Surname	StemUp Model Solution	Centre Number	Candidate Number
Other Names			2

GCE A LEVEL

A400U10-1

S18-A400U10-1

BIOLOGY – A level component 1
Energy for Life

THURSDAY, 7 JUNE 2018 – MORNING

2 hours

For Examiner's use only		
Question	**Maximum Mark**	**Mark Awarded**
1.	**12**	
2.	**18**	
3.	**21**	
4.	**11**	
5.	**17**	
6.	**12**	
7.	**9**	
Total	**100**	

A400U101
01

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. If you run out of space, use the additional pages at the back of the booklet, taking care to number the question(s) correctly.

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 **7**.

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

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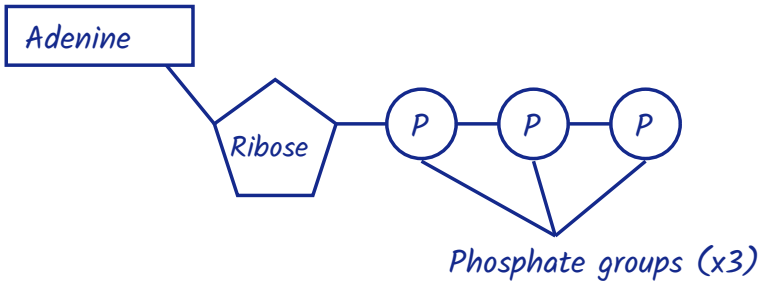
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Answer **all** *questions.*

1. ATP is regarded as a universal energy currency as it is used in all organisms for cellular processes.

(a) Draw a simple, fully labelled diagram of ATP. [2]



(b) The energy released when glucose is broken down in the presence of oxygen is coupled with an endergonic reaction in order to produce ATP. However, only a fraction of the released energy goes into the high-energy bonds of ATP; energy is lost as heat.

Using the following equation, the efficiency of ATP production can be determined by comparing the energy in ATP synthesised with the total energy released in the respiration of one glucose molecule:

$$\text{efficiency} = \frac{N \times E_{ATP}}{E_{react}} \times 100$$

N	number of ATP molecules synthesised
E_{ATP}	energy in terminal ATP bond
E_{react}	total energy released in the respiration of one glucose molecule

Under standard conditions
$E_{ATP} = -7.3$ kcal mol^{-1}
$E_{react} = -686$ kcal mol^{-1}
Assume that 38 molecules of ATP are synthesised.

(i) Calculate the efficiency of ATP production from glucose for the figures above. Give your answer to one decimal place. [2]

efficiency = (38 × 7.3) ÷ 686 × 100

= 277.4 ÷ 686 × 100 = 40.44

Efficiency = 40.4 %

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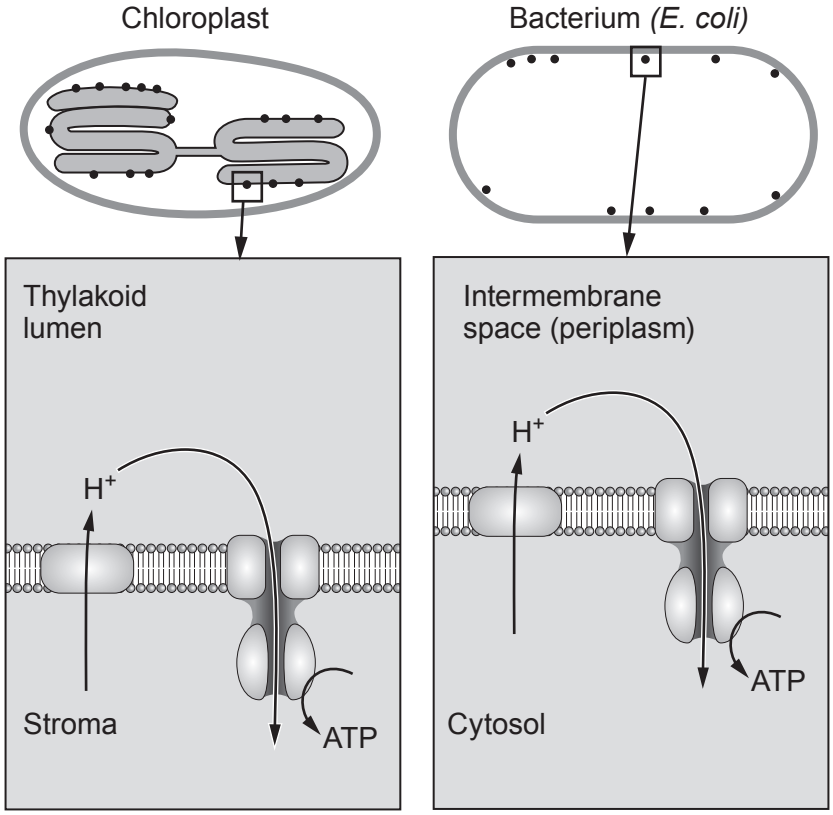
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(ii) The efficiency of an electric motor or petrol engine is between 10% and 20%. Use the result from your calculation to make a quantitative conclusion about the efficiency of ATP synthesis from glucose compared with that of an electric or petrol engine. [1]

At 40.4%, ATP synthesis is approximately twice as efficient as an electric motor or petrol engine (20 to 30% more efficient).

(c) A simple diagram showing ATP synthesis in a chloroplast and a Gram negative bacterium is shown below.



State **four** similarities between the process of ATP synthesis in chloroplasts and the bacterium. [4]

In both, protons (H^+) are pumped across a membrane by proton pumps.

In both, the pumping is driven by energy from electrons passing along an electron transport chain (redox reactions).

