Neap:

Trial Examination 2011

# VCE Biology Unit 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** |



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**Question 1 C**

Alleles are defined as the different forms of a gene. This is due to their different nucleotide sequences which may code for the production of a protein with slightly different levels of functionality. Most sexually reproducing organisms carry two copies of each gene in somatic cells and one copy in gametes. They are located at the same position (locus) along each homologous chromosome.

**Question 2 A**

The four gametes are the product of meiosis. Independent assortment separates this pair of homologous chromosomes but if this was all that occurred there would only be two allele combinations of gametes. When crossing over occurs between homologous chromosomes, more allele combinations are possible through recombination. In the case of the question, four different gamete combinations are formed (**AB Ab aB ab**), indicative of crossing over.

**Question 3 C**

Proteins are sequences of amino acids. The order is translated from the codons along the mRNA which is originally transcribed from the DNA. It is the DNA that replicates and is subsequently passed from cell to cell and generation to generation.

**Question 4 B**

DNA replication occurs when the hydrogen bonds holding the double helices together are broken. Each strand becomes a template for a new strand. Two identical strands are produced. The replication process is semi conservative because half of the original DNA strand is located in each new double helix.

**Question 5 C**

With regards to this disease being autosomal dominant, let the Marfan allele be **M** and the normal allele be **m**. If the couple have a child that is **mm** but the father has the disease, then his genotype must be **Mm**. Since his wife is **mm** the chance they have of producing another unaffected child is 50%.

| | **M** | **m** |
|---|---|---|
| **m** | **Mm** | **mm** |
| **m** | **Mm** | **mm** |

**Question 6 A**

Both parents are homozygous, making the F1 generation heterozygous **AaBb**. When the F1 are crossed the phenotypic ratio of the F2 would be 9 : 3 : 3 : 1. The big light phenotype could have a genotype of **Aabb** or **AAbb**. There is $\frac{3}{16}$ chance that this phenotype will appear in a population of 100.

**Question 7 C**

Cloning technology occurs when a fully differentiated somatic cell (body cell) is fused with an ovum that has had its nucleus removed. The resultant cell is then ‘tricked’ to behave like a zygote. The genome within the zygote is identical to the genome in the original somatic cell.

**Question 8 D**

This is a dihybrid cross involving the inheritance of two genes, each with two alleles. If the two genes were located on different pairs of homologous chromosomes they would be inherited independently of each other in Mendelian fashion, i.e. by independent assortment. Therefore, if the F2 generation was the product of a test cross involving independent assortment, the four phenotypes shown would be expected to occur in the ratio 1 : 1 : 1 : 1. This is not true, so **A** and **B** are incorrect. Autosomal linkage is involved. In this case, most F2 offspring of the test cross would be expected to show parental phenotypes (normal/red and dympy/brown). Option **C** is incorrect, because only a minority of offspring would show the recombinant phenotypes (normal/brown and dumpy/red) that arise from the crossing-over of chromatids during Meiosis I. In this example, since 100 out of 1000 F2 offspring are recombinant, crossing-over occurred in the formation of about 10% of the gametes produced by each parent.

**Question 9 B**

When mRNA is extracted from specialised cells it can be mixed with an enzyme called reverse transcriptase which converts the mRNA into cDNA. This sequence will not contain any introns but will contain exons and the stabilising factors on either side. The promoter region is located on the original DNA strand and is an important factor in switching a gene on by allowing transcription factors to bind to it but this section is not transcribed.

**Question 10 D**

Gene B codes for the production of enzyme B. Enzyme b catalyses the conversion of ornithine to citrulline. This biochemical pathway illustrates how amino acids can be manufactured within a cell. To produce arginine within a cell with this type of mutation, it would need to be fed citrulline as enzyme c would catalyse its conversion into arginine.

**Question 11 A**

Single nucleotide changes can lead to three main scenarios. One is that the change makes no difference to the amino acid being coded for (silent). Second is that it may become a stop sequence, which will lead to a smaller protein (nonsense). Third is that the change may lead to a different amino acid being coded for (point). A frameshift mutation occurs when nucleotides are missing or added in. This can lead to the codons downstream from the mutation all being affected.

