BIOLOGY

Units 3 & 4 – Written examination

2021 Trial Examination

SOLUTIONS

SECTION A: Multiple-choice questions (1 mark each)

Question 1

Answer: C

Explanation:
Small, non-polar molecules can pass directly through the phospholipid bilayer as they are not repelled by the non-polar, hydrophobic fatty-acid tails. Therefore, oxygen will diffuse into the cell without the need for protein channels or carrier proteins.

Question 2

Answer: A

Explanation:
Pheromone signalling acts between individuals of the same species. The chemical signal is released by one individual and detected by the other. Some pheromone signals travel through the air. Others, like those released in urine, are more localised.

Question 3

Answer: B

Explanation:
In photosynthesis, chlorophyll molecules are excited by incoming solar radiation. The energy absorbed is used to split water into hydrogen and oxygen. The H^+ ions attach to $NADP^+$ molecules to form NADPH, and NADPH enters the stroma. The energy released through the conversion of NADPH back into NADP is used to synthesise glucose molecules.

Question 4

Answer: A

Explanation:
B plasma cells are a part of the adaptive, or specific, immune response. They secrete antibodies that are complementary in shape to a specific antigen. The antibodies opsonise extracellular pathogens.

Question 5

Answer: B

Explanation:
Enzymes increase the rate of reaction by lowering the activation energy required for the reaction to proceed. This allows reactions to occur at a faster rate.

Question 6

Answer: C

Explanation:
The rate of reaction was highest at 35^0C. The solution in this test tube remained clear after iodine was added, meaning there was no starch remaining. If there were no starch remaining, we can conclude that all the starch had been broken down into glucose, indicating high activity of amylase.

Question 7

Answer: A

Explanation:
The substrate is the reactant being catalysed by the enzyme. In this reaction, starch is the substrate, amylase is the enzyme, and glucose is the product.

Question 8

Answer: D

Explanation:
The independent variable is the variable that is being changed by the experimenter, to measure its effects on the dependent variable. In this experiment, the variable being deliberately changed was temperature.

Question 9

Answer: D

Explanation:
Antivenom is an example of passive immunity because Tom's immune system does not need to produce its own antibodies against the snake venom. Rather, the antibodies are injected directly into his system, to target the antivenom antigens. This type of immunity is short-lived, because Tom does not produce memory cells against the snake venom. Therefore, if he is bitten by the same species of snake in the future, he will not have immunity against it.

Question 10

Answer: D

Explanation:
Small populations are more susceptible to genetic drift because there is a higher chance of some alleles disappearing from the population by chance. Equal emigration and immigration rates may keep population numbers fairly constant, but alleles could be lost through emigration, and new alleles could be introduced through immigration, changing the gene pool of the population. A bottleneck effect will increase a population's susceptibility to environmental changes, because genetic diversity is reduced. Populations in unstable environments are more likely to evolve, as a changing environment presents new selection pressures and certain phenotypes will have a selective advantage over others.

Question 11

Answer: B

Explanation:
The diagram depicts divergent evolution, in which two separate populations of species A diverged to evolve into species B and C. For species B and C to be considered distinct species, they must not be able to interbreed and produce viable offspring. Geographical isolation between two populations of species may have been the isolating mechanism, preventing gene flow between the two populations.

Question 12

Answer: A

Explanation:
The various breeds of domestic dog exist through human intervention. Humans artificially select which individuals can breed, selecting for desirable traits. This is artificial selection as humans, rather than natural environmental changes or events, provide the selection pressure.

Question 13

Answer: D

Explanation:
Ions (charged particles) are polar and hydrophilic. Therefore, they require a channel protein that provides a hydrophilic environment to pass through the plasma membrane. They cannot pass directly through the membrane, as they will be repelled by the fatty-acid tails.

Question 14

Answer: A

Explanation:
All viruses are intracellular pathogens. This means that they can only survive and reproduce inside a host cell. Antibiotics target bacteria, not viruses. Viruses contain genetic material, but they are non-cellular so do not contain mitochondria.

