Candidate Name	Centre Number					Candidate Number				
StemUp Model Solution										

A LEVEL BIOLOGY

COMPONENT 1

Energy for Life

SPECIMEN PAPER

2 hours

For Examiner's use only		
Question	**Maximum Mark**	**Mark Awarded**
1.	**13**	
2.	**10**	
3.	**10**	
4.	**11**	
5.	**16**	
6.	**16**	
7.	**7**	
8.	**8**	
9.	**9**	
Total	**100**	

ADDITIONAL MATERIALS

In addition to this examination paper, you will need a calculator and a ruler.

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen. Do not use gel pen. Do not use correction fluid.
Write your name, centre number and candidate number in the spaces at the top of this page.
Answer **all** questions.
Write your answers in the spaces provided in this booklet.

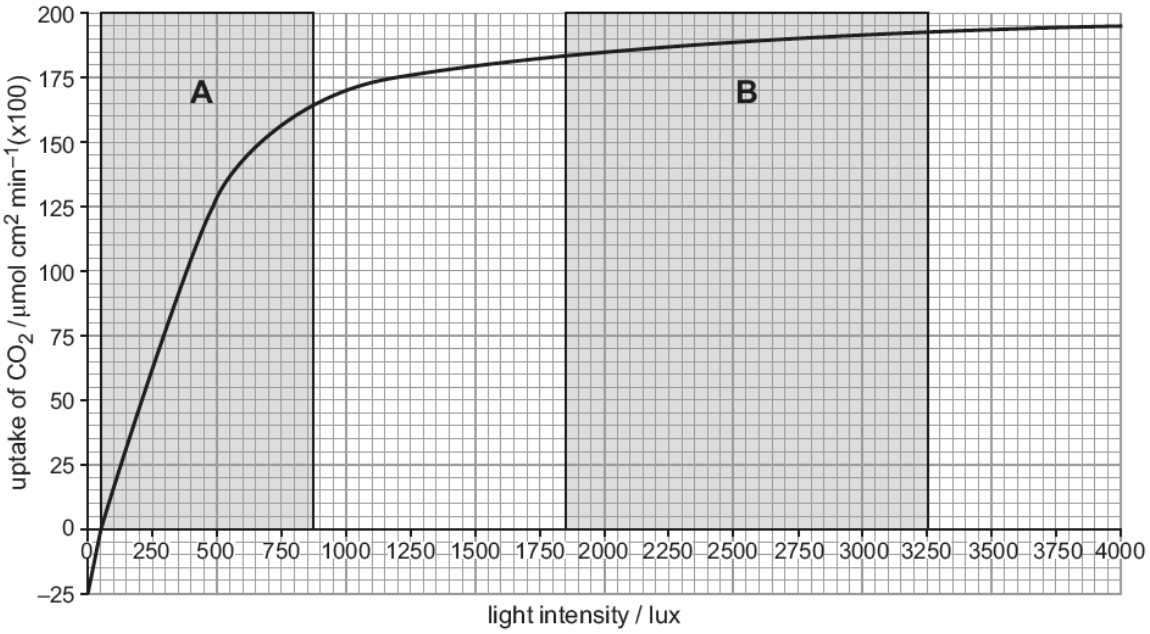
INFORMATION FOR CANDIDATES

The number of marks is given in brackets at the end of each question or part-question.
The assessment of the quality of extended response (QER) will take place in question 9.

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*Answer **all** questions.*

1. The diagram below shows the rate of uptake of carbon dioxide for a species of grass at different light intensities. Measurements were taken at a constant external carbon dioxide concentration and a temperature of 15 °C.



(a) Calculate the rate of uptake of carbon dioxide between 250 and 750 lux. Express your answer in standard form. [2]

Rate = (155 – 65) ÷ (750 – 250) = 90 ÷ 500 = 0.18

0.18 ÷ 100 = 0.0018 = 1.8×10^{-3} ≈ 2×10^{-3}

Rate of uptake of carbon dioxide = ...*1.8×10^{-3}*..... µmol cm^{-2} min^{-1} lux^{-1}

(b) Explain the differences in the rate of uptake of carbon dioxide between parts A and B of the graph. [2]

Part A: CO_2 is in excess and light is limiting, so as light intensity increases so does the rate of CO_2 uptake.

Part B: CO_2 concentration has become the limiting factor for photosynthesis.

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(c) Below a light intensity of 50 lux, photosynthesis takes place even though there is no uptake of carbon dioxide. What conclusions can be made regarding the rates of photosynthesis and respiration taking place at light intensities up to and including 50 lux? [2]

Below 50 lux the rate of respiration is higher than the rate of photosynthesis, as CO_2 is being produced (negative uptake of CO_2). At 50 lux the CO_2 produced in respiration equals the CO_2 used in photosynthesis: the compensation point.

(d) Diuron is a weed-killer which is a very specific and sensitive inhibitor of photosynthesis.
It blocks the electron carrier binding site on Photosystem II. This stops the electron flow from where it is generated in Photosystem II, to the electron carrier. This reduces the ability of the plant to convert light energy into chemical energy.
Diuron only blocks electron flow from Photosystem II. It has no effect on Photosystem I or other reactions in photosynthesis, such as light absorption or carbon fixation in the Calvin cycle.

