

decode:VCE

Decode CSI Diagnostic Tests 2021

								Letter
STUDENT NUMBER								

BIOLOGY

Written Examination (Trial)

Day Date

Reading time: *.* to *.* (15 minutes)

Writing time: *.* to *.* (2 hours 30 minutes)

QUESTION AND ANSWER BOOK

Structure of book

<i>Section</i>	<i>Number of questions</i>	<i>Number of questions to be answered</i>	<i>Number of marks</i>
A	40	40	40
B	9	9	80
			Total 120

- Students are permitted to bring into the examination room: pens, pencils, highlighters, erasers, sharpeners and rulers.
- Students are NOT permitted to bring into the examination room: blank sheets of paper and/or correction fluid/tape.
- No calculator is allowed in this examination.

Materials supplied

- Question and answer book of 34 pages.

Instructions

- Write your **student number** in the space provided on the front cover of the answer book.
- Unless otherwise indicated, the diagrams in this book are **not** drawn to scale.
- All written responses must be in English.

Students are NOT permitted to bring mobile phones and/or any other unauthorised electronic devices into the examination room.

SECTION A - Multiple-choice questions

Instructions for Section A

Answer **all** questions in pencil on the answer sheet provided for multiple-choice questions.

Choose the response that is **correct** or that **best answers** the question.

A correct answer scores 1, an incorrect answer scores 0.

Marks will **not** be deducted for incorrect answers.

No marks will be given if more than one answer is completed for any question.

Unless otherwise indicated, the diagrams in this book are not drawn to scale.

Question 1

Which of the following chemicals is **MOST** likely to enter a cell via simple diffusion?

- A. sodium ions
- B. glucose
- C. cholesterol
- D. proteins

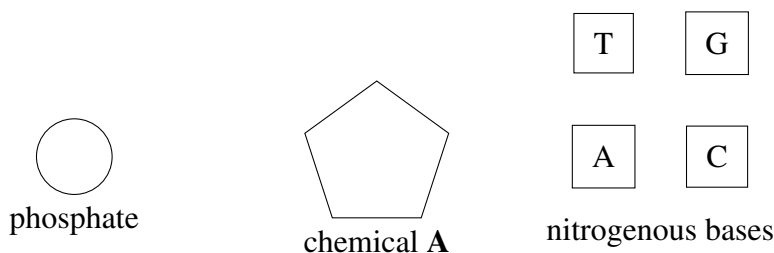
Question 2

Which of the following organelles does **NOT** contain molecules that encode the amino acid sequence of the proteins within a plant cell's proteome?

- A. mitochondria
- B. vacuoles
- C. chloroplasts
- D. nucleus

Question 3

The three components of a nucleotide are shown below.



The name of chemical A is

- A. ribose.
- B. deoxyribose.
- C. xylose.
- D. glucose.

Question 4

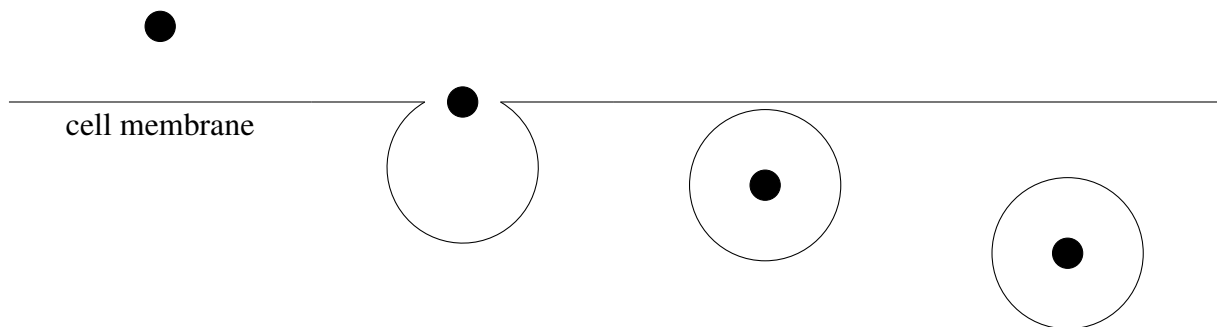
Human skin contains large quantities of ribonucleases, enzymes that can break down RNA into its constituent RNA nucleotides.

Ribonucleases break

- A. phosphodiester linkages.
- B. hydrogen bonds.
- C. peptide linkages.
- D. ionic bonds.

Question 5

Which biochemical process is depicted below?



- A. facilitated diffusion
- B. exocytosis
- C. endocytosis
- D. active transport

Question 6

Which of the following best describes regulatory genes?

- A. genes whose expression is regulated by transcription factors
- B. genes that are "switched off"
- C. genes that, directly or indirectly, alter the expression of other genes
- D. genes that act as "housekeeping genes"

Question 7

Which of the following regions of a gene would be most likely to code directly for the amino acids that constitute its corresponding protein?

- A. first intron
- B. third exon
- C. the region between the 3' region of a primary mRNA transcript and a STOP codon
- D. promoter

Question 8

The START codon

- A. would be reasonably expected to be present in all mRNA strands.
- B. is the binding site of RNA polymerase in transcription.
- C. is the main regulator of the rate of transcription of the associated gene.
- D. codes for phenylalanine.

Question 9

The *lac* operon is a system in which the expression of three bacterial genes, the *lacZ*, *lacY* and *lacA* genes, are controlled.

