

Victorian Certificate of Education 2022

Unit 3 and 4 Trial Paper

Letter

STUDENT NUMBER

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STUDENT NAME

BIOLOGY

Written examination

Reading time: 15 minutes

Writing time: 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	12	12	80
			Total 120

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** for 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.

Question 1

Every protein

- A. has quaternary structure.
- B. is a polymer of amino acids.
- C. functions as an enzyme.
- D. is exported from a cell by the Golgi apparatus.

Question 2

Both prokaryotic and eukaryotic genes

- A. contain introns.
- B. have an operator upstream of the start codon.
- C. have a promoter region at their 5' end.
- D. are transcribed to make pre-mRNA which undergoes RNA processing to form mRNA.

Question 3

The amino acid isoleucine is encoded by three different codons: AUU, AUC and AUA. For this reason, the genetic code is described as

- A. degenerate.
- B. universal.
- C. unambiguous.
- D. a triplet code.

Question 4

A difference between mRNA and rRNA is that

- A. mRNA contains uracil whereas rRNA contains thymine.
- B. rRNA is double-stranded whereas mRNA is single-stranded.
- C. rRNA is not translated as mRNA is.
- D. mRNA contains deoxyribose, whereas rRNA contains ribose.

Question 5

The diagram below shows the generalized structure of a nucleotide. Three moieties (parts) of the nucleotide are labelled.

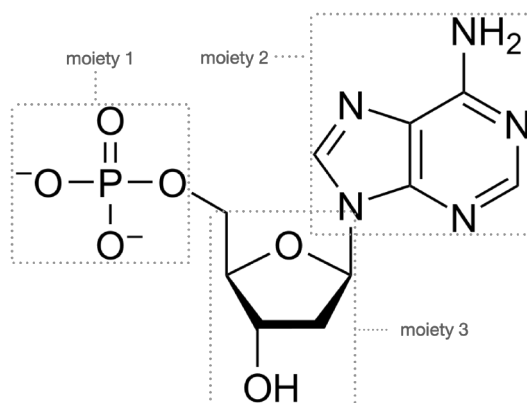


Figure 1. nucleotide. Image source: <https://en.wikipedia.org>

Based on your knowledge of the structure of nucleotides and the drawing above, it is reasonable to say that

- A. this is an RNA nucleotide.
- B. moiety 2 is a pentose sugar.
- C. moiety 3 is a side chain (R-group).
- D. moiety 1 is at the 5' end of the nucleotide.

Question 6

One of the enzymes involved in the Krebs cycle is succinate dehydrogenase. It oxidises (removes a hydrogen from) succinate, to form fumarate. Diethyl malonate acts as a reversible competitive inhibitor of succinate dehydrogenase. Based on this information it can be concluded that

- A. a high concentration of diethyl malonate in a cell will cause an increase in the concentration of CO_2 in the cell.
- B. the inhibitory effect of diethyl malonate would be lowered if the concentration of succinate in the cell increases.
- C. succinate dehydrogenase is an anabolic enzyme.
- D. diethyl malonate binds to an allosteric site on succinate dehydrogenase.

Question 7

The trp operon is a well-known and relatively simple example of gene regulation that is found in some prokaryotes, including *Streptococcus pyogenes* bacteria. It functions to regulate the biosynthesis of the amino acid tryptophan. Which of the following statements is most likely to be true of the trp operon within an *S. pyogenes* cell when the concentration of tryptophan in a cell is **low**?

- A. An attenuator hairpin loop forms between regions 3 and 4 of the leader.
- B. A repressor protein is attached to the operator.
- C. RNA polymerase completes the transcription of the attenuator region.
- D. A ribosome translating the leader mRNA stalls at the STOP codon (UGA) between regions 1 and 2.

Question 8

When a molecular biologist inserts a foreign gene into a plasmid, they add the enzyme ligase. For what purpose is ligase used?

- A. It creates sugar-phosphate bonds on the 'backbone' of a recombinant plasmid.
- B. It cuts the plasmid open at a specific base sequence within an antibiotic resistance gene.
- C. It makes bacteria competent to take up plasmids from their surroundings.
- D. It creates hydrogen bonds between the sticky ends of the foreign gene and plasmid.

Question 9

CRISPR-Cas9 is a simple prokaryotic adaptive immune system. All adaptive immune systems need to be able to distinguish between 'self' and 'non-self' to avoid responding destructively to the cell's own molecules.

What prevents Cas9 enzymes from cutting the bacteria's own DNA?

- A. The bacteria has no DNA sequence that is complementary to the gRNA in the Cas9 enzyme.
- B. Cas9 is kept in the cytoplasm and unable to enter the nucleus to interact with the CRISPR array.
- C. Cas9 is only able to cut single-stranded viral DNA, not double-stranded DNA in the bacterial chromosome.
- D. The beginning of each CRISPR repeat begins with a non-PAM sequence.

Question 10

During PCR, the temperature is cycled between 55°C, 72°C and 95°C. Which of the following correctly describes the events that take place at these temperatures?

- A. At 55°C the strands of double-stranded DNA separate.
- B. At 72°C DNA nucleotides are added to the 3' end of the primers.
- C. At 95°C primers anneal to the 5' end of the DNA region of interest.
- D. 55°C is the optimal temperature of Taq polymerase.

Question 11

Which of the following accurately lists inputs of the Krebs cycle?

- A. 2 Pyruvate, 2 ADP, 2 P_i , 2 FAD, 2 NAD^+
- B. 2 Pyruvate, 6 CO_2 , 10 NADH, 2 $FADH_2$
- C. 12 water, 12 NADPH, 18 ADP, 18 P_i
- D. 2 Pyruvate, 2 ADP, 2 P_i , 2 $NADP^+$, 2 H^+

Question 12

NADPH is a coenzyme. This means that it

- A. it is inorganic molecule that binds tightly to the active site of an enzyme and increases the affinity of the enzyme for its substrate.
- B. it is an enzyme that works cooperatively with another enzyme.
- C. it is a small protein that carries energy from one part of a cell to another.
- D. it is an organic non-protein that binds loosely to the active site of an enzyme and increases the enzyme's ability to convert substrate to product.

Question 13

The rate of photosynthesis in a C3 plant will be greatest under which conditions?

- A. High temperature, with bright sunlight, and high atmospheric humidity.
- B. Low temperature, with bright sunlight and high atmospheric humidity.
- C. High temperature with low light levels and low atmospheric humidity.
- D. Low temperature, with low light levels and low atmospheric humidity.

Question 14

Although Spanish moss (*Tillandsia usneoides*) has a “mossy” appearance, it is neither Spanish, nor a moss. It is an epiphytic flowering plant that grows on the branches of trees in dense wet tropical rainforests of Central and South America. It has no roots. Instead, its leaves absorb water vapour from the air, and from rain that falls on them.



Figure 2. *T. usneoides*. Image source: <https://unsplash.com/photos/kEoBvjv1c2U>

T. usneoides is a ‘CAM plant’; it uses crassulacean acid metabolism for photosynthesis instead of the C3 pathway used for photosynthesis by most plants.

Which of the following challenges does CAM photosynthesis most help *T. usneoides* to overcome?

- A. Photorespiration by rubisco, due to high temperatures in the tropics.
- B. A lack of sunlight light, due to growing beneath a thick rainforest canopy.
- C. Inefficient water-uptake by the plant, due to its absence of roots.
- D. A low atmospheric concentration of CO₂ concentration, due to competition for available CO₂ by other plants in the vegetation-dense forest.

Question 15

The picture below shows an electrophoresis gel, containing DNA in three gel lanes (i, ii and iii), a negative control (iv), the locations of the positive and negative electrodes and eleven numbered DNA bands. Two other gel regions are also labelled (r and s).

