INSIGHT

Trial Exam Paper

2011

BIOLOGY

Written examination 1

Solutions book

This book presents:

- correct solutions
- explanatory notes
- mark allocations

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SECTION A – Multiple-choice questions

Question 1

A polypeptide is

A. formed when many amino acids join together in sequence due to the formation of ionic bonds.

B. **formed when many amino acids join together in sequence due to the formation of covalent bonds.**

C. a polymer constructed of combinations from the same set of 4 amino acids.

D. a molecule identical to a protein.

Answer is B

Explanatory notes

- A polypeptide is a polymer formed when many amino acids become connected by peptide bonds in sequence.
- A is incorrect – the bonds formed between amino acids are covalent bonds, not ionic bonds.
- B is correct.
- C is incorrect – polymers are constructed from the same set of 20 amino acids, not 4.
- D is incorrect – a polypeptide is a chain which does not show twisting, folding and coiling. A protein has a unique shape (and therefore function) which shows twisting, folding and coiling.

Question 2

The molecular formula for glucose is sometimes represented as (CH_2O). The molecular formula for a polymer made by linking ten glucose molecules would be

A. $C_{60}H_{102}O_{60}$

B. $C_{60}H_{100}O_{51}$

C. $C_{60}H_{120}O_{50}$

D. $\mathbf{C_{60}H_{102}O_{51}}$

Answer is D

Explanatory notes

- The formation of glucose polymers occurs when glucose molecules are linked in condensation reactions. In a condensation reaction, a water molecule is lost each time a link is made between each CH_2O molecule. If there are 10 unlinked glucose molecules, in total there would be 60C, 120H, 60O respectively; however, as a result of the condensation reaction, there will be 9 water molecules (18H and 9O) released. This results in a total of 60C, 102H and 51O.
- A is incorrect – whilst the number of C and H atoms is correct, there are too many O atoms present
- B is incorrect – whilst the number of C and O atoms is correct, there are not enough H atoms present.
- C is incorrect – the number of C atoms is correct however there are too many H atoms and too few O atoms present
- D is correct – this molecular formula shows the correct number of C, H and O atoms.

Question 3

In a segment of double-stranded DNA, a particular region has the following sequence of nitrogenous bases:

5′ – CCGATCG – 3′

The complementary strand has the sequence

A. 3′ – CCGATCG – 5′

B. 5′ – CCGATCG – 3′

C. 5′ – GGCTAGC – 3′

D. **3′ – GGCTAGC – 5′**

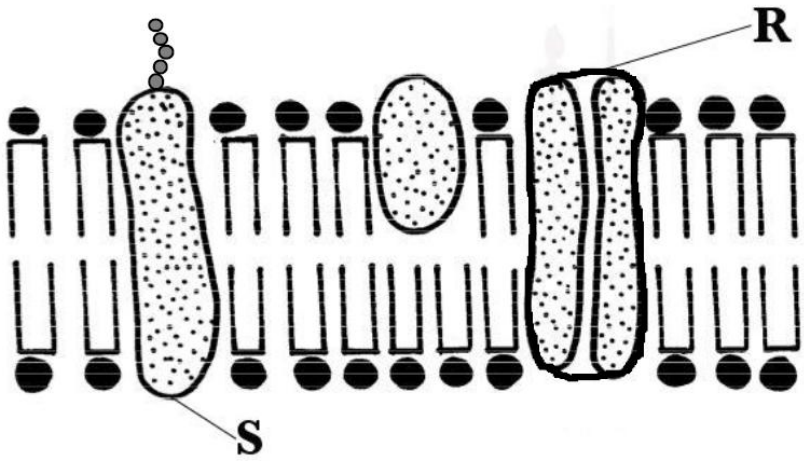
Answer is D

Explanatory notes

- A is incorrect – whilst the orientation of the segment is correct (3′ – 5′), this is an identical (not complementary) strand of DNA.
- B is incorrect – when the strand is considered in its correct orientation (3′ – 5′), the sequence of nucleotides is not complementary to the segment in the question.
- C is incorrect – whilst complementary to the segment of nucleotides shown in the question, the orientation has been reversed and shows a segment from 5′ – 3′, it should be 3′ – 5′.
- D is correct – the orientation of the sequence is correct (3′ – 5′) and the nucleotide bases are complementary to the sequence in the question.

The following information relates to Questions 4 and 5.

The diagram below shows a section from a plasma membrane.



Question 4

Molecule R is a

A. **globular protein.**

B. fibrous protein.

C. glycoprotein.

D. glycolipid.

Answer is A

Explanatory notes

- A is correct – globular proteins are generally spherical in appearance and can be found embedded in plasma membranes.
- B is incorrect – a fibrous protein tends to be shaped in long fibres and include keratins (hair), collagens (connective tissue) and elastins (ligaments), they do not form part of the plasma membrane.
- C is incorrect – a glycoprotein is a protein that has one or more carbohydrates covalently bonded to it, this molecule does not have any carbohydrate attached.
- D is incorrect – a glycolipid is a lipid that has one or more carbohydrates covalently bonded to it, this molecule does not have any carbohydrate attached and is not a lipid.

Question 5

Structure S was synthesised during formation of the plasma membrane and transported to the cell surface. The synthesis of structure S is most likely to have occurred

A. at a ribosome.

B. in the nucleus.

C. **in the endoplasmic reticulum.**

D. in a lysosome.

Answer is C

Explanatory notes

- A is incorrect – the ribosome is the site of protein synthesis, not the site of glycoprotein synthesis.
- B is incorrect – the nucleus is the site of DNA synthesis, not glycoprotein synthesis.
- C is correct – the synthesis of structure S (a glycoprotein) is most likely to have occurred in the endoplasmic reticulum where carbohydrates are attached to proteins.
- D is incorrect – the lysosome contains hydrolytic enzymes and is not associated with the synthesis of glycoproteins.

Question 6

The enzyme succinate dehydrogenase is involved in the Krebs cycle and the electron transport chain and is inhibited by the chemical malonate. A student hypothesised that malonate is a competitive inhibitor of succinate dehydrogenase. She performed an experiment using succinate dehydrogenase, malonate and the substrate succinate. The result which supports her hypothesis is

	Concentration of succinate	**Rate of Reaction**
A.	**increase**	**speeds up**
B.	increase	slows down
C.	decrease	speeds up
D.	decrease	no reaction

Answer is A

Explanatory notes

- Malonate is a competitive inhibitor of succinate dehydrogenase and acts by mimicking the substrate, competing for the active site of the enzyme. If the concentration of the substrate is increased (with the amount of malonate kept constant), the rate of reaction should increase as there will be an increased opportunity for the substrate and enzyme to interact. As active sites become available, more substrate molecules than inhibitor molecules are present to gain access to active sites. In effect, the malonate will be outcompeted.
- A is correct – this supports the explanation given above.
- B is incorrect – the rate of reaction should increase, not slow down (there is more substrate present).
- C is incorrect – if the amount of substrate is decreased, the effect of malonate as a competitive inhibitor will cause the rate of reaction to slow down.
- D is incorrect – there will always be some reaction occurring if there is a substrate and its associated enzyme present, the rate of reaction will be reduced if there is less substrate in the presence of a competitive inhibitor.

Question 7

Which of the following processes could be described as one that follows a catabolic pathway?

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

B. amino acids → protein

C. ADP + Ⓟi → ATP + H_2O

D. glucose + galactose → lactose

Answer is A

Explanatory notes

- A reaction that follows a catabolic pathway releases energy by breaking down complex molecules to simpler compounds.
- A is correct – the oxidation of glucose to produce carbon dioxide and water follows a catabolic pathway.
- B is incorrect – the linking of amino acids with peptide bonds to form a protein is a process that follows an anabolic pathway.
- C is incorrect – the building of an ATP molecule by reacting ADP and P i follows an anabolic pathway.
- D is incorrect – the building of a lactose molecule follows an anabolic pathway.

Question 8

A botanist extracted pigments from the leaves of a green plant. The pigments were suspended in an isotonic solution and then white light was passed through the mixture. What effect will the leaf pigments have on the white light?

