

VCE Biology Units 3&4

Written Examination

Suggested Solutions

SECTION A – MULTIPLE-CHOICE QUESTIONS

1	A	B	C	D
2	A	B	C	D
3	A	B	C	D
4	A	B	C	D
5	A	B	C	D
6	A	B	C	D
7	A	B	C	D
8	A	B	C	D
9	A	B	C	D
10	A	B	C	D
11	A	B	C	D
12	A	B	C	D
13	A	B	C	D
14	A	B	C	D
15	A	B	C	D
16	A	B	C	D
17	A	B	C	D
18	A	B	C	D
19	A	B	C	D
20	A	B	C	D
21	A	B	C	D
22	A	B	C	D
23	A	B	C	D
24	A	B	C	D
25	A	B	C	D
26	A	B	C	D
27	A	B	C	D
28	A	B	C	D
29	A	B	C	D
30	A	B	C	D
31	A	B	C	D
32	A	B	C	D
33	A	B	C	D
34	A	B	C	D
35	A	B	C	D
36	A	B	C	D
37	A	B	C	D
38	A	B	C	D
39	A	B	C	D
40	A	B	C	D

Question 1 B

The proteins from both the mouse and the human cell are clearly mobile within the hybrid membrane, as they are found mixed together. This supports the fluid mosaic model of membrane structure and function. Cholesterol plays an important role, but this experiment does not provide evidence of this.

Question 2 C

The diagram illustrates a cell (probably a bacterium) that is being consumed by a eukaryotic cell. The process is called endocytosis. This is an active process (requiring energy) but does not fit the definition of active transport because the cell membrane is wrapping around the bacterium.

Question 3 D

To answer this question, the amino acid codons need to be converted into DNA triplets, which do not contain uracil, so **B** is incorrect. The first amino acid in the polypeptide is met, which has the codon AUG, and hence the triplet TAC, so **A** is incorrect. The solution lies in the second last amino acid in the polypeptide – glycine. The codon starts with GG, and so the triplet would need to have the sequence CC, so **C** is incorrect.

Amino acid	met	leu	ile	gly	gly	leu
Codons (mRNA)	AUG	CUU	AUA	GGG	GGA	CUU
DNA triplets	TAC	GAA	TAT	CCC	CCT	GAA

Question 4 A

There are only twenty different amino acids, but there are 64 different codon sequences. Some codons signal the termination of the polypeptide (stop codons). As seen in the table, some codons code for the same amino acid, which enables some variation in the final codon sequence (but still the same amino acid order). These are known as silent mutations and demonstrate degeneracy (or redundancy) in the genetic code.

Question 5 C

The sixth nucleotide is the third nucleotide of the second codon. The second amino acid is leucine, which has four codons. The third nucleotide of leucine can be any of the four nucleotides (A, G, C or U), which means any change in this position will not change the amino acid being coded for. This is also known as a silent mutation.

Question 6 D

A proteome is the proteins and their interactions within a cell at a particular time. A genome provides a blueprint for the proteins, but the molecular arrangement of DNA and proteins is different; **A** and **B** are incorrect. It could be argued that a proteome is more complicated than a genome due to the nature of proteins and their interactions within a cell.

Question 7 C

The three types of RNA are mRNA (involved in protein synthesis with codons), tRNA (involved in translation with anticodons) and rRNA (part of ribosome structure). There is no such molecule in mitochondria called mtRNA.

Question 8 A

In the *lac* operon model, when the repressor is bound to the operator portion (2), the RNA polymerase cannot bind to the promotor (1). The only solution that identifies this correctly is **A**.

Question 9 C

If lactose is present, it is important for the *lac* operon to be activated so that the lactose can be absorbed and broken down. The lactose binds to the *lac* repressor and this leads to the repressor changing shape. This shape change means the repressor detaches from the operator. When RNA polymerase binds to the promotor it is not impeded by the repressor and so the genes 3, 4 and 5 can be transcribed.

