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Candidate surname

StemUp Model Solution

Other names

Centre Number

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Pearson Edexcel Level 3 GCE

Time 2 hours

Paper
reference

9BN0/03

Biology A (Salters Nuffield)

Advanced

PAPER 3: General and Practical Applications in Biology

You must have:

Ruler, HB pencil and scientific calculator and a copy of the scientific article adapted from *Scientific American* (enclosed)

Total Marks

Instructions

- Use **black** ink or ball-point pen.
- **Fill in the boxes** at the top of this page with your name, centre number and candidate number.
- Answer **all** questions.
- **Show all your working out** in calculations and **include units** where appropriate.
- Answer the questions in the spaces provided
– *there may be more space than you need.*

Information

- The total mark for this paper is 100.
- The marks for **each** question are shown in brackets
– *use this as a guide as to how much time to spend on each question.*
- You may use a scientific calculator.
- In questions marked with an **asterisk** (*), marks will be awarded for your ability to structure your answer logically, showing how the points that you make are related or follow on from each other where appropriate.

Advice

- Read each question carefully before you start to answer it.
- Try to answer every question.
- Check your answers if you have time at the end.

Turn over ►

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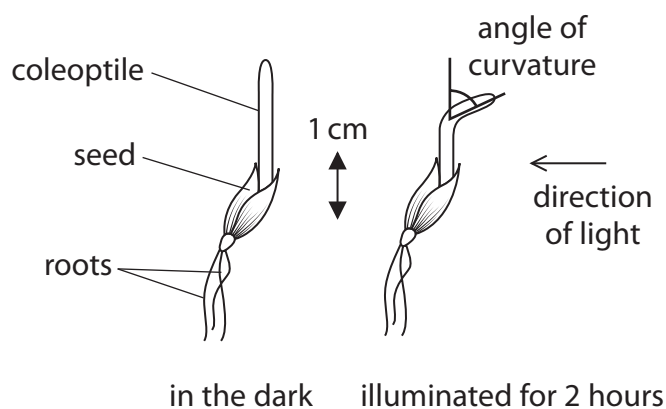
Answer ALL questions.

Write your answers in the spaces provided.

1 When oat seeds germinate, they produce roots and a coleoptile.

(a) The effect of shading the tip of the coleoptile was investigated.

The diagram shows how the coleoptile of an oat seedling can bend towards light.



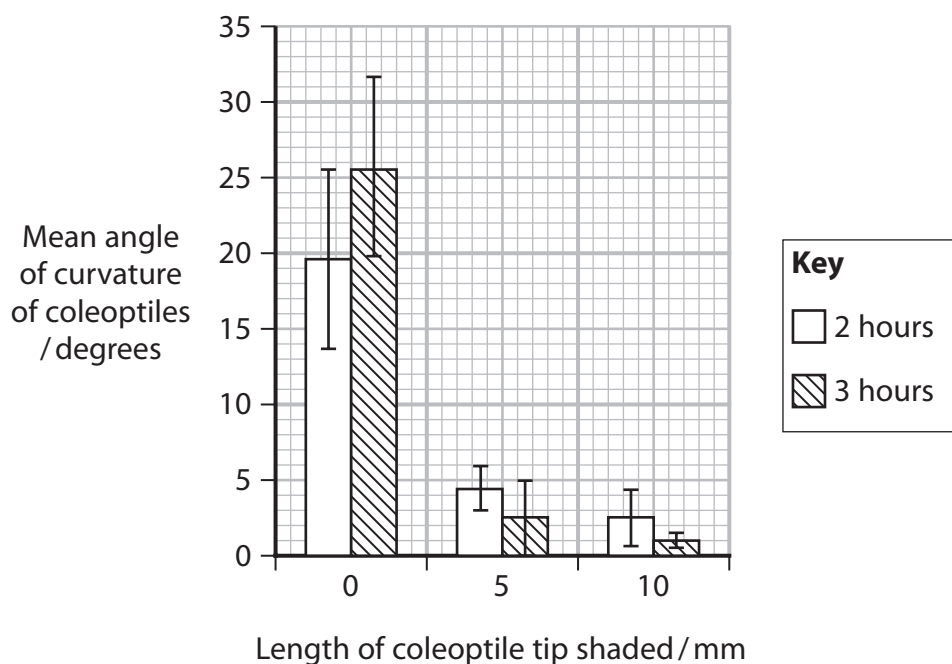
Oat seeds were germinated. When the coleoptiles were 2 cm long the seedlings were split into three groups.

- Group 1 none of the tip of the coleoptile was shaded
- Group 2 5 mm at the tip of the coleoptile was shaded
- Group 3 10 mm at the tip of the coleoptile was shaded

All the coleoptiles were then exposed to light from one side.

The curvature of the coleoptiles was measured after intervals of 2 hours and 3 hours.

The results of this investigation are shown in the graph.



- (i) Describe two conclusions that can be drawn from the results of this investigation.

(2)

As the length of tip shaded increases, the mean angle of curvature decreases, so shading the coleoptile tip reduces (stops) bending towards the light.

The light-sensitive part of the coleoptile is in the first 5 mm of the tip; the part that bends is below the part that detects light.

There is no significant difference between 2 and 3 hours of exposure, or between shading 5 mm and 10 mm, as the error bars overlap.

- (ii) The results of this investigation were analysed using the Student's t-test.

A p value of 0.05 was used to interpret the results of the t-test.

Explain what a p value of 0.05 means.

(2)

There is a 5% (1 in 20) probability that the results (the difference) occurred by chance.

So we can be 95% confident that the results did not occur by chance, i.e. the difference is significant.