Transcription of these three genes is facilitated by the binding of lactose to a repressor protein, and the subsequent separation of the repressor protein-lactose complex from the

- A. operator.
- B. promoter.
- C. intron.
- D. exon.

Question 10

The necessity of enzymes in sustaining human life is due to their ability to

- A. increase the temperature of their surroundings to maintain life.
- B. code for the production of proteins to maintain life.
- C. react with other biomolecules in humans to maintain life.
- D. facilitate chemical reactions at rates sufficient to maintain life.

Question 11

Photosynthesis

- A. indirectly enables plants to synthesise large carbon-based biomolecules from inorganic compounds.
- B. is an essential part of the nitrogen cycle.
- C. is solely to facilitate the production of glucose in plants for energy.
- D. leads to the production of large quantities of carbon dioxide.

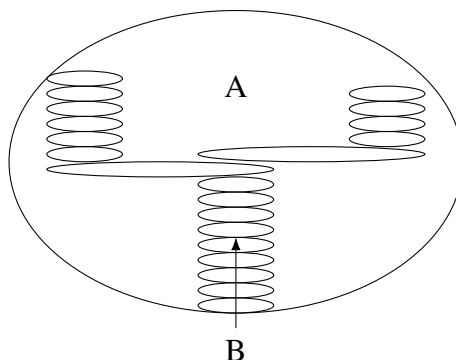
Question 12

How many different coenzymes (in their loaded forms) are produced in the light-dependent stages of photosynthesis?

- A. 0
- B. 1
- C. 2
- D. 3

Question 13

A representation of a chloroplast is shown below.



An input in one of the stages of photosynthesis is

- A. oxygen, at structure A.
- B. oxygen, at structure B.
- C. carbon dioxide, at structure A.
- D. carbon dioxide, at structure B.

Question 14

Which of the following is **LEAST** likely to increase the rate of glucose production in plants?

- A. higher industrial carbon dioxide emissions
- B. higher intensity green light
- C. higher intensity red light
- D. somewhat warmer climates

Question 15

The production of pyruvate from glucose

- A. occurs in the mitochondria.
- B. occurs in the citric acid cycle.
- C. leads to a net yield of 2 ATP molecules.
- D. is a single-step reaction.

Question 16

Which of the following reactions is carbon dioxide neither a reactant nor a product?

- A. photosynthesis
- B. anaerobic respiration in yeast
- C. aerobic cellular respiration
- D. anaerobic respiration in cows

Question 17

Consider the following factors that affect cellular respiration.

- I temperature
- II intracellular glucose concentration
- III intracellular oxygen concentration

Which one or more of the above would, if **increased** in isolation, be likely to increase the rate of **anaerobic** cellular respiration?

- A. I only
- B. I and II only
- C. I and III only
- D. III only

Question 18

Red blood cells lack mitochondria.

Which of the following chemicals are red blood cells **MOST** likely to produce via the metabolism of glucose?

- A. FADH_2
- B. NADH
- C. carbon dioxide
- D. water

Question 19

Venetoclax is a drug that is used to treat a group of diseases. Its mode of action is binding to and inhibiting the protein Bcl-2, which is situated on the outer membrane of mitochondria.

Bcl-2 inhibits the function of two other mitochondrial proteins, Bax and Bak, both of which ordinarily increase the release of mitochondrial contents into the cytosol, which initiates the process of apoptosis.

Based on the information provided, venetoclax would be most appropriate in the treatment of

- A. bacterial infections such as pneumonia.
- B. cancers such as small follicular lymphoma, where the cancer cells are lymphocytes.
- C. immunodeficiency disorders such as the acquired immunodeficiency syndrome.
- D. viral infections such as chickenpox.

Question 20

The table below depicts the mechanism of action of a number of different monoclonal antibodies used in the treatment of various diseases.

Monoclonal antibody	Target	Notes
ustekinumab	IL-12 and IL-23	Interleukin-12 (IL-12) and interleukin-23 (IL-23) are cytokines that promote the proliferation and differentiation of helper T cells.
bevacizumab	VEGF-A	Vascular endothelial growth factor A is a signalling molecule that promotes the proliferation of cells within blood vessels, as part of the development of new blood vessels (known as angiogenesis). Angiogenesis occurs as a result of the production of new cells that require their own blood supply.
cetuximab	EGFR receptor	Epidermal growth factor is a signalling molecule used primarily in paracrine signalling to stimulate cell growth, repair and division.
blinatumomab	CD19 and CD3	Blinatumomab is a modified synthetic monoclonal antibody whose two binding sites bind to cell surface proteins CD19 and CD3. CD19 is present in large quantities on the cell membranes of B cells, but not in plasma cells. CD3 is a receptor present in both helper and cytotoxic T cells which, when stimulated, leads to the activation of these cells.

Which of the following monoclonal antibodies would be **LEAST** useful in the treatment of either solid organ (eg. bowel) or haematological cancers (eg. cancers of leukocytes)?

- A. ustekinumab
- B. bevacizumab
- C. cetuximab
- D. blinatumomab

Question 21

The liver is an organ with a wide variety of functions including the synthesis of various proteins and hormones essential for life and the metabolism of toxins produced by the body as well as drugs. The primary cell type that carries out these functions is the hepatocyte. The hepatocyte is not a specialised immune cell.

Based on the information provided, the cell type that hepatocytes are most likely to be able to present antigens to are

- A. cytotoxic T cells.
- B. B cells.
- C. helper T cells.
- D. macrophages.

Question 22

Which cells of the **innate** immune system destroy virally infected cells?

