

Please check the examination details below before entering your candidate information

Candidate surname <i>StemUp Model Solution</i>		Other names	
Pearson Edexcel		Centre Number	Candidate Number
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 National Geographic (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 your working in any calculation questions and include units in your answer where appropriate.
- Answer the questions in the spaces provided
– *there may be more space than you need.*
- 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.

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.*

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.
- Good luck with your examination.

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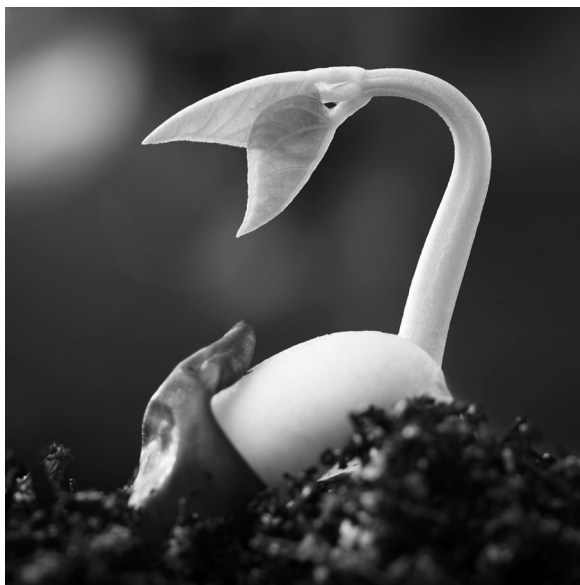


Answer ALL questions.

Write your answers in the spaces provided.

- 1** Plants can respond to and use light.

The photograph shows a seedling starting to grow from a germinating seed.



- (a) Explain why the seedling needs a supply of magnesium ions.

(2)

Magnesium ions are needed to make chlorophyll, because chlorophyll is required for photosynthesis.

Once the food stored in the seed is used up, the shoot needs chlorophyll to carry out photosynthesis so that it can grow.



(b) Describe the role of IAA (auxin) in the phototropic response of plants.

(4)

IAA is produced in the tip of the shoot.

When light comes from one side, IAA diffuses (moves) to the opposite, shaded side of the shoot, so IAA accumulates on the dark side and a diffusion gradient is established.

IAA stimulates cell elongation, so cells on the dark side elongate more than cells on the light side.

This causes the shoot to bend and grow towards the light source (positive phototropism).

(Total for Question 1 = 6 marks)



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2 Acetylcholinesterase is an enzyme involved in regulating the transmission of nerve impulses across some synapses.

- (a) Acetylcholinesterase is found on the cell surface membranes of neurones and red blood cells.

These acetylcholinesterase molecules have different primary structures.

In humans, a single gene codes for acetylcholinesterase.

- (i) Explain how a single gene can give rise to acetylcholinesterase molecules with different primary structures.

(2)

The acetylcholinesterase gene is made up of several exons and introns. After transcription, the pre-mRNA undergoes splicing (post-transcriptional modification).

Different exons can be removed, or the exons joined in different sequences, therefore producing different mRNA sequences and so different sequences of amino acids.

- (ii) Explain how the acetylcholinesterase gene can be expressed in some tissues but not others.

(3)

Hormones (signal molecules) bind to receptors found only in some tissues (cells), so they only act on some cells.

This regulates a transcription factor, which binds to the promoter region of the acetylcholinesterase gene.

This allows (or prevents) binding of RNA polymerase, therefore switching transcription of the gene on (or off) in that tissue.



- (b) Alzheimer's disease is associated with the loss of neurones that produce acetylcholine.

It has been suggested that inhibitors of acetylcholinesterase may be useful in the treatment of Alzheimer's disease.

- (i) Explain why inhibitors of acetylcholinesterase could be useful in the treatment of Alzheimer's disease.

(3)

Acetylcholinesterase breaks down acetylcholine in the synaptic cleft.

The inhibitor blocks acetylcholinesterase, preventing the breakdown of acetylcholine, so higher concentrations of acetylcholine are maintained in the synapse.

So more acetylcholine is available to bind to receptors on the postsynaptic membrane, compensating for the reduced production of acetylcholine due to the loss of acetylcholine-producing neurones.