**Question 12 A**

There are multiple cutting sites for each restriction enzyme. The shortest strand would be produced by mixing the DNA strand with *Taq* I because this is close to the end of the strand.

**Question 13 D**

The lion and tiger must be closely related genetically to still be able to produce a hybrid offspring. Pre-zygotic mechanisms such as sexual behaviour and gamete viability have not reproductively isolated the organisms. However, due to the different chromosome numbers it is reasonable to assume the liger is unable to produce viable gametes during meiosis because homologous pairing of chromosomes would not occur.

**Question 14 B**

The study of populations can give data about many factors relating to change. With large populations, frequency of alleles (causing genetic disease) can be determined. The same study could be done several times over many years to see if any changes in allele frequencies are occurring. This may show if certain alleles are increasing (selected for) or decreasing (selected against). What it cannot do is predict what will happen in the future as populations are exposed to environmental change, which is not usually predictable.

**Question 15 A**

For sexual selection there must be a factor that is selecting for the different colouration of the feathers in the two sexes of the pheasant. Alternative **A** illustrates the scenario that bright colouration is important in males, as if they are dull coloured, they are not selected for breeding.

**Question 16 D**

Genetic drift is the change in allele frequencies over time due to random, non-biological processes, i.e. random chance. This will happen in every population, regardless of the size of the population and whether or not other processes are operating on the allele frequencies within it (e.g. selection and mutation).

**Question 17 B**

The transfer of alleles between populations of the same species is called gene flow. This process obviously occurs when organisms, even the embryonic plants found in seeds, move from place to place. In the scenario of this question, no new species has formed and no new population is being founded in a previously uncolonised habitat. A genetic bottleneck, where the size of a population is reduced by some catastrophe to a very small number of individuals, has also not occurred.

**Question 18 D**

Individuals of different species do not naturally interbreed to produce fertile offspring. This complete reproductive isolation must therefore occur between two populations if one (or both) of the populations is to become a new species. Geographical isolation often leads to reproductive isolation.

**Question 19 C**

0.125 is one eighthof 1. To reduce the initial amount of $^{14}C$ to this fraction requires three half-lives

$3 \times 5500 \text{ years} = 16\,500 \text{ years}$.

**Question 20 A**

The lowermost layer of sedimentary rock in a sequence is the oldest. The most reasonable pattern of tusk evolution, given these specimens, is for the lower tusks to disappear and the length of the upper tusks to increase over time. This makes Tusk 4 the oldest. In the earliest animals, the upper tusks curved downwards, so as tusk length increased, Tusk 2 and Tusk 5 followed Tusk 4. Upward-curving tusks then evolved (Tusk 3).

**Question 21 C**

Students should have a fair idea of the order of hominins involved in the evolution of *Homo sapiens*. The evidence suggests that

*A. afarensis* was earliest (3 – 4 million years ago)

then *A. africanus* (2 – 3 million years ago)

then *H. habilis* (1.5 – 2 million years ago)

then *H. erectus* (0.5 – 1.8 million years ago)

then *H. neanderthals* (0.5 – 0.05 million years ago)

This fossil being about 2 million years old would fit nicely between *Homo habilis* and *Australopithecus africanus*.

**Question 22 B**

These seven pentadactyl limbs show the same arrangement (in order) of a ball-and-socket shoulder joint, a long bone, a hinged 'elbow' joint, two parallel long bones, a gliding 'wrist' joint, and five digits. These limbs are homologous structures: while anatomically similar, the forelimb performs a different function in each of these seven animals. Homologous structures are evidence of divergent evolution from a common ancestor.

**Question 23 C**

GM food often involves transferring DNA from one organism to another (such as an antifreeze gene from an ocean pout put into the genome of GM salmon to help them to grow faster). Currently, human insulin is produced using a genetically modified bacterial plasmid and so involves transfer of genes between species. Gene therapy that utilises a virus as a vector involves splicing genes into the genomes of the virus so the gene can be transferred into the target cells. Stem cell production does not involve gene transfer but does involve controlling the expression of genes within cells so they differentiate into particular cell types.