Question 10 C

A signalling molecule secreted from a gland into the bloodstream is referred to as an animal hormone. Pheromones move between species to cause a response, cytokines are released from (usually) white blood cells and act locally, and plants do not have a bloodstream; **A**, **B** and **D** are incorrect.

Question 11 A

The cristae are the finger-like projections along the inner membrane of the mitochondria and are the site of the electron transport chain, which generates a theoretical 34 ATP molecules per glucose molecule compared to the remaining four ATP molecules (two from glycolysis and two from the Krebs cycle). Acetyl coenzyme A is integrated into the Krebs cycle, but this occurs in the matrix, not the cristae. Glucose converts into pyruvic acid through glycolysis, but this occurs in the cytosol, not the cristae. The cleaving of hydrogen from NADH occurs in the electron transport chain, not the cleaving from NADPH.

Question 12 D

The only evidence shown in the diagram that supports the endosymbiotic theory is the presence of a double membrane. The inner membrane is similar in structure to the membrane of the original aerobic prokaryote consumed, and the outer membrane is from the plasma membrane of the original eukaryotic cell that engulfed the bacterium. The other responses are correct statements, but the diagram does not provide evidence that support the statements.

Question 13 B

If pyruvic acid and oxygen are available in optimal conditions (temperature and pH), the Krebs cycle and the electron transport chain function. This leads to more ATP, carbon dioxide and water forming. **A** is incorrect because glucose is broken down during respiration, not manufactured. NADH is used as a reactant for the electron transport chain within the mitochondria, making **C** incorrect.

Question 14 C

It is difficult to compare data in an experiment such as this because there is more than one variable being tested (salt and plant growth-promoting rhizobacteria (PGPR)). When comparing the presence of PGPR with or without salt, populations III and IV can be compared. PGPR is present in both and salt is only added to one.

Question 15 A

Water-soluble signalling molecules bind to extracellular receptors as they are unable to move freely through the plasma membrane; **A** is correct. If they were lipid-soluble they could move through the membrane and bind to intracellular receptors. The mode of action can be different depending on the type of cell being stimulated; gene activation is one type of response but there are others such as secretion (insulin), enzyme activation (glycogen synthase), gated protein channel opening (acetyl choline).

Question 16 A

PGPR can promote the opening of ion gated channels to bring in more ions to the cell; the internal concentration of the ions increases, thus allowing less water to exit or move into the cell. This could enable the plant to survive better in salty conditions, so **A** is correct. Stomatal opening would increase water loss; this would be a disadvantage when water is needed inside cells, so **B** is incorrect. The plant functioning at higher temperatures is not relevant to the context of the question, so **C** is incorrect. Absorbing salt from the soil would increase internal salt concentration but would not change the salt concentration in the soil, so **D** is incorrect

Question 17 B

Adenosine promotes sleep and the presence of excess caffeine negates sleep or acts as a stimulant. Four cups of coffee will not promote sleep, making **A** incorrect. Although caffeine and adenosine act at the same receptors, they are opposite in their effect, making **C** incorrect. The level of adenosine will be maintained but the caffeine consumed will be acting as a stimulant, making **D** incorrect.

Question 18 C

Non-self antigens should activate the immune system in a specific manner, making **C** correct. Self-antigens are on the surface of all body cells. They are a series of proteins coded for by several genes to give a unique immunological identity to an individual. Self-antigens do not change during an individual's lifetime because they are coded for by genes that do not change, making **A** incorrect. With no history of allergies, the allergen is not recognised as foreign, making **B** incorrect. If non-self antigens changed to self-antigens on the surface of a pathogen, the original response would remain (immunological memory) but there would not be a response against the self-antigen, making **D** incorrect.

Question 19 B

A physical barrier is something 'solid' that pathogens are unable to penetrate, such as unbroken skin, a thick waxy cuticle, prickles and thick bark. Chemical barriers are molecules present that decrease the survival of pathogens – examples include jasmonic acid and tears (the mucus and the leaves closing up are physical barriers). A microbiological barrier is an organism present that is detrimental to the survival of a pathogen – examples include bacteria on the skin or healthy gut flora (stomach acid is a chemical barrier).