- A. helper T cells
- B. macrophages
- C. natural killer cells
- D. cytotoxic T cells

Question 23

Gout is an illness characterised by the deposition of crystals of monosodium urate in joints. Monosodium urate is a breakdown product of cells that are released into the blood.

The crystal deposition leads to the development of severe acute inflammation in joints characterised by fluid accumulation in the joint, hotness of the skin around the joint and excruciating pain.

Gout can be diagnosed by inserting a needle into an inflamed joint, removing fluid and viewing the fluid under a microscope.

In patients with gout, monosodium urate crystals and a large number of white blood cells can be seen under the microscope.

Given the information provided in the question stem, which white blood cell type is most likely to be predominant in the joint fluid?

- A. neutrophils
- B. lymphocytes
- C. macrophages
- D. eosinophils.

Question 24

Antibodies can, in some cases, facilitate the killing of virally infected cells if viral proteins are directly expressed on the cell surface without the use of MHC class I markers.

However, if viral proteins remain intracellular in a virally infected cell, antibodies would be unlikely to have significant efficacy against virally infected cells.

The reason for this is that

- A. antibodies are large molecules.
- B. the cell-mediated immune response is predominant in viral infections.
- C. antibodies can only bind to one type of protein.
- D. they are lipid-soluble.

Question 25

Which of the following is **LEAST** likely to be a function of helper T cells in the adaptive immune response?

- A. activation of macrophages to kill intracellular organisms
- B. secretion of cytokines to stimulate cytotoxic T cell proliferation and differentiation
- C. phagocytosis of extracellular organisms
- D. stimulation of B cells

Question 26

Snake antivenom consists of antibodies against toxins present in snake venom that can lead to rapid onset severe illness and death.

In the treatment of patients with snakebite with antivenom, identifying the species of snake that bit the patient is important as

- A. it indicates whether snake antivenom would be effective in the treatment of snakebite.
- B. a particular antivenom is likely to only work for bites from a particular species of snake.
- C. some snakes produce less venom than other snakes.
- D. snakebite victims could potentially remain untreated so as to acquire natural immunity against the snake venom.

Question 27

Inheritable illnesses are endemic to a number of breeds of dog.

English cocker spaniel¹

For example, pure-bred English cocker spaniels are prone to a number of deleterious health conditions, such as retinal atrophy and cataracts, abnormal development of the hip joint (hip dysplasia), early-onset chronic kidney disease and impaired thyroid function, many of which limit their lifespan.

The most likely mechanism leading to the accumulation of these health conditions among English cocker spaniels is

- A. natural selection.
- B. selective breeding to select for dogs with said health conditions.
- C. inbreeding.
- D. gene flow.

¹Meet Walter, my fiancée's beloved English cocker spaniel. He loves food, walks, massages and his adoptive mum. He has his own Instagram page ([walter_the_cocker](#))!

Question 28

During the historical evolution of terrestrial vertebrates from aquatic life

- A. the genetic diversity among the first organisms to become completely terrestrialised is likely to have been greater than that of its most recent aquatic or amphibious ancestor.
- B. competition between species for limited resources would have been likely to be greater on land compared to water.
- C. the ability to maintain a moist gas exchange barrier on land would likely have **first** arisen in the population as a result of the terrestrialisation of vertebrates.
- D. the traits of strong endoskeletons and weight-bearing musculature to withstand gravity would have become increasingly common among newly terrestrialised vertebrates.

Question 29

With respect to the molecular clock concept, which of the following molecular techniques would be most suited to determining more precise evolutionary relationships between very closely related species?

- A. comparison of hypervariable regions of mitochondrial DNA
- B. DNA base sequences of housekeeping genes
- C. DNA hybridisation
- D. amino acid sequences of proteins essential to sustain life

Questions 30 to 33 refer to the following information.

The Galapagos finches evolved in the Galapagos islands in Ecuador off the west coast of South America. These islands are home to a wide diversity of ecosystems due to, at least in part, the presence of mountainous regions giving rise to ecosystems at various altitudes. It is known that the Galapagos finches evolved from a population of a single common ancestor.

BMP4 (bone morphogenetic protein 4) is a protein coded by the BMP4 gene, which is found in the genomes of the various species of Galapagos finches.

Previous research performed by developmental biologists in the US on embryos of various Galapagos finches and obtained the following results:

- Embryos that developed into finches with larger beaks (both longer and wider) had expressed the BMP4 gene earlier in development, and at higher spatial regions within the developing upper beak.
- Prior to BMP4 expression among embryos, there were already differences in the developing beak shapes.
- Genetically modified chicken embryos who constitutively overexpressed BMP4 within its beak cell precursors developed beaks that were larger in all three dimensions.

The chicken embryos described above were genetically modified by means of injection of multiple copies of a modified retrovirus containing a single-stranded DNA copy of the BMP4 gene directly into the developing embryo beak prominences.

The retrovirus replicates within the developing beak cells and causes them to constitutively express BMP4.

Question 30

The presence of many different ecosystems led to the evolution of a large number of species of finch due to an evolutionary process **best** described as

- A. the founder effect.
- B. divergent evolution.
- C. natural selection.
- D. adaptive radiation.

Question 31

The single-stranded DNA used as the genetic material for the retrovirus can be produced by sourcing BMP4 mRNA from chicken cell samples, amplifying it, and then using an enzyme to synthesise the single-stranded DNA.

