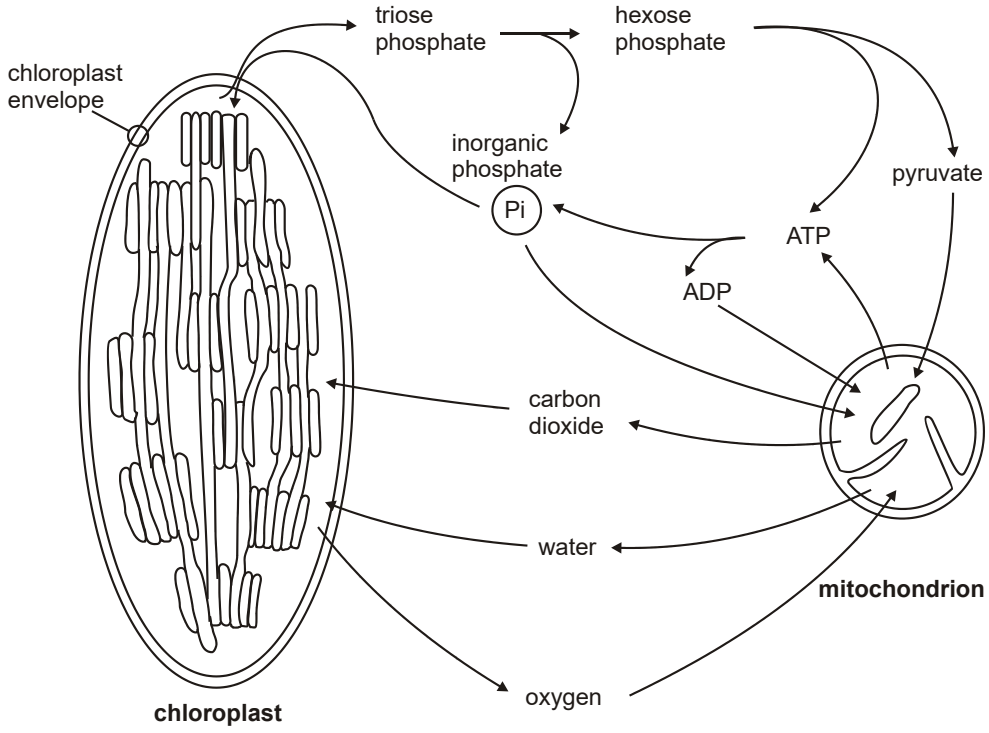
[Total 5 marks]

24. Palisade cells have both chloroplasts and mitochondria. Exchanges between a mitochondrion, a chloroplast and the cytoplasm surrounding them are shown in the figure below.



(a) A leafy shoot can be sealed inside a transparent container. The concentration of oxygen in the atmosphere within this container can be measured. In the dark, the oxygen concentration falls. At high light intensities, the oxygen concentration increases. At a particular light intensity, the oxygen concentration in the container remains constant.

Use the figure above to explain how it is possible for the oxygen concentration to remain constant.

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[4]

(b) Explain why there is no build up in the concentration of phosphate ions inside mitochondria as a result of the inward passage of phosphate ions.

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[2]

(c) Triose phosphate moves out of chloroplasts by passing through carrier proteins that are part of the chloroplast envelope. These proteins allow an inorganic phosphate ion to pass inwards at the same time as triose phosphate moves outwards.

Suggest why the movement of triose phosphate out of chloroplasts is an example of facilitated diffusion rather than active transport.

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[2]

(d) Many biologists believe that both mitochondria and chloroplasts evolved, at an early stage in the history of the earth, from prokaryotic organisms that inhabited the cytoplasm of eukaryotic host cells.

State **two** structural features of mitochondria and chloroplasts that are also present in prokaryotic cells.

1 .....

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2 .....

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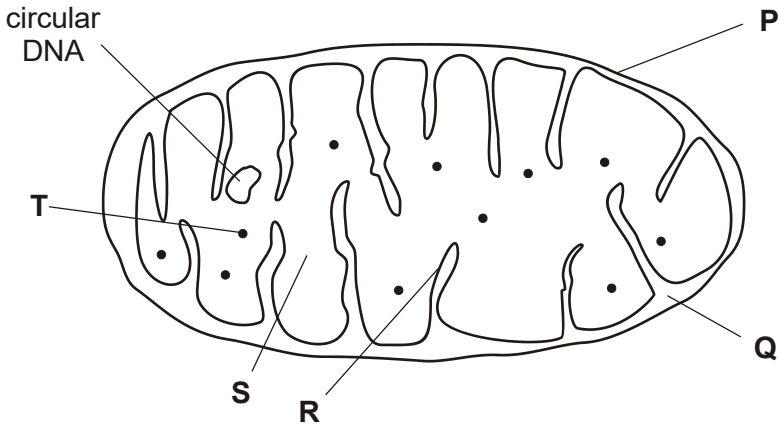
[2]

[Total 10 marks]

25. The figure below is a diagram of a section through a mitochondrion.



In each case, state the letter which indicates the site of:

the Krebs cycle …….

oxidative phosphorylation …….

decarboxylation …….

[Total 3 marks]

26. Name a hydrogen carrier that links the Krebs cycle to the electron transport chain.

.....

[Total 1 mark]