Question 15

Answer: B

Explanation:
Cytotoxic T cells target specific intracellular pathogens, so are part of the adaptive, or specific, immune response. They destroy virus-infected cells through a process called degranulation, which involves signalling to an infected cell to undergo apoptosis.

Question 16

Answer: C

Explanation:
The purpose of isolating the spike proteins and using them in a vaccine is to allow the immune system to recognise these proteins. The subsequent immune response develops long-term immunity against the spike proteins, and therefore against the virus itself. An antigen is anything that initiates an immune response. The spike proteins do not act as a pathogen, because they are isolated from the virus itself, therefore do not cause the disease. Antibodies are what the humoral response produces against pathogens.

Question 17

Answer: D

Explanation:
Anaerobic respiration is less efficient than aerobic respiration, as only two molecules of ATP are produced for every molecule of glucose. Anaerobic respiration does not involve the mitochondria and occurs in the cytosol of the cell. In animal fermentation, the by-product is lactic acid, not ethanol.

Question 18

Answer: C

Explanation:
During post-transcription modification, introns, not exons, are spliced out. When the introns are spliced out, the remaining exons may re-combine in several ways, allowing for different variants of the final mRNA molecule, and therefore of final protein produced. mRNA contains uracil, not thymine.

Question 19

Answer: D

Explanation:
Carbon dioxide is an input in the second stage of photosynthesis, which is the light-independent reactions. These reactions occur in the stroma of the chloroplasts, and carbon dioxide combines with free hydrogen atoms in this stage to produce glucose.

Question 20

Answer: A

Explanation:
A vector is something that is used to insert foreign DNA into an organism. In the case of golden rice, the bacterium *Agrobacterium tumefaciens* is used as a means of inserting the foreign DNA into the rice to create golden rice.

Question 21

Answer: B

Explanation:
A transgenic organism is one that contains foreign DNA. In other words, it contains genes that would not otherwise be found in that species, were it not for genetic modification. Golden rice contains two genes that are not normally found in that species of rice: The Psy gene from *Narcissus pseudonarcissus* and the Crt1 gene from *Erwinia uredovora.*

Question 22

Answer: B

Explanation:
Polymerase chain reaction (PCR) is a method used to amplify, or make multiple copies of, a sequence of DNA that codes for a given gene.

Question 23

Answer: B

Explanation:
Hydrophilic signal molecules are unable to cross the plasma membrane through simple diffusion because they are repelled by the hydrophobic fatty-acid tails. Therefore, they bind to a transmembrane, or extracellular, receptor, named as such because it crosses the membrane. This initiates a change in shape of the part of the receptor inside the cell, releasing secondary messengers and causing a response in the cell.

Question 24

Answer: A

Explanation:
Neuron signalling requires neurons to be in close contact to each other. The cell signal acts over a short distance. Cell signalling over short distances is called paracrine signalling. Autocrine signalling is when the signal is released and received by the same cell. Endocrine signalling involves hormones and acts throughout the body, not just on the adjacent cells. Pheromone signalling occurs between individuals of the same species, not within the same individual.

Question 25

Answer: A

Explanation:
Anabolic is the term used to describe reactions which form larger molecules from smaller molecules. The reaction shown is also a condensation reaction, which produces water, not a hydrolysis reaction, which requires water. Anabolic reactions are typically endergonic rather than exergonic; as they require energy.

Question 26

Answer: B

Explanation:
The reaction shows two amino acids joining to form part of a peptide chain. This indicates that the molecule produced is part of a protein. Of the options provided, the only option that is a protein is an enzyme.

Question 27

Answer: D

Explanation:
Convergent evolution describes the evolution of traits independently in different groups. These traits are selected for due to similar selection pressures and are not inherited from a common ancestor.