A. Green wavelengths will be absorbed and red and blue wavelengths will be transmitted.

B. **Red and blue wavelengths will be absorbed and green wavelengths will be transmitted.**

C. Blue wavelengths will be absorbed and green and red wavelengths will be transmitted.

D. Green and red wavelengths will be absorbed and blue wavelengths will be transmitted.

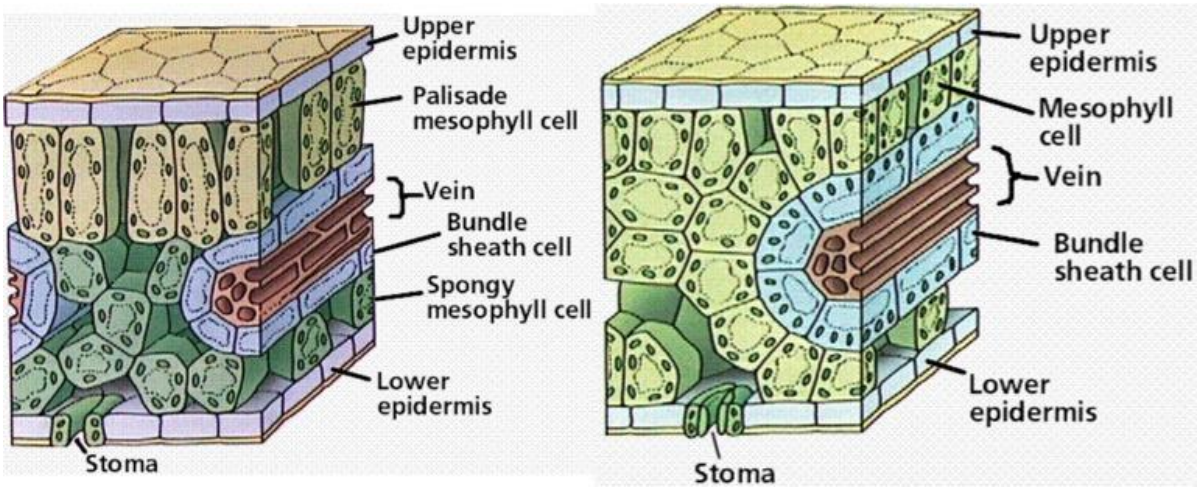
Answer is B

Explanatory notes

- A is incorrect – green wavelengths will be transmitted (not absorbed), red and blue wavelengths will be absorbed (not transmitted).
- B is correct – green wavelengths will be transmitted (not absorbed), red and blue wavelengths will be absorbed (not transmitted).
- C is incorrect – blue wavelengths will be absorbed and green wavelengths will be transmitted BUT red wavelengths will be absorbed (not transmitted).
- D is incorrect – red wavelengths will be absorbed, blue wavelengths will be absorbed (not transmitted) and green wavelengths will be transmitted (not absorbed).

The following information relates to Questions 9 and 10.

In the leaves of some plants, photosynthesis usually occurs solely in mesophyll cells. These are known as C_3 plants. Some plants that live in hot, dry habitats have a ring of photosynthetic cells that surround the vascular bundles in addition to the mesophyll cells. These are known as C_4 plants. The diagrams below show two leaf cross-sections.



Question 9

An example of a C_4 plant could be

A. rice.

B. **maize.**

C. wheat.

D. barley.

Answer is B

Explanatory notes

- A is incorrect – rice is an example of a C_3 plant.
- B is correct – maize is an example of a C_4 plant.
- C is incorrect – wheat is an example of a C_3 plant
- D is incorrect – barley is an example of a C_3 plant.

Question 10

In C_3 plants the Calvin cycle occurs in mesophyll cells whereas in C_4 plants it occurs in the bundle sheath cells deeper in the leaf tissue. C_4 plants are able to pick up and use more carbon dioxide with greater efficiency than C_3 plants because

A. there are potentially fewer photosynthetic cells present in the leaves of C_4 plants.

B. there are potentially more photosynthetic cells present in the leaves of C_3 plants.

C. in comparison to C_3 plants, there is a steeper concentration gradient of carbon dioxide from outside the leaves in C_4 plants to the cells in the leaf where the Calvin cycle occurs.

D. in comparison to C_4 plants, there is a steeper concentration gradient of carbon dioxide from outside the leaves in C_3 plants to the cells in the leaf where the Calvin cycle occurs.

Answer is C

Explanatory notes

- A is incorrect – the bundle sheath cells contain chloroplasts, thereby potentially increasing (not decreasing) the number of photosynthetic cells present in the leaves, the more efficient pick up and use of carbon dioxide is due to the steeper concentration gradient.
- B is incorrect – the leaves of C_3 plants do not contain potentially more photosynthetic cells than C_4 plants.
- C is correct – there is a steeper concentration gradient of carbon dioxide from outside the leaves in C_4 plants to the cells in the leaf where the Calvin cycle occurs, compared to C_3 plants.
- D is incorrect – the concentration gradient of carbon dioxide from outside the leaves in C_3 plants to the cells in the leaf where the Calvin cycle occurs is less steep than the concentration gradient observed in C_4 plants.

Question 11

A G-protein is

A. a neutrotransmitter.

B. a signalling molecule.

C. a signal transducing molecule.

D. a specific type of membrane-receptor protein.

Answer is C

Explanatory notes

- A G-protein is a protein that relays signals from a plasma membrane signal receptor to other signal transduction proteins inside a cell. It is a signal transducing molecule.
- A is incorrect – a neurotransmitter is a molecule released from the synaptic terminal of a neuron, binding to a postsynaptic cell, initiating a response; it does not act as a signal transducer.
- B is incorrect – signalling molecules are chemicals involved in transmitting information between cells, not within cells.
- C is correct – a G-protein is a signal transducing molecule.
- D is incorrect – membrane-receptor proteins are incorporated in the plasma membrane and do not perform the function associated with G-proteins.

Question 12

In plants, the growth pattern of a shoot sprouting in darkness to gradually break through the ground is known as etiolation. Once the shoot emerges from the surface, stem elongation slows down, leaves expand, the root system elongates and the production of chlorophyll begins. This latter process, the 'greening' of a plant, is known as de-etiolation. The signal in the process of de-etiolation is most likely to be

A. gravity.

B. **light.**

C. contact.

D. temperature.

Answer is B

Explanatory notes

- A is incorrect – gravity influences directional growth in plants and is not associated with elongation of roots, expansion of leaves and chlorophyll production.
- B is correct – red and blue light are involved directly in the process of de-etiolation.
- C is incorrect – contact influences directional growth in plants and is not associated with elongation of roots, expansion of leaves and chlorophyll production.
- D is incorrect – temperature influences dormancy and flowering in plants and is not associated with elongation of roots, expansion of leaves and chlorophyll production.

Question 13

Beer is an alcoholic beverage produced by the brewing and fermentation of starches derived from cereal grains such as malted barley. It is possible to accelerate the process of germination by spraying the barley seeds with

A. abscisic acid.

B. auxin.

C. ethylene.

D. **gibberellin.**

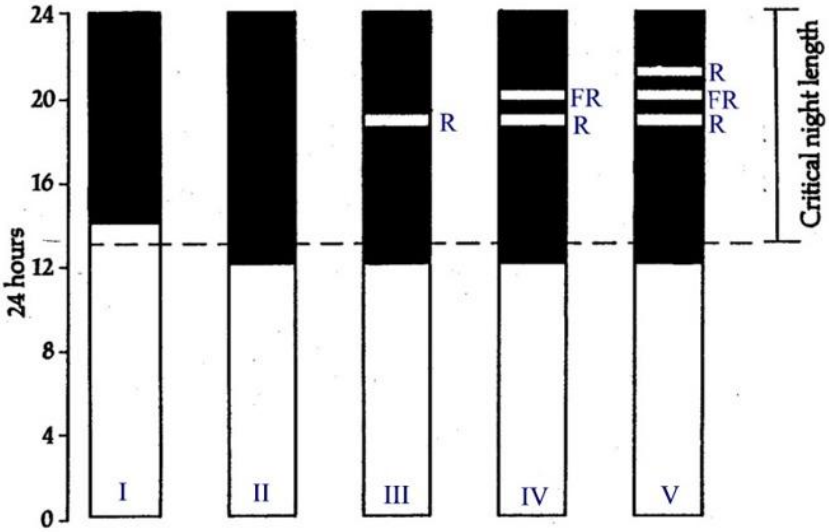
Answer is D

Explanatory notes

- The process of seed development and germination is initiated by gibberellins.
- A is incorrect – abscisic acid is a growth inhibitor and is not associated with seed germination, therefore it would not be used to accelerate the process of germination.
- B is incorrect – auxins stimulate stem elongation, formation of roots, regulates development of fruit and are not associated with seed germination, therefore they would not be used to accelerate the process of germination.
- C is incorrect – ethylene promotes ripening of fruit and leaf abscission and is not associated with seed germination, therefore it would not be used to accelerate the process of germination.
- D is correct – gibberellins stimulate seed development and germination.

Question 14

In some plants, he relative length of day and night is crucial to flowering. Plants are highly sensitive to light and detect night length very precisely. Some short-day plants will not flower if the period of night is 1 minute shorter than the critical length. It is known that a flash of red light (R) can interrupt a period of darkness; however, if it is followed by a flash of far-red light (FR) then the plant detects no interruption of night length. An experiment was done in which a species of short-day plant and a species of long-day plant were exposed to particular light conditions. The experiment is represented in the diagram below.



Plant 1 Plant 2 Plant 3 Plant4 Plant 5

Short-day plants

Plant 6 Plant 7 Plant 8 Plant 9 Plant 10

Long-day plants

Which set of results below shows the expected sequence of flowering for the experiment described above?