**Question 24 B**

PCR (polymerase chain reaction) and DNA cloning are both methods for increasing the number of copies of a fragment of DNA. Genetic transformation refers to the process by which the genetic material carried by an individual cell is altered by the incorporation of foreign (exogenous) DNA into its genome. Gel electrophoresis separates DNA fragments according to their negative electrical charge and their relative molecular size.

**Question 25 D**

The bases added at the end of the growing fragment are (in order):

| **Order of bases** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| **Colour added** | red | red | black | blue | green | black | black | blue |
| **Dideoxynucleotide** | T | T | G | C | A | G | G | C |
| **Template base sequence (complementary to the base added)** | **A** | **A** | **C** | **G** | **T** | **C** | **C** | **G** |

## SECTION B: SHORT-ANSWER QUESTIONS

### Question 1

**a.** In this case, a 'probe' is a short length of single-stranded, radioactive or fluorescent DNA or RNA which has a base sequence complementary to the base sequence of the DNA of the gene being investigated in this RFLP analysis. 1 mark

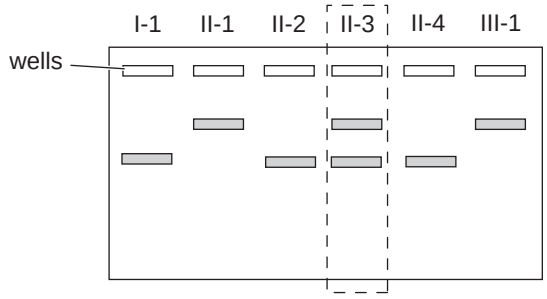
**b.** **i.** *Either one of:*

- Person II-2 is female and therefore her cells contain two alleles of this sex-linked gene (one on each X chromosome).
- Person II-2 is homozygous for the normal allele.

1 mark

Because her two alleles are the same, their DNA is digested in the same way and produce only one band, corresponding to the smaller (2.3 kb) fragment. This fragment represents the normal allele. 1 mark

**ii.** In order to give birth to an affected boy (III-1) by a normal father (II-4), Person II-3 must be a heterozygous 'carrier' of Menkes' disease. She must therefore possess both the normal allele (indicated by the smaller 2.3 kb fragment) and the mutant allele (indicated by the larger, 5.2 kb fragment that does not move as far through the gel).




1 mark

**c.** The disorder is recessive. 1 mark

Unaffected parents (e.g. I-1 and I-2 or II-3 and II-4) have affected offspring (e.g. II-1 or III-1). *(Note that the parents and their corresponding offspring must be correctly identified from the pedigree.)* 1 mark

**d.** The probability is zero. To have Menkes' disease, a girl must inherit the mutant allele from both her parents. Person III-2 cannot inherit the mutant allele from her normal father (II-4). 1 mark

### Question 2

**a.** Eukaryotic chromosomes are linear 1 mark

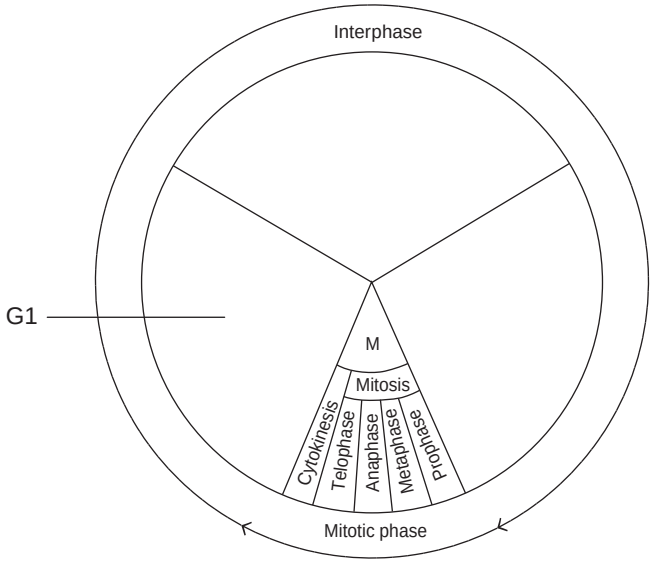
and consist of 2 chromatids connected to each other by 1 centromere. 1 mark