This enzyme is most likely to be

- A. reverse transcriptase.
- B. RNA polymerase.
- C. DNA polymerase.
- D. RNA primase.

Question 32

Based on the information provided, it is reasonable to suggest that the evolution of the various species of finches was mediated, at least in part, by

- A. the formation of new alleles of the BMP4 gene.
- B. the formation of new alleles of regulatory genes.
- C. a loss-of-function mutation within the promoter of the BMP4 gene.
- D. a gain-in-function mutation within the promoter of the BMP4 gene.

Question 33

Injecting a fertilised chicken egg with the BMP4 gene would

- A. invariably increase beak size.
- B. have an unknown effect on the developing embryo due to generalised overexpression of BMP4 throughout development.
- C. be incompatible with life.
- D. only be possible with the use of a retrovirus.

Questions 34 and 35 refer to the following information.

Homo denisovans is a hominin species, remains of which were discovered over the past two decades in Central Asia.

A comparative analysis of mitochondrial DNA samples within the Denisova fossils, as well as Neanderthal (*Homo neanderthalensis*) and modern-day human samples shows that the diversity of mitochondrial DNA among Denisova samples is similar to that of modern-day humans, and considerably greater than Neanderthal samples.

Question 34

The mtDNA evidence suggests that

- A. *Homo denisovans* evolved from *Homo sapiens*.
- B. Neanderthals evolved later than did Denisovas.
- C. *Homo denisovans* and *Homo sapiens* must have been the same species.
- D. *Homo sapiens* evolved from *Homo denisovans*.

Question 35

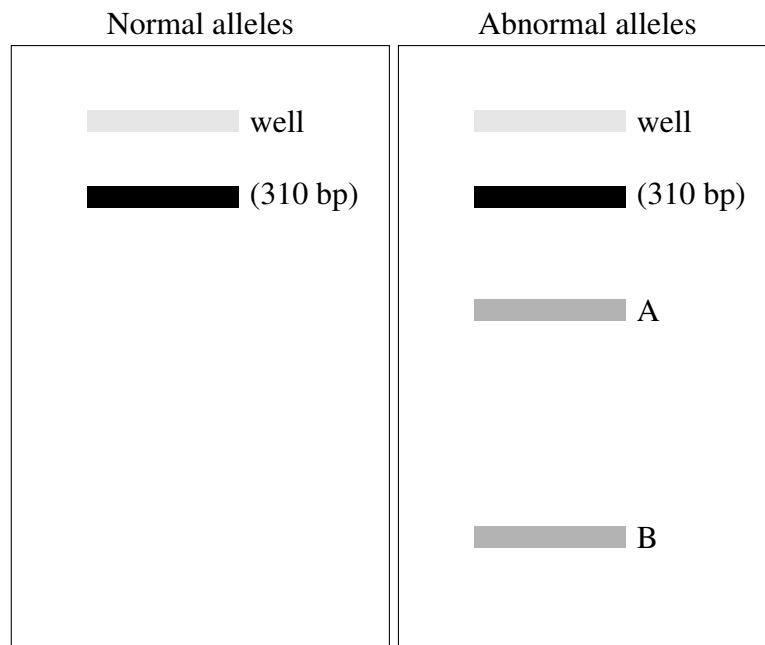
Which of the following phenomena could cause the age of a species, as determined by analysis of mtDNA samples from individuals from that species and applying the molecular clock concept, to be underestimated?

- A. gene flow
- B. mutations in nuclear DNA
- C. crossing-over and recombination in meiosis
- D. bottleneck effect

Questions 36 and 37 refer to the following information.

Genetic screening of an embryo for a nonfunctional allele for a particular gene can be performed by obtaining a DNA sample from the embryo and amplifying the gene in question, treating the product with endonucleases before performing gel electrophoresis. It is known that the abnormal allele arose as a result of a T to G mutation.

A pictorial representation of two gel runs of two different individuals is shown below. Both individuals are homozygous.

**Question 36**

The size of the fragments depicted in the two gel runs are 310 base pairs, 259 base pairs and 51 base pairs. Which of the following statements is **TRUE**?

- A. Band B contains fragments of 51 base pairs in size, and is closer to the positive terminal of the gel run compared to band A.
- B. Band B contains fragments of 259 base pairs in size, and is closer to the positive terminal of the gel run compared to band A.
- C. Band B contains fragments of 51 base pairs in size, and is closer to the negative terminal of the gel run compared to band A.
- D. Band B contains fragments of 259 base pairs in size, and is closer to the negative terminal of the gel run compared to band A.

Question 37

Based on the information provided, it is reasonable to conclude that

- A. a T to A mutation (as opposed to a T to G mutation) is likely to give rise to a single band in a homozygote possessing the mutated allele if the same endonuclease were used.
- B. this method would differentiate between a homozygote for the abnormal allele and a heterozygote.
- C. the use of a different endonuclease is likely to give the same gel run profiles as the ones depicted above.
- D. ligase is likely to have been used in this experiment.

Question 38

The introduction of a recombinant plasmid containing a human gene into bacteria is known as

- A. transfection.
- B. transduction.
- C. transformation.
- D. infection.

Questions 39 and 40 refer to the following information.

Two men, Daniel and Scott, are arguing over the paternity of a young girl, Gladys. In an attempt to resolve the situation, she and her mother Anna decide to undergo a paternity test.

Genotypes at two STR (short tandem repeat) loci for each individual are shown below.