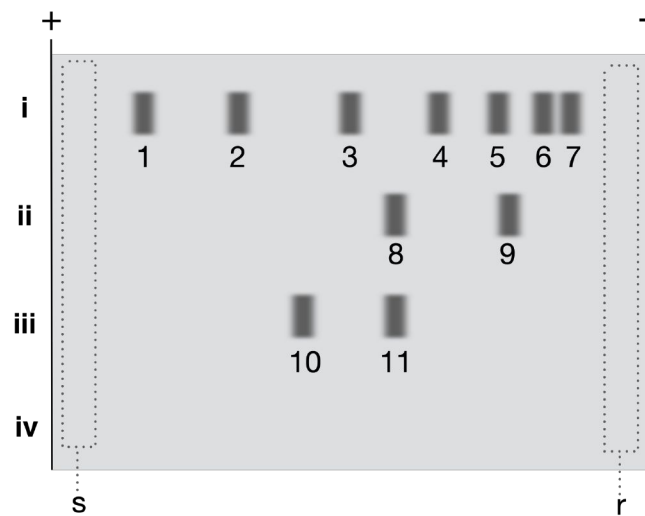


Figure 3. electrophoresis gel

The human DNA samples loaded in lanes ii and iii, were amplified from an STR called D5S818, located on the long arm of chromosome 5.

Using the drawing of the gel above, and your knowledge of gel electrophoresis for DNA profiling, which of the following is true?

- A. The loading wells are in region r.
- B. The DNA in lane ii, could be a plasmid that was cut in one place.
- C. DNA in band 8 is larger than that in band 4.
- D. The DNA in bands 8 and 11 could be from the same person.

Question 16

When human insulin (Humulin[®]) was produced by Genentec in the late 1970s, the Insulin A and B chains were cloned separately in two different transformed *E. coli* strains. To begin the process a plasmid, pBR322, was cut using two restriction endonucleases. One of these, BamHI, was chosen to cut the plasmid within a gene for resistance to tetracycline (TET^r).

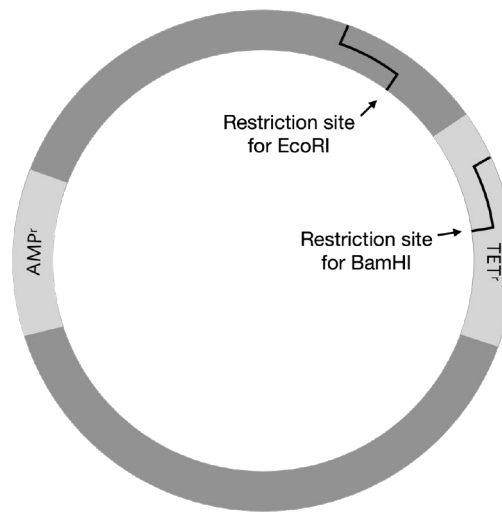


Figure 4. plasmid used to clone human insulin

What was the purpose of cutting the plasmid *within* the TET^r gene?

- A. So that scientists could distinguish bacteria that contained a plasmid with both the insulin A gene and β -galactosidase gene from those which contained a plasmid with only the insulin A gene.
- B. So that scientists could tell the difference between bacteria that contained a plasmid with the insulin A gene, and those which contained a plasmid without the insulin A gene.
- C. So that scientists could determine which bacteria which had taken up a plasmid and which had not taken up a plasmid.
- D. To prevent bacteria which contained the human insulin A gene from being killed by the antibiotic tetracycline.

Question 17

A bacterium can be referred to as 'transformed' if it

- A. has taken up a plasmid from its environment.
- B. has taken up a recombinant plasmid.
- C. has taken up a plasmid containing DNA from another species.
- D. has undergone a mutation.

Question 18

A biologist measured the rate of photosynthesis in *Begonia* plant cells in culture, at a range of light intensities. At each light intensity, the cells were kept in a sealed gas jar, in a medium containing carbon dioxide and water, at 37°C with a pH of 6.8. After 45 minutes the concentration of oxygen in the gas jar was measured. The graph below represents the data collected.

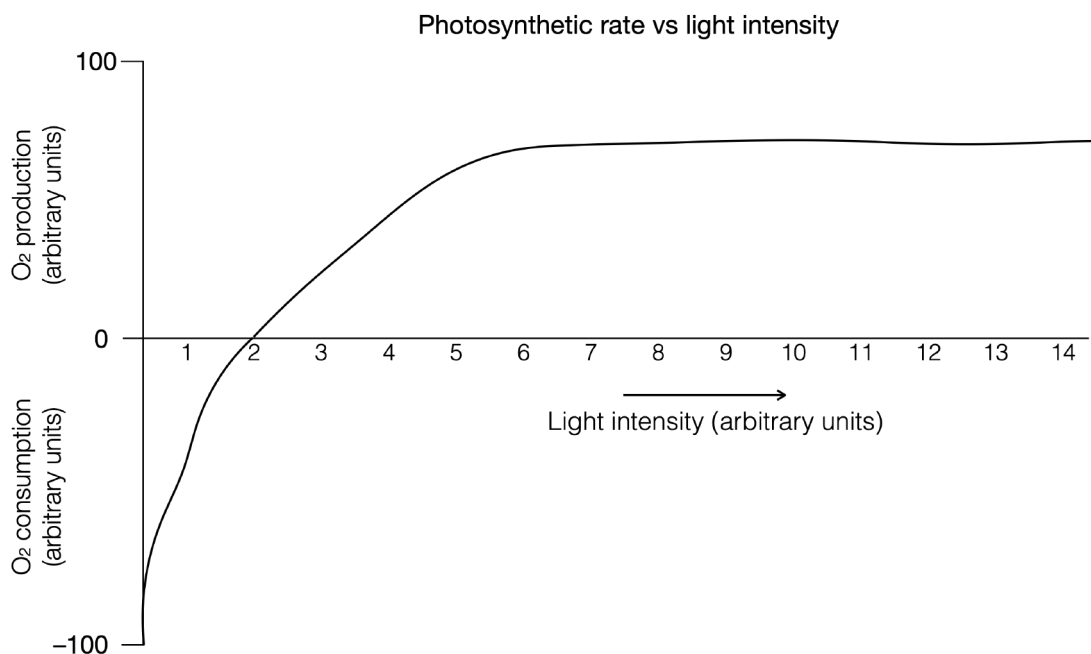


Figure 5. Photosynthetic rate vs light intensity

Based on the graph and your knowledge of photosynthesis, which of the following is a reasonable conclusion?

- A. Photosynthesis is not taking place at a light intensity of 1.
- B. At light intensity 4 increasing the concentration of CO₂ in the medium would likely increase the rate of photosynthesis.
- C. Photosynthesis has stopped at light intensity 11.
- D. At light intensity 12, the limiting factor is something other than light intensity.

Question 19

During the process of anaerobic fermentation in an animal cell,

- A. two molecules of lactic acid and two molecules of CO₂ are produced.
- B. NADH is converted to NAD⁺ and a H⁺ ion.
- C. pyruvate molecules are converted to acetyl CoA.
- D. 30 or 32 ATP are produced.

Question 20

E10 fuel sold at most Australian service stations may contain

- A. esterified vegetable oil from genetically modified soybeans.
- B. synthetic petroleum produced by transformed bacteria.
- C. alcohol from fermentation of sugar cane mixed with petrol.
- D. methane gas collected from cattle, fed with genetically modified beans.

Question 21

Which of the following is considered part of the body's first line of defence against bacterial infection?

- A. Lysozyme is produced by tear glands
- B. Histamine produced by mast cells
- C. Death ligands produced by natural killer (NK) cells
- D. Cytokines produced by helper T (Th) cells

Question 22

Amoebas (*Entamoeba histolytica*) are eukaryotic parasites that can infect the gut of humans and cause the disease amoebic dysentery. A dendritic cell in the large intestine can identify an amoeba as non-self because

- A. amoebas lack self antigens.
- B. intestinal cells have self antigens.
- C. amoebas have non-self antigens.
- D. intestinal cells lack non-self antigens.