	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7	Plant 8	Plant 9	Plant 10
A.	✓	✓	✓	✓	✓	×	×	×	×	×
B.	×	×	×	×	×	✓	✓	✓	✓	✓
C.	×	✓	×	✓	×	✓	×	✓	×	✓
D.	✓	×	✓	×	✓	×	✓	×	✓	×

✓ – flowering × – no flowering

Answer is C

Explanatory notes

- Critical night length is 11 hours as indicated in the diagram, AND conditions II–V show equal day/night length. The significant difference, however, is to do with R (flash of red light) and FR (flash of far red light). If R occurs the plant detects an interruption of night length. If R then FR occurs, the plant does not detect an interruption of night length. If R, then FR, then R occurs, the plant detects an interruption of night length.
- Plants 1–5 are short-day plants and have a critical night length of 13 hours. For this reason, Plants 1, 3 and 5 will not flower as the critical night length of 13 hours has been interrupted. Plants 6–10 are long-day plants and will only flower if the night length is shorter than a critical dark period. For this reason, Plants 7 and 9 will not flower because the night length is longer than the critical dark period.
- A is incorrect – Flowering plants should be 2, 4, 6, 8, 10; non-flowering plants should be 1, 3, 5, 7, 9.
- B is incorrect – Flowering plants should be 2, 4, 6, 8, 10; non-flowering plants should be 1, 3, 5, 7, 9.
- C is correct – Flowering plants are 2, 4, 6. 8, 10; non-flowering plants are 1, 3, 5, 7, 9.
- D is incorrect – Flowering plants should be 2, 4, 6, 8, 10; non-flowering plants should be 1, 3, 5, 7, 9.

Question 15

An invasion by pathogens in plants can trigger the release of substances which can communicate with the whole plant. Methylsalicylic acid has been identified as one such substance which is transported throughout the plant in the phloem and is converted to salicylic acid in areas quite removed from the initial site of infection. Salicylic acid is most likely to act by

A. destroying infected tissues by hydrolysing cells.

B. closing stomata and thereby preventing the entry of pathogens.

C. destroying pathogens directly.

D. activating defences throughout the plant before infection spreads.

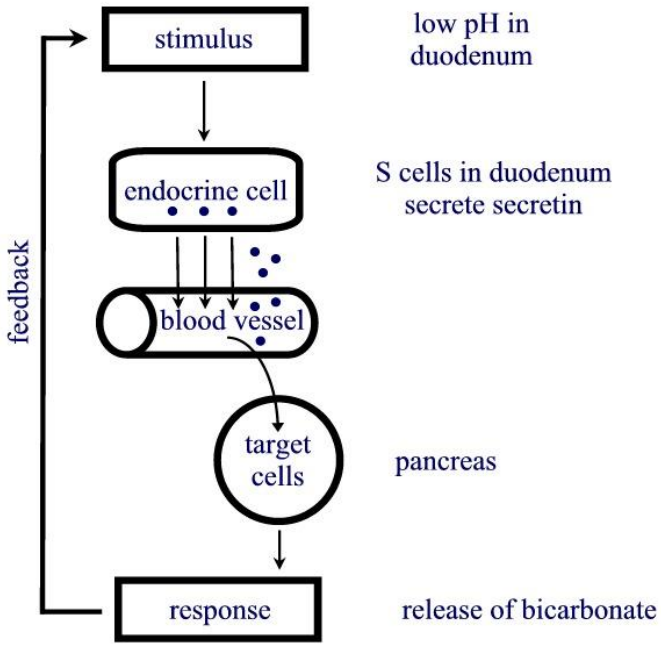
Answer is D

Explanatory notes

- A is incorrect – salicylic acid does not destroy infected tissues by hydrolysing cells.
- B is incorrect – salicylic acid is not involved in the closing of stomata to prevent the entry of pathogens.
- C is incorrect – salicylic acid does not destroy pathogens directly.
- D is correct – salicylic acid activates defences throughout the plant before infection spreads.

The following information relates to Questions 16, 17 and 18.

Secretin is a hormone that stimulates pancreatic secretions and is produced by S cells in the small intestine (duodenum). Secretin enters the bloodstream and reaches receptors at target cells in the pancreas, triggering signal transduction, inducing them to release bicarbonate which raises the pH in the duodenum. This process is modelled in the diagram.



Question 16

The kind of chemical signalling shown in the secretin model is

A. **endocrine.**

B. paracrine.

C. autocrine.

D. synaptic.

Answer is A

Explanatory notes

- The model clearly shows the release of hormone from an endocrine cell into a blood vessel through which it travels to a target cell.
- A is correct – in endocrine signalling, chemicals are secreted into the blood and carried by blood and tissue fluids to the cells they act upon.
- B is incorrect – in paracrine signalling, chemical signals diffuse into an immediate area and interact with receptors on nearby cells, they are not transported through the blood to a target cell.
- C is incorrect – in autocrine signalling, the cell signals itself through a chemical that it synthesises and then responds to, the chemical is not transported through the blood to a target cell.
- D is incorrect – in synaptic signalling, a nerve cell releases neurotransmitter into a synapse stimulating a target cell across the synaptic cleft, there is no transport through the blood.

Question 17

An example of a stimulus that would trigger S cells to release secretin would be

A. **the release of acidic stomach contents into the duodenum.**

B. the release of alkaline stomach contents into the duodenum.

C. the release of acidic contents into the large intestine.

D. the release of alkaline contents into the large intestine.

Answer is A

Explanatory notes

- A is correct – low pH (increased acidity) in the duodenum (small intestine) triggers the release of secretin from S cells in the duodenum.
- B is incorrect – high pH (decreased acidity) will not trigger the release of secretin from S cells.
- C is incorrect – S cells in the duodenum will not respond to the increased acidity of cells in the large intestine.
- D is incorrect – S cells in the duodenum will not respond to a decrease in the acidity of cells in the large intestine.

Question 18

This response pathway is an example of a

A. positive feedback loop which serves to reinforce the initial stimulus.

B. positive feedback loop which results in a reduction of the initial stimulus.

C. negative feedback loop which serves to reinforce the initial stimulus.

D. **negative feedback loop which results in a reduction of the initial stimulus.**

Answer is D

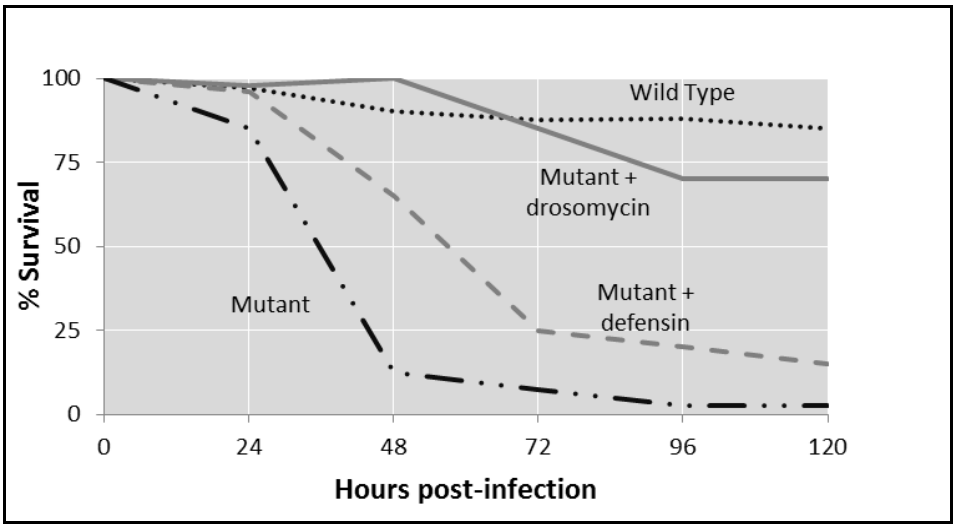
Explanatory notes

- The secretin response pathway involves negative feedback in which the response (release of bicarbonate) acts to reduce the initial stimulus (low pH in the duodenum) and results in an increase in the pH in the duodenum.
- A is incorrect – the secretin response pathway is not a positive feedback loop.
- B is incorrect – the secretin response pathway is not a positive feedback loop and a positive feedback loop does not reduce the initial stimulus, it reinforces it.
- C is incorrect – whilst the secretin response pathway is an example of a negative feedback loop, it does not reinforce the initial stimulus, it reduces it.
- D is correct – the secretin response pathway is an example of a negative feedback loop, which reduces the initial stimulus.