Describe the effects of Diuron on non-cyclic photophosphorylation and explain why cyclic photophosphorylation is not affected. [4]

It stops electrons from PSII being moved to PSI, so non-cyclic photophosphorylation stops and less ATP is made, so blocking the reduction of $NADP^+$ to NADPH. No photolysis of water takes place.
Cyclic photophosphorylation is not stopped as the electrons pass from PSI and return to PSI.

(e) Explain why a plant would die when the weed-killer Diuron is sprayed onto it. [3]

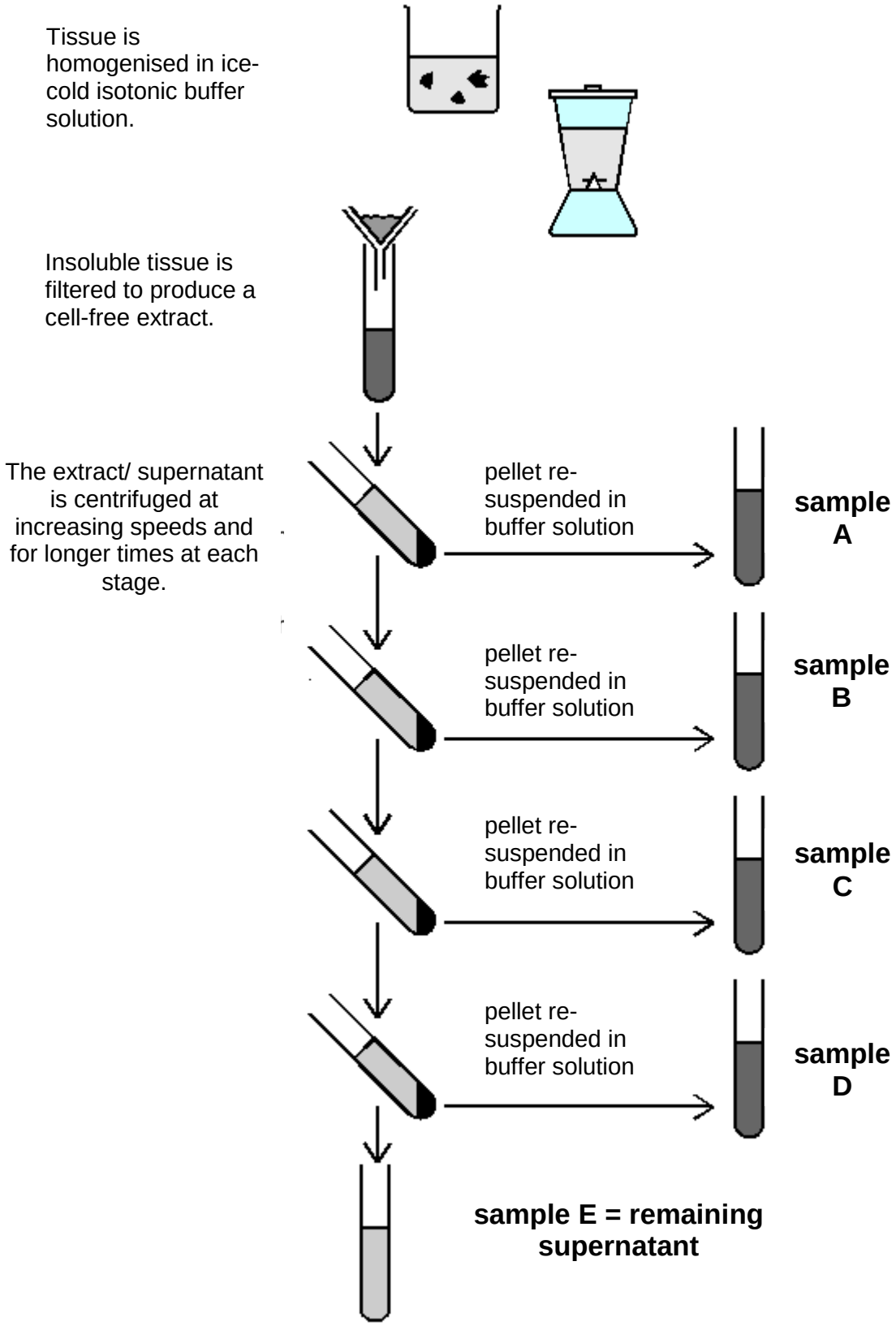
The plant cannot generate NADPH and less ATP is synthesised in the light-dependent stage.
So the Calvin cycle stops and no glucose is made.
Growing parts of the plant (sinks) will not have glucose for respiration, so the plant dies.

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2. The process shown in the diagram below shows the preparation of animal cell fractions. Each fraction contains only one type of cell component.



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Each sample was then incubated with glucose and pyruvate and the production of carbon dioxide and lactate was noted.