Question 23

During an inflammatory response, mast cells and basophils produce histamine. The effects of histamine include

- A. constriction of blood vessels.
- B. decreased permeability of blood vessels.
- C. attraction of phagocytes.
- D. down-regulation of protein synthesis in nearby cells.

Question 24

Neutrophils and macrophages are both phagocytes. In addition to their role as phagocytes, macrophages also act as professional antigen-presenting cells (APCs).

In what way are macrophages different to neutrophils that explains why macrophages are APCs and neutrophils are not?

- A. Macrophages present antigens on MHC II markers whereas neutrophils present antigens on MHC I markers.
- B. Neutrophils are too small to interact with Th cells, whereas macrophages are much larger.
- C. Macrophages can migrate into the lymphatic system, whereas neutrophils are only found within the circulatory system.
- D. Neutrophils digest the antigens they engulf, whereas macrophages present them on the cell surface.

Question 25

The drawing below represents an IgG antibody. Some parts have been labelled.

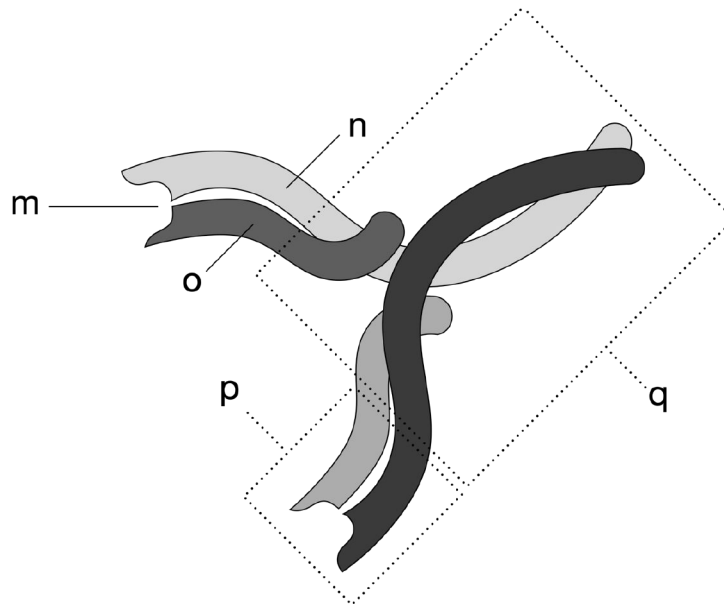


Figure 6. IgG

Which of the following is an accurate label?

- A. n is a light chain.
- B. q is a variable region.
- C. m is an antigen-binding site.
- D. p is a constant region.

Question 26

Cells involved in a humoral immune response include

- A. B lymphocytes, Plasma cells and helper T cells.
- B. cytotoxic T cells and B lymphocytes.
- C. Macrophages, helper T cells and mast cells.
- D. Plasma cells, neutrophils and helper T cells.

Question 27

According to the United States National Institutes of Health (NIH), people who have been vaccinated against chicken pox are likely to have life-long immunity to the virus. What type of immunity has such a person acquired to chicken pox?

- A. Natural active immunity.
- B. Natural passive immunity.
- C. Artificial active immunity.
- D. Artificial passive immunity.

Question 28

The mutation rate in RNA viruses can be up to a million times greater than the mutation rate in the host cells they infect. It has been estimated that in some RNA virus species, each new virus particle contains two new mutations. Due to this high mutation rate, it is not uncommon for mutations to occur, which affect the shape of its surface proteins, which may cause the acquired immunity of previously infected hosts to be less effective.

This evolution in the shape of viral surface proteins is referred to as

- A. transmutation.
- B. antigenic shift.
- C. antigenic drift.
- D. transformation.

Question 29

Some people in the community are unable to be vaccinated because they have a compromised immune system. This may be because they are undergoing chemotherapy treatment for cancer or because they take immune suppressing drugs following an organ transplant.

Although being unvaccinated, such immunocompromised people are afforded protection from disease when a large percentage of the community are immunised, because the spread of disease from person to person is more unlikely.

What term describes such a high community immunisation rate to a disease?

- A. Homogeneity
- B. Herd immunity
- C. Artificial passive immunity
- D. Immunization programming

Question 30

One form of immunotherapy for the treatment of cancer involves the use of monoclonal antibodies. Which of the following is **NOT** true of monoclonal antibodies?

- A. They are produced in a laboratory by cancerous bone marrow cells fused with plasma cells.
- B. They may be used as a vector to transport a radioactive compound to cancer cells.
- C. Each has antigen-binding sites for two different antigens.
- D. Each binds specifically to proteins expressed on the surface of self-cells.

Question 31

A pair of fruit flies (*Drosophila melanogaster*) were bred, and their offspring were bred with each other for many generations. The fruit fly population was kept in a sealed, climate-controlled enclosure. After 30 generations, researchers found that there were genes present in the genome of the fruit fly population that were not present in the parental genotype.

This genetic variation has arisen because of what biological process?

- A. Natural selection
- B. Mutation
- C. Crossing-over during meiosis
- D. Gene flow

Question 32

The Hawaiian monk seal is a seal that is only found in the Hawaiian Islands. It was hunted to near extinction in the late 19th Century. The species is now protected by the Endangered Species Act. It is illegal to kill, capture, or harass a Hawaiian monk seal. As a result of protection, the population has recovered. In 2010 there were 1100 individuals. That number had increased to 1400 by 2016. Despite this population growth, the Hawaiian monk seal is still listed as endangered because its genetic diversity is extremely low.

Which of the following explains the low genetic diversity of the Hawaiian monk seal?

- A. A genetic bottleneck.
- B. Artificial selection.
- C. The founder effect.
- D. Genetic drift.

Question 33

Some bacterial diseases which were once treatable with antibiotics, are now problematic because some strains of bacteria have become “super-bugs”, genetically resistant to common antibiotics. Several factors are responsible for this. Over-prescription of antibiotics is one contributing factor. A second is that many patients cease taking the medicine when their symptoms are gone. As a result, some bacterial cells which were not killed by the antibiotic, reproduce, and the population recovers with reduced susceptibility to amoxicillin.

The resistance of “super-bugs” as described above

- A. is caused by bacteria acquiring adaptive immunity to the antibiotic administered.
- B. is an example of natural selection taking place in the bacterial colony.
- C. can best be thought of as selective breeding by the doctor prescribing the antibiotic.
- D. is an example of innate immunity.

Question 34

Which of the following correctly lists in order from oldest to youngest, the first appearance of taxa in the fossil record?

- A. Fish – reptiles – birds
- B. Reptiles – fish – mammals
- C. Mammals – birds – amphibians
- D. Fish – birds – dinosaurs

Question 35

Scaphites are an ammonite genus that lived during the late Cretaceous period. Many species such as *Scaphites hippocrepis* are useful index fossils.



Figure 7. *Scaphites hippocrepis*. Image credit: <https://commons.wikimedia.org/wiki/File:SmallScaphites.jpg>

Which of the following is a reason for Scaphites being useful index fossils?

- A. They were quite rare.
- B. They existed on Earth for a very long period.
- C. Their range was constrained to a very small location.
- D. They are distinctive and easy to identify.

Question 36

Which of the following scenarios is most likely to lead to sympatric speciation?

- A. Canada geese from one region, migrate and breed with Canada geese from a different region.
- B. A grass growing on north-facing slopes of a mountain range, flowers several weeks earlier than the same grass species growing on south-facing slopes.
- C. A river divides a population of lizards into two separate populations that are unable to cross the river to interbreed.
- D. The myxomatosis virus spreads through a population of rabbits, killing all but a few individuals, which had a gene that made them more resistant to the virus than other individuals. After a few years, the whole population is resistant to myxomatosis.