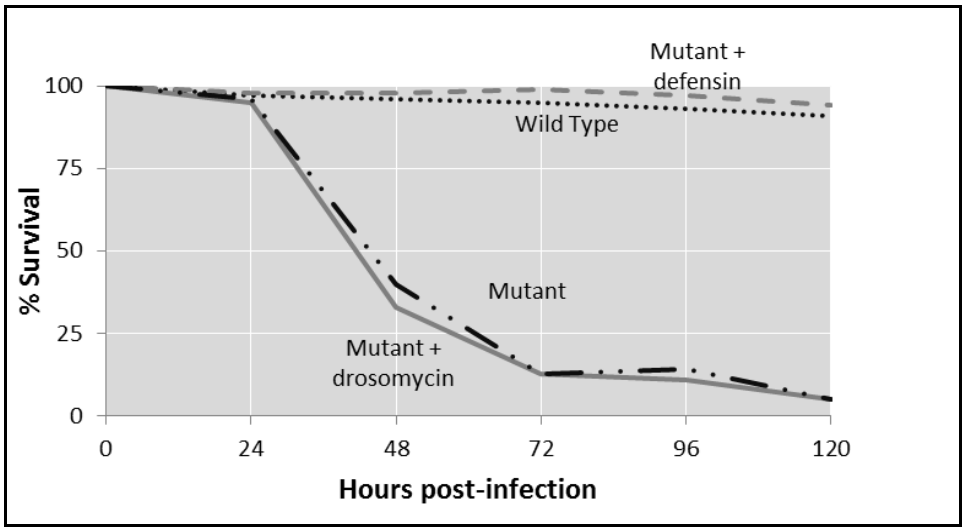
The following information relates to Questions 19, 20 and 21.

Terrestrial and aquatic habitats support a diverse population of microbes. The success of insects despite these microbes has been attributed to their effective innate immune system, the first line of which is the exoskeleton, composed principally of chitin. If a pathogen breaks through the first line of defence, immune cells called haemocytes which circulate within the haemolymph (the insect equivalent of blood) perform phagocytosis. Other haemocytes will trigger the production of chemicals that kill microbes and trap multicellular parasites. Following encounters with specific pathogens, haemocytes also secrete substances known as antimicrobial peptides which circulate around the body of the insect. Once encountering the bacteria or fungi, they disrupt their plasma membranes inactivating or killing them.

In 2002, geneticist Bruno Lemaître and colleagues reprogrammed the immune system of a population of the fruit fly *Drosophila* to test the function of a single antimicrobial peptide in response to a pathogen. The signalling that would normally trigger innate immune response in a mutant strain of *Drosophila* was blocked. Genetic engineering was then used to make some of the mutant fruit flies express significant amounts of a single antimicrobial protein (either drosomycin or defensin). The fruit flies were first infected with the fungus *Neurospora crassa*. The experiment was repeated, infecting the fruit flies with the bacterium *Micrococcus luteus*. The results are shown in the graphs below.



Fruit fly survival after infection by *N. crassa* fungi



Fruit fly survival after infection by *M. luteus* bacteria

Question 19

The exoskeleton of insects is composed primarily of chitin which is a

A. protein.

B. lipid.

C. **polysaccharide.**

D. polypeptide.

Answer is C

Explanatory notes

- A is incorrect – chitin is a polysaccharide which is made of β–glucose molecules, not protein.
- B is incorrect – chitin is a polysaccharide which is made of β–glucose molecules, not lipid.
- C is correct – chitin is a polysaccharide which is made of β–glucose molecules.
- D is incorrect – chitin is a polysaccharide which is made of β–glucose molecules, not a polypeptide.

Question 20

Like insects, vertebrates also display a non-specific immune response to pathogens. Internal components of non-specific immune defence in vertebrates are

A. mucous membranes.

B. **natural killer cells.**

C. antibodies.

D. cytotoxic lymphocytes.

Answer is B

Explanatory notes

- A is incorrect – mucous membranes are part of the barrier (external) non-specific immune defence.
- B is correct – natural killer cells are part of the internal non-specific immune defence.
- C is incorrect – antibodies are part of the humoral response in specific immune defence.
- D is incorrect – cytotoxic lymphocytes are part of the cell-mediated response in specific immune defence.

Question 21

The results of the experiment show that

A. the control has no protective immune response when infected by *N. crassa* and *M. luteus*.

B. the mutant strain shows a protective immune response when infected by *N. crassa* and *M. luteus*.

C. both of the antimicrobial peptides enable a protective immune response, with drosomycin being effective against *M. luteus* and defensin being effective against *N. crassa*.

D. **both of the antimicrobial peptides enable a protective immune response, with drosomycin being effective against *N. crassa* and defensin being effective against *M. luteus*.**

Answer is D

Explanatory notes

- A is incorrect – the control is the wild type *Drosophila*, the results clearly show that survival rates are very high, therefore they have a strong protective immune response after infection by *N. crassa* and *M. luteus*.
- B is incorrect – the mutant strain of *Drosophila* demonstrates significantly low survival rates after infection by *N. crassa* and *M. luteus*, therefore they have effectively no protective immune response.
- C is incorrect – both of the antimicrobial peptides enable a protective immune response HOWEVER drosomycin is effective against *N. crassa* and defensin is effective against *M. luteus*, NOT drosomycin being effective against *M. luteus* and defensin being effective against *N. crassa*.
- D is correct – both of the antimicrobial peptides enable a protective immune response, drosomycin is effective against *N. crassa* and defensin is effective against *M. luteus*.

Question 22

The specific immune system relies entirely on the coordination of the humoral and cell-mediated responses. The cell-mediated immune response

A. involves the activation of B cells.

B. **uses toxic gene products to kill infected cells.**

C. involves the clonal expansion of B cells.

D. is also known as the antibody-mediated response.

Answer is B

Explanatory notes

- A is incorrect – the activation of B cells is associated with the humoral immune response.
- B is correct – the cell-mediated response uses toxic gene products to kill infected cells.
- C is incorrect – the clonal expansion of B cells is associated with the humoral immune response.
- D is incorrect – the antibody-mediated response is an alternative name for the humoral immune response.

Question 23

Myasthenia gravis is a condition in humans in which circulating antibodies bind to and block the acetylcholine receptors at the post-synaptic neuromuscular junctions, preventing muscle contractions. This condition would best be described as an

A. immunodeficiency disorder.

B. allergic response.

C. **autoimmune disorder.**

D. immune rejection.

Answer is C

Explanatory notes

- A is incorrect – an immunodeficiency disorder occurs when the immune system cannot protect itself against pathogens. There are no pathogens associated with myasthenia gravis.
- B is incorrect – an allergic response is a hypersensitive reaction to a normally harmless substance (allergen). There are no hypersensitive reactions to allergens in myasthenia gravis.
- C is correct – the immune system is producing antibodies against self molecules (ACh receptors) therefore this is an autoimmune disorder.
- D is incorrect – immune rejection occurs when cells from non-self are identified and attacked by immune defences. In myasthenia gravis, self molecules are being attacked, not non-self cells.

The following information relates to Questions 24 and 25.

In Australia, rotavirus is the most common cause of severe gastroenteritis in infants and young children. It is caused by group A rotaviruses. The live, weakened vaccine is administered orally (by mouth) to infants at the age of 2 months, 4 months and 6 months. There is still a small chance of catching a rotavirus infection even after receiving the vaccine. However, it is usually a much milder illness than if immunisation had not occurred.

Question 24

Following oral administration, rotavirus vaccination stimulates production of antibodies which protect against gastroenteritis. This response should provide the immunised infant with

A. induced passive immunity.

B. **induced active immunity.**

C. natural passive immunity.

D. natural active immunity.

Answer is B

Explanatory notes

- A is incorrect – not passive immunity (antibodies have been actively made).
- B is correct – induced active immunity (antibodies have been actively made following administration).
- C is incorrect – not natural immunity (exposure is induced) or passive (antibodies have been actively made).
- D is incorrect – not natural immunity (exposure is induced).

Question 25

Effective protection requires the administration of three consecutive doses of rotavirus, preferably at 4 to 8 week intervals. It is necessary to schedule three consecutive doses because

A. **immunity is usually not acquired until the third administration.**

B. the immature immune system cannot produce antibodies until the third administration of toxoids.

C. at this early stage of life, the toxoids are naturally reabsorbed from the infant bloodstream.

D. the antibodies provided in the vaccination have a short lifespan.

Answer is A

Explanatory notes

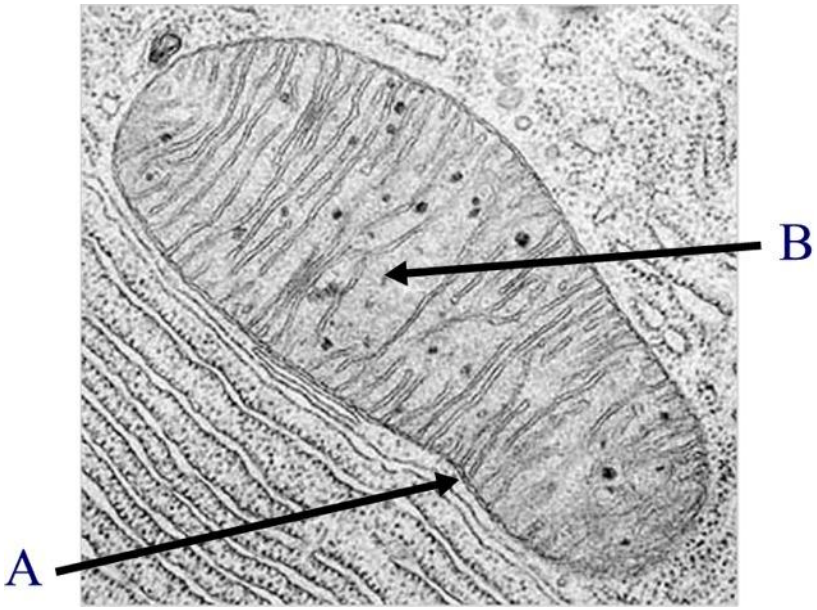
- A is correct – full immunity is not acquired until the third administration.
- B is incorrect – the immune system produces antibodies after the first dose however it takes time to build up full immunity.
- C is incorrect – toxoids are not reabsorbed from the bloodstream.
- D is incorrect – there are no antibodies provided in the vaccination, only toxoids.