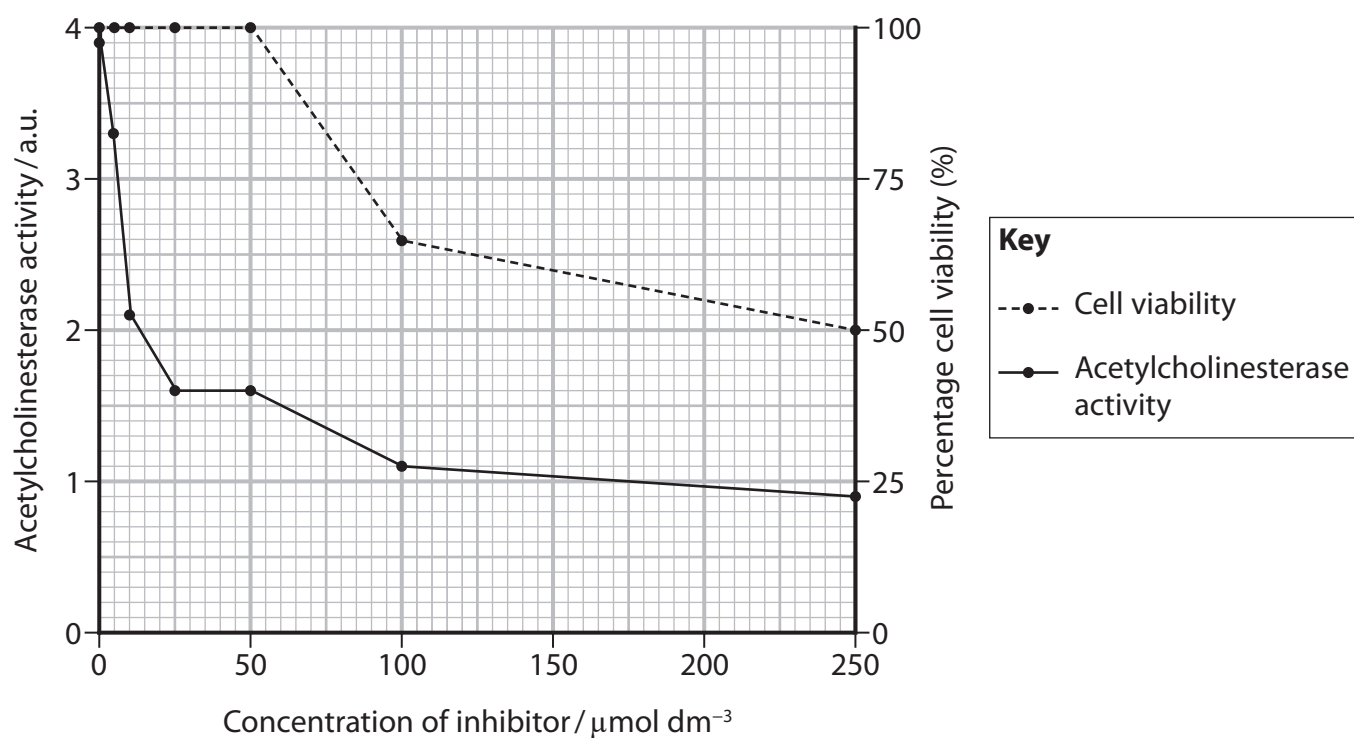


(ii) Trials of a new inhibitor were carried out using tissue cultures.

The effect of the concentration of the inhibitor on acetylcholinesterase activity and cell viability was measured.

Percentage cell viability was measured as the percentage of cells that were not killed by the inhibitor.

The graph shows the results for this inhibitor.



State and justify a suitable concentration of inhibitor to use in clinical trials.

(3)

A concentration of about $40 \mu\text{mol dm}^{-3}$ (between 25 and $50 \mu\text{mol dm}^{-3}$).

This concentration has the greatest inhibitory effect while being safe: it reduces enzyme activity from 4.0 to 1.6 a.u., by more than 50% (60% , 2.4 a.u.).

But it has no effect on cell viability, which remains at 100% ; above $50 \mu\text{mol dm}^{-3}$ cells start to be killed.