Question 20 A

A virus is not a cell; it is referred to as an infectious agent. A virus is made up of a protein shell (capsid) with a nucleic acid (RNA or DNA) core. **B**, **C** and **D** are incorrect because they include prokaryotes (bacteria) or eukaryotes (malarial plasmodium).

Question 21 C

The innate immune response refers to a series of internal actions that occurs in a similar way regardless of the type of threat a body is under. The action of mast cells secreting histamine when stimulated leading to an inflammatory response is innate even though the antigens bind to antibodies on the surface of the mast cell. The action of the mast cell releasing histamines is non-specific and becomes more refined in situations such as allergies, making **C** correct. Complement proteins can bind to bacteria and lyse them, but this action alone does not lead to a fever, making **A** incorrect. Pathogens do not secrete cytokines – cells of the immune system do, making **B** incorrect. Neutrophils are the most prolific type of white blood cell and so are usually first at the site of infection, making **D** incorrect.

Question 22 C

Antibodies are comprised of four polypeptide chains, two light and two heavy, that form a Y-shape. The tip of both ends of the Y-shape form the antigen binding site and are the same shape. As this bacterium has two different antigenic shapes, two different antibodies would be made, so **A** and **B** are incorrect. The light chains are found underneath the heavy chains, so **D** is incorrect.

Question 23 B

The influenza vaccine stimulates the immune system for antibodies against the 3–4 injected antigens, and so is a form of active immunity and provides long-term immunity. The fact the antigens have been injected means it is an artificial form of immunity. Passive immunity provides short-term immunity and can be acquired by obtaining the antigens naturally or artificially.

Question 24 B

Gene flow is the movement of alleles between populations via reproduction and, as populations Q and R are reproductively isolated, this cannot occur, making **A** incorrect. The founder effect is the rapid change in allele frequency as a result of the relocation of a small unrepresentative population; **C** is incorrect. **D** is incorrect as, even though the populations are isolated, there is no evidence of speciation. A population bottleneck could lead to a rapid change in the gene pool; as a population declines rapidly, there is little variation in the gene pool. In the case of population R, allele A is virtually 0, meaning the small population is homozygous A.

Question 25 C

Each species originates from an ancestral population. The original shrimp, when geographically isolated, displayed variations due to pre-existing mutations. When the shrimp were in different environments, the most favoured variants became the ancestors to the currently existing species; **C** is correct. Deep-sea predators would not exist in a shallow ocean, making **A** incorrect; organisms do not mutate to suit their environment, making **B** incorrect; and there is no evidence given regarding artificial selection, making **D** incorrect.

Question 26 B

By looking carefully at both strands, changes can be seen from the ninth nucleotide to the fifteenth nucleotide. The nucleotides within that section were inverted between the first and second strand. **B** is correct. Substitution and point mutations are effectively the same and relate to a single nucleotide change. Addition mutations add in a nucleotide, increasing the total number of nucleotides, which is not the case in this question.

Question 27 D

When population numbers dramatically drop in a short space of time in a particular area, the gene pool is reduced. This phenomenon is referred to as a genetic bottleneck.

Question 28 D

Index fossils are found in many different locations; the living things from which the fossils formed usually only existed for a short time period and usually fossilized well. They can be used as an effective reference point to compare to other fossils. In this case, fossils **B** and **C** are found in numerous layers and fossil **A** is only found in three of the four locations. Fossil **D** is found in all four locations and in only one layer; it is therefore the most appropriate to use as an index fossil.

Question 29 D

If there were 1 unit of the potassium isotope in fresh rock, it would take 1.3 billion years for there to be 0.5 units of the isotope found in the rock and a further 1.3 billion years for there to be 0.25 units of the isotope. $1 \rightarrow 0.5 \rightarrow 0.25 \rightarrow 0.125 \rightarrow 0.0625$ is four half-lives. Each half life is 1.3 billion years, making the rock 5.2 billion years old. Since the earth is only around 4.6 billion years old, the rock probably came from a meteor.