END OF SECTION A

SECTION B – Short-answer questions

Question 1

From 1933 to 1938, a drug called 2,4-dinitrophenol (DNP) was used extensively in diet pills due to its ability, in large doses, to significantly increase metabolic rate and assist in weight loss. DNP allows protons to leak across the inner mitochondrial membrane bypassing the protein complex ATP synthase which makes ATP from ADP and inorganic phosphate. Bypassing ATP synthase makes energy production less efficient because part of the energy that is normally produced from cellular respiration is released as heat. The amount of heat released is proportional to the dose of DNP taken. As the dose of DNP increases, energy production becomes increasingly inefficient, metabolic rate increases in order to compensate for the inefficiency and to meet energy demands. The diagram below shows a mitochondrion.



1a. **i.** What is the principle constituent of the membrane of the mitochondrion?

1 mark

Solution

phospholipid

1a. ii. Identify a property of DNP that enables it to pass through the mitochondrial membrane.

1 mark

Solution

lipophilic or hydrophobic

Explanatory notes

- The membrane of a mitochondrion, like all organelles and the cell membrane, is comprised of two layers of phospholipid (phospholipid bilayer) which have proteins embedded in it.
- The chemical nature of the membrane enables it to regulate the passage of materials across it. The phospholipids have an affinity with small, non-polar, uncharged molecules. These molecules can be described as hydrophobic or lipophilic.

Total 1 + 1 = 2 marks

1b. Identify the structures and their associated function by completing the following table.

2 marks

Solution

	Structure	**Function**
A	ribosome	synthesis of protein
B	matrix	site of and contains enzymes used in Krebs cycle

DNP is probably the best-known agent for uncoupling oxidative phosphorylation.

1c. What processes are normally coupled in oxidative phosphorylation?

1 mark

Solution

In oxidative phosphorylation the processes of electron transport and chemiosmosis are coupled.

Explanatory note

- A coupled reaction is one in which energy is transferred from one side of the reaction to the other. During oxidative phosphorylation (the final stage of cellular respiration) chemiosmosis couples electron transport to ATP synthesis. DNP causes this coupled reaction to become unhitched.

Following the deaths of several patients who had been prescribed DNP, its use as a weight-loss medication was stopped.

1d. Explain what was most likely to have caused death in patients who used DNP for weight loss.

2 marks

Solution

An overdose of DNP would have caused fatal hyperthermia. The increased dose would lead to increased metabolism, increased amount of heat released and greatly increased body temperature, ultimately producing a positive feedback loop.

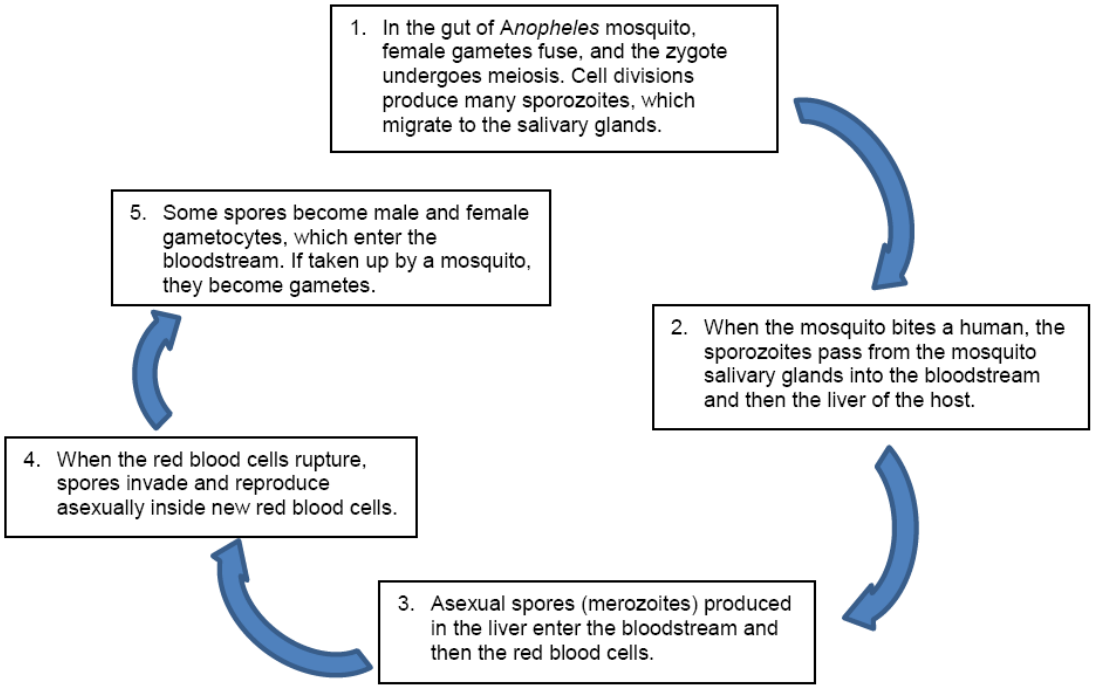
Explanatory note

- The information provided in the stem indicates that the amount of heat released is proportional to the dose of DNP taken. In the case of an overdose of DNP, energy production becomes increasingly inefficient, with increasing metabolic rate comes increasing body temperature climbs, altering the set point for body temperature, causing a positive feedback loop, leading to hyperthermia.

Total 2 + 2 + 1 + 2 = 7 marks

Question 2

Malaria is an infection of the blood that kills over one million people globally each year. It is caused by a protist of the genus *Plasmodium*. The control of malaria is hindered by anti-malarial drug resistance. The lifecycle of the malarial parasite is shown in the diagram below.



2a. What is the vector in this lifecycle?

1 mark

Solution

The mosquito

Explanatory notes

- A vector is any agent responsible for the transmission of a pathogenic organism from one host to another. In the lifecycle shown, the mosquito fulfils this role.

Red blood cells contain haemoglobin, a protein responsible for the transport of oxygen. Haemoglobin A (HbA) is found in normal red blood cells. The parasite infects red blood cells that contain HbA but cannot survive in red blood cells containing haemoglobin S (HbS). The mutation which produces HbS is usually benign and has no apparent effects under conditions of normal oxygen concentration. However, at low oxygen levels, hydrophobic interactions cause HbS molecules to cluster which causes the haemoglobin molecules to crystallise. As a result, red blood cells show sickling, are fragile and become susceptible to breaking within capillaries.

Consider the information in Tables A and B.

Table A – Selection of the Hbb sequence in adult haemoglobin

	DNA nucleotide sequence	Amino acid sequence
Hbb sequence in normal adult haemoglobin (Hb A)	CCT GAG GAG	pro - glu - glu
Hbb sequence in affected adult haemoglobin (Hb S)	CCT GTG GAG	

Table B – Selection of the genetic code

FIRST BASE	SECOND BASE					THIRD BASE
	T	C	A	G		
T	phe	ser	tyr	cys	T	
					C	
	leu		stop	stop	A	
			stop	trp	G	
C	leu	pro	his	arg	T	
					C	
			gln		A	
					G	
A	ile	thr	asn	ser	T	
					C	
			lys	arg	A	
	met/stop				G	
G	val	ala	asp	gly	T	
					C	
			glu		A	
					G	

2b. i. What is the mutation that produces HbS?

1 mark

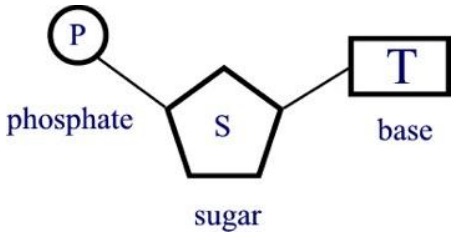
Solution

The normal single nucleotide adenine is replaced by the nucleotide thymine

2b. ii. Draw a diagram of the DNA nucleotide that causes the mutation found in HbS.

1 mark

Solution



Total 1 + 1 = 2 marks

Explanatory note

- Table A shows that in the second triplet, the A is replaced by T. T represents the nucleotide base thymine. A DNA nucleotide is comprised of three groups: a sugar, a phosphate and a nitrogen base. The sugar and phosphate make up the 'spine' of a DNA strand and the nitrogen base binds to the sugar.

2c. **i.** What is the amino acid sequence for an adult with HbS?

1 mark

Solution

pro - val - glu

2c. **ii.** Explain how changing a single amino acid in the haemoglobin polypeptide chain can cause it to behave so adversely at low oxygen concentrations.