(Total for Question 2 = 11 marks)



3 Doctors sometimes prescribe beta-blockers for their patients.

Beta-blockers are a type of drug with antihypertensive properties.

- (a) In one study, the effect of beta-blockers on the heart rate during exercise was investigated.

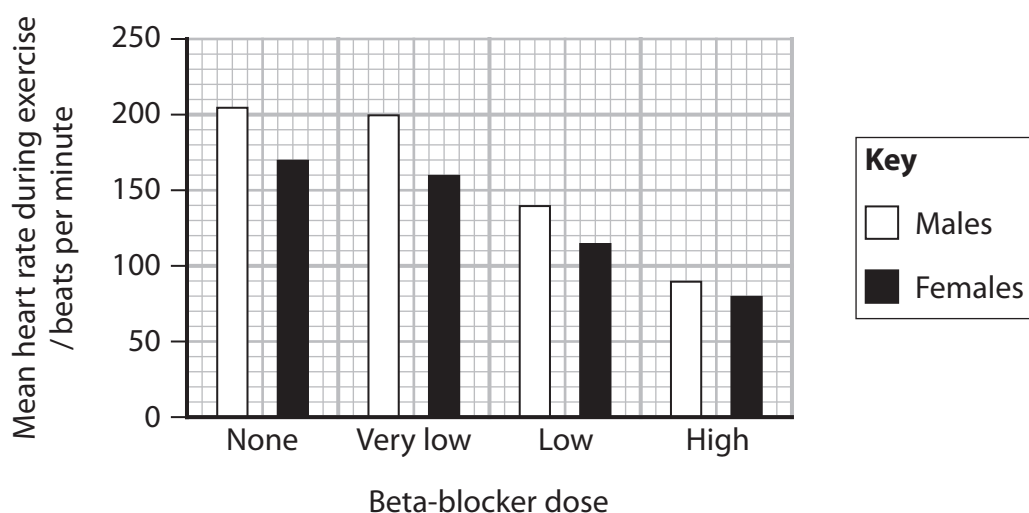
In this study, volunteers were placed randomly into one of four groups shown in the table.

Group	Dose of beta-blocker
A	none
B	very low
C	low
D	high

The heart rate of each volunteer was recorded during a period of exercise.

A mean value was calculated separately for the males and females in each group.

The graph shows the results of this study.



- (i) Calculate the percentage change in male heart rate caused by increasing the dose of beta-blocker from very low to high.

(2)

very low dose = 200 bpm, high dose = 90 bpm

$$(200 - 90) \div 200 \times 100 = 55$$

Answer 55 % decrease



- (ii) Deduce the effect of beta-blockers on the supply of blood to muscle during exercise.

(4)

The larger the dose of beta-blocker, the greater the decrease in heart rate during exercise (at a very low dose there is little change).

Reducing the heart rate reduces the cardiac output (cardiac output = heart rate $\times$ stroke volume).

Therefore the supply of blood to the muscles during exercise is reduced.

Increasing the dose has a greater effect on males than females: from very low to high dose the heart rate decreases by about 55% in males (200 to 90) but by about 50% in females (160 to 80).

- (b) Explain why beta-blockers are prescribed for some people.

(2)

Beta-blockers reduce blood pressure, so they are prescribed to people with high blood pressure (or an irregular heartbeat or anxiety).

Therefore they reduce the risk of atherosclerosis, heart disease (CVD) and heart attack, because high blood pressure can damage the endothelium of arteries.



(c) Beta-blockers work by blocking the effects of a hormone called adrenaline.

Adrenaline is produced by the adrenal glands located on top of each kidney.

Adrenaline acts on the heart to cause changes in heart rate.

Deduce how adrenaline can cause a change in heart rate.

(4)

Adrenaline is carried in the blood from the adrenal glands to the heart.

It acts on the sinoatrial node (SAN), the pacemaker of the heart.

It increases the frequency of impulses (depolarisations) produced by the SAN that spread across the atria and then to the ventricles via the AVN.

This increases the rate at which the atria and ventricles contract, so heart rate increases.

(Total for Question 3 = 12 marks)



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4 Lipoprotein lipase is an enzyme found in different tissues including the brain.

(a) The enzyme lipoprotein lipase is involved in the metabolism of lipids in the brain.