Question 30 A

There are many conditions that would lead to the preservation and fossilisation of animal remains. The most important of the given conditions is that if an animal is rapidly buried then the remains are less likely to be scavenged, so **A** is correct. If the creature died in water, then the decomposition rate decreases with increasing depth and the downward pressure increases. Both of these conditions are conducive to fossilisation. Teeth and bones are the most likely remains to be fossilised, but they are not conditions.

Question 31 A

Each species needs to be compared to each of the other species based on the number of common (or different) nucleotides. Species L and M have the fewest differences and so share the most recent common ancestor. The table below shows the number of differences.

	L	M	N	O
L		1	3	5
M	1		4	6
N	3	4		6
O	5	6	6	

Question 32 C

Humans are hominins (big brained bipeds), hominids (tail-less apes) and primates (forward-facing eyes and an opposable fifth digit). Humans fit into the hierarchical classification of all of the given categories.

Question 33 D

The hominin line includes the *Australopithecines*, who occurred longer ago than the *Homo* genus. The *Australopithecine* was credited with clear evidence of bipedalism prior to an increase in intelligence. Most *Australopithecine* fossils show a smaller cranial capacity than most *Homo* fossils; **D** is correct. The majority of both *Australopithecine* and *Homo* fossil show a bowl-shaped pelvis and a central foramen magnum, and all primates have opposable thumbs, so **A**, **B** and **C** are incorrect.

Question 34 D

During polymerase chain reaction (PCR), primers anneal to on either side of specific target sections of DNA so the sections of the genome spanning the target sections can be replicated. Denaturation occurs at temperatures greater than 90°C, and replication occurs at 72°C, as this is optimal for the Taq polymerase enzyme. Prior to replication, the enzyme binds to the primer and then moves along the template strand in a 3' to 5' direction.

Question 35 C

There are seven different restriction enzyme cutting sights on the plasmid. If each restriction enzyme were mixed with the plasmid, the plasmid would be cut in seven places. If a circle (plasmid) is cut, then the number of fragments is equal to the number cutting sights – in this case, seven.

Question 36 B

The modified bacteria have had their ampicillin (Amp) gene cut, which means it no longer confers the bacteria resistance to Amp (making **A** and **D** incorrect). The bacteria would be resistant to tetracycline (Tet), as this gene was not cut during the transformation process. All bacteria should survive in the control plate, as this can be used to determine how successful the transformation process has been, so **C** is incorrect and **B** is correct.

Question 37 C

If the four restriction enzymes were mixed with a plasmid, the plasmid would be cut into four fragments (making **D** incorrect). The scale on the plasmid can be used to determine the size of each fragment. Each fragment would be 276, 516, 1644 or 2064 nucleotides long. On a gel, the smallest fragments move the furthest, making **A** and **B** incorrect. In **A**, the + and – ends of the gel are also reversed. The location of the fragments in **C** are in a reasonable location, and thus **C** is the most accurate representation of the expected band pattern.

Question 38 A

An economic argument against the new test revolves around money, a biological argument mainly revolves around the impact the test may have on the gene pool and a social argument is how the test may affect people. Socially, choices **A**, **C** and **D** are the only options that provide appropriate social arguments against the new test, so **B** is incorrect. **A** and **D** are the only options that provide appropriate biological arguments, so **C** is incorrect. **D** provides an argument in favour of the test, so it is incorrect. **A** is correct.

Question 39 B

Based on the data, there are more bacterial-resistant colonies present after treatment compared to before treatment. This means each colony would be genetically different based on a pre-existing mutation that has been selected for (bacterial resistance) over the duration of the treatment, so **A** and **C** are incorrect and **B** is correct. If the antibiotics had been prescribed for longer, it would be expected that all colonies would be highly resistant, rendering the antibiotics less effective.

Question 40 A

Accuracy refers to the true value, which in biology is difficult to ascertain. However, rigorous planning in preparation for investigation can produce results that would more likely revolve around a true value. A scientific investigation should only test one independent variable (validity); **C** is incorrect. An investigation should be carried out multiple times by an investigator until concordant results are obtained (repeatability and precision); **B** and **D** are incorrect. The same investigation should also be carried out by different investigators using the same method. The results obtained should also be concordant with the results obtained by other investigators (repeatability).