	Incubated with glucose		Incubated with pyruvate	
Sample	**Carbon dioxide produced**	**Lactate produced**	**Carbon dioxide produced**	**Lactate produced**
A	**NO**	**NO**	**NO**	**NO**
B	**NO**	**NO**	**YES**	**NO**
C	**NO**	**NO**	**NO**	**NO**
D	**NO**	**NO**	**NO**	**NO**
E	**NO**	**YES**	**NO**	**NO**

(a) Based on these results, identify the cell components which are present in samples **B** and **E**? Explain how you reached these conclusions. [5]

Sample B must contain mitochondria, because only mitochondria can use pyruvate as a substrate, and CO_2 is only produced in the link reaction and Krebs cycle, which only take place in the matrix. Sample E must contain only cytoplasm as it does not contain organelles, so only glycolysis can take place.

(b) Cyanide inhibits the enzyme cytochrome oxidase and prevents the regeneration of NAD. Explain why cyanide could be used to confirm which sample contained resuspended mitochondria. [3]

Cyanide only affects mitochondria, as cytochrome oxidase is part of the electron transport chain. No NAD is available as hydrogen acceptor, so the Krebs cycle stops and no CO_2 is produced.

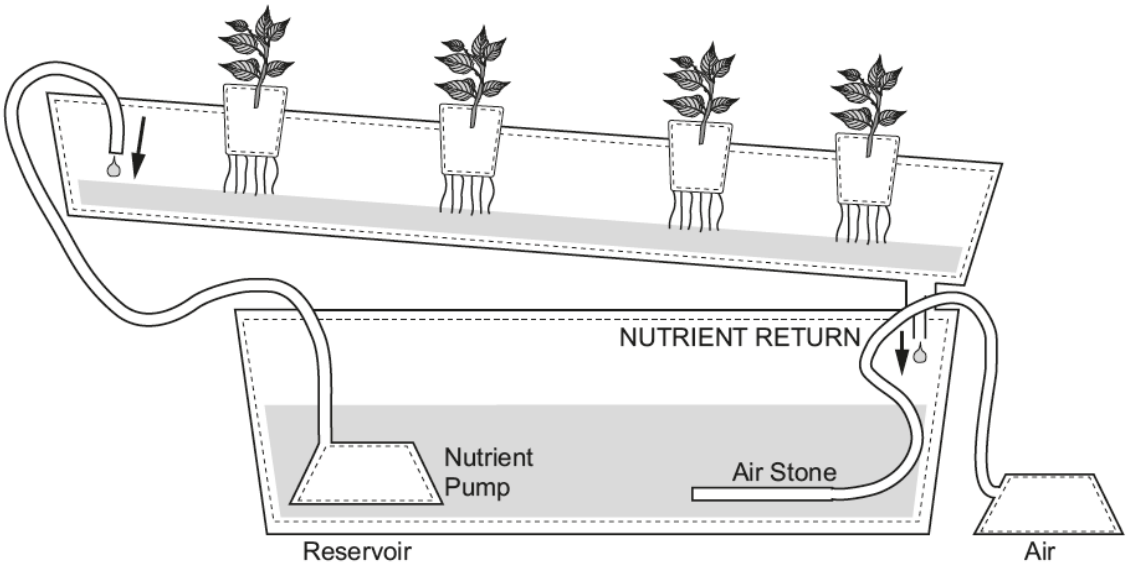
(c) Explain why the preparation of the cell fractions was carried out using an isotonic solution rather than pure water. [2]

So the water potential inside and outside the organelles is the same. In pure water, water enters by osmosis and organelles burst (lyse).

10

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3. Hydroponics is a method used to grow crops without soil. It involves growing plants in an aerated solution of nutrients as shown in the diagram below.



(a) Tomatoes are often grown using hydroponic systems. A commercially available hydroponic nutrient solution contained the following concentrations of six of the elements essential for plant growth.

element	concentration (mg dm^{-3})
N	70
P	50
K	120
Ca	11
Mg	40
S	55

Explain why the concentration of nitrogen and magnesium would need to be increased during the growing period of the tomato plants. [2]

As the plants get older and larger, more N is needed for protein and nucleic acid synthesis.

More Mg is needed for chlorophyll synthesis as more leaves grow.

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(b) Explain how ions pass from the soil water into the xylem and why the solution must be aerated for this to take place. [4]

Oxygen is needed for aerobic respiration to synthesise ATP, and ATP is needed for the active transport of ions into the root hair cells, so ions follow the symplast route.

At the endodermis the Casparian strip blocks the apoplast, so ions are moved from the apoplast into the symplast route.

Pericycle cells then control (actively pump) the movement of ions into the xylem.

.....

(c) A tomato grower who used a hydroponic system was concerned over reports that nitrate levels in the nutrient medium either lower or higher than an optimum could have a negative impact on root growth and subsequently, a reduced yield. He adapted his hydroponic system to determine the optimum nitrate levels needed to achieve maximum yield.

Identify the independent, dependent and controlled variables he could have used in his investigation. (You are not expected to provide values for the variables.) [4]

Independent variable: the concentration of nitrate in the nutrient solution.

Dependent variable: the change in mass of the roots (root growth), and the yield of tomatoes.

Controlled variables: the time the plants are exposed to each nitrate concentration;

the same temperature, light intensity and volume of growth medium;

the same concentrations of other ions, aeration, pH and variety and age of tomato plants.