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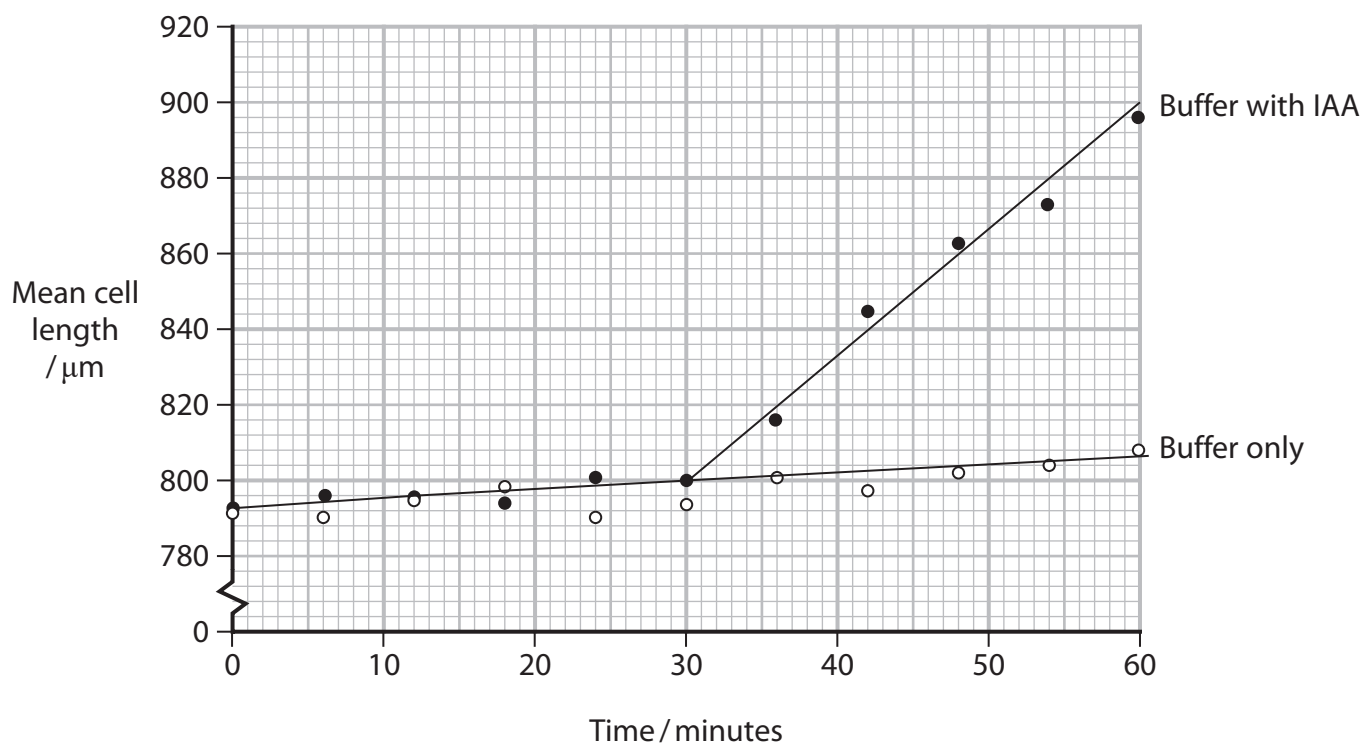


(b) In a second investigation, cells were taken from below the tip of the coleoptile.

These cells were soaked in buffer alone or buffer containing IAA (auxin), for a period of 60 minutes.

The lengths of the cells were measured every six minutes.

The results of this investigation are shown in the graph.



- (i) Give one abiotic factor, other than pH, that would need to be controlled in this investigation.

(1)

Temperature (of the buffer).

- (ii) Calculate the difference in the rates of change in cell length from 30 to 60 minutes, in the presence of IAA and in the absence of IAA.

(2)

With IAA: $(900 - 800) \div 30 = 3.33 \mu\text{m min}^{-1}$

Buffer only: $(806 - 800) \div 30 = 0.20 \mu\text{m min}^{-1}$

Difference = $3.33 - 0.20 = 3.13 \mu\text{m min}^{-1}$

Answer *$3.13 \mu\text{m min}^{-1}$*

- (c) Explain how the evidence from these investigations indicates that plant hormones are involved in the phototropic response of oat coleoptiles.

(3)

IAA (auxin) is a plant hormone. The second investigation showed that cells grew longer in buffer with IAA than in buffer only, so IAA stimulates cell elongation.

The first investigation showed that the light-sensing (IAA-producing) cells are in the tip of the coleoptile, as shading the tip stopped the bending.

The cell elongation happened in cells below the tip, a different part to the light-sensing structures, so a chemical (hormone) must travel from the tip to the cells below.

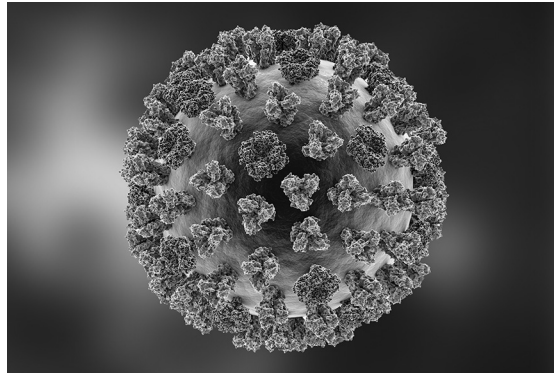
The response to IAA is relatively slow and prolonged (cells only lengthened after 30 minutes, and curvature continued from 2 to 3 hours), typical of a hormone.