SECTION B**Question 1 (7 marks)**

- a.** amino acids 1 mark
- b.** Secondary level of arrangement: The interaction between amino acids within a single polypeptide chain form certain shapes (α -helices or β -sheets) within the ATP synthase molecule. 1 mark
- Quaternary level of arrangement: Multiple polypeptide chains are held together by bonds (disulphide bonds) that form the functional protein. In this case, twenty polypeptide bonds bind together forming the functional ATP synthase protein. 1 mark
- c.** The ATP synthase allows a pathway for excess hydrogen ions (protons) to move across a membrane (thylakoid or inner mitochondrial) because there is a proton gradient on either side of the membrane in both organelles. 1 mark
- As the protons diffuse through the ATP synthase, the functional protein revolves and provides the energy to join a phosphate onto ADP, forming ATP (used for cellular energy from the mitochondria or to drive the Calvin cycle in photosynthesis). 1 mark
- Note: Award 1 mark only if response does not relate to either photosynthesis or respiration.*
- d.** cyanobacteria 1 mark
- Bacteria are prokaryotic and so do not contain membrane-bound organelles, such as the mitochondria or chloroplast. 1 mark

Question 2 (7 marks)

- a.** RNA polymerase binds to the operator (switch) upstream from the gene (DNA molecule) to be expressed. 1 mark
- RNA polymerase moves down the template strand. 1 mark
- RNA nucleotides that are complementary to the template strand form pre-mRNA. 1 mark
- b.** The process is RNA processing. 1 mark
- Structures 2, 4 and 6 are introns, which are cleaved out, and structures 1, 3, 5 and 7 are exons, which are joined together to form the shorter mRNA strand. 1 mark
- c.** The input molecule (mRNA) is read in groups of three nucleotides (codons), of which there are 64 different types. 1 mark
- The output molecule (protein) is made up of amino acids from a pool of 20 different types. Each amino acid can have more than one codon coding for it, allowing the correct amino acid to be added to the growing polypeptide. 1 mark

Question 3 (9 marks)

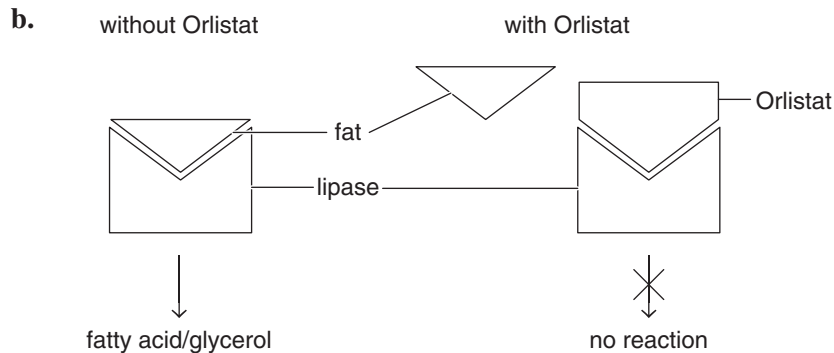
- a. i.** hydrolysis, as the reaction is breaking down fat 1 mark

ii. The four conditions are:

- specific temperature (37°C)
- specific pH (close to neutral)
- large surface area : amount of substrate
- high level of lipase (enzyme)

2 marks

*Note: Award 1 mark only for three conditions.
Award 0 marks for two or fewer conditions.*



2 marks

*1 mark for appropriate diagram.
1 mark for appropriate labelling.*

c. A control group is a group of individuals that are given medication that does not contain the active ingredient being tested, in this case Orlistat.