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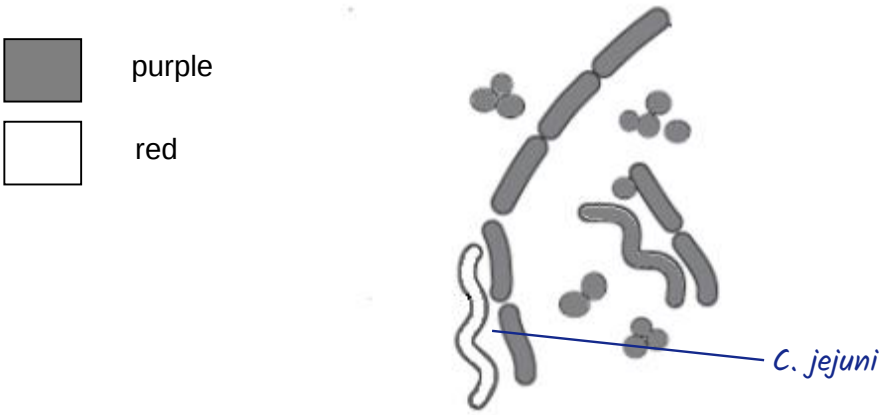
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4. Following an outbreak of food poisoning in a school, samples were taken from infected patients. The Gram staining technique was used, in conjunction with the shape of bacterial cells, to identify potentially pathogenic bacteria in the samples.

The diagram below shows part of a bacterial smear stained using the Gram staining technique.



Tests showed that the bacterium responsible for the food poisoning was *Campylobacter jejuni*. This helical, Gram negative bacterium colonises the digestive tract of many birds and cases of food poisoning by this bacterium are usually associated with poor preparation of poultry.

(a) (i) On the diagram above label a bacterium that could be *C. jejuni*. Explain your choice of bacterium. [1]

C. jejuni is helical so it has a spiral shape, and it is Gram negative so it would stain red.

(ii) Explain why this bacterium might be resistant to treatment by antibiotics. [2]

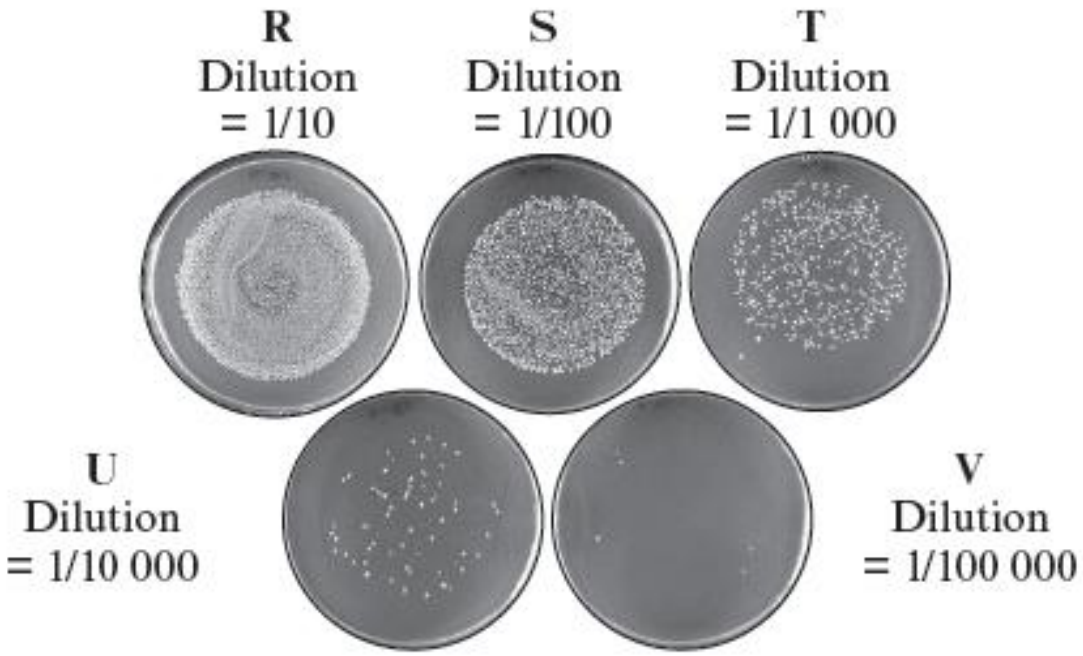
Being Gram negative, it has a lipoprotein/lipopolysaccharide layer outside the cell wall. So penicillin/antibiotics cannot penetrate this layer to reach the cell wall.

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(iii) Birds have a higher body temperature than mammals. One diagnostic tool used to identify *C.jejuni* involves culturing samples from infected people at 42°C. Explain how this helps identify *C.jejuni* from a mixture of bacteria. [1]

Most human pathogens have an optimum temperature of 37 to 38 °C, so only C. jejuni (adapted to the higher body temperature of birds) would grow well at 42 °C.

(b) The source of the infection was traced to a poultry dish that had been prepared in the school canteen. Using the viable count method Environmental Health Officers made an estimate of the number of bacteria in a sample of the food. Dilutions of 1/10, 1/100, 1/1 000, 1/10 000 and 1/100 000 were prepared and 0.5 cm^3 of each dilution were spread evenly over the surface of agar plates. The plates were incubated at 35°C for 24 hours. A photograph of the results is shown below.