Question 28

Answer: C

Explanation:
Introns are transcribed, but not translated, as they are spliced out during post-transcription modification. Therefore, they do not contain nucleotide sequences that code for the production of protein. RNA polymerase, not DNA polymerase, binds to the upstream region of the gene and produces a molecule of mRNA. Transcription factors, which are enzymes that control the rate of transcription of genetic information from DNA to mRNA (eg RNA polymerase) do this by binding to the promoter region of a gene.

Question 29

Answer: A

Explanation:
Glucose will enter a cell through facilitated diffusion. Because glucose is water-soluble it is lipophobic, so cannot cross the lipid layer of the plasma membrane. Therefore, it requires carrier proteins to pass through.

Question 30

Answer: A

Explanation:
Catabolic process is those that break down large molecules into smaller molecules. Glycogen, a complex carbohydrate, is broken down into individual glucose molecules. All the other options are describing anabolic reactions; reactions that build larger molecules from smaller molecules.

Question 31

Answer: D

Explanation:
Aneuploidy refers to the addition or removal of a single chromosome, whereas polyploidy refers to multiple whole sets of chromosomes.

Question 32

Answer: B

Explanation:
The insulin protein is sequenced to determine the gene sequence. This is used to make an artificial gene. Insulin genes are inserted into plasmids, and the plasmids are used to transform bacteria.

Question 33

Answer: D

Explanation:
Although all the traits listed are typical of hominins, they are also shared by some other species of primates. The characteristic that separates hominins from other primate species is that they are bipedal.

Question 34

Answer: B

Explanation:
The foramen magnum is the hole in the base of the skull. A centrally positioned foramen magnum, rather than one that is located at the back of the skull, is an adaptation to bipedalism.

Question 35

Answer: D

Explanation:
Cancerous tumours are a result of too little apoptosis. The rate of cell growth exceeds the rate of cell death.

Question 36

Answer: A

Explanation:
The node representing when C and A had a common ancestor is later than when C and D or C and E diverged, therefore C shares its most recent ancestor with A. The least amount of time has passed since these two species (C and A) diverged from a common ancestor.

Question 37

Answer: B

Explanation:
By targeting T helper cells, the HIV virus supresses the adaptive immune response. This is because T helper cells are required for clonal expansion, and thus the production of B plasma cells, B memory cells, cytotoxic T cells and T memory cells. This makes the individual vulnerable to any type of infection.

Question 38

Answer: D

Explanation:
The mutation could be described as a point mutation, as there is a single nucleotide substitution. Since the bacteria with this mutation are resistant to penicillin, it is reasonable to infer that the mutation results in the production of a different protein. Therefore, it is not a silent mutation. A missense mutation describes a point mutation that results in the production of a different amino acid, and therefore an altered protein. Chromosomal deletions and translocations are block mutations, referring to whole or parts of a chromosome, rather than a single nucleotide change.

Question 39

Answer: C

Explanation
In RNA, adenine is complementary to uracil, and guanine is complementary to cytosine. The corresponding mRNA sequence would be UGG.

Question 40

Answer: B

Explanation:
The electron transport chain in cellular respiration produces the most ATP. Glycolysis produces some ATP, but much less – only two molecules of ATP per molecule of glucose. Synthesis of polypeptide molecules and conversion of FAD requires an input of energy, so will use up ATP.

SECTION B: Short Answer Questions

Question 1

a. Glucagon is a hydrophilic molecule and therefore cannot pass directly through the plasma membrane (1) so needs to bind to a signal receptor molecule that has part of it located on the outside of the cell (1)

2 marks

b. To amplify the signal (1)

1 mark

c. In facilitated diffusion, molecules move down their concentration gradient (1) through a channel protein or via a carrier protein (1)

2 marks

d. The concentration of glucagon would decrease (1)