(Total for Question 1 = 10 marks)



P 6 7 0 9 2 R A 0 5 2 8

2 The diagram shows an RNA virus that causes influenza.



(Source: © Kateryna Kon/Shutterstock)

(a) Influenza cannot be treated with antibiotics.

Explain why antibiotics cannot be used to treat influenza.

(2)

Influenza is caused by a virus, not a bacterium. Antibiotics target bacteria (prokaryotes) only, e.g. by inhibiting cell wall synthesis or 70S ribosomes.

The structure of a virus is different to that of a bacterium: it has no cell wall and no ribosomes of its own, so there is nothing for the antibiotic to act on.



(b) The surface of this virus capsid is covered with 'spike' proteins.

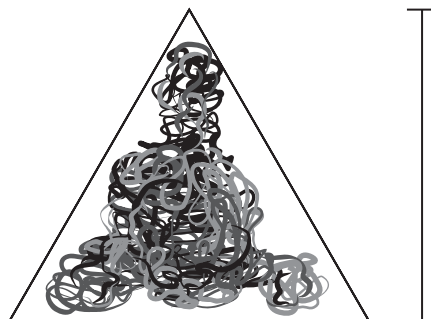
The diameter of the capsid of this virus is 240 nm.

Diagram of the surface of the virus showing each spike protein as a triangle



240 nm

The diagram shows the area occupied by one spike protein



b = 20.0 nm

h = 22.4 nm

Calculate the maximum number of spike proteins that can be packed on the surface of one virus particle.

The formula for calculating the surface area of a sphere is $4\pi r^2$

The formula for calculating the area of a triangle is $\frac{h \times b}{2}$

(3)

$$r = 240 \div 2 = 120 \text{ nm}$$

$$\text{surface area of virus} = 4 \times \pi \times 120^2 = 180\,955.7 \text{ nm}^2$$

$$\text{area of one spike protein} = (22.4 \times 20.0) \div 2 = 224 \text{ nm}^2$$

$$\text{number} = 180\,955.7 \div 224 = 807.8$$

Answer 808

- (c) Changes in the RNA of influenza produce new strains of the virus with an altered spike protein.

Devise a procedure to determine the similarity of the strains of influenza in saliva samples collected from different people.

(4)

Collect a saliva sample from each person and isolate (extract) the viral RNA from each sample.

Use reverse transcriptase to make DNA from the RNA, then amplify the DNA by PCR so there is enough to analyse.

Cut the DNA into fragments using the same restriction enzymes for every sample.

Separate the fragments by gel electrophoresis, with a DNA ladder, and stain to show the bands.

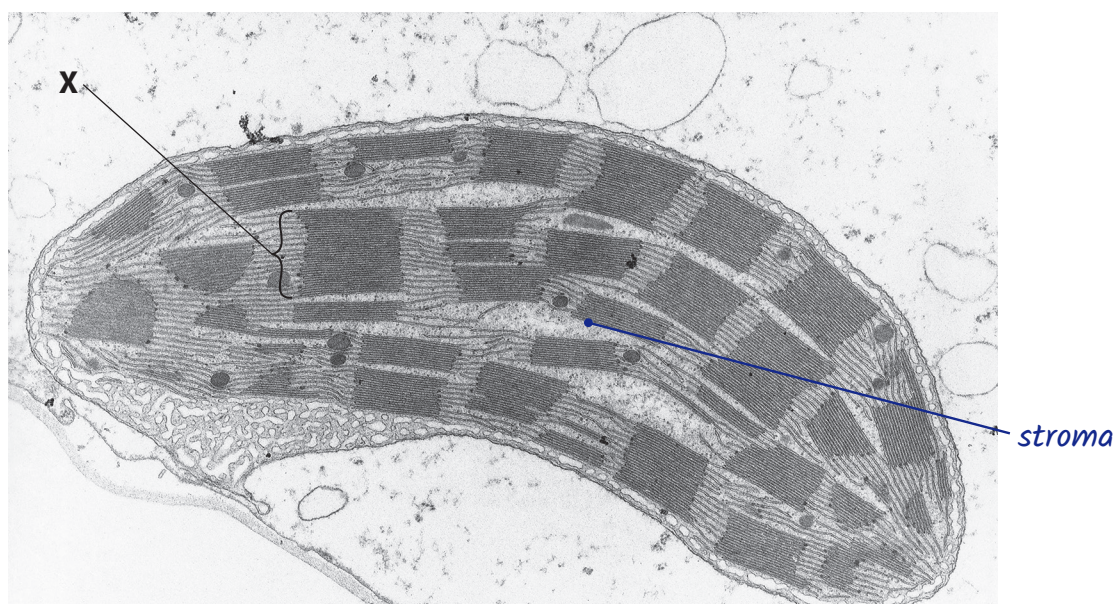
Compare the banding patterns (profiles): the more similar the banding profile, the more closely related the strains. (Or sequence the virus genome: the fewer the base changes, the more similar the strains.)

(Total for Question 2 = 9 marks)



3 Eukaryotic cells contain membrane-bound organelles.

(a) The photograph, obtained using an electron microscope, shows an organelle.



(Source: © Science History Images/Alamy Stock Photo)

(i) Label a part of this organelle where carbon fixation occurs.

(1)

(ii) Give the name of the component labelled X.

(1)

Granum (a stack of thylakoids)

(iii) Describe how the structure of a membrane in the part labelled X is related to its function.

(3)

The thylakoid membranes are stacked into grana, giving a large surface area.

The membranes contain chlorophyll and other photosynthetic pigments in photosystems

(PSI and PSII), to absorb as much light as possible.

The membranes contain the electron transport chain and ATP synthase, for the synthesis of ATP in the light-dependent reactions.