Questions 37 and 38 refer to the following information and diagrams.

The bones of a horse's lower foreleg are equivalent to the bones of the human middle finger. The other "fingers" of the horse are greatly reduced and exist as partially fused bones alongside of the weight-bearing metacarpal (bone 5) of the lower horse leg. The carpals (wrist bones) of the horse are not pictured in the below but sit directly above bone 6 and comprise the "knee" of the horse.

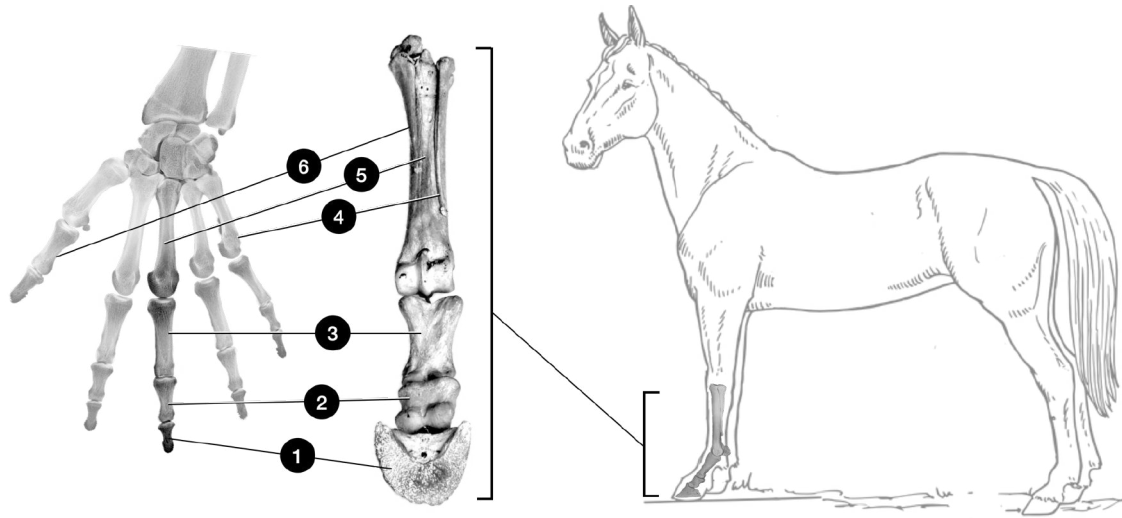


Figure 8. images modified from: <https://commons.wikimedia.org/wiki/File:Equine-dist-forelimb-bones.png>, <https://ndla.no/nn/subject:13/topic:1:183831/topic:1:183883/resource:1:163830>, <https://www.pexels.com/photo/black-and-white-bones-hand-x-ray-207496/>, <https://publicdomainvectors.org/en/free-clipart/Outline-drawing-of-standing-horse/34069.html>

Question 37

Which of the following bones in the horse foreleg is vestigial?

- A. Bone 1
- B. Bone 2
- C. Bone 3
- D. Bone 4

Question 38

The middle finger of a human and the foreleg of a horse perform very different functions, but they share a surprisingly similar fundamental skeletal anatomy. This is an example of

- A. analogy.
- B. pentadactyly.
- C. homology.
- D. adaptive radiation.

Question 39

The Madagascan aye-aye (*Daubentonia madagascariensis*) is a strange animal. It is the only living species in its genus. Males and females are almost indistinguishable with large-bat-like ears and large, cat-like, forward-facing eyes. The most distinctive feature of the aye-aye is its spider-like hands. Its middle finger is especially thin. The aye-aye feeds at night in a most unusual way, tapping with its fingers on branches to listen for the movement of grubs. Then it gnaws a hole in the wood with its forward-slanted, continuously growing teeth and uses its thin middle finger to whittle the grubs out of the hole. It is mostly solitary and rests during the day, hanging like a bat, upside-down from branches which it grasps between its big toe and its other toes.



Figure 9. Aye-aye. Image source: https://en.wikipedia.org/wiki/Aye-aye#/media/File:Ayeaye,_Daubentonia_madagascariensis,_Joseph_Wolf.jpg

When it was discovered, the classification of the aye-aye was debated for many years. It was initially classified as a rodent but has since been classified as a primate; a classification that is supported by DNA evidence. It is, however a very unusual primate. It has many features that are uncharacteristic of primates. Which of the following aye-aye feature sets is typical of primates?

- A. Mostly solitary behaviour and teeth that grow continuously throughout its life.
- B. Large forward-facing eyes and an ability to grasp branches between its toes.
- C. Nocturnal feeding behaviour and large ears.
- D. An insectivorous diet, and males and females which look almost identical.

Question 40

In 2015, researchers working in the Afar region of Ethiopia discovered what is now considered the oldest fossil of genus *Homo*. It is dated 2.8 million years old.

Based on this information and your understanding of major trends in hominin evolution, it is reasonable to predict that

- A. the fossil probably belongs to *Homo erectus*.
- B. the fossil probably has a larger cranial capacity than *Homo neandertalensis*.
- C. teeth in the fossil, are probably smaller than those of *Australopithecus afarensis*.
- D. the jaw of the fossil is probably more parabolic than that of *Homo sapiens*.

SECTION B – Short-answer questions

Instructions for Section B

Answer **all** questions in the spaces provided. Write using black or blue pen.

Question 1 (7 marks)

The first 230 nucleotides of the DNA coding (complementary) strand of the TrpE gene from the *Streptococcus pyogenes* Trp operon are shown below. The start codon is in **bold** type.

TrpE
→

```

... ATTA GAGAATAACA ATGAATTTCC AATCAAACAT TTCCGCATTT
TTAGAGGACA GCTTGTCCCA CCACACGATA CCGATTGTGG AGACCTTCAC
AGTCGATACA CTGACACCCA TTCAAATGAT AGAGAAGCTT GACAGGGAGA
TTACGTATCT TCTTGAAAGC AAGGACGATA CATCCACTTG GTCCAGATAT
TCGTTTATCG GCCTGAATCC ATTTCTCACA ATTAAAGAAG AGCAGGGCCG
...
  
```

- a. Beginning with the start codon write out the mRNA sequence transcribed from the first 12 nucleotides of the TrpE gene.

1 mark

- b. Using the genetic code table below, write the amino acid sequence encoded by the first 12 nucleotides of the TrpE gene.

1 mark

		Second Position				
		U	C	A	G	
First Position	U	Phe	Ser	Tyr	Cys	U
		Phe	Ser	Tyr	Cys	C
		Leu	Ser	Stop	Stop	A
		Leu	Ser	Stop	Trp	G
	C	Leu	Pro	His	Arg	U
		Leu	Pro	His	Arg	C
		Leu	Pro	Gln	Arg	A
		Leu	Pro	Gln	Arg	G
	A	Ile	Thr	Asn	Ser	U
		Ile	Thr	Asn	Ser	C
		Ile	Thr	Lys	Arg	A
		START/Met	Thr	Lys	Arg	G
	G	Val	Ala	Asp	Gly	U
		Val	Ala	Asp	Gly	C
		Val	Ala	Glu	Gly	A
		Val	Ala	Glu	Gly	G
		Third Position				

Figure 10. Genetic code in mRNA codons

- c. The underlined trinucleotide in the TrpE gene (GAG) is a ribosome-binding site (RBS). It specifies the binding location for ribosome attachment. When the TrpE gene is transcribed into, will the RBS be included in the mRNA? Justify your answer. 2 marks

- d. Sometimes a point mutation takes place, which does not cause any change to the amino acid sequence of the polypeptide produced. Such a mutation is called a 'silent' mutation. Using the first 12 amino acids of the TrpE gene, describe an example of a mutation which might take place that would be described as silent. 1 mark

- e. Some point mutations are described as 'nonsense' mutations.
i. What is meant by nonsense mutation? 1 mark

- ii. Referring to the first 12 amino acids of the TrpE gene, describe a specific example of a mutation which might take place that would be a nonsense mutation. 1 mark

Question 2 (7 marks)

Figure 10 (below), shows the mRNA transcribed from the trp operon, including the leader sequence as well as the last part of the operator sequence. Several regions of the mRNA leader sequence are labelled. Four codons are also labelled. T is a start codon, U and V are codons for tryptophan and W is a stop codon.