1 mark

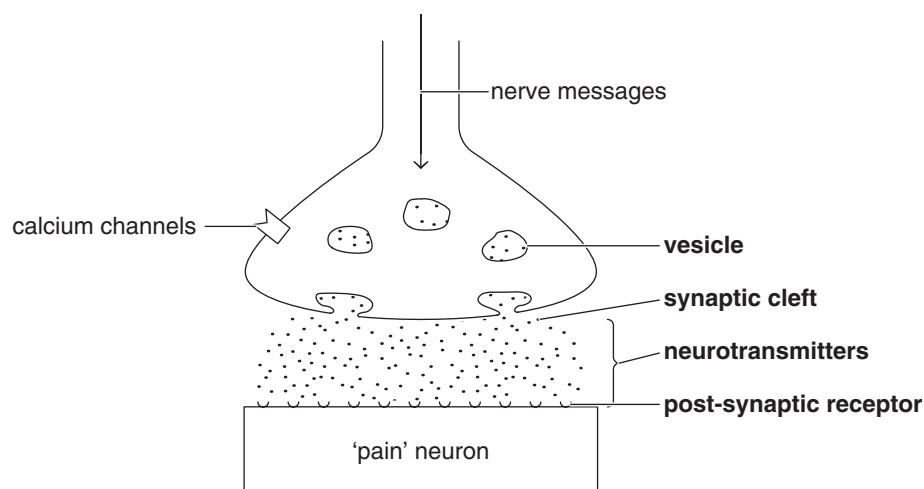
The control group data is compared to an experimental group that have taken the active ingredient. All other factors should be kept the same for the two groups.

1 mark

d.

Side effect	Biological reason for the side effect
oily bowel movement	The Orlistat has bound to the lipase, stopping the breakdown (and absorption) of fat. The waste being excreted would therefore have more fat, making stools oily.
weakness	Fats carry energy and, as the fat is not being broken down and absorbed, less energy is available, which leaves individuals weaker.

2 marks

Question 4 (6 marks)**a.**

2 marks

Note: Award 1 mark for 2–3 correct labels.

- b.** A neurotransmitter binds to a receptor at the pain neuron, which activates a signal–transduction pathway. 1 mark
- The response is a nerve message in the pain neuron, which leads to the experience of pain. 1 mark
- c.** The Ziconotide binds to the calcium channel, preventing the exocytosis of the neurotransmitter into the synapse. 1 mark
- This decreases the activation of the pain neuron as fewer neurotransmitters are available to bind to the post-synaptic receptors. 1 mark

Question 5 (6 marks)

- a. i.** *Any one of:*
- DNA damage
 - mitochondrial stress
 - damaged cells
 - old cells
- 1 mark
- ii.** The main reason why apoptosis may be activated externally is as a response to external signals from immune cells. 1 mark
- b.** Caspase is a proteolytic enzyme that cleaves the cytoskeleton of a cell. 1 mark
- The cytoskeleton no longer holds the cell together and forms small cellular structures called blebs or apoptotic bodies. 1 mark
- c.** *Any two of:*
- a higher temperature, which is detrimental to microbes
 - more blood flow, meaning more white blood cells moving to the wound
 - possible infection
- 2 marks

Question 6 (6 marks)

- a.**
- i.** one-way valves 1 mark
 - ii.** the location where antigens come in contact with lymphocytes (B or T cells) 1 mark
- b.** Dendritic cells carry specific antigens that come in contact with a complementary receptor on the surface of an immature T cell. 1 mark
- The T cell then rapidly divides (clonal expansion) and differentiates into cytotoxic T cells. 1 mark
- Cytotoxic T cells move into the bloodstream to eventually bind to the antigens on the pathogen, which leads to its destruction. 1 mark
- Note: Discussion of T helper cells is not required for full marks.*
- c.** Once the antigen is present, it can bind specifically to T helper cells, which can communicate with both B and T memory cells in order to allow a faster and more refined immune response. 1 mark

Question 7 (5 marks)

- a.** If there were no interaction between the PD-1 on a T cell and the PD-L1 on the cancer cell, the cancer cell would be regarded as non-self and be destroyed. 1 mark
- b.** **G-D-A-F-B-C-H-E** 2 marks