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.....

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(iv) Describe how GP is produced by carbon fixation in this organelle.

(2)

In the stroma, carbon dioxide combines with ribulose biphosphate (RuBP, a 5C molecule), catalysed by the enzyme RUBISCO.

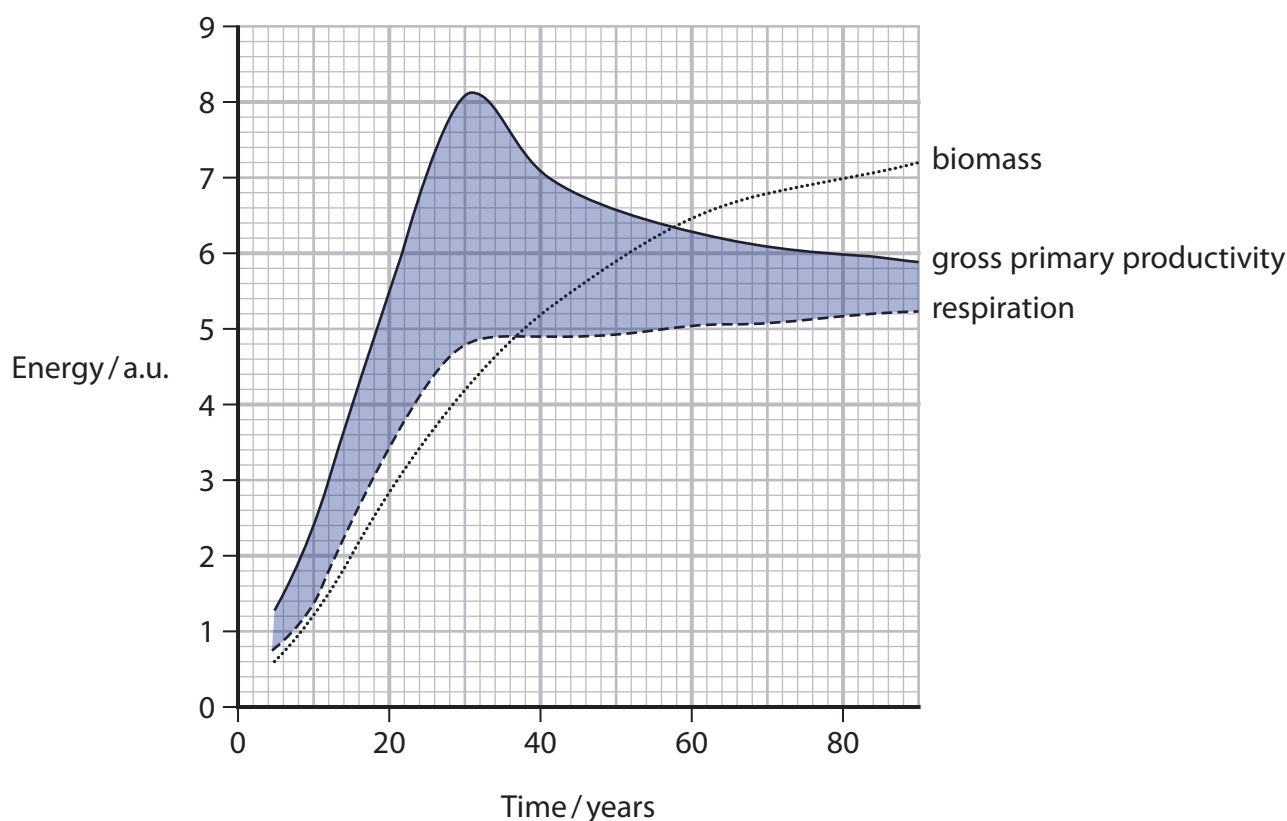
This forms an unstable 6C molecule which breaks down into two molecules of GP (glycerate 3-phosphate).

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(b) The graph shows the changes in biomass, gross primary productivity and the energy used in respiration during succession from grassland to mature forest.



(i) Add shading to the graph to show the area that represents net primary productivity.

(1)

(ii) Describe what is meant by the term succession.

(2)

Succession is the change in the communities (species) present in an area over time.

It goes from pioneer species colonising the area, through a series of stages, to a stable climax community (here from grassland to mature forest).

(iii) Deduce the effect of succession on the level of carbon dioxide in the atmosphere.

(3)

As succession proceeds, the energy lost in respiration levels off (at about 5 a.u. after 30 years), while biomass continues to accumulate.

GPP stays higher than respiration, so more carbon dioxide is fixed by photosynthesis than is released by respiration; the carbon is stored in the biomass (a carbon sink).

Therefore succession reduces the amount of carbon dioxide in the atmosphere.

(Total for Question 3 = 13 marks)



- 4 The photograph shows a plant called lantana (*Lantana camara*).



(Source: © Peter Vrabel/Alamy Stock Photo)

The leaves of lantana contain chemicals known to have antimicrobial properties.

The antimicrobial activity of lantana leaf extracts prepared using three different solvents, A, B and C, was compared.

Fresh lantana leaves were dried and powdered. The dried leaf material was mixed with the solvent and then the extract was purified and dried.

The mass of extract obtained from 5 g of powdered leaf, using each solvent, was measured.

Solvent used	Mean mass of extract $\pm$ SD / μg
A	501.3 ± 3.5
B	721.3 ± 1.5
C	245.6 ± 4.0

- (a) The mass of dried and powdered lantana leaves is 10.5% of the mass of fresh leaves.

Calculate the mass of fresh leaves needed to produce 1 mg of extract using solvent A.

Give your answer to three significant figures.