STR locus	Gladys	Anna	Daniel	Scott
1	14, 16	14, 15	11, 16	12, 17
2	15, 19	19, 21	14, 19	15, 16

Question 39

The most appropriate term to describe the above process is

- A. gene cloning.
- B. DNA fingerprinting.
- C. DNA profiling.
- D. genetic screening.

Question 40

Which of the following statements is **TRUE**?

- A. The evidence provided is sufficient to identify Daniel as the father.
- B. The evidence provided is sufficient to identify Scott as the father.
- C. The evidence provided is sufficient to conclude that neither Scott nor Daniel is the father.
- D. Genotypes at additional STR loci for each individual are needed to arrive at a conclusion.

SECTION B - Short answer questions

Instructions for Section B

Answer **all** questions in the spaces provided.

Unless otherwise indicated, the diagrams in this book are **not** drawn to scale.

Question 1 (13 marks)

Necrotising fasciitis is a severe and potentially lethal infection of the skin, fat and deeper structures of a particular body part. The below diagram depicts an example of necrotising fasciitis of the left leg.

Necrotising fasciitis of the left leg



Source: Late diagnosed necrotizing fasciitis as a cause of multiorgan dysfunction syndrome: A case report. Cases Journal 2008, 1:125. doi:10.1186/1757-1626-1-125. Accessed via Wikimedia Commons. https://commons.wikimedia.org/wiki/File:Necrotizing_fasciitis_left_leg.JPG. Licensed under the Creative Commons Attribution 2.0 Generic license.

This infection can be caused by a variety of pathogens, including the bacterial species *Streptococcus pyogenes*, *Staphylococcus aureus* and anaerobic genera such as *Clostridium*.

a. What is meant by the term "pathogen"?

1 mark

- b.** The image on the previous page depicts the breach of a physical barrier to infection.
- i.** Write down the name of this physical barrier to infection. 1 mark

- ii.** Give an example of a non-physical barrier to infection that would be found on the structure depicted in this image. 1 mark

In necrotising fasciitis, skin cells and those of the surrounding and deeper tissues undergo cell death by necrosis, a process of cell death characterised by cell lysis and spillage of the intracellular contents into the extracellular fluid.

Apoptosis is another mechanism by which cell death occurs.

- c.** Explain how apoptosis is distinct from necrosis. 2 marks

Necrotising fasciitis can cause severe and rapidly progressive illness with the development of the clinical state of septic shock. Septic shock is characterised by high fevers, generalised blood vessel dilatation and leakage of fluid into the extracellular fluid throughout the body causing a massive reduction in blood volume, collapse of the cardiovascular system and eventual death.

Septic shock is caused by overactivation of the inflammatory response. One mechanism by which this occurs in necrotising fasciitis is the secretion of protein-based exotoxins by species such as *Streptococcus pyogenes* and *Staphylococcus aureus*. These exotoxins are "superantigens" in that they can bind directly to multiple helper T cells, leading to their activation and release of massive quantities of cytokines that promote inflammation, in a phenomenon known as "cytokine storm".

- d.** How does superantigen-mediated helper T cell differ from activation of T cells in the normal adaptive immune response to infection? 1 mark

- e.** Explain whether superantigens can be classed as allergens. 1 mark

- f.** Using your knowledge of the steps of the inflammatory response, explain how the cytokine storm phenomenon can lead to the manifestations of septic shock previously described. 2 marks

Penicillin and clindamycin are antimicrobial drugs with distinct modes of action. Penicillins inhibit bacterial cell wall formation in dividing bacteria leading to bacterial cell lysis and death, whereas clindamycin binds to ribosomes, inhibiting their function.

- g.** Explain whether clindamycin can be classed as an antibiotic. 1 mark

- h.** Patients with necrotising fasciitis are generally treated with a combination of penicillin and clindamycin.

- i.** State the function of ribosomes in bacterial cells. 1 mark

- ii.** Therefore, explain how the use of combination clindamycin/penicillin therapy reduces the risk of septic shock from necrotising fasciitis, compared to the use of penicillin monotherapy. 2 marks

Question 2 (12 marks)

Thyroxine is a hormone secreted by the thyroid gland and has multiple effects on various cells of the human body. Thyroxine exerts its effect on cells by binding to the nuclear thyroid hormone receptor (TR).

Human genomes contain multiple isoforms of the thyroid hormone receptor. For example, the TR α isoform binds to thyroxine, with the complex binding to the promoter regions of various genes.

One gene to which TR α binds is the ADBR1 gene; this codes for the β_1 adrenergic receptor. This receptor binds the neurotransmitters noradrenaline and adrenaline, and is abundant on the plasma membranes of heart muscle cells. The sympathetic nervous system provides constant signals to heart muscle cells via constant noradrenaline secretion from synaptic terminals. The sympathetic nervous system can modulate the rate of noradrenaline release from these synaptic terminals.

Stimulation of the β_1 receptor leads to the opening of calcium ion channels leading to increased heart muscle contractile force.

- a. Distinguish between the mode of transmission of the signalling molecules thyroxine and noradrenaline between cells based on the information provided. 2 marks

- b. Complete the following table outlining what happens after β_1 adrenergic receptor stimulation on a heart muscle cell using the stimulus-response model. 2 marks

Stimulus	
Signal transduction (in general terms)	
Response	

- c. Describe the relationship between sympathetic nervous system stimulation, thyroxine and heart muscle contractility. 1 mark

The TR β isoform of the thyroid hormone receptor, when bound to thyroid hormone, leads to the production of UCP, a family of proteins that integrate with the inner membrane of mitochondria. These channel proteins enable passage of hydronium ions (H₃O⁺) passively through the inner mitochondrial membrane.