The effect of temperature on lipid metabolism in the brain tissue of a species of fish was investigated.

The results of this investigation are shown in the table.

Temperature / °C	Lipoprotein lipase mRNA / a.u.	Triglyceride concentration / mmol mg ⁻¹	Fatty acid concentration / μmol mg ⁻¹	Lipoprotein lipase activity per milligram of tissue / a.u.
5	4.50	0.58	0.84	1.70
17	1.00	0.60	0.69	1.55
30	1.10	0.70	0.64	0.99

Comment on the effect of temperature on lipid metabolism in this species of fish.

(3)

As temperature increases, less lipoprotein lipase mRNA is produced (4.50 a.u. at 5 °C, about 1 a.u. at 17 and 30 °C), so less enzyme is made.

This results in reduced lipoprotein lipase activity per milligram of tissue (from 1.70 to 0.99 a.u.).

As temperature increases, triglyceride concentration increases (0.58 to 0.70 mmol mg⁻¹) and fatty acid concentration decreases (0.84 to 0.64 μmol mg⁻¹), because triglycerides are not being broken down into fatty acids.

So lipid metabolism is faster at low temperature in this fish.



(b) Lipoprotein lipase can be extracted from brain tissue to investigate the effect of temperature on the rate of reaction of this enzyme.

(i) State what is meant by the term Q_{10} temperature coefficient.

(1)

The ratio of the rate of an enzyme reaction at one temperature to the rate at a temperature 10 °C lower: $Q_{10} = \text{rate at } (T + 10) \div \text{rate at } T$.

(ii) Devise an investigation to determine Q_{10} for an extract of lipoprotein lipase enzyme.

(5)

Use two water baths to control the temperature with a 10 °C difference, e.g. 25 °C and 35 °C, checked with a thermometer.

Provide an excess of triglyceride substrate (e.g. lipid solution or milk) and keep its volume constant; equilibrate the solutions in the water bath before mixing.

Control the concentration and volume of the lipoprotein lipase extract (at a limiting concentration), and keep the pH constant using a buffer.

Measure the concentration of fatty acids (or triglyceride) at stated time intervals, e.g. every 30 seconds for 5 minutes, e.g. by measuring the fall in pH with a pH probe or the decrease in cloudiness of the lipid solution with a colorimeter.

Plot a graph against time and find the initial rate by drawing a tangent to the curve at time 0; repeat three times at each temperature and calculate the mean.

$Q_{10} = \text{initial rate at } T + 10 \div \text{initial rate at } T$.

(Total for Question 4 = 9 marks)



5 Forests are important habitats.

(a) The effect of cutting down trees on the number of bird species observed in two different forest habitats was investigated.

- (i) Give two biotic factors, other than cutting down trees, that could affect the number of bird species observed in a forest.

(2)

Food availability.

Predation.

Also disease, or interspecific competition with other species for food.

- (ii) Some of the results of the investigation are shown in the table.

Forest	Number of bird species in areas of the forest where no trees are cut down	Number of bird species in areas of the forest where some trees are cut down
A	35	19
B	16	10

Calculate the Chi-squared value (χ^2) for forest B using the formula shown.

$$\chi^2 = \sum \frac{(O - E)^2}{E}$$

$$\text{total} = 16 + 10 = 26, E = 26 \div 2 = 13$$

(3)

$$(16 - 13)^2 \div 13 = 9 \div 13 = 0.69$$

$$(10 - 13)^2 \div 13 = 9 \div 13 = 0.69$$

$$\chi^2 = 0.69 + 0.69 = 1.38$$

Answer *1.38*



(iii) The table gives some critical values for the Chi-squared test.

Probability level	Critical value
0.05	3.84
0.01	6.64
0.001	10.83

The Chi-squared value for forest A is 4.74.

Deduce the effect of some trees being cut down on the number of species of birds in these two forests.

(2)

Cutting down trees decreases the number of bird species (species richness) in both forests.

In forest A, $\chi^2 = 4.74$ is greater than the critical value of 3.84, so the decrease is significant at $p = 0.05$ (less than 5% probability the reduction is due to chance).

In forest B, $\chi^2 = 1.38$ is less than 3.84, so the decrease is not significant at $p = 0.05$ (more than 5% probability that it is due to chance).