**b.** **i.** about 28 ± 3 years 1 mark

**ii.** Due to wear and tear on her telomeres, her predicted age is about 50. 1 mark

**c.** **i.**




1 mark

**ii.** As telomerase activity is increased, the G1 block in the cell cycle would be removed. 1 mark

This would lead to longer telomeres due to the presence of extra telomerase. 1 mark

The predicted age of individuals would decrease (longer telomeres) meaning increased longevity. 1 mark

**Question 3**

**a.**

| Structure | Name of structure | Role in recombinant DNA process |
|---|---|---|
| *X* | Human insulin gene | Contains the sequence of bases that codes for the sequence of amino acids in insulin. |
| *Y* | Restriction (endonuclease) enzyme(s) | Used to cut the insulin gene out of the chromosome in which it is located AND makes a cut in the bacterial plasmid so that the insulin gene can be spliced into it.<br>OR<br>To cut the human insulin and bacterial plasmid so that they have complementary "sticky ends" and the insulin gene can be spliced into it. |
| *Z* | Recombinant plasmid<br><br>*Note: do not accept only "plasmid"* | This is the vector by which the foreign DNA/exogenous DNA/human DNA/human insulin gene is transferred into the bacterial genome. |

3 marks

*1 mark for each correct row of the table*

**b.** *Any one of the following risks:*

- The human insulin gene may mutate in the bacterial host cell; cloning of the mutated gene may result in the mass production of a mutant 'insulin-like' polypeptide that is ineffective or harmful in humans;
- Inadequate purification processes may result in the contamination of the insulin by bacterial material that may be harmful to human users;
- Human diabetics may refuse treatment with insulin made by genetically-modified bacteria on cultural/religious/ethical grounds.

1 mark

*Any one of the following benefits:*

- The insulin made by recombinant bacteria is coded for by a human gene and is chemically identical to human insulin;
- There is little likelihood of the insulin being ineffective or allergenic when used to treat diabetics;
- There is not likely to be a shortage of human insulin for use in treating diabetics.

1 mark

**Question 4**

**a.** Both parents are unaffected but heterozygous (**Cc**). When they have children the laws of probability predict there is a 25% chance of an affected child and 75% chance of an unaffected child. However, the counsellor is giving advice to the unaffected child who is definitely not **cc**. Of the 3 chances left (see the punnet square below), 2 of them are **Cc**.

The genetic counsellor would say there is a $\frac{2}{3}$ chance.

| | **C** | **c** |
|---|---|---|
| **C** | **CC** | **Cc** |
| **c** | **Cc** | **cc** |

1 mark

**b.** The cholera toxin 1 mark

**c.** **i.** Any mutation in the CFTR gene will lead to a faulty CFTR protein. If an individual carries one of these mutations they will be phenotypically normal but resistant to cholera. 1 mark