- d.** Sections of the inner membrane of mitochondria are sites of a specific biochemical process.
- i.** Explain how the presence of an inner mitochondrial membrane lends credence to its bacterial origins. 1 mark

- ii.** Write down the name of this biochemical process and the name of the sections of the inner mitochondrial membrane where this biochemical process occurs. 1 mark

It is known that a concentration gradient of hydronium ions across the inner mitochondrial membrane, generated by the biochemical process referred to in part **d. ii.**, is essential for the generation of ATP in mitochondria.

- e.** Explain the degree to which excessive thyroid hormone stimulation would affect the overall ATP yield from aerobic cellular respiration, with specific reference to the various steps of cellular respiration. 2 marks

It is known that thyroid storm, the clinical state characterised by lethal quantities of circulating thyroid hormone, is associated with hyperthermia (high body temperatures).

- f.** Suggest a mechanism by which hyperthermia occurs in patients with thyroid storm. 2 marks

It is known that both the $TR\alpha$ and $TR\beta$ isoforms of the thyroid receptor are both derived from the *THRB* gene.

- g.** Suggest an explanation for how the *THRB* gene can give rise to two different proteins. 1 mark

Question 3 (6 marks)

Chimpanzees (*Pan troglodytes*) and bonobos (*Pan paniscus*) are closely related species whose last common ancestor lived approximately 2 million years ago. Chimpanzees and bonobos are primates as well as hominoids.

Pan troglodytes

Source: "Chimpanzee sp.". Authored by "Zooclub.ru". Licensed under the Creative Commons Attribution-ShareAlike 4.0 International License. Accessed via Wikimedia Commons.

Pan paniscus

Source: Authored by Fanny Schertzer. Licensed under the Creative Commons Attribution 3.0 Unported License. Accessed via Wikimedia Commons.

- a. Give **TWO** characteristics that are shared among primates.

1 mark

Chimpanzees and bonobos primarily inhabit territory on opposite sides of the Congo river in Central Africa. The Congo river formed approximately 2 million years ago and is thought to have triggered the divergence of the chimpanzee and bonobo lines via the formation of two separate species.

- b. Name and describe the process by which the population of the common ancestor gave rise to two separate species.

4 marks

It is surmised that, given the speciation process that had occurred, the common ancestor was unlikely to have been skilful at swimming.

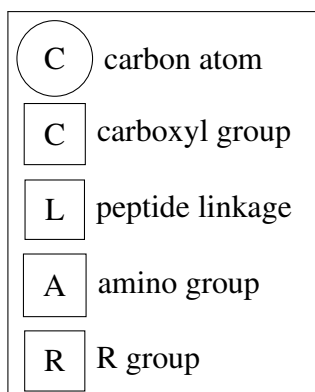
- c.** Explain how this statement is consistent with the mechanism by which the two separate species had formed.

1 mark

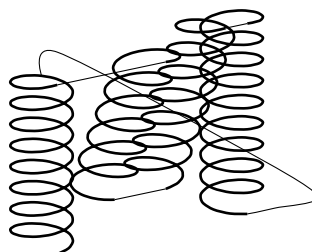
Question 4 (6 marks)

Proteins are composed of amino acids.

- a. Use the following shapes to draw a representation of a dipeptide, which consists of two amino acids bonded together to form a peptide chain. 2 marks



Serum amyloid A (SAA) is a protein produced by hepatocytes, the functional cells within the liver, during the process of acute inflammation. It is composed of six identical constituent polypeptides that interact with one another. The structure of one of its constituent polypeptides is shown below:



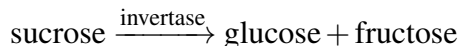
- b. The secondary structure of SAA is depicted above.
- i. Explain what is meant by the "secondary structure" of a protein, including the interactions that give rise to this level of structure. 2 marks

- ii. What is the name of the secondary structure that is depicted in the diagram of the SAA protein? 1 mark

- iii. What is the highest level of structure exhibited by serum amyloid A? Explain your answer. 1 mark

Question 5 (12 marks)

Invertase is an enzyme found in vast quantities in plants and fungi, including yeasts, that catalyse the breakdown of sucrose (found in table sugar) to glucose and fructose. The reaction equation is shown below:



A VCE Biology class performs an experiment so as to determine the effect of pH on the activity of invertase. An extract from a student's scientific poster is shown below.

2. Methods

Two pairs of 6 test tubes containing sucrose solution plus buffer solution^a to a total volume of 3 mL were prepared, with the pH inside each pair of test tubes being 2, 4, 6, 8, 10 and 12. 3 mL of a stock solution of invertase was added simultaneously to only **one** of each pair of test tubes.

All 12 test tubes were incubated side-by-side in an incubator set at 40°C for a period of 3 minutes. The invertase was inactivated, and the mixture subsequently developed via the addition of dinitrosalicylate (DNS)^b and heating to 95°C for a 10 minute period. The colour intensity of each solution is determined instrumentally, and is measured as the dimensionless variable known as "absorbance" (the higher the absorbance, the greater the colour intensity).

The above steps were also repeated in tandem with a test tube containing a solution containing an equivalent amount of glucose and fructose.

^aA buffer solution is a solution of a mixture of salts designed to keep pH constant.

^bThe DNS solution reacts with fructose and glucose (and not sucrose) to produce a dark-red solution.