Both create an electrochemical (proton) gradient across the membrane.

In both, protons diffuse back down this gradient through the stalked particles, using ATP synthase to synthesise ATP (chemiosmosis).

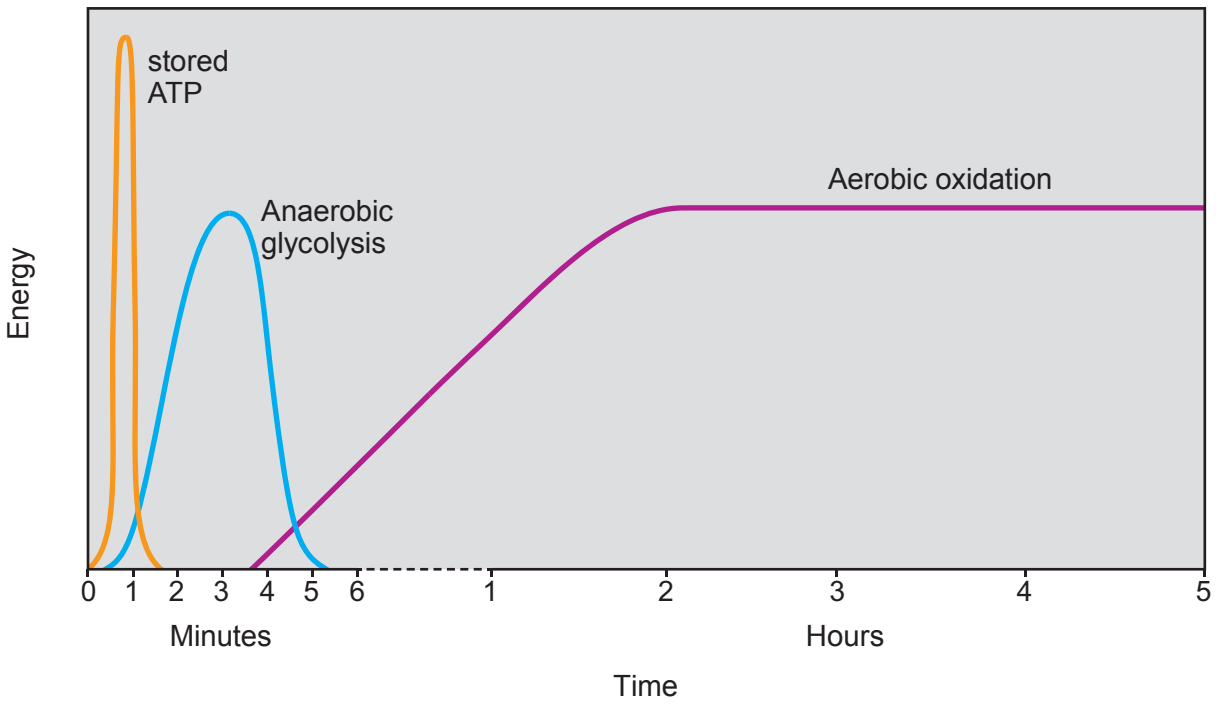
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(d) The diagram below shows the use of ATP from three sources over a 5 hour period, whilst undertaking exercise.



State the conclusions you could draw from this data. [3]

Stored ATP is the immediate, first source of energy, but there is only enough for about 1 minute.

Then anaerobic glycolysis provides the ATP (peak at about 3 minutes) as there is a lack of oxygen for the first 3 to 4 minutes.

From about 5 minutes onwards aerobic respiration (aerobic oxidation) is the only source of ATP and is maintained for the rest of the 5 hours.

12

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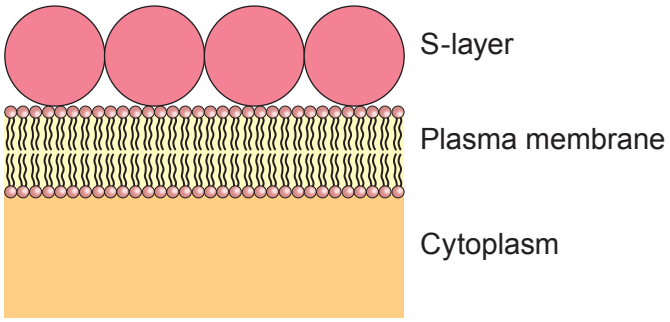
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2. The Archaea are a domain of single-celled microorganisms. These microbes are prokaryotes. Most Archaea possess a cell wall which is assembled from surface-layer proteins. These form an S-layer which is a rigid array of protein molecules that cover the outside of the cell. This layer provides both chemical and physical protection. Unlike bacteria, most Archaea lack peptidoglycan in their cell walls.

(a) (i) Describe **two** major features of a eukaryote which would allow you to distinguish it from a prokaryote. [1]

Eukaryotes have a nucleus (DNA enclosed by a nuclear envelope) and membrane-bound organelles such as mitochondria. They also have 80S ribosomes and linear DNA in chromosomes.

One type of cell wall found in Archaea is shown below.



(ii) Apart from the lack of peptidoglycan, describe how the cell walls of Gram negative bacteria would differ from those of Archaea. [2]

Gram negative bacteria do not have a protein S-layer covering the outside of the cell.

Instead they have an outer layer of lipoproteins and lipopolysaccharides outside the thin peptidoglycan wall.