(i) Explain why it was decided to use Plate U to estimate the number of bacteria in the food rather than the other plates. [3]

U: enough colonies for reliable results and they are easily countable.

R/S/T: cannot distinguish individual colonies, too many to count accurately.

V: too few colonies to provide a reliable estimate.

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(ii) It was found that 69 bacterial colonies were growing on Plate U. Use the information provided to estimate the number of *C.jejuni* bacteria present per cm^3 in the actual food. Show how you reached your answer. [2]

69 colonies × 10 000 (dilution factor) × 2 (as only 0.5 cm^3 spread)

= 1 380 000 bacteria per cm^3

Estimated number of bacteria = 1.38 x 10^6 per cm^3

(iii) Explain why this is likely to be an underestimate of the actual number present in the food. [2]

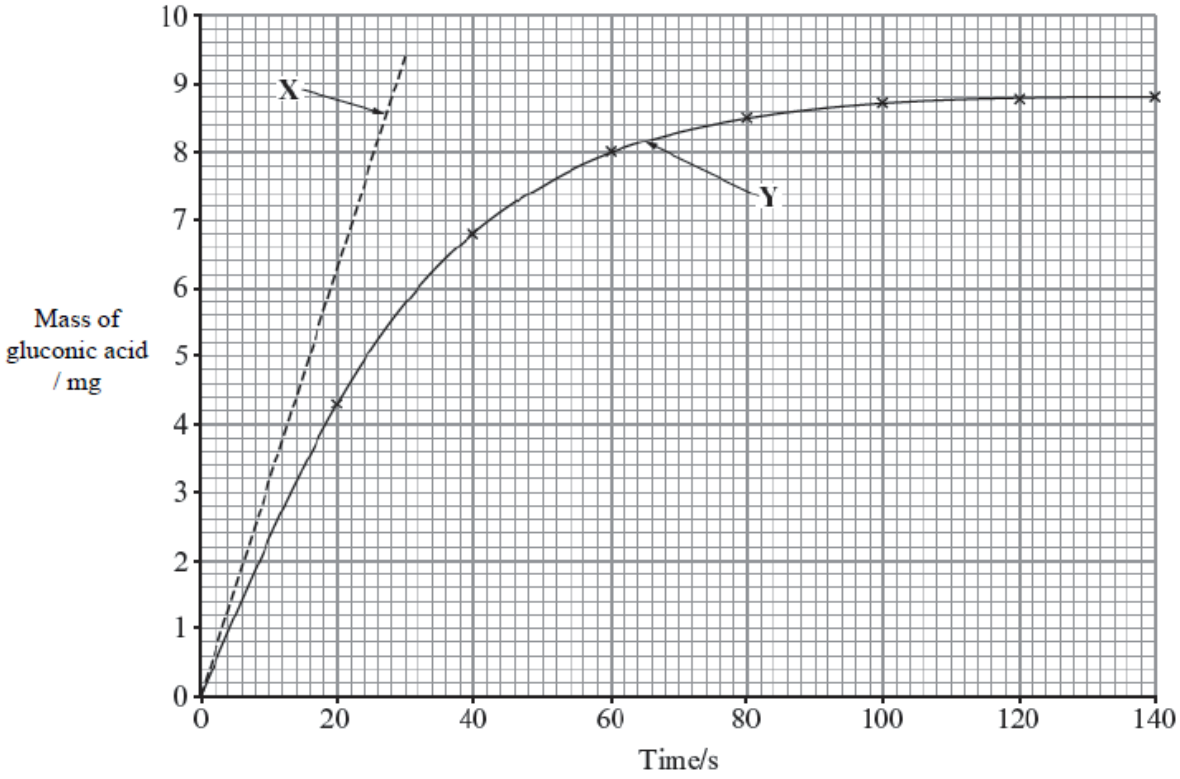
Dead (non-viable) bacteria are not counted, and colonies may grow from clumps of bacteria, not single cells.

11

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5. Glucose oxidase (GOx) is an enzyme that is used in biosensors to determine glucose levels in blood. It converts glucose to gluconic acid and hydrogen peroxide.

An investigation into the action of this enzyme produced the results shown in the graph below.



(a) (i) Use tangent **X** to calculate the **initial** rate of reaction for this enzyme. Express your answer in terms of rate of production of mass of gluconic acid per minute. Show your workings. [2]

From tangent X: 9.4 mg of gluconic acid produced in 30 s

rate = 9.4 ÷ 30 × 60 = 18.8 mg min^{-1}

Initial rate of reaction = ... *18.8 mg min^{-1}* .....

(ii) Explain why the rate calculated for the first 30 seconds would be lower than the initial rate. [2]

At the start glucose concentration is at its maximum, so all active sites are occupied.

As the reaction progresses less glucose is available, so some active sites are vacant and fewer enzyme-substrate complexes form.

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(b) Part of the mechanism for the conversion of glucose to gluconic acid by GOx is shown by the equations below. In these reactions FAD is acting as a co-factor to the enzyme.

Step 1 glucose + GOx – FAD → gluconolactone + GOx-$FADH_2$

Step 2 GOx-$FADH_2$ + oxygen → GOx-FAD + hydrogen peroxide

(i) Suggest the function of FAD in this series of reactions. [1]

FAD acts as a hydrogen (electron) acceptor.