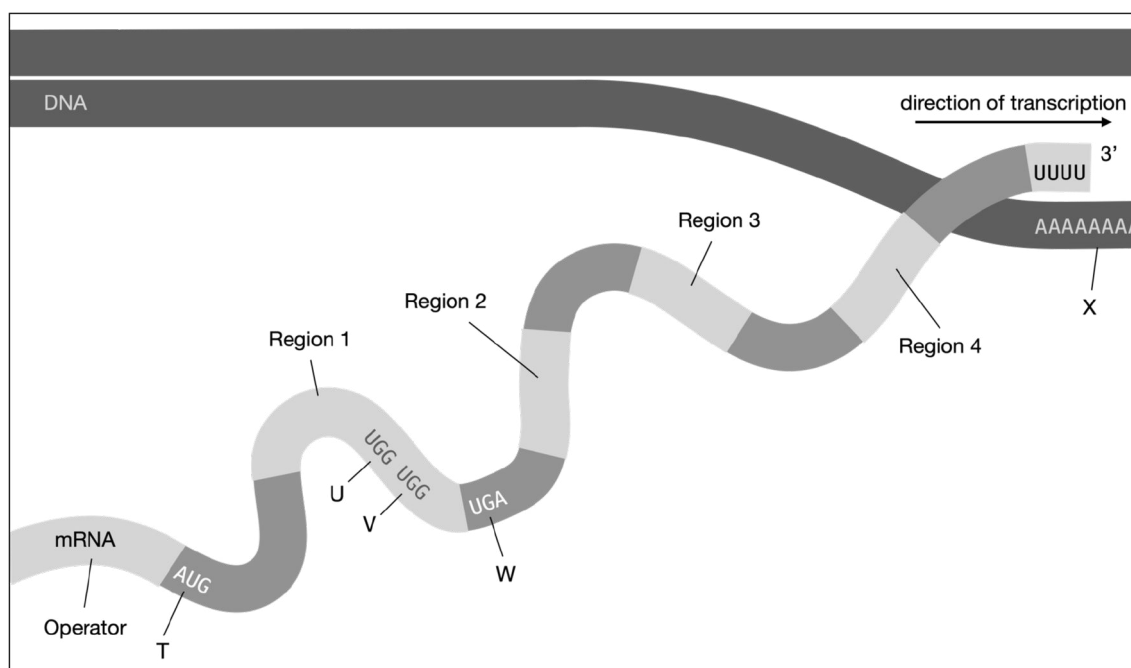


Figure 11. Trp operon

- a.** Notice the region of the DNA leader sequence labelled X which contains many adenine nucleotides.
- i.** What name is given to this sequence of uracil nucleotides downstream of region 4? 1 mark
-
- ii.** Explain the reason for the absence of guanine and cytosine in this sequence. 1 mark
-
-
-

- b.** Consider a *S. pyogenes* cell which contains many tRNA molecules carrying the amino acid tryptophan. Referring to structures labelled in Figure 10, explain how the process of attenuation prevents the cell from producing more tryptophan.

4 marks

- c.** Of what advantage is it to a bacterial cell, to prevent the synthesis of tryptophan when tryptophan is already present?

1 mark

Question 3 (6 marks)

To clone human insulin, Genentech spliced a β -galactosidase (β -gal) gene with a missing stop codon into a plasmid, immediately upstream of the Insulin A chain (InsA) gene as shown in Figure 12. The plasmids were then used to transform *Escherichia coli*, and these were cultured on a medium containing X-gal.

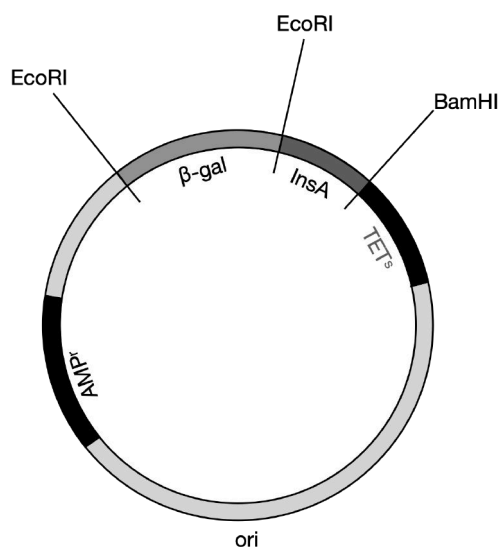


Figure 12. recombinant pBR322 map. Key: AMP^r – ampicillin resistance, TET^r – tetracycline resistance, β -gal – gene for β -galactosidase, InsA – gene for insulin A chain, EcoRI – restriction site for restriction endonuclease EcoRI, BamHI – restriction site for restriction endonuclease BamHI, Ori – site of replication origin.

- a. What is a plasmid? 1 mark

- b. When plasmids are introduced to bacteria only some bacteria take them up. Explain how scientists at Genentech were able to determine which *E. coli* colonies growing on the medium had taken up the recombinant plasmid pictured in Figure 12. 1 mark

- c. When the β -gal gene is transcribed and translated, within an *E. coli* cell, a fusion protein is produced.

- i. What enzyme is responsible for transcribing the β -gal gene? 1 mark

- ii. What is a fusion protein? 1 mark

iii. Explain how, during the expression of the β -gal gene, a fusion protein is synthesised instead of a normal β -galactosidase enzyme?

1 mark

iv. Why, in the cloning of human insulin, was it important for a fusion protein to be produced?

1 mark

Question 4 (9 marks)

The diagram below represents one of three stages of aerobic cellular respiration.