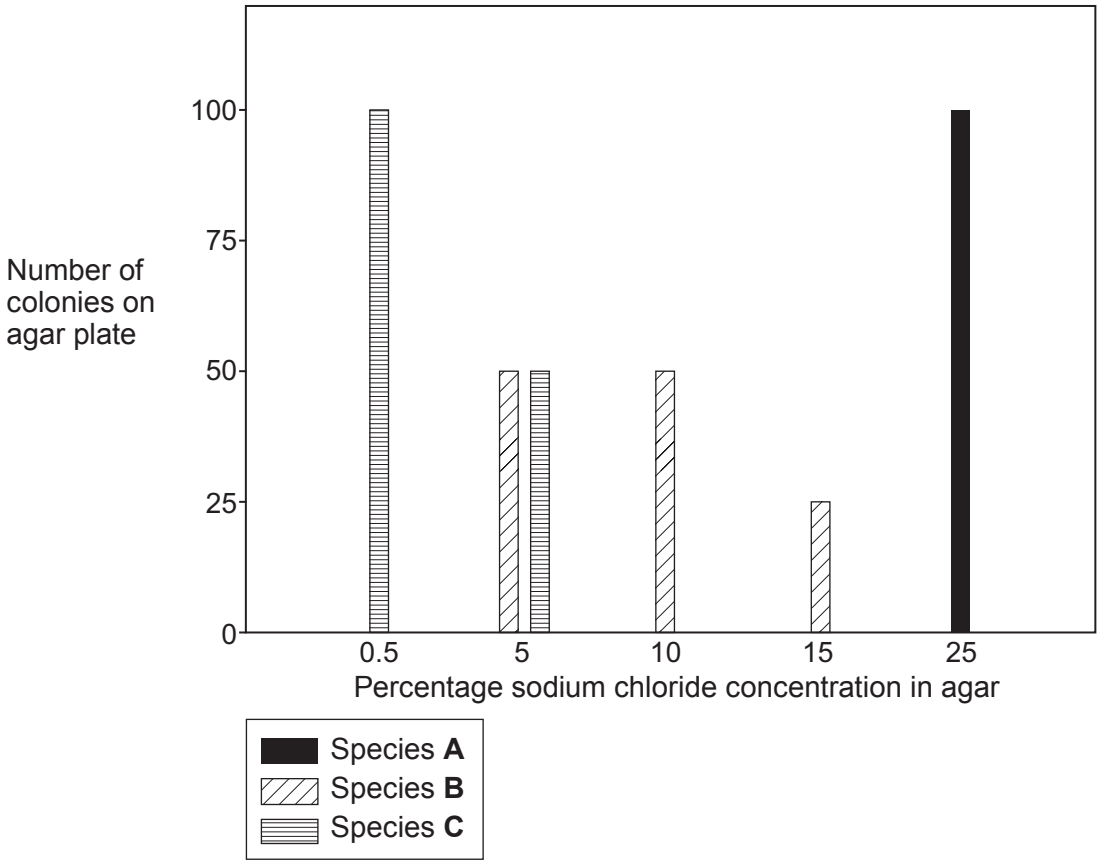
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(b) An experiment was carried out to determine the effect of sodium chloride concentration (salinity) on the growth of different species of prokaryotes. The number of visible colonies of each species was counted on agar plates containing different concentrations of sodium chloride.
A bar chart of the results is shown below.



- *Staphylococcus aureus* is a Gram-positive bacterium that is frequently found on sweaty skin.
- *Halobacterium salinarum* is a marine Gram-negative obligate aerobic archaeon. Despite its name, this microorganism is not a bacterium, but rather a member of the domain Archaea.
- *Escherichia coli* is a Gram-negative, rod-shaped bacterium commonly found in the lower intestine of endothermic (warm-blooded) organisms.

(i) Which agar plate used in this experiment has the lowest water potential? [1]

The 25% sodium chloride plate

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(ii) Identify species **A**-**C** giving reasons for your conclusions. [3]

A Halobacterium salinarum: it only grows at 25% NaCl, as it lives in a marine environment which has a high NaCl concentration.

B Staphylococcus aureus: it grows at 5 to 15% NaCl, as it lives on skin which is often high in salt from sweat.

C Escherichia coli: it grows best at low (0.5%) NaCl, as it lives in the lower intestine where salt is low as most has been absorbed.

(iii) *Enterococcus faecalis* is a Gram-positive bacterium which also inhabits the gastro-intestinal tracts of humans and other mammals.
Briefly describe **two** ways in which you could distinguish between *Enterococcus faecalis* and *Escherichia coli*. [3]

Gram staining (crystal violet, iodine, alcohol, safranin): E. faecalis (Gram positive) stains purple; E. coli (Gram negative) stains red.

Shape: E. faecalis cells are spheres (cocci); E. coli cells are rods (bacilli).

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(c) Some strains of *E. coli* can cause food poisoning. Following an outbreak, samples were taken from suspected food sources and cultured on agar plates. Serial dilutions were carried out to determine the number of viable bacteria in the samples. 0.25 cm^3 was transferred to each agar plate and incubated at 37 °C. The number of colonies on each plate was then counted.

	Number of colonies per plate				
Dilution	Plate 1	Plate 2	Plate 3	Mean	SD
10^{-3}	426	503	521	483	50.5
10^{-5}	444	479	457	460	17.7
10^{-7}	275	293	310	293	17.5
10^{-9}	66	71	78	72	6.0

(i) Calculate the missing standard deviation (SD) using the following formula. [3]

$$s = \sqrt{\frac{\Sigma(x - \bar{x})^2}{n - 1}}$$

s = standard deviation

Σ = sum of

x = each value in the data set

$\bar{x}$ = mean of all values in the data set

n = number of values in the data set

The following table is given to help structure your calculation.

Plate number	Number of colonies per plate	$x - \bar{x}$	$(x - \bar{x})^2$
1	275	−18	324
2	293	0	0
3	310	17	289
Mean	293		Σ 613

$s = \sqrt{(613 \div (3 - 1))} = \sqrt{306.5} = 17.5$

Standard deviation = ... 17.5 .....