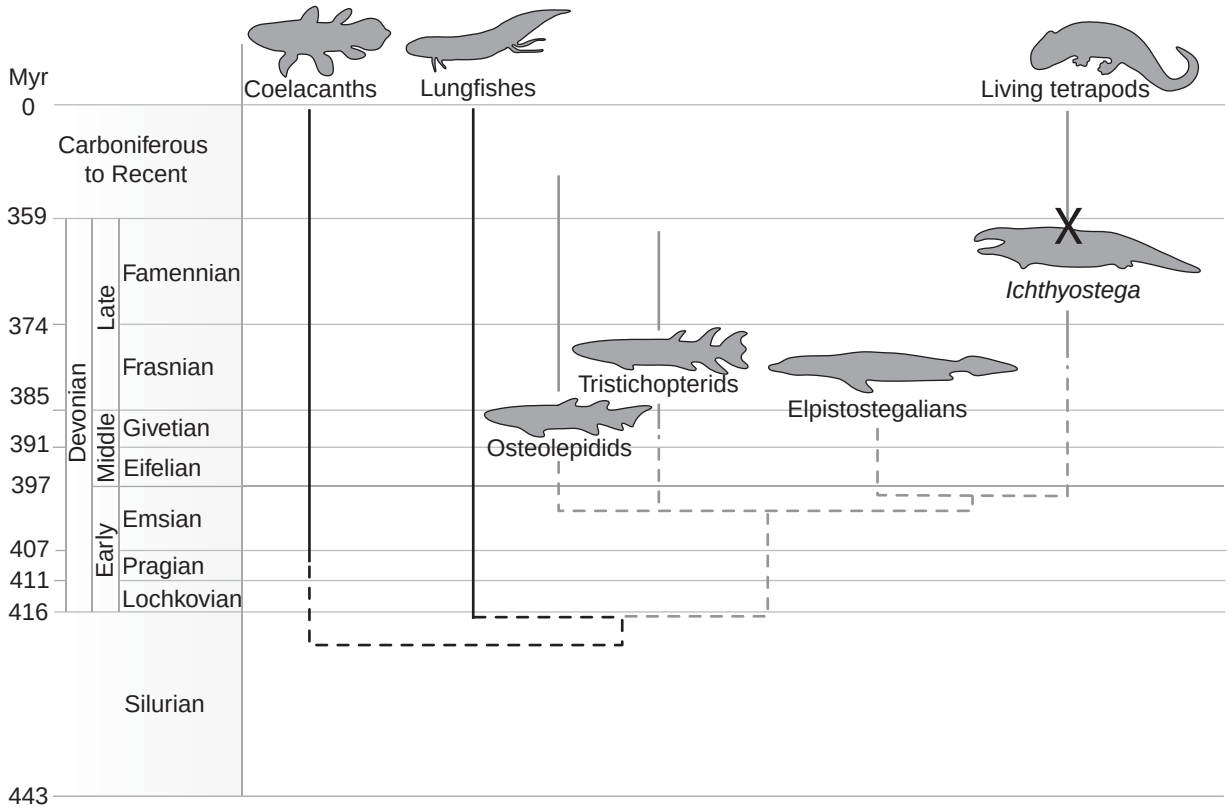
**ii.** If CFTR mutations are more prevalent in populations where cholera is present (or has been previously) then there may have been selection occurring for individuals with the mutation. 1 mark

**iii.** Historically, cholera has been around for a long time. If the CFTR mutation has persisted for a long time, there must be a selective advantage for it, otherwise it would have been selected out. 1 mark

**Question 5**

**a.** **i.**




Near the 360 million year mark — 1 mark

**ii.** Tristichopterids — 1 mark

**iii.** Lungfish — 1 mark

**b.** Fish had existed in the oceans for a lot longer than 360 million years when tetrapods appeared. 1 mark

Longer time for speciation to occur giving rise to an increased number of different kinds of fish. 1 mark

**c.** This comment is inaccurate because the inference is that due to the need of an adaptation, it therefore appeared (legs got longer over time). This is Lamarckian. 1 mark

There must be a pre-existing mutation in the population that was selected for in a changing environment, which over time increased in frequency. This is Darwinian. 1 mark

**d.** Flexible neck: to move laterally to locate food/predators. 1 mark

Limb-like fins: to hold the fish up off the ground making it easier to move. 1 mark

**Question 6**

**a.** The skull gets covered by sediment soon after death, or after the initial decaying process. The sediment layers slowly compact to rock. 1 mark

The chemicals in the skull are slowly replaced with hard minerals which fill the cellular spaces of the bones and crystallise. The shape and structure of the original skull are preserved as rock but none of the original bone remains. 1 mark

**b.** *Either one of:*

- Absolute (radiometric) dating using the amounts and rates of decay of radioisotopes in the rocks containing the skulls, or in the skulls themselves. 1 mark

  This enables scientists to measure the age of the skulls in years. 1 mark

  (*Note: Radiocarbon dating is not acceptable here. Only the* Homo sapiens *skull is young enough to be dated using this radioisotope, which has a 'range' of only 50 000 years*).