(b) Many forests are exploited by humans.

(i) Describe how forests can be managed as a sustainable resource.

(2)

Remove (cut down) older trees and replace the trees that have been cut down by planting seedlings or young, rapidly growing trees.

Or use coppicing, cutting trees near the base so that new shoots regrow.

(ii) Explain the impact of cutting down trees on climate change.

(4)

Fewer trees means less photosynthesis.

So less carbon dioxide is fixed (taken from the atmosphere) and more CO_2 remains in the atmosphere, especially if the wood is burned or decomposes, releasing CO_2 .

CO_2 is a greenhouse gas, so more (heat) energy is trapped in the atmosphere: more infrared radiation is absorbed and re-radiated back to the Earth.

More energy in the atmosphere increases the atmospheric (and Earth's surface) temperature, contributing to global warming and climate change.

(Total for Question 5 = 13 marks)



- 6 The neurones of the central nervous system contain TAU proteins. These proteins help to maintain cell structure.

In humans, six different TAU proteins can be produced from a single gene.

Parkinson's disease has been linked to the different forms of the TAU proteins present in neurones.

Scientists are studying the effect of these different TAU proteins in animal models.

One model used is the fruit fly, *Drosophila*.

- (a) Describe how *Drosophila* flies could be genetically modified to produce one form of the human TAU protein.

(4)

Extract the mRNA for one form of the human TAU protein and use reverse

transcriptase to copy the mRNA into DNA (cDNA).

Use restriction enzymes to cut the DNA and a vector (plasmid) to create

complementary sticky ends.

Ligate (insert) the TAU DNA into the vector DNA using DNA ligase.

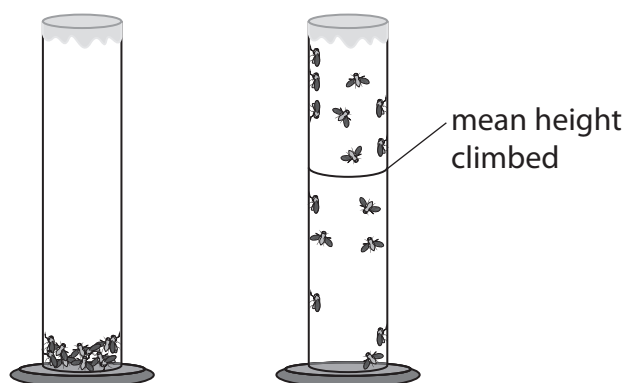
*Introduce the vector into fertilised eggs (zygotes or embryonic stem cells) of *Drosophila*,
e.g. by microinjection, so all cells of the fly contain the gene.*



(b) In one investigation, the effect of ageing on *Drosophila* making different human TAU proteins was studied.

Flies making different forms of human TAU protein were tested in a climbing test.

- Fifteen one-day-old *Drosophila* flies were placed at the bottom of a measuring cylinder.
- A video recording was carried out and paused at 10 seconds. The height climbed by each fly was recorded.
- The test was repeated for flies of different ages.



time = 0 seconds time = 10 seconds

The table shows the results of this investigation.

Age of flies / days	Mean height climbed at 10 seconds / mm		
	Control (no human TAU protein)	0N3R TAU protein	0N4R TAU protein
1	60 ± 6	52 ± 5	54 ± 5
7	61 ± 4	43 ± 1	50 ± 4
14	53 ± 3	18 ± 2	28 ± 8
21	45 ± 9	12 ± 4	18 ± 5
28	32 ± 8	10 ± 5	19 ± 1
35	26 ± 9	3 ± 1	11 ± 1
42	15 ± 3	1 ± 1	3 ± 1



Comment on the effect of TAU proteins on the ability of *Drosophila* flies to climb.

(3)

As they age, all *Drosophila* climb less high (e.g. control falls from 60 mm at 1 day to 15 mm at 42 days).

The expression of ON3R or ON4R further reduces the height climbed at every age after 1 day compared with the control, e.g. at 14 days 18 and 28 mm compared with 53 mm.

ON3R has a greater effect than ON4R, e.g. at 35 days 3 mm compared with 11 mm.