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(ii) Suggest why the **mean values** for the first two dilutions were so close despite there being a 100 times difference in the dilutions. [1]

At the low dilutions the colonies overlap and clump together, so it is difficult to count large colony numbers and many are missed.

(iii) State what the standard deviations of the **first two dilutions** tell you about the data. [1]

The data is very variable (large SD), so 10^{-3} is less reliable than 10^{-5}.

(iv) Calculate the number of bacteria in **1 cm^3** of the original sample using the 10^{-9} dilution. **Give your answer in standard form.** [3]

0.25 cm^3 was plated, so multiply by 4 to get 1 cm^3

72 × 4 = 288 bacteria per cm^3 of the 10^{-9} dilution

$288 \times 10^9 = 2.88 \times 10^{11}$

Number of bacteria = 2.88×10^{11}

A400U101 09

18

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3. Natural, species rich, seasonally-flooded grasslands are one of the rarest forms of flower-rich meadows with rare plants such as orchids. These rare plants survive on flooded meadows where levels of nitrates are low.
Many such meadows have been lost through ploughing and the application of fertilisers to increase yields of hay.
Many species-rich meadows in floodplains next to streams and rivers function as seasonal washlands, by temporarily storing flood water during periods of high water flow.

(a) Explain how the low levels of nitrates are brought about in these meadows. [2]

Flooding waterlogs the soil so conditions become anaerobic. Denitrifying bacteria then convert nitrates to atmospheric nitrogen, and there is less nitrification. Flood water also leaches nitrates, washing them out of the soil.

(b) Explain fully how the change in agricultural practices has led to the loss of this type of meadow. [3]

The use of fertilisers adds nitrates to the soil. Ploughing increases aeration, so conditions are more aerobic and less anaerobic, so less denitrification. Nitrification by nitrifying bacteria increases, raising nitrate levels. Flood water from fertilised land also carries more nutrients, increasing nitrate levels, so the rare plants adapted to low nitrate are outcompeted.

(c) Given that one effect of global warming appears to be more flooding in the UK, discuss why the government is encouraging landowners to preserve and re-instate such meadows in certain areas by compensating them for the loss of productive farm land. [4]

The meadow land retains the flood water, acting as a sponge, and the water is only released slowly into the rivers. This reduces (flash) flooding downstream. The cost of damage from flooding is more than the compensation paid to farmers for the loss of use of the land, although there is a conflict between the loss of farmland and conservation. It also conserves rare species such as orchids and increases biodiversity.

A400U101 11

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(d) Two species of plantain, greater plantain *(Plantago major)* and ribwort plantain *(Plantago lanceolata)* are very common in grassy areas in Britain. Both plantain species are frequently found on trampled ground.



Greater plantain *(Plantago major)*



Ribwort plantain *(Plantago lanceolata)*

The table shows some characteristics of these two species.

Feature	Greater plantain	Ribwort plantain
Main growth form	rosette	rosette
Drought tolerance	tolerant	not tolerant
Resistance to physical damage	very resistant	moderately resistant
Ability to vary growth form under different conditions	can vary	varies readily
Seed germination	best near soil surface on open ground	best on lightly compacted soil either in open ground or amongst vegetation
Overwintering	as small rosettes or underground	as small rosettes

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(i) Describe the technique you would use to carry out an assessment of the abundance of these two species across a moderately trampled footpath. [3]

Lay a tape measure as a line transect across the footpath from one edge to the other. Place quadrats at regular intervals along the transect (e.g. every 0.5 m). In each quadrat estimate the percentage cover (or frequency) of each plantain species. Repeat transects at several random points along the footpath and calculate means.

(ii) Using the information in the table, predict which species would be found mainly in the centre of the trampled path and which species is found mainly at the edges, giving reasons for your choice. [4]

Higher abundance of greater plantain in the centre of the path and higher abundance of ribwort plantain at the edges.

Greater plantain is very resistant to physical damage, so is better adapted to heavily trampled ground than ribwort.

Greater plantain is tolerant of drought (compacted path soil is dry); ribwort is not tolerant.

Greater plantain seeds germinate best on open ground; ribwort seeds germinate best on lightly compacted soil.

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(e) Trophic level transfer efficiency measures the energy that is transferred between trophic levels in ecosystems.
A food chain can usually sustain no more than six energy transfers.
Net Production Efficiency (NPE) measures how efficiently each trophic level uses and incorporates the energy from its food into biomass available to the next trophic level.

(i) Why does a food chain usually sustain no more than six energy transfers? Explain why it would be more energy efficient to produce food in the form of corn, soybeans, and other crops rather than as meat and other animal products. [3]

There is insufficient energy available to support a further trophic level, because at each transfer energy is lost as metabolic heat through respiration, and in waste, when organisms of one trophic level are eaten by the next.
Eating crops means fewer trophic levels, so more energy is available for human food.

(ii) Explain why most warm-blooded organisms have to eat more often than cold-blooded organisms to get the energy they need for survival. [2]

They need to maintain a constant body temperature, which means they use more of their food in respiration to produce heat, so less is converted to biomass.