2 marks

Solution

A single amino acid substitution can change the nature of the bonds formed in the tertiary structure of a polypeptide chain. If the tertiary structure of a protein changes, its shape changes and its ability to function is impeded.

Explanatory notes

- At low oxygen concentrations, hydrophobic interactions change the structure of the haemoglobin chain. Hydrophobic interactions are associated with the formation of the tertiary structure of a protein. When the tertiary structure of a protein is altered, its shape changes and its ability to function is impeded.

Total 1 + 2 = 3 marks

The most common form of malaria is caused by the parasite burrowing into red blood cells where it quickly multiplies leading to severe disease and often death. Currently, all treatments for malaria function by blocking the development of the parasite from within the red blood cell. Antimalarial drug resistance is a major public health problem which hinders the control of malaria. In 2010, a research group presented a new technique for prevention of malaria. The malarial parasite displays a surface protein MSP1 which is essential in the attachment of the parasite to the red blood cell. The study shows that when heparin-like carbohydrates are present, the malarial parasite is unable to infect the red blood cells. In humans, heparin is stored in mast cells in relatively small amounts. Pharmaceutical-grade heparin is derived from porcine and bovine mucosal tissue for its medical use as an anticoagulant.

2d. What is the general term given to a surface protein such as MSP1?

1 mark

Solution

antigen

2e. Explain the likely role of heparin in the human body.

1 mark

Solution

The likely role of heparin is in defence against pathogens and other foreign materials. Mast cells release molecules that trigger inflammation in response to infection and allergic reactions.

Explanatory note

- Heparin is found in mast cells. Mast cells are associated with non-specific immunity and contain substances which are released in response to injury, inflammation and infection. The role of heparin is directly related to defence.

2f. Describe how heparin-like carbohydrates may be able to prevent malarial parasites from infecting red blood cells.

2 marks

Solution

The heparin-like carbohydrates bind with the MSP1 surface proteins preventing them from attaching to the surface of red blood cells thereby blocking the ability of malarial parasites to infect the cells.

Explanatory note

- Blocking malarial parasites from entering red blood cells is a strategy for controlling the spread of the disease. If the heparin-like carbohydrates bind to the surface proteins of the parasites, they will not be able to attach to the surface of red blood cells.

2g. Give one reason why is it necessary to use heparin-like carbohydrates, rather than heparin itself, in the development of new anti-malarial drugs.

1 mark

Solution

Human heparin would be produced in very small quantities. It is stored in the mast cells and not enough is present in the blood for antimalarial activity

OR

pharmaceutical-grade heparin is an anti-coagulant and prevents blood clotting, which could lead to excessive blood loss in the case of an injury.

Explanatory notes

- Using pharmaceutical-grade heparin would be counterproductive because it functions as an anticoagulant. Whilst it would be effective at controlling the action of malarial parasites, it would stop blood from clotting which is dangerous in the case of an injury.

2h. What is a significant advantage of discovering the new treatment for malaria?

1 mark

Solution

The new treatment offers a potential solution to overcoming the problem of drug-resistant malarial parasites.

Explanatory note

- Antimalarial drug resistance hinders the control of malaria. Resistance to drugs using choloroquine and also sulfadoxine-pyrimethamine has spread and it is becoming increasingly difficult to control the disease.

Total 1 + 2 + 3 + 1 + 1 + 2 + 1 + 1 = 12 marks

Question 3

The process of sex determination in mammals is under hormonal control. Scientists investigating the role of hormones in sex determination performed an experiment using rabbit embryos still living inside the uterus of the mother. At a stage of embryonic development before sex differences are visible, the part of the embryo that would form the gonads (ovaries or testes) was surgically removed. When the baby rabbits were born, the chromosome sex and the sexual differentiation of the genital structure was recorded. The results are shown in the table below.

Chromosomal sex	Genital structure	
	No surgery	Embryonic gonad removed
XX (female)	female	female
XY (male)	male	female

3a. What conclusion can be drawn from this study?

2 marks

Solution

In rabbits, the development of male genitals is dependent on a hormonal signal from the male gonad.

OR

In rabbits, female development is the default process in embryos.

Explanatory note

- The results clearly indicate that in rabbits, the absence of an embryonic gonad, female genitalia develop. Thus the development of male genitalia in rabbits is controlled by a signal from the male embryonic gonad.

Mark allocation

- 1 mark for stating ‘in rabbits’ (study does not apply to all mammals)

AND

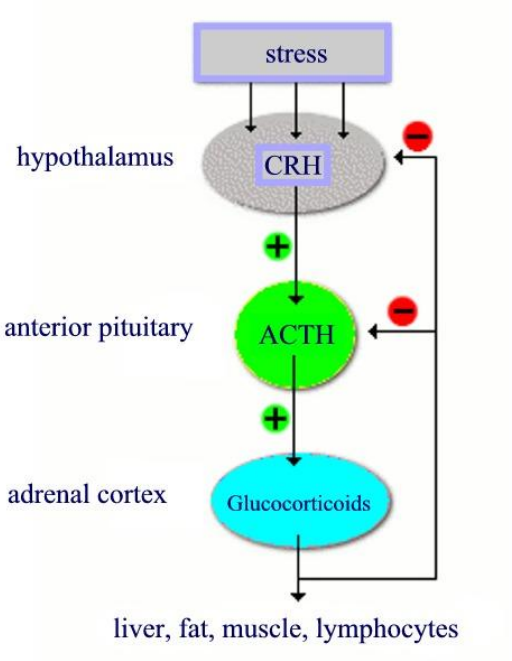
- 1 mark for development of male genitals is dependent on signal from male gonad

OR

- 1 mark for female development is the default process

*****continue to next page*****

Cushing's syndrome is a condition in which prolonged exposure to high levels of the group of hormones known as glucocorticoids can cause severe fatigue, weak muscles, high blood pressure and depression. Glucocorticoids are released as a response to physical or mental stress. Normal effects of glucocorticoids are associated with the breakdown and conversion of proteins (from skeletal muscle) and fats to glucose. Glucocorticoids are secreted in response to a single stimulator: adrenocorticotropic hormone (ACTH). The diagram outlines the hormonal control of glucocorticoid production.



3b. Using the information in the diagram shown above, identify the two glands in which overactivity could directly cause excessive production of glucocorticoids. Circle your choices below.

hypothalamus anterior pituitary adrenal cortex

1 mark

Solution

hypothalamus (anterior pituitary) (adrenal cortex)

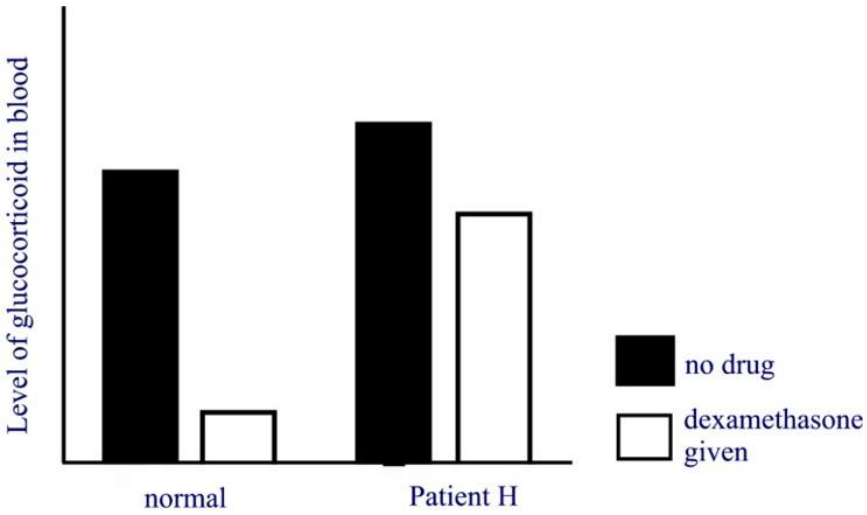
Explanatory note

- Adrenocorticotropic hormone (ACTH) is the hormone which directly stimulates the production of glucocorticoids. Therefore the only two glands that could directly cause overproduction of glucocorticoids are the anterior pituitary and the adrenal cortex, not the hypothalamus because ACTH is not released from there.

Mark allocation

- 1 mark for two correct responses; if only one correct, 0 marks

In order to determine which gland is overactive, dexamethasone, a synthetic glucocorticoid which decreases the release of ACTH is administered to a patient in a test known as a dexamethasone suppression test. The result of the test is shown below.



3c. Explain which gland is affected in patient H.

2 marks

Solution

The pituitary gland is affected. Dexamethasone should decrease the amount of glucocorticoids in the blood (which it does normally); however, in patient H the level of glucocorticoids remains high, indicating that the problem occurs in the pituitary.