1 mark

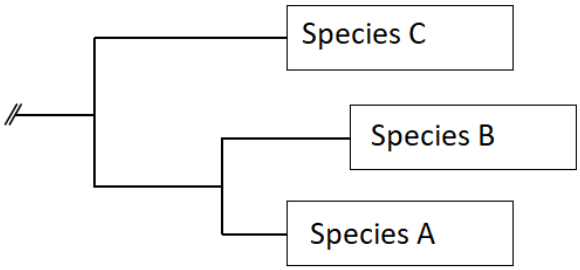
e. Any two of the following:
- Endocrine signalling is longer lasting, while paracrine signalling is short-lived
- Endocrine signals travel throughout the body, while paracrine signalling is localised
- Endocrine signalling takes a longer time to initiate a response, while paracrine signalling is very rapid

2 marks

2 + 1 + 2 + 1 + 2 = 8 marks

Question 2

a. Species A and B have the least number of differences between them, so the length of branches separating them is shortest, representing the least number of nucleotide differences (1). Species B and Species C have more differences between them than Species A and Species C, so Species B is placed further away from Species C (1).



1 mark for correctly labelled phylogenetic tree

3 marks

b. Species C diverged from a common ancestor first (1). This is inferred from the length of the branches separating species C from the other two species as there has been more time to accumulate differences (1)

2 marks

c. According to the molecular clock theory, mutations occur in genes at a constant rate (1). By counting the number of nucleotide differences in a gene between two species, we can estimate how long ago the two species diverged (1)

2 marks

d. DNA from the two species is mixed and heated until the strands separate, then cooled and allowed to anneal, to form hybrid DNA, containing one strand from each species (1). The hybrid DNA is then heated until the two strands separate (1) The temperature at which the two strands separate indicates how similar the two strands are, and therefore how closely related the two species are (1)**.**

3 marks

e. Any of the following:
- It is more robust than nuclear DNA
- There are multiple mitochondria per cell, therefore more copies of a mitochondrial gene are available per cell
- Mitochondrial DNA is not subject to changes due to recombination and meiosis therefore all changes can be assumed to be due to mutations

1 mark

3 + 2 + 2 + 3 + 1 = 11 marks

Question 3

a. Independent variable: the colour of light OR the wavelength of light (1)
Dependent variable: the rate of photosynthesis OR the number of floating leaf discs (1)

2 marks

b. Photosynthesis produces oxygen gas (1). The oxygen gas diffuses into the surrounding leaf, causing it to float (1)

2 marks

c. Green light resulted in the lowest rates of photosynthesis (1), and red light resulted in the highest rates of photosynthesis (1)

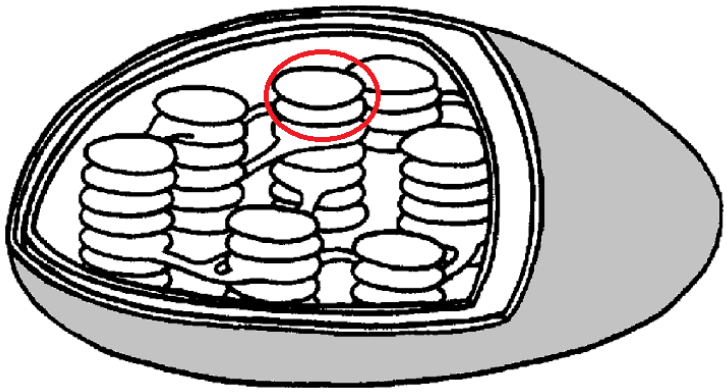
2 marks

d. Any two of the following:
- Light intensity
- Temperature
- Number of leaf discs
- Size of leaf discs