21

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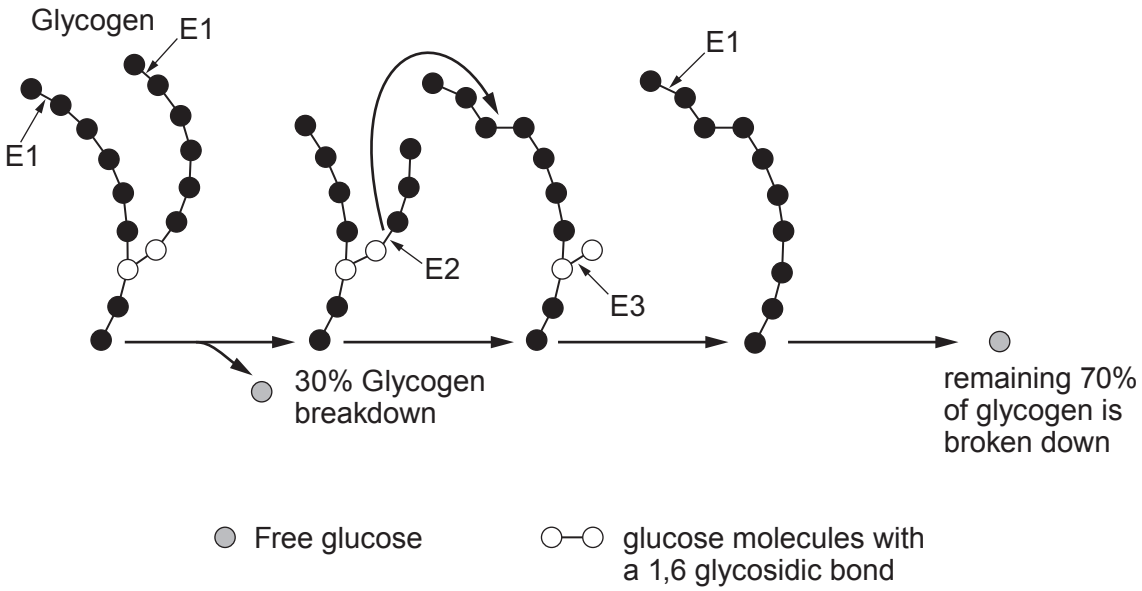
4. Many diseases are caused by deviations of blood glucose from normal levels. The concentration of blood glucose is actively regulated to remain very nearly constant.

(a) What general name is given to this type of negative feedback mechanism? [1]

Homeostasis

Glycogen is a molecule the body uses to store glucose, a source of energy. Glycogen storage disease (Cori's disease) is an inherited disorder caused by the build up of glycogen in the body's cells. The accumulated glycogen is structurally abnormal being a short branched polysaccharide.
The disorder is caused by a deficiency of a debranching enzyme.
From infancy, individuals with Cori's disease have low blood glucose levels.

The diagram below shows normal glycogen breakdown with all enzymes functioning.



Enzyme E1 sequentially hydrolyses 1-4 glycosidic bonds in glycogen from the end of the molecule

Enzyme E2 transfers short chains of glucose from one chain to another

Enzyme E3 is the debranching enzyme

(b) Symptoms of Cori's disease are often more obvious between meals.

(i) What would be the main symptom of low blood glucose? [1]

Fatigue / tiredness, feeling dizzy or faint.

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(ii) Using the diagram opposite explain how the lack of the debranching enzyme causes low blood glucose. [4]

Between meals glycogen is broken down to glucose for use in respiration. E1 can only hydrolyse the 1-4 glycosidic bonds back to the branch points, so there is only partial hydrolysis of glycogen: only about 30% of the glycogen can be hydrolysed. Without the debranching enzyme E3 the 1-6 branches cannot be removed (1-6 bonds cannot be broken), so the remaining 70% stays as short branched glycogen. So less glucose can be released into the blood.

(c) Explain what has happened to produce a non-functional glycogen debranching enzyme. [3]

A mutation in the gene (DNA) coding for the enzyme, e.g. a base substitution, changes the mRNA codons. The primary structure of the protein (sequence of amino acids) is altered, or a stop codon prevents translation. The active site has the wrong shape, so the 1-6 branches no longer fit and fewer enzyme-substrate complexes form.

(d) Both parents are usually unaffected and it affects both males and females equally. How is this gene most likely to be inherited? [1]

Autosomal recessive.

(e) How does glycogen differ structurally from the storage polysaccharide starch? [1]

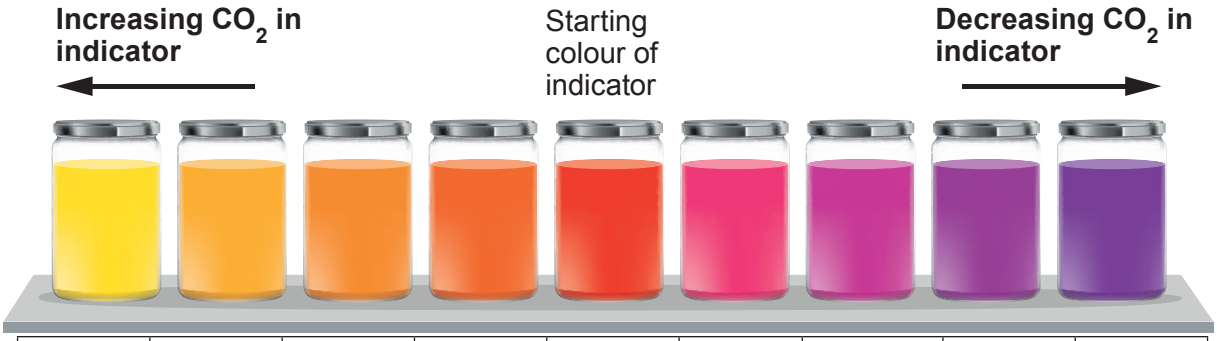
Glycogen has more branching (shorter 1,4 chains) whereas starch is made up of amylose (unbranched, coiled) and amylopectin.