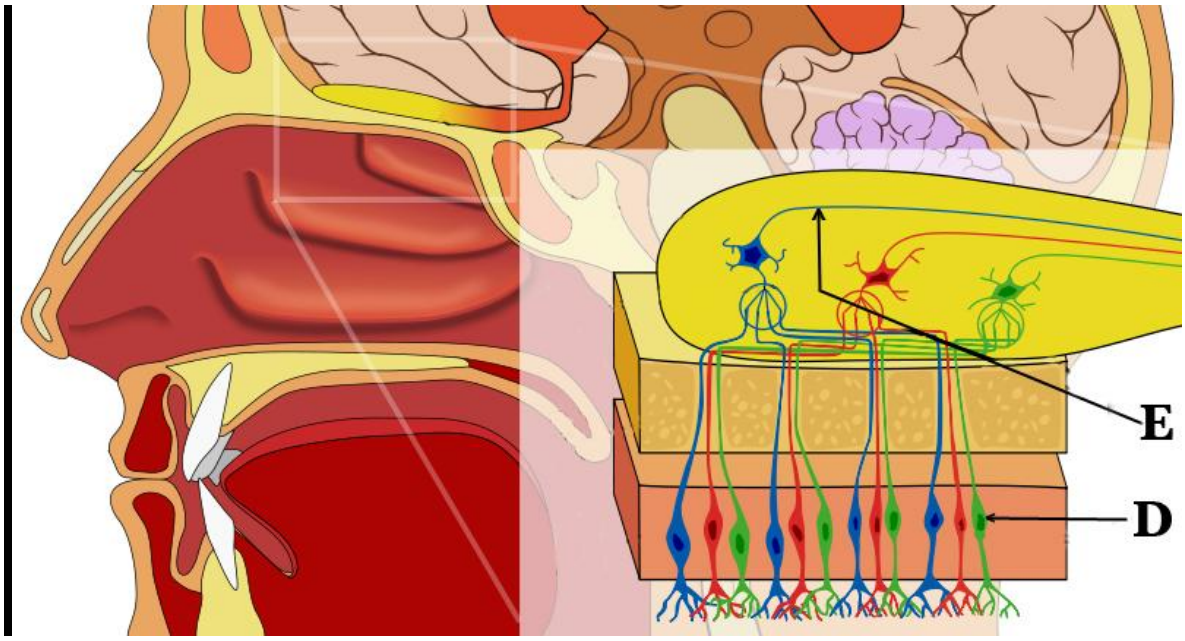
Mark allocation

- 1 mark for correct gland
- 1 mark for reason

Total 2 + 1 + 2 = 5 marks

Question 4

The ability to detect smell in humans relies on sensory receptors in the body that respond to airborne molecules. The receptors for smell are located in the nasal cavity in a small area of tissue known as the olfactory epithelium. The image below shows a sequence of stages in the process of olfaction (smell).



4a. Identify and describe the function of structures D and E.

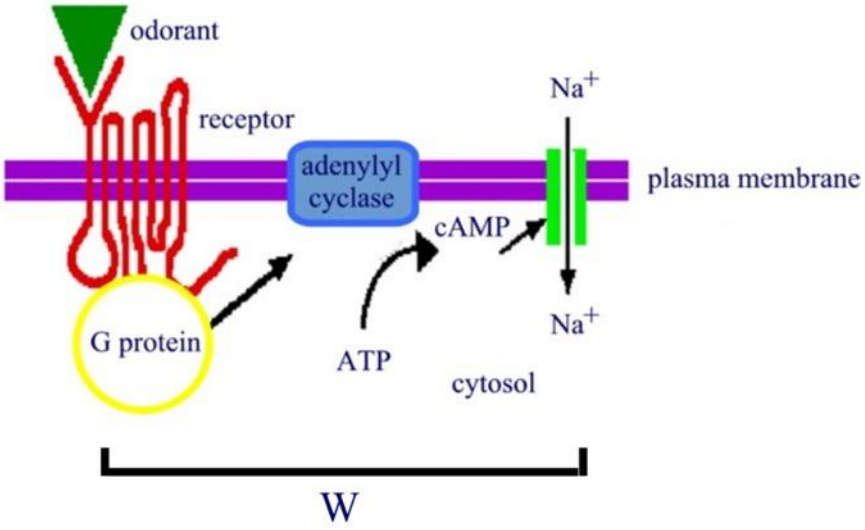
2 marks

Solution

	Name	**Function**
Structure D	*chemoreceptor OR odorant receptor*	*protein that detects a chemical stimulus in the environment (and transduces it into an action potential)*
Structure E	*neuron (olfactory)*	*sends message to central nervous system*

Mark allocation

- 1 mark each correct structure AND correct function



4b. Identify the cell signalling process occurring at W.

1 mark

Solution

W – signal transduction

Explanatory note

- Broadly, signal transduction is the process in which an extracellular signalling molecule, typically a hormone or neurotransmitter, interacts with a receptor at the cell surface, causing a change in the level of a second messenger and ultimately effects a change in the functioning of the cell.

Cell signalling pathways that involve G-proteins are associated with an increase in signal strength, also known as amplification.

4c. Explain one advantage gained from amplifying the strength of an olfactory signal.

2 marks

Solution

It enables a heightened/finely tuned response to a relatively small concentration of molecules associated with finding a mate (reproduction) OR marking a territory OR avoiding dangerous substances.

Explanatory note

- If organisms increase their chances of finding a mate (reproduction) OR marking a territory OR avoiding dangerous substances, they increase their chances of survival.

Mark allocation

- 1 mark for enables a heightened response
- 1 mark for finding a mate OR marking a territory OR avoiding dangerous substances

Chemicals are used for communication within organisms and between organisms.

4d. What is the name given to the group of chemicals used by organisms within a species to communicate with each other?

1 mark

Solution

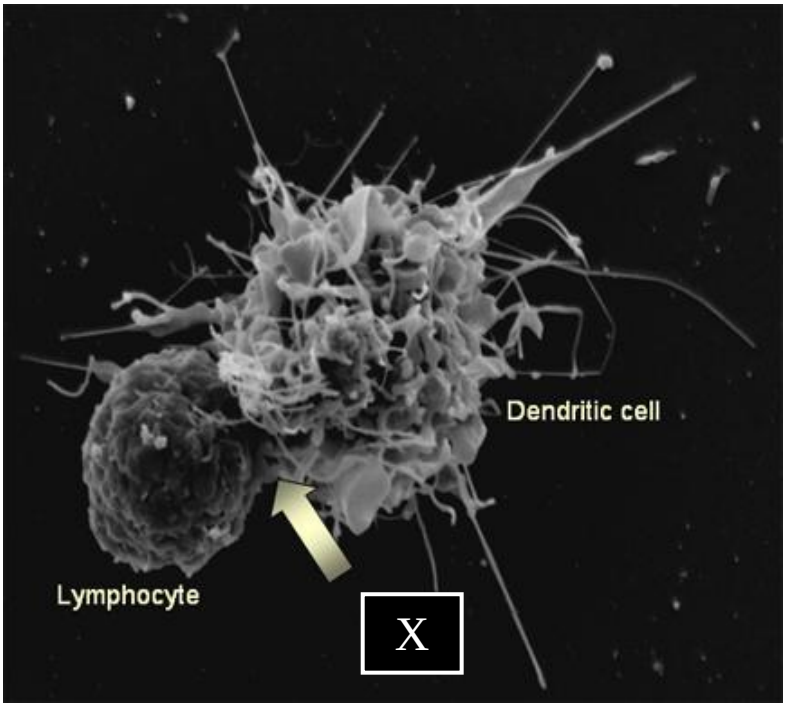
pheromones

Total 2 + 1 + 2 + 1 = 6 marks

Question 5

Cancer is a disease that affects people globally and is caused by abnormal and uncontrolled proliferation of cells. It can be eliminated by the immune system before it turns into a detectable cancer. Sometimes cancer cells are identified as normal healthy cells and escape detection by the immune system. Clinical trials using immunotherapy are currently underway in the search for a new treatment for cancer. Known as Human Initiated Therapeutic Vaccine (HITV) the immunotherapy uses the natural defence system of the body to fight the disease. It involves harvesting the patient's dendritic cells for culturing in the laboratory, before reintroducing them to the patient's body. Dendritic cells are antigen presenting cells and are found in small quantities in tissues that have contact with the external environment such as the skin and the lining of the respiratory system and gastrointestinal tract.

The image below shows a dendritic cell and a lymphocyte.

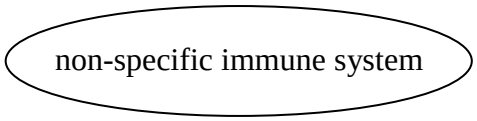


5a. Indicate whether dendritic cells are associated with the non-specific or specific immunity and clearly explain their role in the immune system. Circle your choice below.

non-specific immune system specific immune system

3 marks

Solution



Explanation:

Dendritic cells act as immune sentries in various tissues and, upon encountering a pathogen, engulf and traffic the foreign antigen to secondary lymphoid tissues, stimulating antigen-specific T lymphocytes.

Explanatory note

- Dendritic cells are immune cells that form part of the non-specific immune response. They interact with the specific immune system in their role as antigen presenting cells (APCs).