- a. i.** Devise a hypothesis for this experiment.

1 mark

- ii.** Justify your hypothesis based on your understanding of the determinants of enzyme activity.

2 marks

The student results are shown below.

3. Results

Absorbance of glucose/fructose solution after development = 1.45

Table 1: Absorbance within test samples after development at various pH levels

pH	absorbance	
	no invertase	invertase
2	0.01	0.03
4	0.01	0.10
6	0.00	0.64
8	0.01	1.21
10	0.00	0.59
12	0.01	0.02

- b.** State
- i.** the independent and dependent variables 1 mark
- _____
- _____
- ii.** **TWO** variables that are controlled in this experiment. 1 mark
- _____
- _____
- c.** With regard to the experimental design, explain the purpose of
- i.** the test tubes containing no invertase 1 mark
- _____
- _____
- ii.** the test tube containing the glucose/fructose mixture. 1 mark
- _____
- _____
- d.** Suggest how the reliability of this experiment could be improved. 1 mark
- _____
- _____

Karen, a VCE student, concludes from the data that the optimal pH of invertase is 8.

- e. Evaluate the accuracy of Karen's claim in light of the experimental data provided.

2 marks

Another student, Dinushi, suggests that the experimental design could be improved by adding DNS to the sucrose/buffer solutions prior to adding invertase, and then after adding invertase incubating the mixture at 95°C for a period of 3 minutes to activate the DNS. She reasons that this method would enable the rate of sucrose breakdown to be measured in real time over the three minutes for each of the test tubes.

- f. Evaluate the appropriateness of Dinushi's suggestion.

2 marks

Question 6 (13 marks)

The SARS-CoV-2 coronavirus is an RNA virus responsible for the disease COVID-19, consisting primarily of upper respiratory tract symptoms and, in some cases, infection of the lung tissue. At the time of printing, the spread of COVID-19 is considered a pandemic.

- a.** Distinguish between the terms "epidemic" and "pandemic". 1 mark

The diagnostic test for infection with the SARS-CoV-2 virus involves obtaining a sample of mucosal tissue or mucus from the nasopharynx of an individual, the RNA extracted and complementary DNA strands produced via molecular methods. The synthesised complementary DNA is then subjected to PCR.

- b. i.** What does the abbreviation "PCR" stand for? 1 mark

- ii.** Outline the steps that occur in PCR. 4 marks

- iii.** Explain how, by the use of primers, PCR can be used to differentiate between individuals who have been infected with the SARS-CoV-2 virus against those who have not been infected. 1 mark

After host cell invasion and production of viral proteins inside the host cell, the virus uses "main proteinase" (M^{pro}), a member of the viral proteome, to perform post-translational modifications to its other viral proteins. Other RNA viruses such as the hepatitis C and HIV viruses also possess proteases in their proteomes, against which drugs such as ritonavir (for HIV) and sofosbuvir (for hepatitis C) have previously been developed.

c. What is a proteome?

1 mark

In the development of drugs active against the SARS-CoV-2 virus, researchers are studying the structure of the active site of M^{pro} and its interaction with its protein substrates to determine how this interaction can be inhibited.

d. Explain how this approach to drug development is consistent with the principle of rational drug design.

1 mark

It is expected that any competitive inhibitor of M^{pro} should have properties that are complementary to the corresponding property of the active site of M^{pro} . One such property is molecular shape.

e. Write down another property that fits the above description.

1 mark

Vaccines are a known potent preventative measure for COVID-19 and is considered the mainstay of management and suppression of the current COVID-19 pandemic.

- f.** Explain whether vaccines are an appropriate modality for the treatment of COVID-19, in addition to its prevention. 2 marks

Some types of vaccines to COVID-19, in extremely rare cases, can lead to the development of antibodies against proteins contained within platelets (cell fragments found in blood) which can lead to the development of platelet "clumps" that can lodge in blood vessels. This condition is known as vaccine-induced immune thrombotic thrombocytopenia (VITT).

- g.** What term is used to categorise immune system diseases such as VITT? 1 mark

Question 7 (8 marks)

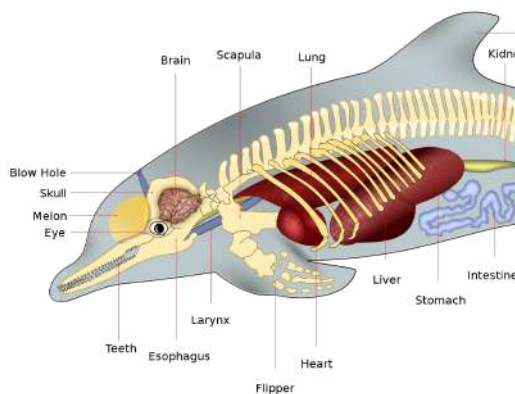
Common dolphins (genus *Delphinus*) and Great White sharks (*Carcharodon carcharias*) are both aquatic creatures with superficially similar anatomical structures, as shown below. Additionally, the bony structure of a dolphin fin and a human hand is also shown below.

Dolphin (*Delphinus*)

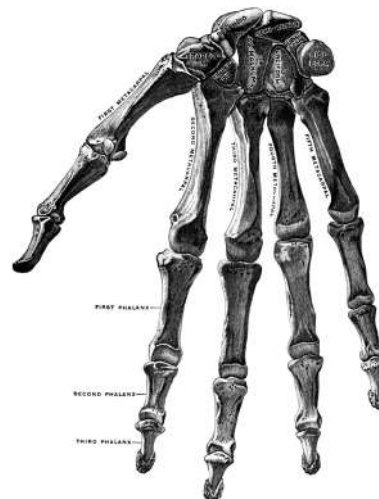
Adapted from image from Wikimedia Commons.