(2)

1 mg = 1000 μg ; 5 g of dry leaf gives 501.3 μg of extract

dry leaf needed = $(1000 \div 501.3) \times 5 = 9.974 \text{ g}$

fresh leaf needed = $9.974 \div 0.105 = 94.99 \text{ g}$

95.0

g



(b) The antimicrobial properties of the extracts produced using these solvents are shown in the table.

Solvent used to prepare extract	Dry mass of extract / μg	Bacteria tested	
		<i>Klebsiella pneumoniae</i> (Gram negative)	<i>Micrococcus luteus</i> (Gram positive)
		Mean diameter of the zone of inhibition / mm	
A	5.0	8.3	7.1
	10.0	10.5	7.0
B	5.0	14.5	12.2
	10.0	18.1	18.0

(i) Deduce the effect of using different solvents on the effectiveness of the extracts against these two bacteria.

(2)

The extract made with solvent B is the most effective against both bacteria (largest zones of inhibition, e.g. 18.1 mm v 10.5 mm at 10.0 μg), and solvent A is the least effective.

Both extracts are more effective against Klebsiella (Gram negative) than Micrococcus (Gram positive), so Gram negative bacteria are more sensitive.

(ii) Devise a method that could be used to collect the data in the table.

(4)

Using aseptic technique, spread a lawn of one of the bacteria (e.g. Klebsiella) evenly over a nutrient agar plate.

Dissolve the extract and add 5.0 μg or 10.0 μg of extract to sterile paper discs (or into wells cut in the agar) and place them on the plate; include a control disc with no extract.

Tape the lid on and incubate the plates at 25 °C for 48 hours.

Measure the diameter of each zone of inhibition (in mm) with a ruler; repeat with at least 3 plates for each extract and bacterium and calculate the mean.

(Total for Question 4 = 8 marks)

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5 Habituation is a learning response observed in many types of animal.

(a) Explain the importance of the habituation response in an animal.

(2)

Habituation allows an animal to learn to ignore repeated, non-threatening (harmless) stimuli.

Therefore it does not waste energy responding to unimportant stimuli and can focus on potentially more relevant stimuli, such as predators or food.

(b) The 'light-off jump' assay can be used to study habituation in fruit flies.

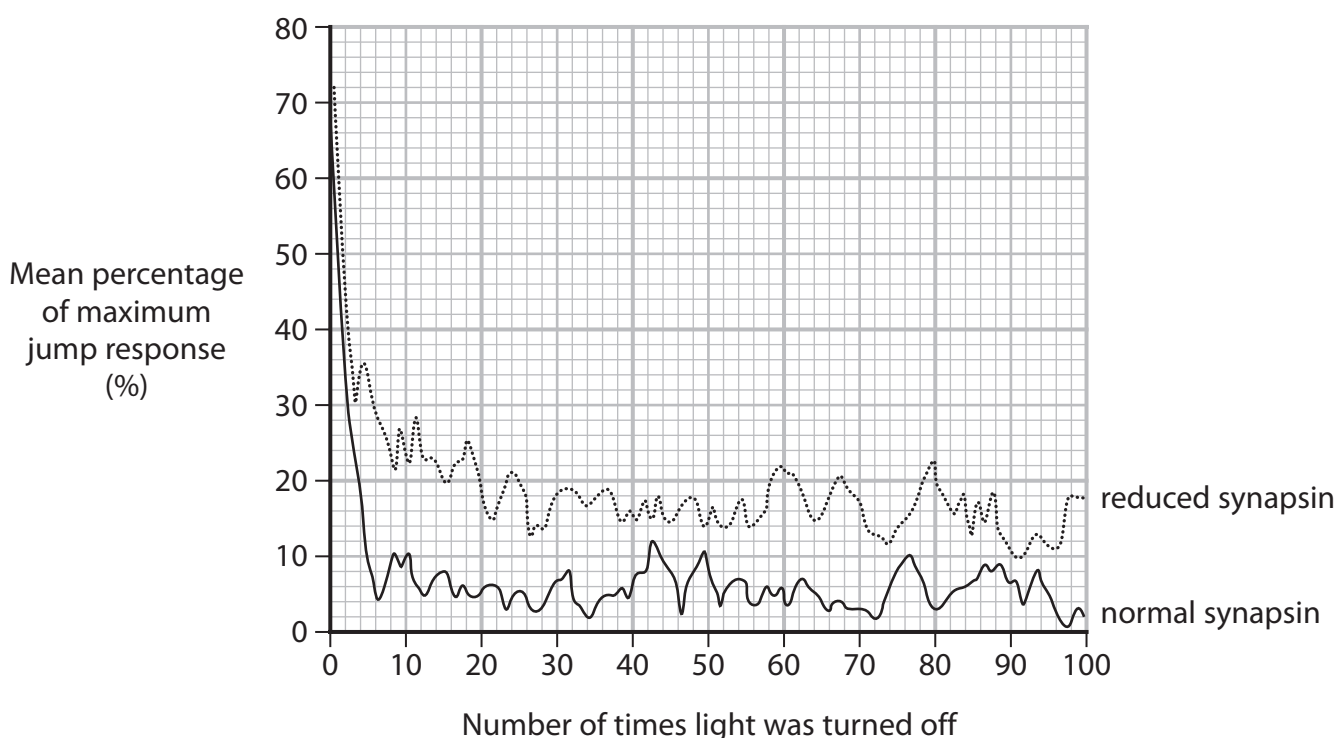
When the light is turned off the flies jump into the air and attempt to fly away.

The strength of this response can be measured by recording the noise made by the flies.

In one experiment, fruit flies with reduced expression of a protein called synapsin were compared with a control group.