(ii) One type of glucose biosensor involves the detection of oxygen concentrations in a sample of body fluid. Name **two** body fluids that could be analysed. [1]

Blood and urine

(iii) With reference to the information above, explain how an oxygen electrode could be used to give a quantitative measurement of the glucose concentration in a sample of a body fluid. [2]

The oxygen electrode could detect the use (depletion) of oxygen.

The number of oxygen molecules used in Step 2 is proportional to the number of glucose molecules broken down.

(iv) When using a glucose biosensor explain why it is important to maintain a constant temperature and use a buffer. [3]

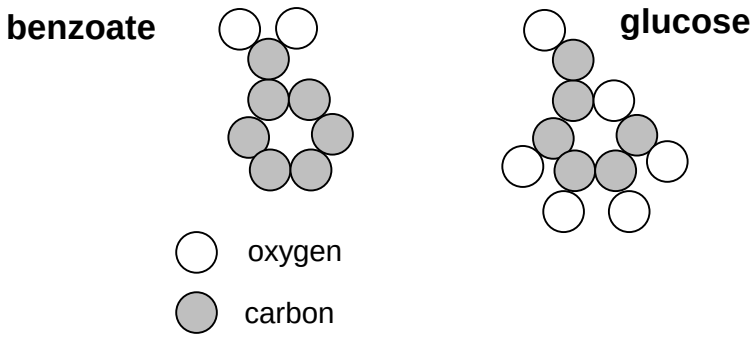
A change in temperature would affect kinetic energy and give readings higher or lower than expected.

Production of gluconic acid would lower the pH, which changes the shape of the active sites, so readings would be lower than expected.

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(c) Experiments have shown that sodium benzoate, a commonly used preservative, can inhibit GOx and affect the accuracy of a glucose biosensor.

The diagrams below show the arrangement of carbon and oxygen atoms in a molecule of glucose and a benzoate ion (hydrogen atoms are not shown).



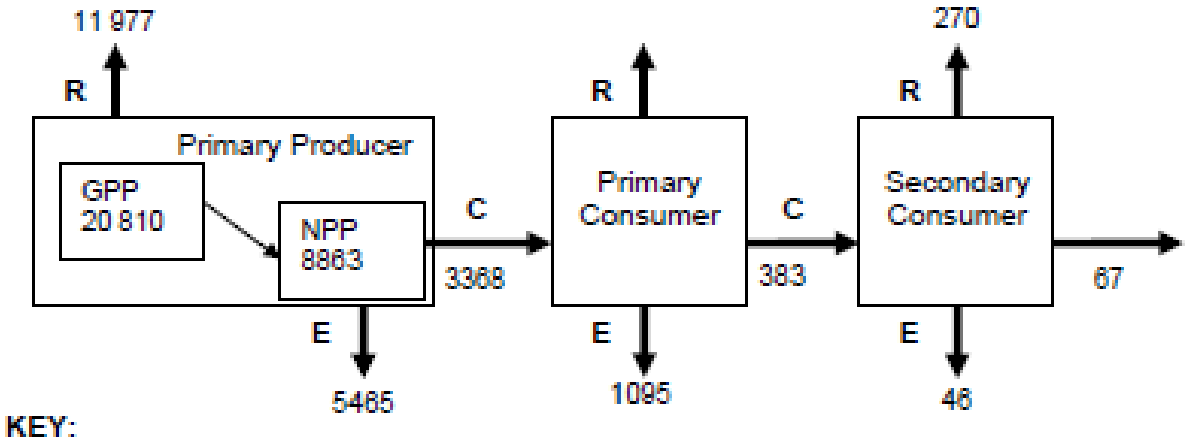
Using the information provided in part (b) and the diagram above explain why contamination of a sample with sodium benzoate would affect the accuracy of the biosensor. [5]

The benzoate ion has a similar shape to glucose, so it would act as a competitive inhibitor of glucose oxidase. Benzoate would occupy the active site and prevent the formation of enzyme-substrate complexes with glucose. Therefore less FAD would be reduced to $FADH_2$ in Step 1, and so less oxygen would be used in Step 2. So the change in oxygen levels would not be proportional to the glucose concentration in the sample, giving a falsely low reading.

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6. The diagram shows the transfer of energy through an ecosystem.

All values given are in kJ m^{-2} yr^{-1}.



KEY:
R = respiratory loss
C = consumed
E = expelled

(a) (i) State what is meant by the abbreviations **GPP** and **NPP** shown in the diagram and explain the difference between them. [3]

GPP = gross primary productivity and NPP = net primary productivity. GPP is the rate at which producers convert light energy into chemical energy in glucose. NPP is the rate at which energy is converted into biomass that can be passed on to consumers, i.e. GPP minus the respiration of the producers.

(ii) What term is used to describe the transfer of energy between consumers? [1]

Secondary productivity

(iii) Calculate the percentage energy lost through respiration by primary consumers. Give your answer to two significant figures. [2]

Respiratory loss = 3368 – 1095 – 383 = 1890
1890 ÷ 3368 × 100 = 56.1163 = 56 % (2 s.f.)