Mark allocation

- 1 mark for act as immune sentries and engulf pathogen
- 1 mark for traffic foreign antigen to secondary lymphoid tissues
- 1 mark for stimulate antigen-specific T lymphocytes

Refer to the image provided for Question 5.

5b. Explain what is occurring at X.

1 mark

Solution

The dendritic cell is acting in the role of an antigen presenting cell (APC) and presenting an antigen fragment to a helper T cell/T lymphocyte receptor or cytotoxic T cell/T lymphocyte receptor.

Explanatory note

- The non-specific and specific immune response interact when APCs display antigens to the receptors on helper T cells/T lymphocytes or receptors on cytotoxic T cells/T lymphocytes. Cytotoxic T cells and helper T cells recognise the antigens which results in the interaction between helper T cells and B cells and leads to the creation of memory helper T cells. Cytotoxic T cells are activated and memory T cells are generated.

5c. Identify another two cells that would normally be involved in an immune response against cancerous cells.

1 mark

Solution

Type of immunity	**Name of cell**
non-specific	*natural killer (NK) cell*
specific	*cytotoxic T cell*

Mark allocation

- both answers must be correct; 0 marks if only 1 correct

Until recently it was unclear whether dendritic cells existed in non-mammalian vertebrates. Scientists now know that zebrafish share many of the cellular elements of the specific immune system, including T and B lymphocytes and dendritic cells. Zebrafish are translucent, reproduce rapidly and are easy to handle.

5d. Explain why zebrafish might offer practical research advantages over some other animal models.

1 mark

Solution

Translucence – individual cells and systems can be tracked directly and viewed in real time in the whole animal

OR

Rapid reproduction – makes it easier to engineer and study mutations; generations of fish can be grown quickly and the genetics can be observed and analysed

OR

Easy to handle – reduces the difficulty of working with larger animals, easier to keep them in a lab, feed them, look after them in general

Total 3 + 1 + 1 + 1 = 6 marks

Question 6

A circadian rhythm is a physiological cycle which continues, in the absence of cues, over what is close to a 24-hour period in all eukaryotes. In hamsters, it is controlled by a group of neurons in the hypothalamus called the suprachiasmatic nucleus (SCN). The eyes transmit sensory information to the SCN which acts as regulator and synchronises the biological clock in body cells to the natural cycles of day length.

A genetic mutation, known as the tau (τ) mutation, alters the period of circadian rhythm in hamsters from the normal 24-hour cycle to one of around 20 hours.

Using the space provided below, outline an experiment that would enable you to determine whether circadian rhythms originate in the SCN.

In your answer you should

- state the hypothesis you are testing
- outline the experimental procedure
- describe ALL the results that would support or negate your hypothesis
- present a graph which summarises the results

6 marks

Solution

Hypothesis That cells associated with the SCN determine the period of circadian rhythm

Procedure Two large groups of hamsters – Group A and Group B

Group A – genetically identical, same weight, no mutation (have normal 24 hour cycle), Group B – genetically identical, same weight, show tau (τ) mutation (have shortened 20 hour cycle)

AND

Maintain identical environmental conditions – temperature, food, hours of light/dark

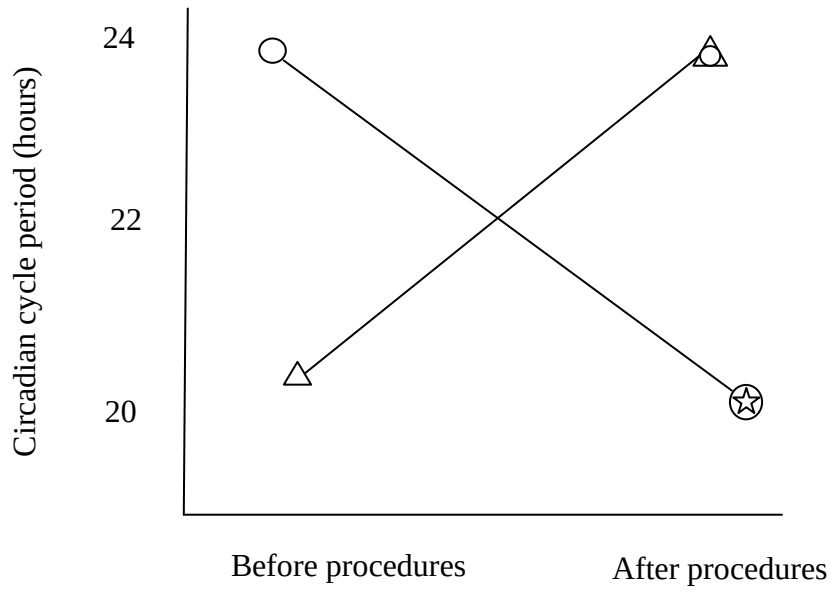
To disrupt circadian rhythms, remove SCN from 50% of the hamsters in both groups, wait several weeks, then transplant SCN from hamsters of opposite genotype.

AND

Make observations, record and analyse results

Results Removing SCN disrupts 20-hour and 24-hour rhythms. Transplanting SCN restores rhythmic activity with Group A showing shortened 20-hour cycle and Group B showing 24-hour cycle.

Graph



normal hamster

τ hamster

normal hamster with SCN from **τ** hamster

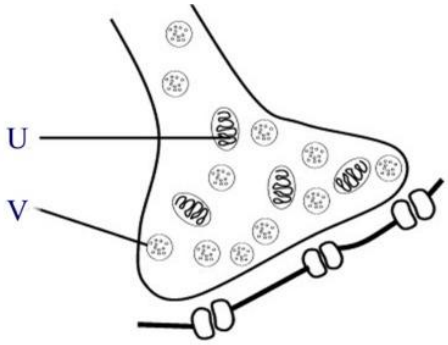
τ hamster with SCN from normal hamster

Mark allocation

- 1 mark – correct hypothesis
- 2 marks – procedure (correct groups – 1 mark; identical conditions – 1 mark)
- 1 mark – results
- 2 marks – graph

Question 7

The diagram below shows a junction between two neurons.



7a. Name and describe the function of structures **U** and **V**.

4 marks

Solution

	Name	**Function**
Structure U	*mitochondrion*	*site of ATP production, exocytosis (of neurotransmitter) is an energy requiring process, the mitochondrion will contribute to the ATP demand*
Structure V	*synaptic vesicle*	*contains chemical neurotransmitter*

Multiple sclerosis is a condition in which myelin sheaths harden and deteriorate over time.

7b. Explain the effect that multiple sclerosis would have on the functioning of the nervous system.

1 mark

Solution

The deterioration of the myelin sheath is equivalent to a loss of insulation along axons and results in disruption to the propagation of action potential along an axon.

Explanatory note

- Multiple sclerosis is a human autoimmune disorder which affects the central nervous system. The immune system attacks myelin, which serves as a nerve insulator and helps in the transmission of nerve signals. When myelin is damaged, nerve fibre conduction is faulty or absent.

Total 4 + 1 = 5 marks

Question 8

Haemolytic disease of the newborn (HDN) is caused by an incompatibility between the rhesus blood group of the mother and baby. D antigens are found on the surface of red blood cells of a rhesus positive (Rh^+) individual, whilst there are no D antigens present on the surface of red blood cells of an individual who is rhesus negative (Rh^-). An Rh^- mother can receive Rh^+ red blood cells if the blood of the baby enters her bloodstream, via the placenta, during birth.

8a. How would an Rh^- mother's immune system respond to the introduction of Rh^+ blood from her baby?

1 mark

Solution

The mother's immune system will begin to make antibodies against the antigen.

Explanatory notes

- The mother's immune system is being sensitised to the rhesus antigen. During birth, the red blood cells of the baby pass across the placenta into the mother's bloodstream. The introduction of non-self antigens triggers a specific immune response leading to the production of B-plasma cells (which produce antibodies) and B-memory cells (which are primed to produce more antibodies should she become pregnant with another Rh^+ baby).

In a second pregnancy with an Rh^+ baby, HDN takes effect and red blood cells are attacked and broken down. The condition can be mild but can also lead to jaundice, cause brain damage or even the death of the child.

8b. Explain how the mother's immune system will respond to a second Rh^+ baby.

2 marks

Solution

The antibodies produced by the mother after the first pregnancy will cross the placenta into the foetal bloodstream forming antibody–antigen complexes which will result in the destruction of the foetal red blood cells.

Explanatory note

- The mother's immune system has been primed following her initial encounter with Rh^+ antigens from her first baby. B memory cells will produce antibodies which will bind to the Rh^+ antigens. The baby may be affected during the pregnancy or after birth depending on the severity on the condition. Red blood cells rupture (haemolysis) which can lead to conditions known as hydrops fetalis, reticulocytosis and anaemia.

Mark allocation

- 1 mark – antibodies produced by the mother will enter foetal bloodstream
- 1 mark – antigen–antibody complexes form leading to destruction of red blood cells

Total 1 + 2 = 3 marks

END OF SECTION B
END OF SOLUTIONS BOOK