Or any other suitable answer

2 marks

e. Any of the thylakoid membranes / grana should be circled

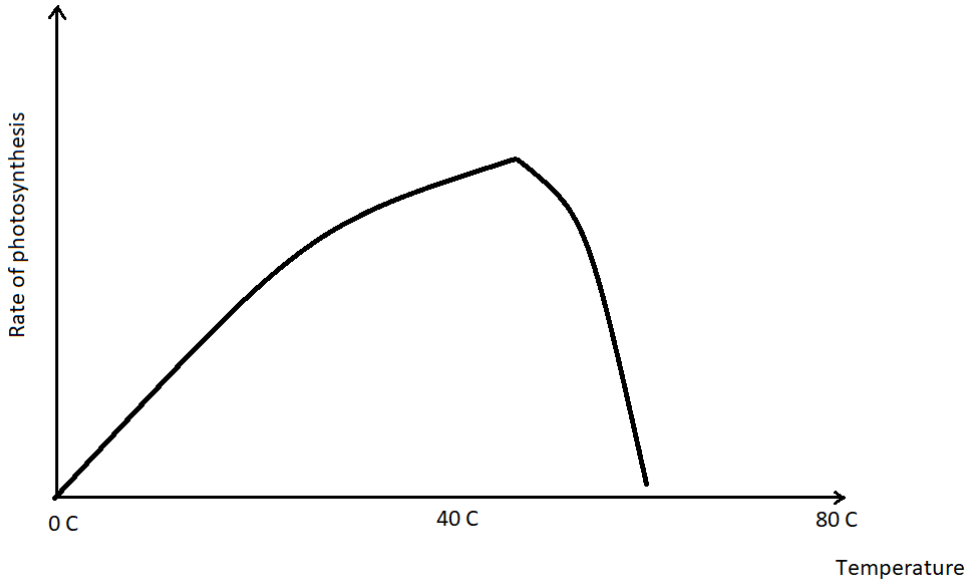


1 mark

f. Thylakoid membranes OR grana

1 mark

g. Photosynthesis rates should increase with temperature up to a point, then reduce rapidly. (The actual point at which photosynthesis rates reduce can vary, but should be somewhere between 30^{o}C and 70^{o}C)



1 mark

h. As temperature increases the rate of photosynthesis increases because molecules increase their movement due to more kinetic energy, so reactants come into contact more frequently (1). As the temperature continues to increase, the enzymes that control the reactions denature, so photosynthesis rates drop rapidly (1).

2 marks

2 + 2 + 2 + 2 + 1 + 1 + 1 + 2 = 13 marks

Question 4

a. Spleen OR tonsils

1 mark

b. During clonal selection, the receptors of T helper cells match up to the antigens presented by an antigen-presenting cell (1). This stimulates T helper cells to send cytokines (interleukins) to naïve B and T cells that also have complementary antibodies or receptors, signaling to them to multiply (1)

2 marks

c. Cytotoxic T cells send death ligands to infected cells that are displaying the antigens of the virus (1). This signals to the infected cell to undergo apoptosis, thus destroying the virus (1)

2 marks

1 + 2 + 2 = 5 marks

Question 5

a.

Trait	*A. afarensis*	*H. erectus*
Cranium	Smaller, less rounded cranium (1)	Larger, rounded cranium / greater cranial capacity (1)
Position of foramen magnum	Positioned towards the back of the skull / posterior foramen magnum (1)	More centrally positioned foramen magnum (1)
Angle of femurs	Straight / not angled (1)	Inward angled femurs (1)
Jaw and teeth	Robust jaw, larger specialized teeth (1)	Smaller jaw, less specialized / more generalized, smaller teeth (1)

8 marks

b. (i) Any of the following:

- More centrally positioned foramen magnum (1). Having the spinal cord connect to the bottom of the skull, rather than at the back, supported an upright stance (1)
- Inward-angled femurs (1). This would have allowed for better balance / weight distribution for a bipedal stance (1)
- Arched feet (1). They provide more balance and support for bipedalism (1)

Or any other suitable answer

2 marks

(ii) Any of the following:

- Enabled hominins to carry tools, supplies, young while travelling, allowing for more frequent travel and use of resources.
- Allowed for more refined tool use, improving hunting and methods for finding food
- Allowed for use of the hands for cave paintings / markings enabling communication and the transmission of culture

Or any other suitable answer

1 mark

(iii) Cultural evolution is the transmission of knowledge, language and art from one generation to the next. It is not biologically inherited.