Synapsin is a protein that inhibits the binding of presynaptic vesicles to the cell membrane.

The results of this experiment are shown in the graph.



- (i) State two variables associated with the light-off stimulus that need to be controlled in this experiment.

(2)

1. The frequency of the light-off pulses (the interval between turning the light off).

2. The duration of each light-off pulse.

- (ii) Determine the effect of reduced synapsin on the habituation of fruit flies in this experiment.

(3)

With reduced synapsin, habituation is not as complete: the flies keep a greater percentage of maximum jump response.

Habituation also takes place more slowly: the jump response decreases more slowly with reduced synapsin.

e.g. after 100 light-off stimuli the response is about 18% with reduced synapsin compared with about 2% with normal synapsin, 16% higher; normal flies fall to about 5% after only 5 stimuli, but reduced synapsin flies never fall below about 10%.



(iii) Explain how reduced expression of synapsin could produce these results.

(3)

Synapsin normally inhibits vesicles binding, so with reduced synapsin more vesicles can (continue to) fuse with the presynaptic membrane.

This causes more exocytosis (release) of neurotransmitter into the synapse with each stimulus.

Therefore there is more depolarisation of the postsynaptic membrane, so action potentials continue to be generated in the postsynaptic neurone.

Therefore the flies continue to respond (jump) to the light-off stimulus.

- (c) Scientists are using fruit fly habituation to investigate the role of genes associated with human autism spectrum disorders (ASD).

Before they can do this, the scientists first identify genes linked to human ASD.

Describe how genes linked to human ASD could be identified.

(2)

Sequence the genomes (DNA) of a large number of people with ASD and people without ASD and compare them.

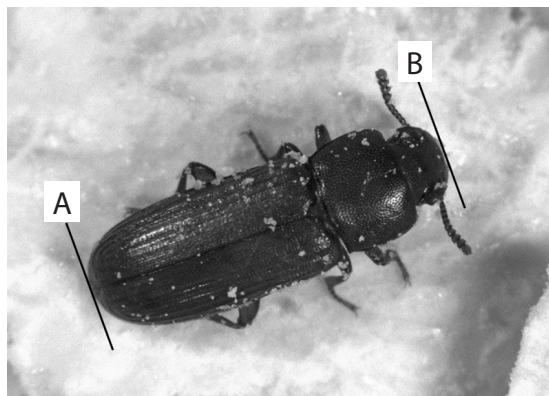
Identify genes that have mutations (differences in base sequence) found in people with ASD but not in people without ASD.

(Total for Question 5 = 12 marks)



- 6 The red flour beetle (*Tribolium castaneum*) is a food pest found in flour.

The photograph shows a red flour beetle.



(Source: © Nigel Cattlin/Alamy Stock Photo)

magnification $\times 15$

- (a) Calculate the length of the red flour beetle between A and B.

(1)

$$50 \text{ mm} \div 15 = 3.33$$

3.3 mm

- (b) The main food source for adult red flour beetles is starch.

Red flour beetles lay eggs that contain all the nutrients required for the development of the embryo.

The main food source in the eggs is glycogen.

Describe how starch can be used to make glycogen.

(3)

Starch is broken down into glucose (α -glucose) by amylase and maltase.

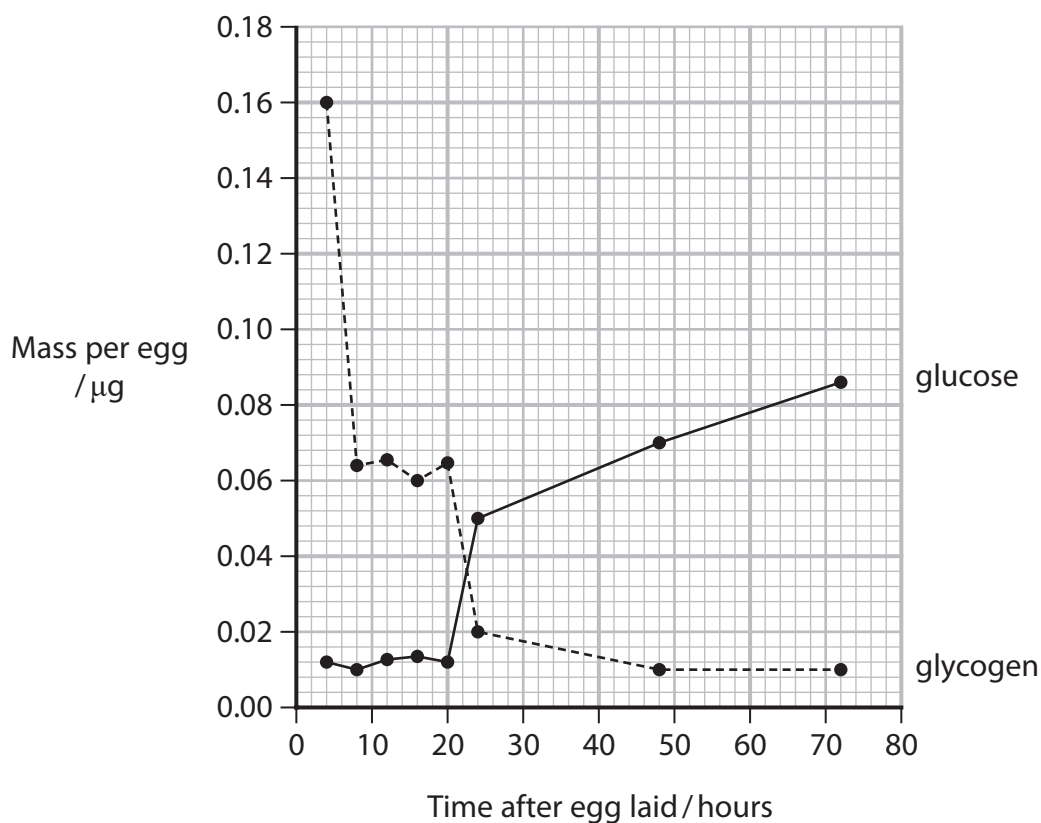
This is by hydrolysis of the glycosidic bonds (α -1,4 and α -1,6), using water.