Answer …*56*…… %

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(b) The values given are for marshland. Energy is expelled from the system at each trophic level.

(i) Identify **three** ways that energy could be expelled from the system. [2]

Excretion and egestion

Death

Emigration / removal of organisms by humans

(ii) The values given in kJ m^{-2} yr^{-1}. The area of the marshland is 17 000 m^2.

Calculate the total amount of energy 'expelled' by this ecosystem in one year. Express your answer in standard form. [2]

Expelled = 5465 + 1095 + 46 = 6606 kJ m^{-2} yr^{-1}

6606 × 17 000 = 112 302 000 = 1.12302×10^8 kJ

Answer 1.12×10^8 kJ

(iii) Describe what happens to this expelled energy. [2]

It passes to decomposers (detritivores), which respire it, so it is lost as heat.

(c) The principles of energy transfer through food chains can be employed to compare the efficiency of different farming methods. With reference to the information provided, explain the increase in the use of factory farms for rearing herbivores such as cattle. [4]

Factory farms are more efficient as less energy is lost, so more is converted into biomass.

The temperature is controlled, so less energy is lost via respiration to maintain body temperature.

Animals are stocked at high densities, which restricts movement, so less energy is lost (via respiration) for muscle contraction.

Herbivores are lower down the food chain than carnivores, so less energy is lost via respiration or being expelled.

16

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7. In 2009, a group of 28 internationally renowned scientists identified and quantified a set of nine planetary boundaries.
The table below shows the planetary boundaries for some of these global processes.

Global Process	Variable	Units of measurement	Boundary	Pre-industrial value	Recent data
Biodiversity loss	Extinction rate	species becoming extinct per million species per year	10	1	100 - 1 000
Climate change	Atmospheric carbon dioxide	ppm (parts per million)	350	280	390
Land use	Land used for crops	%	15	5	12
Fresh water	Use of fresh water	km^3 per year	4 000	415	2 600

(a) Explain what you understand by the term planetary boundary. [2]

A threshold value for a global process affected by human activity.

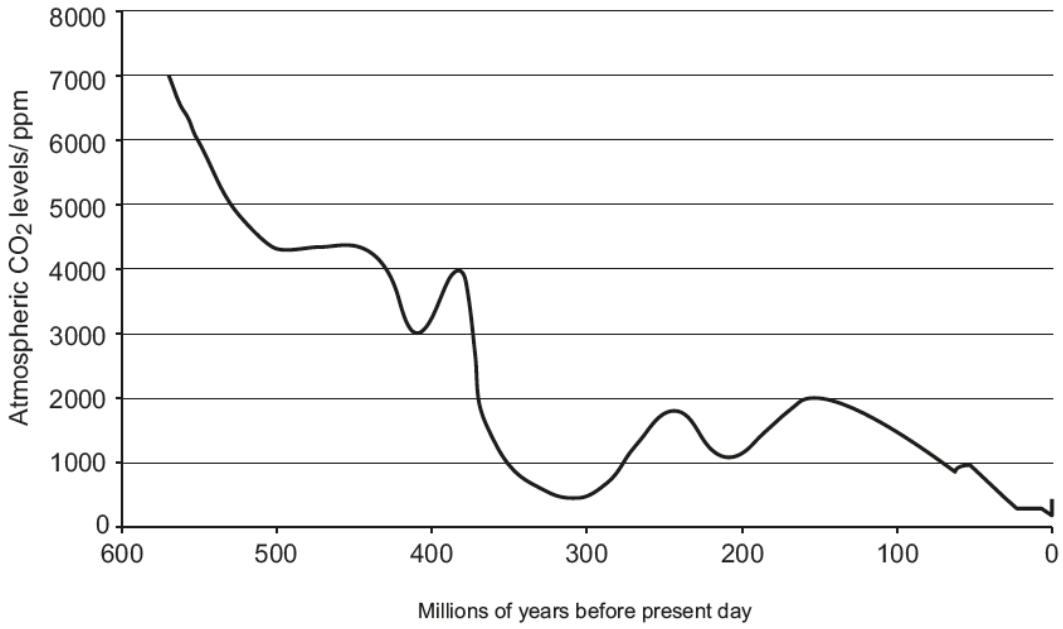
Crossing it could cause abrupt or irreversible environmental change.

(b) Define the term biodiversity and describe **one** action that could delay biodiversity loss. [2]

The number of species and number of organisms of each species in an area. Action: captive breeding programmes.

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(c) It has been claimed that the increase in extinction rate observed in recent years is purely down to increasing atmospheric carbon dioxide levels. However, the graph below shows that carbon dioxide levels in the past have far exceeded current levels and in addition to this the extinction rate at those times was significantly lower.



Analyse the data given in the table and draw alternative conclusions as to the possible causes of the increasing extinction rate. Explain how you reached these conclusions. [3]

Increasing demand for fresh water and land for crops are possible causes of the increase in extinction rate.

Use of fresh water is 627 % of the pre-industrial value (415 to 2600 km^3) and land for crops rose from 5 % to 12 %.

More land for crops and dams to provide fresh water lead to the destruction of habitats, so species become extinct.

7

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8. Nucleic acids are formed from units called nucleotides. Each nucleotide contains an organic base and a phosphate group bonded to a pentose sugar.