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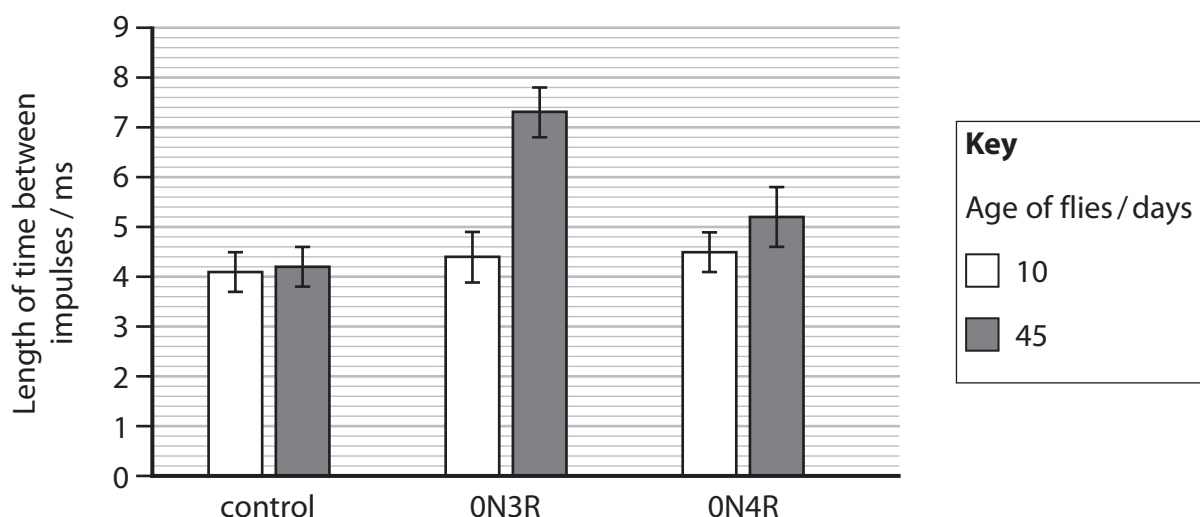


P 6 5 4 6 2 A 0 1 9 3 2

- (c) In another investigation, the effect of these TAU proteins and age on the conduction of nerve impulses along the axon of neurones was studied.

The length of time between impulses was measured for *Drosophila* flies of different ages.

The results are shown in the graph.



Determine the effect of these TAU proteins on the maximum frequency at which nerve impulses can be conducted along the axon of the neurone.

(4)

At 10 days the frequency is similar for all flies (about 240, 230 and 220 impulses per second), as the time between impulses is about 4.1 to 4.5 ms.

For older (45 day) flies with ON4R the error bars overlap with the control, so ON4R has little effect on the frequency of impulses (frequency decreases from about 220 to 190 impulses per second).

For older flies with ON3R the error bars do not overlap with the control, so ON3R significantly decreases the maximum frequency of impulses, from about 227 to 137 impulses per second (time between impulses increases from 4.4 to 7.3 ms).

(Total for Question 6 = 11 marks)