The glucose is then joined to form glycogen by condensation reactions between

α -glucose molecules, forming α -1,4 and α -1,6 glycosidic bonds (giving a highly branched molecule).



- (c) The graph shows the changes in mass of glucose and glycogen in the eggs of the red flour beetle during embryo development.



- (i) Calculate the percentage of glycogen used from 4 to 8 hours after the eggs were laid.

(2)

glycogen at 4 h = 0.16 μg , at 8 h = 0.064 μg

glycogen used = 0.16 - 0.064 = 0.096 μg

percentage = (0.096 $\div$ 0.16) $\times$ 100 = 60

60 %



- (ii) A student suggested that between 20 and 24 hours the cells in the developing embryo switched from anaerobic to aerobic respiration.

Describe how a respirometer could be used to test this suggestion.

(3)

Put a known number of eggs in a respirometer with soda lime (a carbon dioxide absorber), with a control tube of glass beads, in a water bath at constant temperature.

Measure the distance moved by the coloured liquid in the capillary tube in a set time, before 20 hours (e.g. 12 to 20 h) and after 24 hours (e.g. 24 to 30 h).

In anaerobic respiration no oxygen is used, so the liquid does not move; in aerobic respiration oxygen is taken up, so the liquid moves towards the eggs. If it only moves after 20 to 24 h, the suggestion is supported.

(Total for Question 6 = 9 marks)

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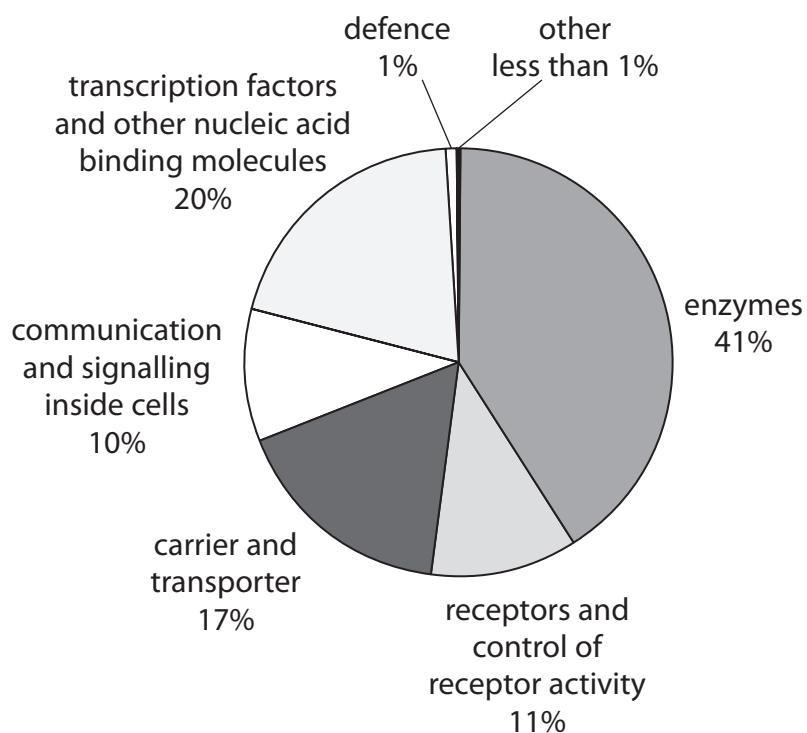
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*7 The human genome codes for approximately 20 000 different proteins.

The pie chart shows the proportion of proteins carrying out different functions.



The 20 amino acids used to make proteins can be classified according to the properties of their side chains (R groups).

Table 1 shows the number of amino acids with these properties.

Property of the side chain group	Number of amino acids with the property
Non-polar	9
Polar, uncharged	6
Negatively charged	3
Positively charged	2

Table 1



Table 2 shows three amino acids, used to synthesise proteins, that have unique properties.

Amino acid	Comment on structure
Cysteine	The side chain contains a thiol group (-S-H) that is chemically reactive.
Glycine	The side chain is a hydrogen atom which is much smaller than any other side chain. This allows tight coiling of polypeptide chains.
Proline	The side chain forms a peptide bond with the nitrogen in the amino group. This makes a polypeptide chain more rigid.

Table 2

Discuss the importance of the amino acid side chain to the structure, function and location of proteins.

(9)

The genome codes for about 20 000 different proteins with many different functions, e.g. 41% are enzymes, 17% carriers and transporters and 11% receptors. This variety is possible because there are 20 different amino acids, each with a different R group, which can be joined in any sequence, giving a huge number of combinations.

Structure: the sequence of amino acids determines how the chain folds, because R groups interact to form hydrogen bonds, ionic bonds and disulfide bonds, which determine and stabilise the 3D (tertiary) shape. The thiol groups of cysteine react to form disulfide bridges, so the location of cysteine determines where these strong bonds hold the chain together. Glycine's small R group allows tight coiling: in collagen every third amino acid is glycine, so three chains wind tightly into a strong triple helix, and proline makes the chain more rigid.

Function: as R groups determine the specific 3D shape, they determine the function.