11

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5. Hydrogen carbonate indicator can be used to assess the carbon dioxide concentration in solution.
The colours displayed by hydrogen carbonate indicator at different concentrations of CO_2 are shown below.



yellow		orange		red		magenta		purple
pH 7.6	pH 7.8	pH 8.0	pH 8.2	pH 8.4	pH 8.6	pH 8.8	pH 9.0	pH 9.2

An experiment was carried out to find the light intensity where the rate of respiration and photosynthesis are exactly equal (the compensation point) in a species of alga immobilised in algal balls.

- Six glass bottles were set up each containing 50 algal balls and 25 cm^3 hydrogen carbonate indicator at the same CO_2 concentration. A range of five light intensities at the same wavelength were used.
- One was covered in aluminium foil to exclude all light.
- All of the bottles were left for one hour.
- The absorbance of the six solutions was measured in a colorimeter.
- The colorimeter measured the light absorbed by the sample as less than or greater than the initial colour of the tube.

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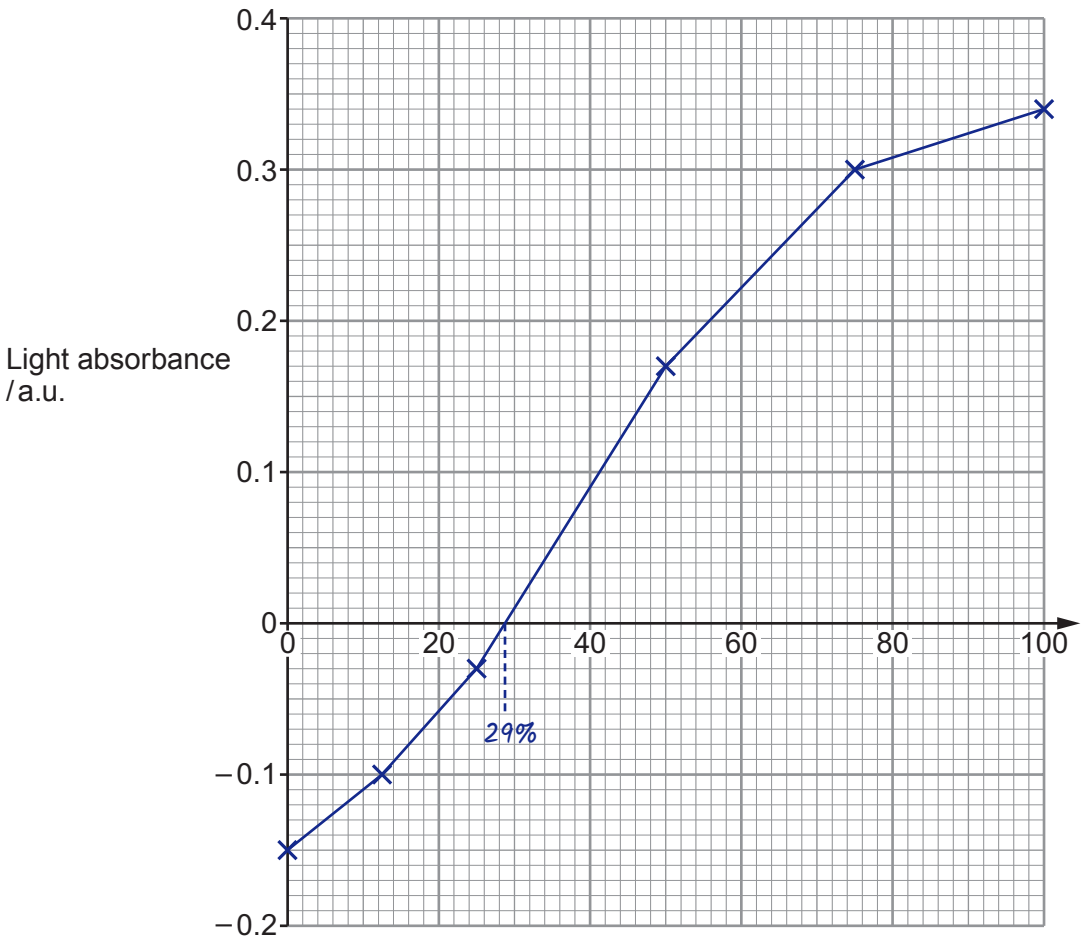
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The results are shown in the table.

Light intensity as a percentage of maximum / %	Light absorbance of the sample / a.u.
0.0	–0.15
12.5	–0.10
25.0	–0.03
50.0	0.17
75.0	0.30
100.0	0.34

(a) (i) Plot the data on the grid below. [2]



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(ii) **Use the graph** to determine the compensation point. [1]

29% of maximum light intensity

(iii) With reference to the biochemical pathways of photosynthesis and respiration, explain how a light absorbance of 0 a.u. could be observed in this experiment. [4]

At 29% light intensity the rates of photosynthesis and respiration are equal.

The uptake of CO_2 by the alga through the Calvin cycle (light independent reaction) is equal to its release of CO_2 through the link reaction and Krebs cycle.

So there is no change in the concentration of dissolved CO_2 and no change in pH, so the indicator colour does not change (stays red) and the absorbance is 0 a.u.

(b) Explain why the colorimeter was used rather than visually assessing the change in colour of the indicator. [1]

Visual assessment is too inaccurate and subjective, as different people see different shades (or may be colour blind); the colorimeter gives quantitative data.

(c) State **two** *other* variables that should have been controlled in this experiment. [2]

The temperature (e.g. a water bath at 25 °C).

The size of the algal balls (and the concentration of algae in them).

(d) A shade plant such as primrose must be able to photosynthesise effectively at lower light intensities, whilst grass species such as maize grow on open land.
How would you predict the compensation points of maize and primrose to differ?
Explain your answer. [2]

The compensation point of maize will be higher than that of primrose, because maize grows in open fields and needs lots of light, whereas primrose has efficient photosynthesis in low light in shaded woodland.