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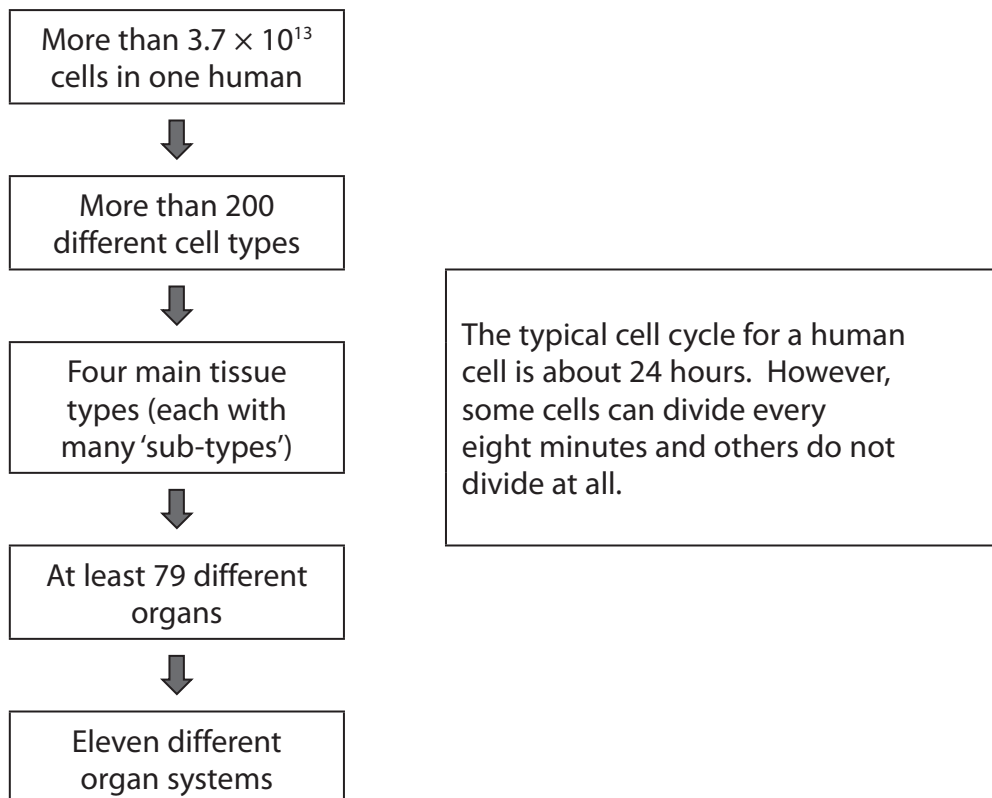


***7** Humans are complex multicellular organisms.

Cell division is involved in:

- the production of gametes
- the development of tissues
- the development of tumours
- the response to infection in humans.

The figure summarises some information about the organisation of cells in a human.



The table summarises some information about human genetics and cancers.

Number of protein coding genes	Approximately 20 000
Number of different genetic disorders	Approximately 2200
Proportion of cancers caused by an inherited genetic defect	5 to 10%



Evaluate the role of cell division in processes affecting human health and disease.

(9)

Mitosis is essential for health: it produces genetically identical cells for growth and for repair of damaged tissues. From a zygote to a fetus, cells proliferate by mitosis and then differentiate, giving more than 200 different cell types, four main tissue types, at least 79 organs and eleven organ systems, over 3.7×10^{13} cells in total.

Meiosis produces gametes (haploid cells), so the diploid number is restored at fertilisation. Independent assortment and crossing over in meiosis produce genetic variation, which can be an advantage to the species.

However, gametes can also pass on alleles that cause or predispose a person to genetic disease: there are about 2200 genetic disorders, e.g. cystic fibrosis. Errors in meiosis, such as non-disjunction, can cause chromosome disorders.

Mutations in genes controlling the cell cycle (proto-oncogenes and tumour suppressor genes) result in loss of control of mitosis, so cells divide uncontrollably, forming tumours (cancer). Only 5 to 10% of cancers are caused by an inherited genetic defect, so most are due to mutations acquired during mitosis, e.g. caused by carcinogens. Cells that divide rapidly (some every eight minutes) have more chance of mutation, whereas cells that do not divide at all, e.g. neurones, cannot be replaced.

In the response to infection, B and T lymphocytes with a complementary receptor undergo clonal selection and clonal expansion by mitosis, producing plasma cells that secrete antibodies, and memory cells.

Bacteria that cause disease divide rapidly by binary fission, but some antibiotics work by inhibiting bacterial cell division, e.g. by preventing cell wall synthesis.

Overall, cell division is vital for health, through growth, repair, reproduction and immunity, but when it is uncontrolled or goes wrong it causes cancer and genetic disease, so it plays a role in both health and disease.

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(Total for Question 7 = 9 marks)



8 The scientific article you have studied is adapted from *National Geographic*.

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

- (a) Explain how two populations of mosquito could be shown to belong to different species (paragraph 4).

(2)

Mate males and females from the two different populations.

If they cannot breed together to produce fertile offspring, the populations are different species.

- (b) Explain why scientists believe CRISPR could be used to prevent AIDS developing in people infected with HIV (paragraph 7).

(4)

When HIV infects a cell, its RNA is reverse transcribed into DNA by reverse transcriptase.

The DNA produced is integrated into the DNA of the host cell (T helper cell).