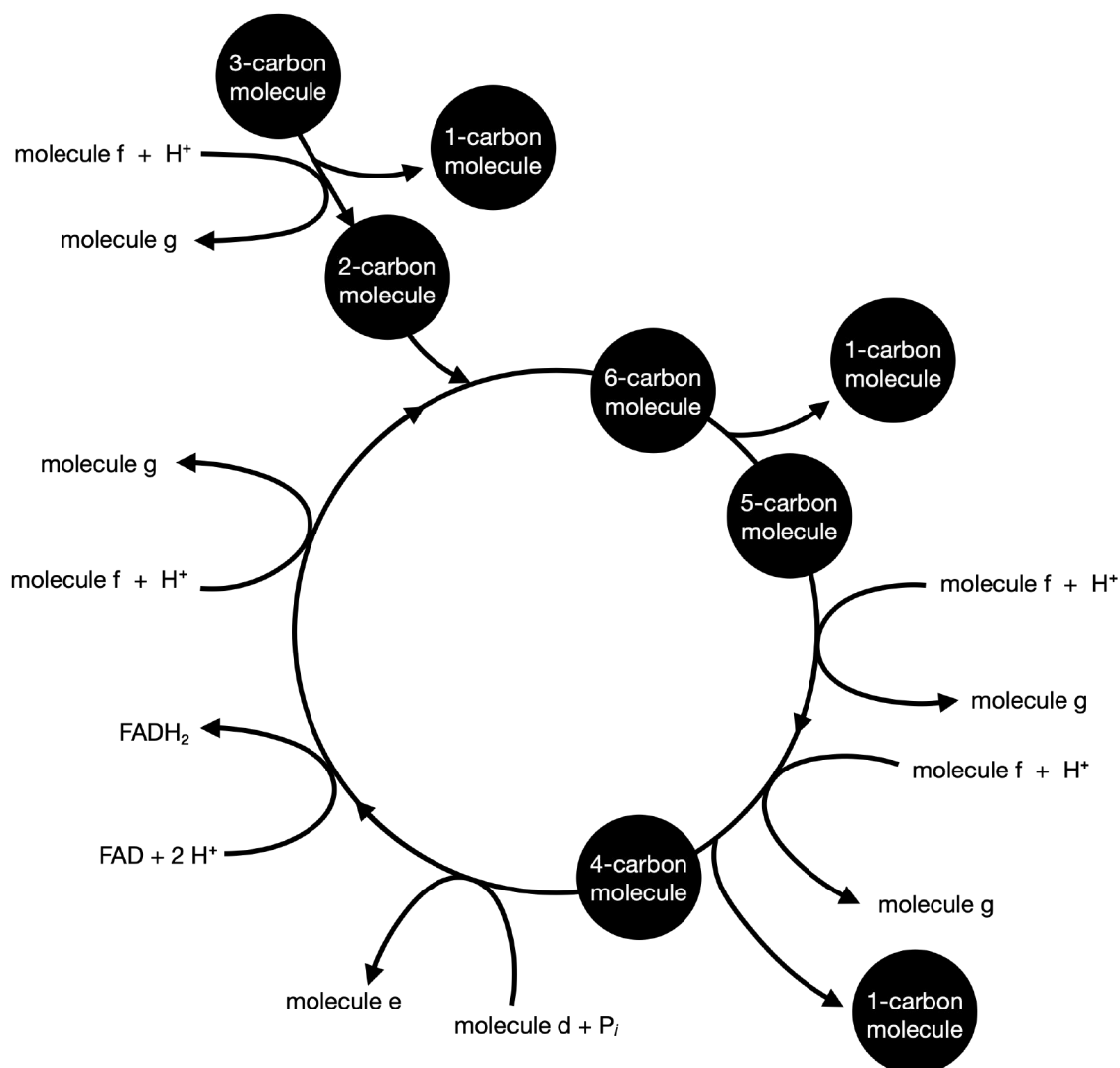


Figure 13. one of the biochemical processes involved in aerobic cellular respiration

- a. What name is given to the process depicted above?

1 mark

- b. One of the coenzymes involved in the process is FAD and its charged form FADH₂ which are labelled on the diagram. Two other coenzymes are also involved in the process. Referring to the diagram in Figure 13 complete the following table to show the names of these coenzymes.

2 marks

Label	molecule name
molecule d	
molecule e	
molecule f	
molecule g	

- c.** In the diagram several carbon-containing molecules are shown with the number of carbons they contain, indicated. The 2-carbon molecule is acetyl-CoA. 2 marks

i. What is the name of the 3-carbon molecule?

ii. What name is given to the 1-carbon molecules?

- d.** Where, within a eukaryotic cell does the process depicted in Figure 13 take place? 1 mark

- e.** Explain the purpose of producing FADH_2 in this stage of cellular respiration. 1 mark

- f.** Give an example of a process in the cell for which molecule **e** is used. 1 mark

- g.** What is the source of molecule **f**? 1 mark

Question 5 (3 marks)

Students performed an experiment to test the effect of light intensity on the rate of photosynthesis. They purchased 15 small Button fern plants (*Pellaea rotundifolia*) from a nursery and placed each in a small conical flask which was fully sealed so that no gasses could enter or leave the flask.

Each flask was placed near a light globe. Five jars were placed 1 cm from the light globe. Five jars were placed 30 cm from the light globe. Five jars were placed 1 m from the light globe.

A carbon dioxide probe was placed inside each flask to measure the concentration of atmospheric carbon dioxide.

The plants were left in the flasks for 30 minutes and then the carbon dioxide concentration measured and averaged. It was noted by the students that the results at each light intensity were very precise.

The results of the experiment are shown in the graph below.

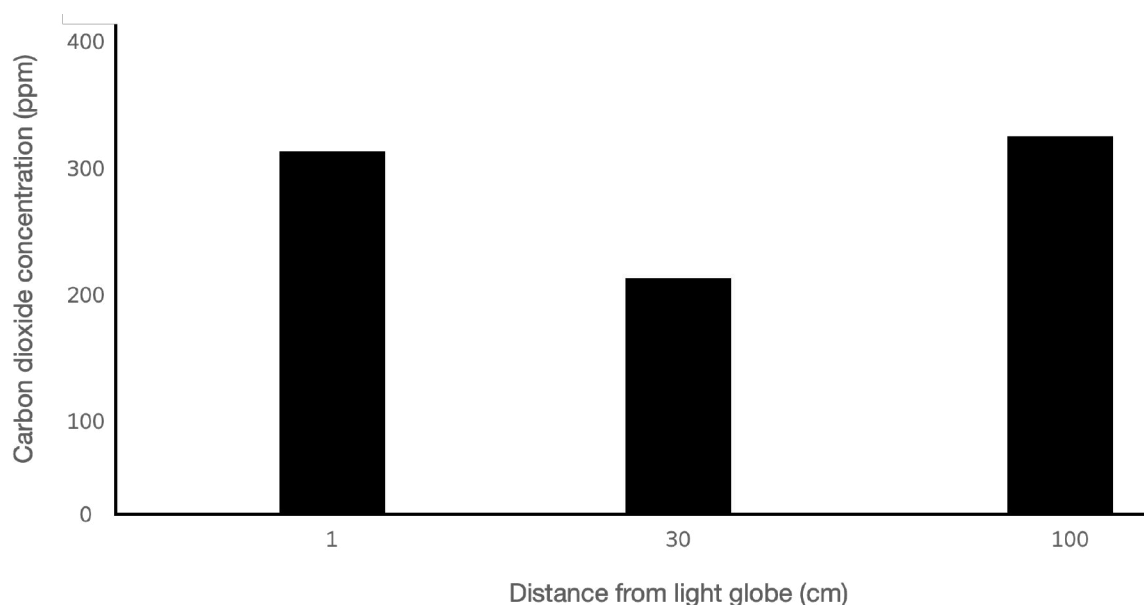


Figure 14. CO₂ Conc in conical flasks after 30 minutes

- a. What is the independent variable in the students' experiment? 1 mark

- b. Suggest an uncontrolled confounding variable in the experiment. 1 mark

- c. Suggest an explanation for the fact that the CO₂ concentration in the conical flask 1 cm from the light globe was higher than the CO₂ concentration in the flask 30 cm from the light globe. 1 mark

Question 6 (9 marks)

In Australia, the waiting list for a heart transplant is 6 months.

Scientists working at the biotechnology company eGenesis, are working to genetically modify pigs so that they can provide a source of pig hearts that are safe for transplant into humans.

Until recently, it was not feasible to transplant a pig heart into a human for several reasons.

One important reason is that the pig genome contains a group of viruses called porcine endogenous retroviruses (PERVs) that are harmless in pigs but could cause disease in humans if they were incorporated into the human genome.

The scientists have used CRISPR-Cas9 to knock out PERV genes from pig DNA. They have already produced several PERV-free pigs in this way, and in early 2022, the first successful pig-to-human heart transplant was performed by surgeons at the University of Maryland Medical School.

- a.** What does it mean to say that scientists have ‘knocked out’ PERV genes? 1 mark

- b.** What general name describes a disease caused by a virus that enters the genome of a human from the genome of another species? 1 mark

Cas9 is a kind of endonuclease. Restriction enzymes are also endonucleases.

- c.** Describe two ways that Cas9 is like a restriction enzyme. 2 marks

- d.** In what important way is Cas9 different to a restriction enzyme? 1 mark

- e. i.** Explain another reason that transplanting a heart from a pig to a human was not feasible, prior to CRISPR-Cas9 technology. 2 marks

ii. Suggest how CRISPR-Cas9 may have been used to overcome the challenge you outlined in question e *i*.