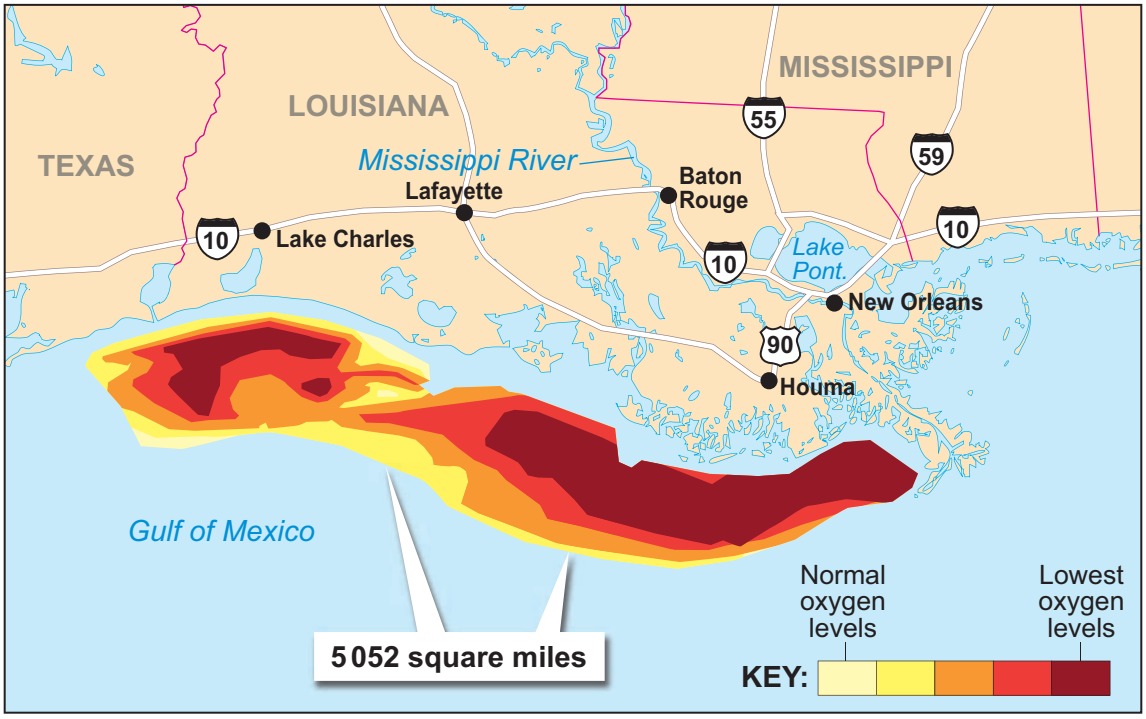
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(e) The coloured area on the map below shows an area of 5 052 square miles, sampled in 2014, in the Gulf of Mexico which has extremely low oxygen levels at certain times of the year. The Mississippi River drains a large area of agricultural land, growing crops such as maize and soybean. It drains into the Gulf of Mexico.

2014 DEAD ZONE Area of oxygen-deprived water



Using your knowledge of algal growth explain how the area of oxygen-deprived water in the Gulf of Mexico has occurred. [5]

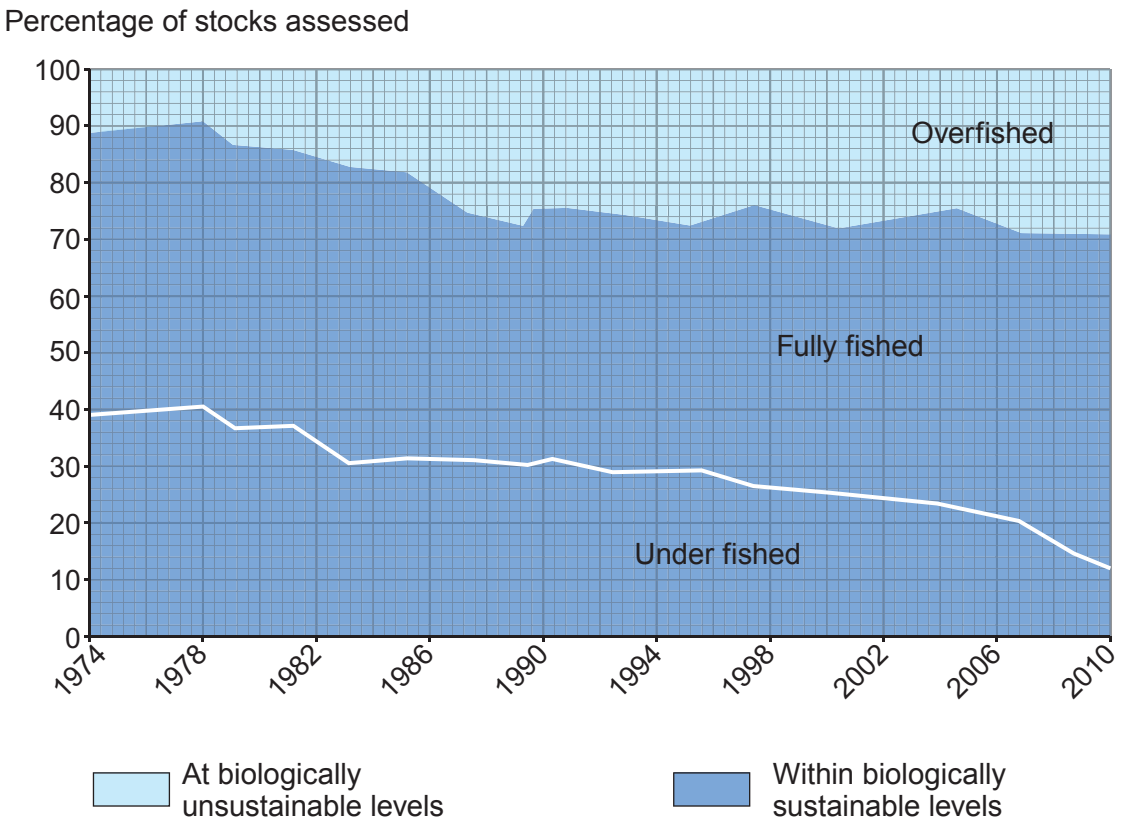
Water from the Mississippi River drains the agricultural land and contains nitrates from fertilisers (and slurry), causing high nitrate levels in the area shown. This causes an algal bloom, as the algae grow rapidly at the surface and block light from plants below. The algae and plants then die, and there is decay of the algae by aerobic decomposers (bacteria). O_2 is used up by these decay organisms (high BOD), creating the oxygen-deprived dead zone.