CRISPR could be used to cut out (delete), mutate or modify the viral DNA in the host DNA.

Therefore this prevents the synthesis of new virus RNA and new virus particles (or changes the structure or function of the viral proteins).

This slows the destruction of T helper cells, so the immune system is not weakened and AIDS does not develop.



- (c) Describe how plant biologists could demonstrate the effect of deleting genes that attract pests to crops (paragraph 8).

(3)

Grow the same species of plant with and without the (CRISPR) deleted genes.

Grow them in similar (controlled) biotic and abiotic conditions, e.g. same light, temperature, water and the same exposure to pests, with a large number of plants of each type.

Record a suitable dependent variable, e.g. the number of pests on the plants, the frequency of pests visiting the plants or the plant damage by pests, and compare the two groups.

- (d) Explain why the editing of the germ line of a human embryo would result in the changes being inherited by the next generation (paragraph 9).

(2)

The germ line is the population of cells that give rise to gametes, containing the genetic material that is inherited.

Editing the germ line of an embryo results in the changes being in all gametes produced, so they are passed on to offspring.



- (e) Explain why an RNA guide can be used to identify the precise nucleotides that Cas9 has been sent to cut (paragraph 12).

(2)

The RNA guide has a specific sequence of bases.

These bases are complementary to the target DNA sequence, so the RNA guide binds (base pairs) only to that precise sequence, where Cas9 then cuts.

- (f) Gene drives can be used to 'force almost any genetic trait through a population' (paragraph 16).

Multiple genetic crosses were carried out between individuals homozygous for a recessive allele and individuals heterozygous for the same gene.

Describe how the outcome of these crosses would be affected if a gene drive was used with the recessive allele.

(3)

Without a gene drive, the expected outcome would be 50% heterozygous (Aa) and 50% homozygous recessive (aa) offspring (Aa × aa gives Aa, Aa, aa, aa).

With a gene drive, the recessive allele is copied onto the other chromosome, so the proportion of homozygous recessive offspring would increase (above 50%).

The stronger (more effective) the gene drive, the greater the proportion of homozygous recessive offspring, up to 100%.



(g) Dengue is a disease caused by a virus carried by *Aedes aegypti*.

Using CRISPR and a gene drive, it may be possible to stop the reproduction of *Aedes aegypti* mosquitoes (paragraphs 20 and 21).

Explain why stopping the reproduction of this species of mosquito might not stop the spread of this disease.

(3)

Aedes aegypti is a vector, not the disease-causing organism, and it occupies its own niche.

If this species is eliminated, the niche it occupied will become vacant.

Other species of mosquito (or other insects) may evolve to occupy the niche, and these species may also carry the dengue virus and transmit it.

(h) Deduce how PERVs present in pig tissues could infect human cells (paragraph 25).

(2)

PERVs are retroviruses present in the pig genome (pigs inherit them in their genomic DNA), so PERV virus particles are produced by, and bud off from, pig cells.

PERVs bind to membrane receptors on human cells (or enter by endocytosis) and insert their nucleic acid into the human cells.



- (i) Explain why some pig genes can cause reactions in the human immune system (paragraph 27).

(3)

Pig genes are transcribed and translated to produce proteins (pig genes code for antigens).

The structure of some of these proteins is different from those in humans, so they are recognised as foreign (as antigens).

This activates lymphocytes (T and B cells), triggering a specific immune response, which leads to rejection.

- (j) Explain how a vaccine developed against human plague can provide lifelong immunity to sylvatic plague in the black-footed ferret (paragraph 33).

(3)

The same bacterium causes human plague and sylvatic plague, so they have the same antigens.

Antigens in the (human plague) vaccine are processed and presented to lymphocytes in the black-footed ferret, therefore stimulating active immunity to sylvatic plague.

Memory cells are produced against these antigens, enabling a fast secondary immune response on infection for life.



(k) State what is meant by the term endemic (paragraph 35).

(1)

A species that is found only in one particular location.

(l) Deduce the pattern of inheritance for Tay-Sachs disease (paragraph 39).

(1)

Recessive (autosomal recessive).

(Total for Question 8 = 29 marks)

TOTAL FOR PAPER = 100 MARKS



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