1 mark

f. Outline a bioethical issue that is raised using pigs to produce transplant organs for human recipients.

1 mark

Question 7 (11 marks)

In March 2022, an outbreak of scarlet fever occurred at Bowker Vale Primary School in Manchester, UK. The outbreak was reported in the news because it is quite rare in the 21st century. It was almost eradicated by 1940.

Scarlet fever mostly affects children between the ages of 5 and 12. It is much less common in adults and children younger than 3.

The disease is caused by a strain of the gram-positive bacterium *Streptococcus pyogenes*. Its symptoms are a red, sore throat, swollen lymph nodes in the neck, a fever, “strawberry” tongue, and a red rash on the skin.

S. pyogenes can be spread from one individual to another in aerosol droplets, through body fluids such as saliva, or by direct contact with the skin of an infected person.

- a. Do you expect scarlet fever to be treatable with antibiotics? Justify your answer. 1 mark

- b. Suggest one reason that scarlet fever affects children more frequently than adults. 1 mark

- c. Suggest why children under the age of 3 are less likely to get scarlet fever than children who are aged 5 years or older. 1 mark

- d. Before a microorganism can cause disease, it must first gain entry to living tissues of the body. The outer skin surface provides a natural physical barrier to the entry of microorganisms. *S. pyogenes*, however, is known to spread from one child to another by direct contact.

Describe one way that *S. pyogenes* can enter the living tissues of a child, when he touches the skin of another child who has scarlet fever.

1 mark

- e. It is unusual for a child who has recovered from scarlet fever to get the disease again because they now have immunity to the strain of *S. pyogenes* that causes it.

i. What type of immunity does a recovered child have to scarlet fever?

2 marks

ii. Name a cell type present in the recovered child's body that is responsible for the immunity the child now has to scarlet fever.

1 mark

iii. Explain how, during the original *S. pyogenes* infection, the child's immune system produced the cell type you named in question e. ii.

3 marks

- f. Suggest a strategy that should be employed by the administration at Bowker Vale Primary School to control the spread of scarlet fever through the school.

1 mark

Question 8 (7 marks)

The adrenal cortex is part of the adrenal glands positioned above each kidney. The adrenal cortex secretes several hormones, including aldosterone.

Aldosterone helps the kidneys reabsorb sodium and water into the bloodstream, which increases blood pressure. It also helps the kidneys to eliminate excess potassium.

Addison's disease is a non-infectious disease caused when the adrenal cortex is damaged by the body's own immune system if it mistakenly identifies cells of the adrenal cortex as non-self and kills them. It results in a cluster of symptoms referred to as primary adrenal insufficiency.

- a. What type of disease is Addison's disease? 1 mark
-
- b. Which cells in the immune system are directly responsible for killing cells of the adrenal cortex, because of Addison's disease? 1 mark
-
- c. Predict a symptom that you expect in a person suffering primary adrenal insufficiency due to Addison's disease. 1 mark
-
- d. A student suggested that scientists should be funded to develop a vaccine against Addison's disease. Do you think this is a reasonable suggestion? Explain your answer. 2 marks
-
-
-
-
-
- e. The clinical test for Addison's disease involves a blood test. The blood of a person showing the symptoms of Addison's disease is tested for the presence of a specific protein.
- i. What type of protein is the blood tested for? 1 mark
-
- ii. Explain why the blood of a person suffering Addison's disease would contain this type of protein, but the blood of a healthy person would not. 1 mark
-
-
-
-
-

Question 9 (4 marks)

Bruton's tyrosine kinase (BTK) is an enzyme found only in B lymphocytes. When an antigen binds to the B lymphocyte's antigen receptor (BCR), the BCR undergoes a conformational change, which activates BTK. BTK then catalyses a biochemical pathway in the cell, which results in transcription factors binding to DNA, and the B lymphocyte proliferating to form B memory and plasma cells.

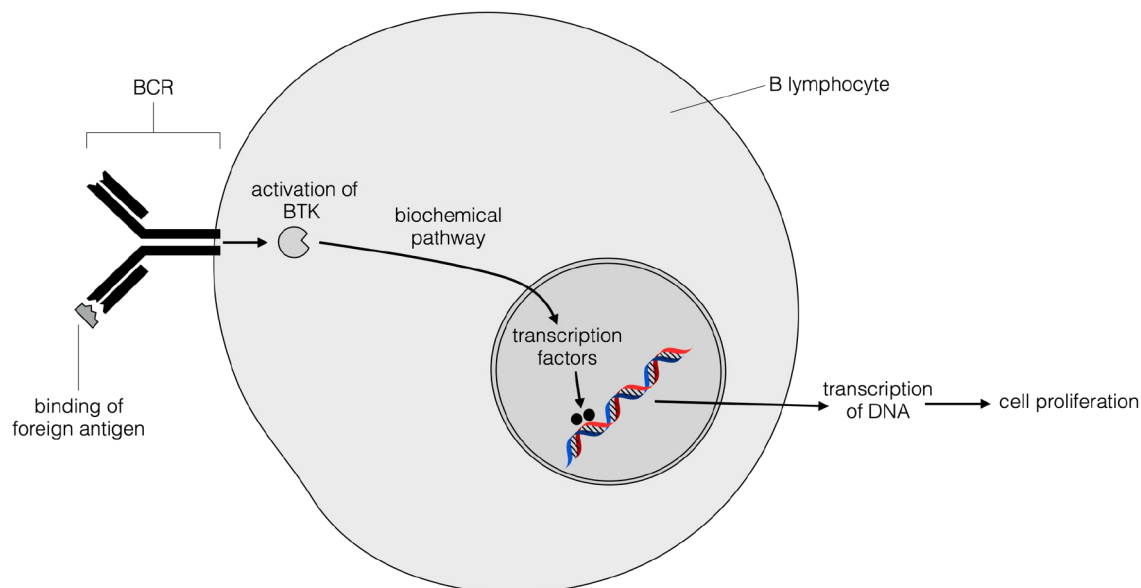


Figure 15. Simplified diagram showing the involvement of BTK in B cell proliferation

Recently it has also been shown that BTK is crucial to the proliferation of B lymphocytes in the development of chronic lymphocytic leukemia, a type of blood cancer.

Ibrutinib, sold in Australia under the brand name Imbruvica, is a new immunotherapy drug, used in the treatment of chronic lymphocytic leukemia. It is an irreversible competitive inhibitor of BTK.

- a. Specifically, what does it mean to say that Imbruvica is a competitive inhibitor of BTK? 1 mark

- b. What advantage does the prescription of Imbruvica have for a leukemia patient, compared to the use of traditional chemotherapy drugs? 1 mark

- c. Describe one adverse effect, that you anticipate a leukemia patient to experience whilst being treated with Imbruvica. Explain your answer. 2 marks

Question 10 (7 marks)

Jackson's chameleon (*Trioceros jacksonii*) is a small, tree-dwelling lizard native to Kenya, Africa.



Figure 16. Male Jackson's chameleon (*Trioceros jacksonii*). image source: <https://www.flickr.com/photos/kahunapulej/6087696317>

The chameleon is famously able to change colour to camouflage with its background to avoid predation by snakes and birds. Usually, they are a mottled dull green or brown. When mating, however, males change to a bright lime green to attract females and to ward off male competitors.

In 1972 a pet shop owner on the island of Oahu, Hawaii, imported 36 Jackson's chameleons to sell in his shop. He accidentally allowed the chameleons to escape into the wild. Without any natural predators in Hawaii, the lizards have flourished and are now quite common in the forests of Oahu.

Research published in May 2022, in the journal *Science Advances*, involved measuring the 'reflectance' of male chameleons in Kenya and Oahu. The results showed that male chameleons in Oahu have a higher reflectance (they turn an even brighter shade of green) than those in Kenya.