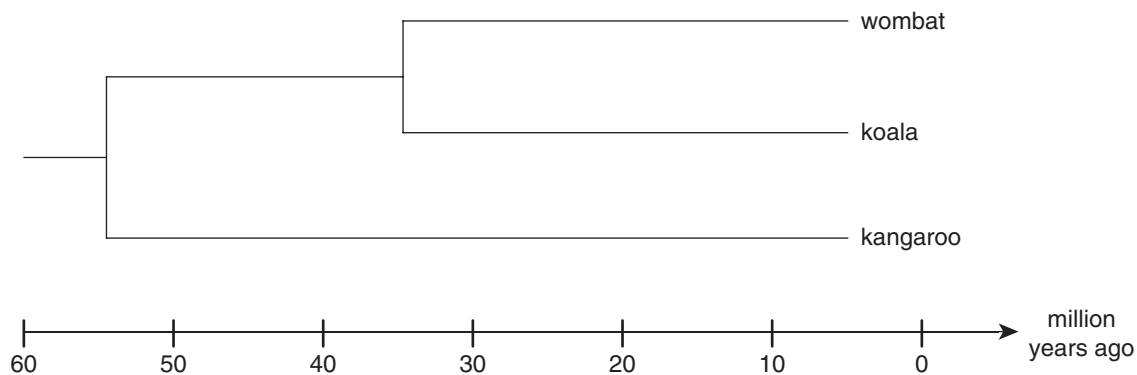
G	A mouse is injected with the PD-1 antigens.
D	Specific B cells against the PD-1 antigens clone and differentiate.
A	The mouse makes antibodies against the PD-1 antigens.
F	Blood samples are taken from the mouse.
B	Specific B cells are isolated from the mouse blood samples.
C	Specific B cells are hybridised with tumour cells.
H	A cell line of hybridomas are grown in culture.
E	Antibodies against PD-1 are extracted and used for therapy.

Note: Award 1 mark for 6 steps in the correct position.

- c.** The number of individuals alive after two years with Pembrolizumab was 21 more than the number of individuals alive after two years with Ipilimumab (188 compared to 165). 1 mark
- There are three times more individuals with smaller tumours when treated with Pembrolizumab compared to Ipilimumab (91 to 33). 1 mark

Question 8 (9 marks)

- a.** The common ancestor would have some features in common with all the descendants (homologies). 1 mark
- There would need to be evidence of the common ancestor having lived before all of their descendants. 1 mark

b.

3 marks

*1 mark for appropriate scale.**1 mark for correct branching.**1 mark for scaled/labelled tree.*

c. The two wombats would need to be unable to produce fertile offspring. 1 mark

d. i. Larger bones and teeth would be expected to belong to larger organisms because larger organisms would require stronger/larger bones to carry them around. 1 mark

By comparing the bone sizes with those of modern organisms, a reasonable estimation of size and weight could be calculated. 1 mark

ii. *For example:*

Indigenous Australians have been in the country for over 50 000 years, so it is reasonable to assume that they hunted the megafauna to extinction. 1 mark

Question 9 (8 marks)

a. The term 'hominin' describes modern humans and their ancestors that share bipedalism, increased brain size and reduced canine size. 1 mark

b. As 96% of the non-African modern human genome is shared with the African human genome, the two groups are likely to have interbred with each other originally within Africa. 1 mark
1 mark

c. i. Only a few Neanderthal males cross-bred with modern human females. 1 mark
Nuclear DNA was passed to children, but mtDNA was not. 1 mark