1 mark

c. The diet of *Homo erectus* would have included meat and is likely to have been more generalised (1). Evidence for this includes a smaller jaw and smaller, more generalised teeth in *Homo erectus*. For a diet that does not rely on plants, thick jaw muscles and large, grinding teeth are not required, so these traits were selected against as hominins evolved towards an omnivorous diet (1) OR with the advent of fire and cooking of meat, stronger teeth were not required as cooked meat is softer (1)

2 marks

8 + 2 + 1 + 1 + 2 = 14 marks

Question 6

a. When there is no lactose present, the repressor is bound to the operator (1). This prevents RNA polymerase from moving past the operator and transcribing the three lac genes (1)

2 marks

b. When lactose is present, allolactose binds to the repressor (1). This causes it to change shape and detach from the operator, allowing the three lac genes to be transcribed (1)

2 marks

c. Structural genes code for the production of proteins (1), while regulatory genes control the action of other genes / determine whether another gene is active or not (1)

2 marks

d. Any two of the following:

- Prokaryotic DNA is contained in a single, large chromosome and in several smaller plasmids, while eukaryotic DNA is contained in several chromosomes
- Prokaryotic DNA condenses into circular chromosomes, while eukaryotic DNA condenses into linear chromosomes
- Eukaryotic DNA is contained within a nucleus, while prokaryotic DNA is not

2 marks

2 + 2 + 2 + 2 = 8 marks

Question 7

a. Genetic screening programs are generally population-wide and used as early diagnosis tools, while genetic testing provides specific DNA analysis of a targeted gene and is done on a case-by-case basis.

1 mark

b. Parents may wish to terminate the pregnancy if there is a positive test for Down Syndrome, which raises issues regarding the right to life

Or any other reasonable response

1 mark

c. The DNA is heated to 90^0C to separate the two strands (1). DNA polymerase (Taq polymerase), primers and free nucleotides are added (1). The DNA is cooled to 72^oC to allow the primers to anneal to the upstream region of the gene to be copied (1). DNA polymerase moves along the gene, creating a complementary strand (1)

4 marks

1 + 1 + 4 = 6 marks

Question 8

a. When the population was reduced on island number three, some alleles were permanently lost from the population (1) Although the population was able to increase to its original number, its gene pool would remain smaller (1)

2 marks

b. If a new threat to the population arises, such as a disease or change in food availability, there is less chance that some individuals within the population will be resistant or adaptable to the new conditions (1). This makes it more likely that the entire population will be destroyed, without leaving any individuals with favourable traits who are able to re-establish population numbers (1)

2 marks

c. Immigration of individuals who bring new alleles into the population.

1 mark

2 + 2 + 1 = 5 marks

Question 9

a. If the fossil contains half the amount of carbon-14, then one half life has passed. The fossil is 5730 years old.

1 mark

b. If the fossil is 11 460 years old, two half lives have passed. The fossil would contain one quarter of the amount of carbon-14 when compared to the recently deceased wombat skull.

1 mark

c. The fossils are too old / the half life of carbon-14 is too short, so all the carbon-14 in these fossils will have already decayed into nitrogen-14.

1 mark

d. According to the law of superposition, layers of sediment closer to the surface are newer than deeper layers of sediment. The relative ages of fossils can be determined from their relative depths in the same layer of sediment.

1 mark

1 + 1 + 1 + 1 = 4 marks

Question 10

a. (i) The amount of molecule C would be increased.

1 mark

(ii) The production of molecule D would stop.

1 mark

b. The coenzyme is required for the catalysation of the second reaction, which produces molecule D, but not for the first reaction, which produces molecule C. Molecule C would still be produced, but would not then be converted into molecule D.

1 mark

c. (i) The concentration of molecule C would decrease.

1 mark

(ii) In competitive inhibition, the inhibitor binds to the enzymes active site, preventing the substrate from binding there (1). In non-competitive inhibition, the inhibitor binds to the allosteric site, which changes the shape of the active site, preventing the substrate from binding (1).

2 marks

1 + 1 + 1 + 1 + 2 = 6 marks