- Relative dating using the principle of superposition. 1 mark

  Using the assumption that fossils found in lower rock strata are older than those found in strata at higher levels, scientists could rank the skulls in order of relative age. 1 mark

**c.** *Any one of:*

- Increase in number or decrease in size or specialisation of teeth (e.g. canines) from *A. afarensis* to *H. sapiens* 1 mark

  due to an increase in the variety or quality of diet accompanying increased intelligence, or (specifically relating to canines) due to reduced sexual dimorphism or reduced need for threat display as a result of changes in social behaviour. 1 mark

- Increased size or volume of cranium (brain case) 1 mark

  due to an increase in brain size as higher intelligence was selected for. 1 mark

- Reduction in size or prominence of eyebrow ridges 1 mark

  due to an increase in cranial volume as larger brain size was selected for. 1 mark

- Reduction in size or prominence of zygomatic bones (projections from cheekbones) 1 mark

  due to reduction in size of the attached facial muscles as less chewing is required for higher quality or cooked food. 1 mark

  *Note: To score both marks, the reason must relate to the change and be a plausible explanation of it.*

**d.** **i.** The process by which culture (a shared, learned system of behaviour transmitted from generation to generation) changes over time as an adaptive response to some environmental stimulus. 1 mark

**ii.** *Homo habilis* is believed to have first mastered the use of stone flakes as tools. (Hence the name for this species – '*habilis*' is Latin for 'handy'). 1 mark

*Note: Stone flakes were more advanced than any tools previously used by* Australopithecus, *and gave* H. habilis *the edge it needed to prosper in hostile environments previously too formidable for primates.*

**Question 7**

**a.** *Either one of:*

- Divergent evolution is the process by which the number of related species increases, or the process by which two or more related species become more and more dissimilar, over the passage of time from a single common ancestral species. 1 mark

- Divergent evolution is the accumulation of differences between populations of the same organism, resulting from diffusion of groups of individuals of the same species into different and isolated habitats. 1 mark

  *Note: Divergent evolution does not necessarily involve speciation. If divergent evolution blocks the gene flow between the populations, and different rates of genetic drift and natural selection occur within each population, this can lead to the formation of new species.*

**b.** **i.** *Any two of:*

- Unlike nuclear DNA, parts of which are inherited from all ancestors, mtDNA is inherited only from the mother in each generation, which allows tracing of a direct (matrilineal) genetic line from a single common ancestor.
- Mitochondria are abundant in a cell, which contains a single nucleus, so it is easier to obtain samples, especially from human remains.
- mtDNA has a higher rate of substitution (mutations where one nucleotide is replaced with another) than nuclear DNA making it easier to resolve differences between closely related individuals.
- mtDNA does not recombine. The process of recombination (crossing over) in nuclear DNA (except the Y chromosome) mixes sections of DNA from the mother and the father creating a garbled genetic history.

2 marks

*Note: This is a comparison question. For each mark to be awarded, the student must make a statement that contrasts the situation for nuclear DNA clearly with the case relating to mtDNA (or vice versa).*

**ii.** Somewhere between now and then, these women had female descendants who had only sons (or no children at all). When this happened, the passing on of their mtDNA halted.

1 mark

**c.** The Neanderthal genome had an average of 269 differences from modern humans which is more than 3 times the average difference between modern humans (79).

1 mark

The smallest difference between any human and the Neanderthal was 200, which is greater than the largest difference between any two humans (146).

1 mark

*Note: It is not enough simply to re-state the data in the table. The data must be used in some way to describe the differences.*

**d.** The hypothesis is not supported because the differences between the Neanderthal genome and the human genome are greater than the differences between humans. 1 mark

The Neanderthal genome lies well outside the limits of diversity for modern humans and this makes it highly unlikely that Neanderthals and the ancestors of modern humans were both part of an interbreeding population or shared a recent MRCA.

1 mark