Enzymes have an active site complementary to their substrate, antibodies have a variable region specific to one antigen and receptors bind specific molecules such as acetylcholine. Haemoglobin is a globular protein folded so that each of its four chains



holds a haem group that binds oxygen. Collagen is fibrous and insoluble with high tensile strength, suited to a structural role.

Location: 9 of the 20 R groups are non-polar and 11 are polar or charged. In soluble proteins such as haemoglobin, hormones and antibodies, non-polar R groups face inwards and polar or charged R groups are on the outside, so they dissolve in the cytoplasm of red blood cells, plasma or tissue fluid. Membrane proteins have non-polar R groups where they sit in the hydrophobic layer, while polar R groups line ion channels. Collagen has non-polar R groups on its outside, so it is insoluble and found outside cells in tendons, skin and artery walls.

Therefore the R groups determine the structure of a protein, which determines its function and where in the body it is located.

(Total for Question 7 = 9 marks)



8 The scientific article you have studied is adapted from *Scientific American*.

Use the information from the scientific article and your own knowledge to answer the following questions.

- (a) Explain why natural selection took place in Darwin's Galapagos finches (paragraph 3).

(3)

The finch populations were isolated on different islands (different locations).

Each island had different selection pressures, e.g. different food sources such as seeds of different sizes or insects.

Random mutations produced variation in beak shape in the different populations.

Finches with better adapted beaks were more likely to survive and reproduce, passing on their favourable alleles, so the allele frequency changed and each population adapted to its selection pressures.

- (b) Explain how inflammation and the immune response can cause damage to tissues (paragraph 4).

(3)

Damaged cells and mast cells release chemical mediators such as histamine.

These increase blood flow and capillary permeability, so fluid leaks out causing oedema (swelling).

More white blood cells are recruited and activated in the area, e.g. phagocytes, macrophages and T killer cells.

These release (catabolic) enzymes and increase phagocytosis, which can destroy healthy tissue as well as damaged tissue.



(c) Describe how tumour shrinkage could be observed (paragraph 6).

(2)

Use MRI (or CT or PET) scans to measure the size of the tumour.

Scan before treatment and then at regular intervals (e.g. every month) after treatment, and compare the tumour size.

(d) "Why is aging, smoking or radiation exposure associated with cancer?" (paragraph 8).

Explain why "These things cause mutations".

(3)

Carcinogens in smoke and radiation can damage DNA, changing the DNA base sequence or chromosome number (or causing epigenetic changes such as methylation of DNA).

With age there have been a greater number of cell divisions and a longer exposure to mutagens, so a greater chance of an error in the base sequence of the DNA during replication.

(e) Explain why a cancer cell needs to 'use the resources of the tissue immediately around it' (paragraph 12).

(2)

Cancer cells grow and divide rapidly.

Therefore they need oxygen and glucose for respiration, to provide ATP.

They also need amino acids, nucleotides and lipids for growth and cell division, e.g. for protein synthesis, DNA replication and new cell membranes.



P 6 7 0 9 2 R A 0 2 5 2 8

- (f) Explain how 'a cancer-causing mutation' could increase the rate of division in stem cells (paragraph 14).

(3)

A mutation (change in base sequence) in a gene for a cell cycle control (checkpoint) protein means there is no checkpoint.

This could activate an oncogene or deactivate a tumour suppressor gene (such as p53).

Therefore cell division is no longer inhibited and the cell cycle is shortened (e.g. a shorter G1 stage), giving uncontrolled cell division.

- (g) Describe how a cell that is 'a key player in the body's immune system' differs from a stem cell (paragraph 14).

(4)

A stem cell is undifferentiated (unspecialised), whereas a key player is differentiated (specialised) to carry out a specific function.

For example, a B cell (plasma cell) is a key player specialised to produce antibodies specific to one antigen.

The key player has undergone differential gene expression, so only certain genes are switched on (e.g. antibody genes), whereas in a stem cell they are not.

A stem cell can divide an unlimited number of times, whereas a key player can only divide a limited number of times (the Hayflick limit).



- (h) Describe how the effects of 'competitive release' could be demonstrated (paragraphs 18 and 19).

(4)

Select two groups of patients with the same type and stage of cancer, matched for age, sex and health.

Treat one group with a high (maximum) dose of a chemotherapy drug and the second group with a lower (minimum) dose.

Measure the size of the tumours using MRI or CT scans.

Repeat the scans regularly over a period of time, e.g. every month for a year.

Competitive release is shown if the cancer eventually responds better to the low dose than the high dose: the high dose kills the sensitive cells, so resistant cells no longer compete and the tumour regrows, while the low dose keeps sensitive cells that hold the resistant cells in check.

- (i) Describe how evasion mechanisms can enable pathogens to become drug-resistant (paragraph 20).

(2)

Mutations accumulate, changing the shape of the target (e.g. antigens or receptor binding proteins), so the drug or host can no longer recognise and bind to it.

Genes coding for resistance can be transferred between bacteria on plasmids, e.g. a gene for an enzyme that breaks down the antibiotic.

- (j) Discuss the ethical issues relating to the use of mice in experiments such as those described in the article (paragraph 25).

(4)

For: utilitarian argument, the overall benefits of the experiments (new cancer treatments for many people) are greater than the harm done to the mice.

Welfare argument: mice can be used if they are treated as well as possible, e.g. their use is regulated, the minimum number is used and pain is minimised.

Against: rights argument, all animals have rights, so it is not acceptable to keep mice in laboratory cages or cause them pain and suffering.

Mice cannot give consent, as is required for human trials.

The results in mice may not be applicable to humans, as their physiology is different.

(Total for Question 8 = 30 marks)

TOTAL FOR PAPER = 100 MARKS