17

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6. The graph below shows the trends in the state of world stocks of marine fish from 1974 to 2010.



Fully fished = fished at maximum sustainable yield
Underfished = currently believed to be fished at below maximum sustainable yield

(a) Using the data, what conclusions can be drawn about the world fishing stocks since 1974. [4]

Overfished stocks have increased (from about 11% in 1974 to about 29% in 2010), fully fished stocks have increased (about 50% to 59%) and underfished stocks have decreased (about 39% to 12%). So fish stocks are decreasing and some species could become extinct, because unsustainable fishing has increased and sustainable fishing has decreased. Since about 2007 overfished stocks have stayed constant (plateaued at about 29%). Within sustainable levels there are more fully fished and fewer underfished stocks.

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(b) Describe **three** strategies, apart from aquaculture, which can be used to prevent overfishing and explain how each would help to conserve stocks. [3]

A minimum net mesh size, so young, smaller fish are not caught and can reach breeding age.

Exclusion zones or seasonal restrictions, so breeding fish and juveniles are not caught and stocks can recover.

Quotas (or smaller fleets), so fewer fish are caught.

(c) One method of decreasing demands on wild fish stocks is the use of aquaculture. The Scottish salmon industry is one such example. One problem with raising salmon this way is the high build up of parasites, such as lice, which feed on the blood and tissue of salmon.

(i) Why are the farmed fish more susceptible to infection by lice than wild fish and why is eliminating the lice a problem for fish farms? [2]

The fish are closely packed, so lice (parasites) can easily spread from fish to fish.

The lice cannot be easily killed as they are resistant to pesticides.

(ii) There are important environmental concerns that farmed fish can escape from their pens. Explain **three** reasons why it is important to the environment that the escape of farmed fish is prevented. [3]

They are a foreign (invasive) species in new areas and may displace indigenous species, reducing wild fish numbers and biodiversity.

They compete with wild fish for food, mates and habitat, affecting food chains.

They spread disease and parasites such as lice to wild fish, and breed with wild fish, reducing genetic diversity (diluting the gene pool).

12

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7. More than a billion years ago, aerobic bacteria colonised primordial eukaryotic cells that lacked the ability to use oxygen metabolically. A symbiotic relationship developed and became permanent. The bacteria evolved into mitochondria, thus enabling the host cells to carry out aerobic metabolism, a much more efficient way to release energy than anaerobic glycolysis.

Describe the role of mitochondria in eukaryotic cells using your knowledge of respiratory pathways.
Explain how the original aerobic bacteria and primordial eukaryotic cells benefitted from this relationship.
Detailed diagrams are not required. [9 QER]

Mitochondria are the site of the aerobic stages of respiration. Glycolysis happens in the cytoplasm, producing pyruvate, reduced NAD and a small amount of ATP. Pyruvate is then actively transported from the cytoplasm into the mitochondrial matrix.

Link reaction: in the matrix each pyruvate (3C) undergoes decarboxylation (CO_2 removed by decarboxylase) and dehydrogenation (hydrogen removed by dehydrogenase, reducing NAD). The 2C acetyl group combines with coenzyme A to form acetyl coenzyme A.

Krebs cycle: acetyl coenzyme A (2C) combines with a 4C molecule (oxaloacetate) to give a 6C molecule (citrate). This is progressively decarboxylated, removing carbon as CO_2, to reform the 4C molecule.

Dehydrogenases remove hydrogen, forming reduced NAD and reduced FAD, and one ATP is made per turn by substrate-level phosphorylation.

Electron transport chain: on the inner mitochondrial membrane (cristae), reduced NAD and reduced FAD are the source of high-energy electrons, which pass along a chain of carriers in a series of redox reactions. The energy released is used to pump protons from the matrix into the intermembrane space, forming an electrochemical gradient. Protons diffuse back through ATP synthase in the stalked particles (chemiosmosis), synthesising ATP from ADP and Pi. Oxygen is the final electron acceptor, combining with electrons and protons to form water. This oxidative phosphorylation produces most of the

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ATP, far more than glycolysis alone.

Benefits to the bacteria: the host cell provided a source of pyruvate (respiratory substrate) and oxygen, a constant environment (e.g. stable pH and water potential), and protection from predation.

Benefits to the eukaryote: much more ATP became available, allowing an increased metabolic rate, more active transport and increased cell division, and the ability to metabolise other respiratory substrates such as fatty acids. Compartmentalisation of reactions in the mitochondria made metabolism more efficient, which allowed eukaryotic cells to increase in size and complexity.

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9

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