Scientists are still seeking to explain the evolution of greater reflectance in the Oahu population. It is likely that an allele for higher reflectance exists in the gene pool of Kenyan populations, too, but with a frequency much lower than that in the Oahu population. Alternatively, it is possible that a new allele for greater reflectance has arisen in the Oahu population.

- a. If it is discovered that the allele for greater reflectance does not exist in the gene pool of Kenyan chameleons, by what process must the allele have arisen in the Oahu population?

1 mark

- b. If it is discovered that the allele for the greater reflectance exists in the Kenyan population, then its high frequency in the Oahu population must be due either to genetic drift or natural selection.

- i. If the evolution of greater reflectance is due to genetic drift, what type of genetic drift would this be?

1 mark

- ii.** Explain how genetic drift might account for the greater reflectance of Hawaiian male chameleons, compared to their Kenyan counterparts.

2 marks

- iii.** Explain the process of natural selection that may have taken place in Oahu, leading to an increase in the frequency of the more reflectant phenotype in Jackson's chameleons in Oahu.

3 marks

Question 11 (5 marks)

The fish class Chondrichthyes contains fish which have a cartilaginous skeleton (rather than a bony skeleton). It includes sharks, rays, skates, sawfish, as well as chimaeras (or ‘ghost sharks’).

The phylogenetic tree below shows the evolutionary relationships between some of the members of the Chondrichthyes.

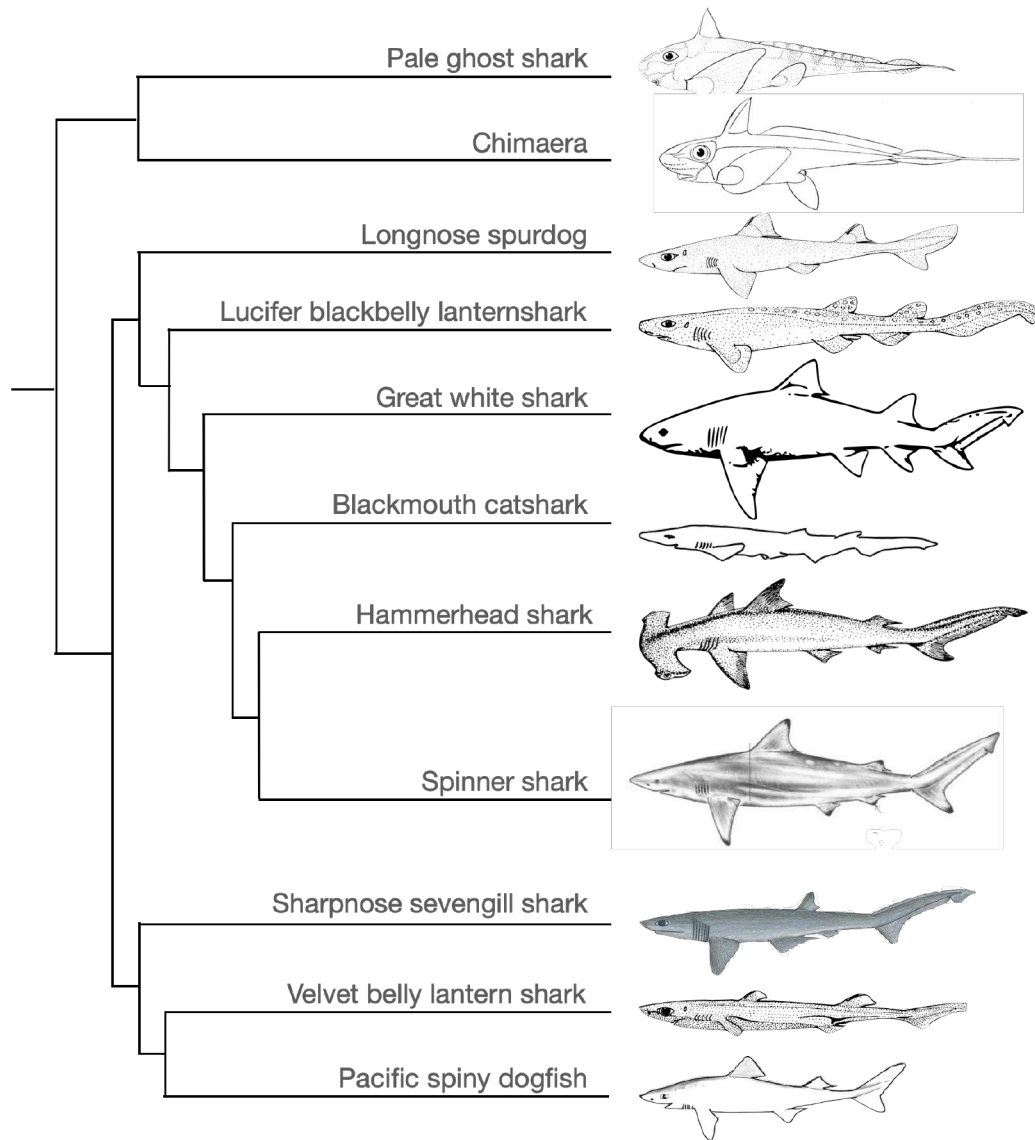


Figure 17. Phylogenetic tree of some shark genera. Images sourced from Wikimedia commons

- a. Is the Lucifer blackbelly lanternshark more closely related to the Velvet belly lantern shark or the Spinner shark? Explain your answer.

2 marks

- b. Scientists investigated the DNA sequence for the gene **CTNNBL** which codes for the protein **β -Catenin-like-protein**. They compared the nucleotide base sequence of CTNNBL from the Great white shark to that that from the Blackmouth catshark. There were 25 differences. Complete the table below by ticking one box for each species pair listed. The first row is completed as an example.

2 marks

Species compared	More than 25 base differences	25 base differences	Fewer than 25 base differences
Great white shark and Blackmouth catshark		✓	
Great white shark and Lucifer blackbelly lantern shark			
Great white shark and hammerhead shark			

- c. The scientists also compared the amino acid sequence of β -Catenin-like protein between the Great white shark and the Blackmouth catshark. They differed by only 13 amino acids. Explain why there were fewer than 25 amino acids different.

1 mark

Question 12 (5 marks)

In May 2022, researchers found a molar tooth in a cave called Tam Ngu Hao 2 in Laos. They claim that the tooth is from a Denisovan girl, as the shape of the tooth is very similar to that of a tooth found in a fossil jawbone unearthed in Tibet. If the tooth is indeed a Denisovan fossil, it is a remarkable find since all other preserved evidence of Denisovans is from northern Asia (Tibet and Siberia). This would be the first Denisovan fossil found in Southeast Asia. The scientists used luminance dating on the rock containing the fossil to conclude that the tooth is about 140,000 years old.

- a. Explain whether it might be possible to use radiocarbon dating to confirm the age of the tooth.

1 mark

Some scientists have questioned the find, thinking it possible that the tooth is Neanderthal, not Denisovan. Further investigation is required to be certain that it is a Denisovan tooth.

- b. What is one way that scientists might be able to determine whether the fossil is Denisovan or Neanderthal?

1 mark

Although this Laotian tooth is the southernmost discovery of a Denisovan fossil, Denisovan DNA has been found in people indigenous to places much further south than Laos, including Papua New Guinea highlanders, the Ayta Magbukon people of the Philippines and Aboriginal Australians.

- c. Suggest how the genome of the Ayta Magbukon people came to include Denisovan DNA, even though there is no evidence that Denisovans ever lived in the Philippines.

1 mark

To date, no fossils of Denisovan skulls have been found anywhere in the world.

- d. Were a complete fossil Denisovan skull to be discovered, describe two differences you would predict between it and the skull of a *Homo sapiens*

2 marks

END OF QUESTION AND ANSWER BOOK