Erwin Chargaff analysed the percentage composition of the different bases found in DNA. Some of his results are shown in the table below.

organism	Percentage composition of DNA				$\frac{A+T}{C+G}$	$\frac{C+T}{A+G}$
	A	G	T	C		
maize	26.8	22.8	27.2	23.2	1.17	1.02
human liver	29.3	20.6	30.0	20.1	1.45	1.01

(a) (i) Identify the types of bases represented by A, G, T and C and use this information to explain why the **C+T : A+G** ratio is approximately 1.0 in both maize and humans but the **A+T : C+G** ratio is different. [3]

C and T are pyrimidines and A and G are purines.

DNA is double stranded and a purine in one strand bonds to a pyrimidine in the complementary strand, so % purine = % pyrimidine.

Maize and humans have different DNA base sequences, so the A+T : C+G ratio is different.

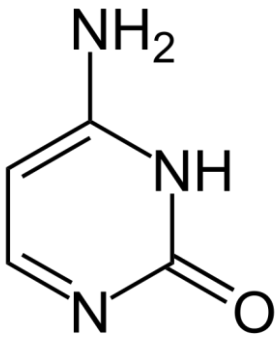
(ii) Suggest why the C+T:A+G ratio is not exactly 1.00. [1]

Due to experimental error / loss of material during the experimental process.

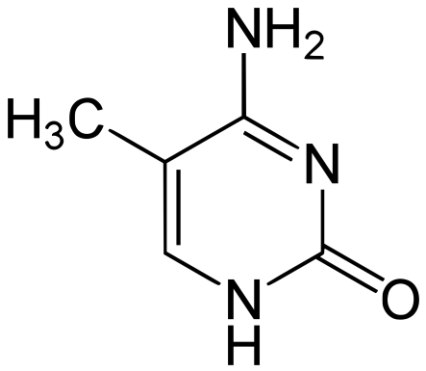
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(b) The diagrams below show the structures of the base cytosine and a modified version called 5-methyl cytosine.

cytosine



5-methyl cytosine



Exposure to some chemicals can cause the modification of cytosine bases to 5-methyl cytosine. Genes with a high proportion of these modified bases may not be transcribed.

(i) Explain why this modification to the DNA would not result in a change to the structure of a protein. [2]

The change does not alter the DNA base sequence, so no effect on the primary structure (amino acid sequence) of the protein.

(ii) Explain how this change could have an effect on the phenotype of a person. [2]

Epigenetic: the change alters the ability of the gene to be transcribed. So the protein is not made, changing appearance or ability to digest.

8

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9. Human activity and bacteria play a vital role in making nitrogen available to increase the yield of crops.
Explain the ways that human activity and bacterial action can influence nitrogen availability and the negative impacts that this may have on the environment.
(The quality of your extended response will be assessed in this question.) [9QER]

Nitrogen is needed by crops to make amino acids, proteins and nucleic acids, but plants can only absorb it as nitrate (or ammonium) ions, so human activity and bacteria are used to increase the nitrate available in the soil.

Farmers can improve soil fertility by adding manure or dead animal and plant material. This is decomposed by saprobiontic bacteria (and fungi), which break down proteins and urea into ammonium compounds (ammonification). This gives a slow release of nitrogen in a suitable form.

Nitrifying bacteria then convert the ammonium into nitrates: Nitrosomonas converts ammonium ions into nitrites, and Nitrobacter converts nitrites into nitrates. These bacteria need oxygen, so nitrification only happens in aerobic soil.

Farmers can also apply inorganic nitrate fertilisers, which are soluble and already in a form that can be taken up by roots (by active transport). This is a faster way of improving soil fertility than adding manure.

Farmers could also plant leguminous plants such as clover, peas or beans to increase nitrate levels. Legumes have the nitrogen-fixing bacterium Rhizobium in their root nodules. Rhizobium uses the enzyme nitrogenase to reduce nitrogen gas from the air to ammonium and combines it with glucose from the plant to form amino acids, while the plant supplies the glucose (mutualism). If the leguminous crop is ploughed in and not removed, it is decomposed and nitrified, so soil fertility increases (crop rotation).

Ploughing and drainage aerate the soil, encouraging aerobic conditions. This favours nitrification and discourages denitrification by anaerobic denitrifying bacteria (e.g. Pseudomonas), which would otherwise convert nitrates back into nitrogen gas, so

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more nitrate stays in the soil.

However, improving soil fertility by adding organic and inorganic nitrogen has a negative environmental impact if nitrate is leached by rain into rivers and lakes, causing eutrophication. The nitrate causes rapid growth of algae (an algal bloom) which blocks light, so aquatic plants below cannot photosynthesise and die. Saprobiontic bacteria decompose the dead material and respire aerobically, increasing the biochemical oxygen demand, so oxygen levels fall and fish and other aerobic organisms die.

In addition, the energy (electrical input) needed to produce inorganic fertilisers is very large and mostly comes from burning fossil fuels. This leads to increased carbon dioxide production, which enhances the greenhouse effect and consequently increases global warming.

Therefore human activity and bacteria together increase nitrogen availability and crop yield, but the benefits must be balanced against eutrophication and global warming.

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