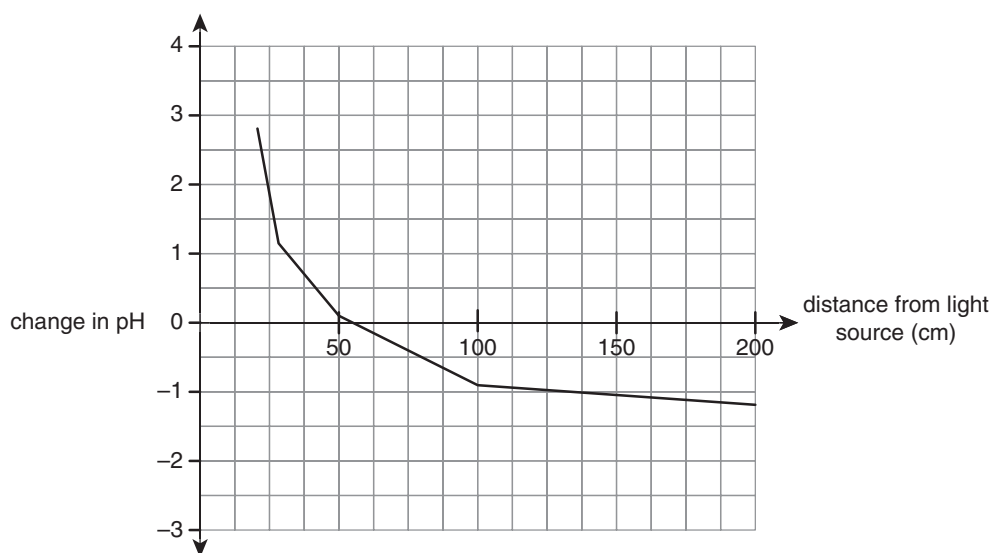
ii. A chromosomal block mutation could leave evidence of Neanderthal DNA within the nuclear DNA of modern humans, as an exchange of segments of Neanderthal chromosomes/chromatids with human chromosomes/segments could have remained in the gene pool. 1 mark

d. Shared DNA sequences (homologous molecules) within modern humans and Neanderthals is used as a reference point, because the number of differences in the molecules can be used as a molecular clock to determine the ages of both modern humans and Neanderthals. 1 mark

These sections of DNA may have more differences in them that are reflective of human–Neanderthal interbreeding occurring 100 000 years ago rather than 50 000 years ago. 1 mark

Question 10 (7 marks)

- a.** The daffodil genome is isolated and exposed to polymerase chain reaction to amplify the psy gene. 1 mark
- The amplified psy gene and the plasmid used to insert the gene are exposed to a restriction enzyme that cuts the plasmid once and the psy gene twice (on either side of the gene). 1 mark
- The psy gene and the plasmid are then mixed together with DNA ligase so that a recombinant plasmid with the psy gene is formed. 1 mark
- b.** Golden Rice is genetically modified because its genome has been manipulated. 1 mark
- Golden Rice is transgenic because it has genetic material from other species (daffodil and bacteria) inserted into its genome. 1 mark
- c.** Any two of:
- In the Philippines, growing rice may be more productive than growing vegetables, such as sweet potato, and so could be more profitable.
 - The vitamin A level being 23 times higher per unit of food for Golden Rice 2 could provide more vitamin A than any of the vegetables available.
 - Growth of the Golden Rice 2 crop could be cheaper overall than the growth of the other crops due to infrastructure and farming practices.
 - The majority of the population may be more likely to consume rice than the vegetables.
- 2 marks

Question 11 (10 marks)**a.**

3 marks
 1 mark for labelled axes.
 1 mark for graph line.
 1 mark for scaling.

- b.** At a short distance from the light source (20 cm), the pH change is +2.8, which means that the solution is more alkaline. This means more photosynthesis has occurred because there is a lower level of carbon dioxide in the solution (a higher pH). 1 mark
- As the distance from the light source increases, there is less light available for photosynthesis and the change in pH becomes less positive, dropping from +2.8 at 20 cm to -1.2 at 200 cm. 1 mark
- Respiration is always occurring, producing the more acidic carbon dioxide, as the sample that was not exposed to light had a pH change of -2.1, which is more acidic than the result at 200 cm. 1 mark
- c.** *Any two of:*
- Two to three test tubes could have been prepared per light intensity rather than one, making the experiment repeatable.
 - Other investigators could have performed the same experiment to gather similar results, showing that it was reproducible.
 - More light intensities could have been investigated to give a clearer idea of trends.
- 2 marks
- d.** Researcher A is correct because only one independent variable was changed, making the experiment valid. 1 mark
- Researcher B is incorrect because each independent variable was only tested once, meaning there were not multiple results for comparison (no precision). 1 mark