Great White shark (*Carcharodon carcharias*)

Source: "Great White Shark Cage Diving" by Hermanus Backpackers. Accessed via Wikimedia Commons. Licensed under the Creative Commons Attribution 2.0 Generic license.

Dolphin anatomy

Source: Wikimedia Commons. Contributor: WikipedianProlific. Licensed under the Creative Commons Attribution-Share Alike 4.0 International license.

Human hand

Source: Gerrish's Text-book of Anatomy (1902). Accessed via Wikimedia Commons.

Shark fins are composed primarily of cartilage.

Dolphins belong in the class of mammals (*Mammalia*), whereas sharks belong in the class of cartilaginous fishes (*Chondrichthyes*).

a. Write down the term used to describe

i. the type of evolution that had occurred between the shark and dolphin lineages

1 mark

ii. the relationship between shark and dolphin fins.

1 mark

- b.** Draw a simple phylogenetic tree to depict the evolutionary relationships between sharks, dolphins and humans. 1 mark

Fossils of the genus *Mesonyx* have been found in both the United States of America and in China and are deemed to be an early ancestor of the cetacean line, consisting of sea-dwelling mammals such as dolphins and whales. This genus is thought to have existed approximately 50 to 100 million years ago. *Mesonyx* was a four-legged terrestrial animal that obtained its food from the water.

Numerous transitional fossils along the cetacean line have been found and documented and based on this evidence, it is surmised that descendants of *Mesonyx* became increasingly aquatic and less terrestrial until they ultimately became sea-dwelling creatures. It is known that the cetacean line of evolution is among the best documented in the fossil record.

- c.** With reference to the process of fossilisation, suggest a reason why the cetacean line is likely to be prominent in the fossil record. 1 mark

- d.** What is meant by the phrase "transitional fossil"? 1 mark

- e.** Describe the sequence of events that led to the evolution of the dolphin fin from the *Mesonyx* limb. 3 marks

Question 8 (5 marks)

The *Golden Rice project* was an initiative to engineer genetically-modified rice plants that can produce rice containing larger quantities of the orange-coloured beta-carotene, a precursor of vitamin A.² This is in the context of severe vitamin A deficiency being highly endemic in the developing world, where it can lead to blindness.

Precursor cells of the rice plant were transfected with a bacterial gene coding for the enzyme *crt I* and a gene from a daffodil coding for the enzyme *psy*. These two enzymes open a biochemical pathway leading to the production of significant quantities of beta-carotene.

- a. Is the genetically modified rice plant that gives rise to "golden rice" also a transgenic organism? Explain your answer. 1 mark

- b. Describe **TWO** social or ethical issues that may arise as a result of a widespread uptake of Golden Rice seeds by the developing world. 2 marks

²Beta-carotene is what gives carrots their orange colour. It can also be used to modify individuals' skin tone, and is famously used by a certain highly polarising former world leader.

Below is a (hypothetical) social media post³ from an individual:

Say no to GMO! The GMO foods genetically modify your DNA and gives you cancer!

c. Evaluate the accuracy of this particular social media post.

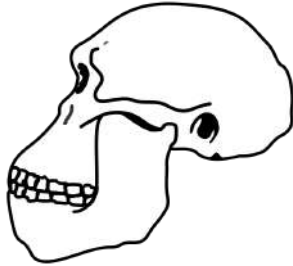
2 marks

³I have to resort to making up "pretend" social media posts as opposed to obtaining excerpts from real-life online media so as to not infringe on anyone else's copyright. Apologies if it does sound somewhat contrived.

Question 9 (5 marks)

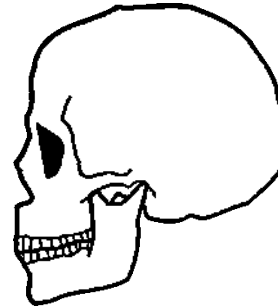
The skulls of *Australopithecus afarensis* and *Homo sapiens* are shown below.

Australopithecus afarensis



Source: "Chimpanzee sp.". Authored by "Ichthyovenator". Licensed under the Creative Commons Attribution-Share Alike 3.0 Unported License. Accessed via Wikimedia Commons.

Homo sapiens



Source: Wikimedia Commons.

Two differences between the skulls of the two species are the presence of smaller teeth and the increased cranial capacity in the *Homo* skull.

- a.** A paradigm to explain the decrease in teeth size is that *Homo* became increasingly carnivorous (meat-eating) and therefore "no longer needed the larger teeth" of the australopithecene species.

- i.** Identify one additional feature, apart from teeth size, of the australopithecene skull that suggests that its diet was largely herbivorous (plant-based), consisting of largely hard seeds. 2 marks

- ii.** Write down one other distinguishing feature of the australopithecene skull compared to the human skull. 1 mark

Another paradigm used to explain the decrease in teeth size is the development of a smaller jaw as a consequence of the increase in cranial capacity, with large teeth being associated with teeth crowding, increasing the risk of dental infections.

- b.** Critically evaluate the extent to which the two paradigms described in the question stem are accurate. In your answer, suggest a possible mechanism by which smaller teeth evolved, with appropriate reference to cranial capacity, jaw size and dental infections. 2 marks

END OF QUESTION AND ANSWER BOOK