



NATIONAL SENIOR CERTIFICATE EXAMINATION  
NOVEMBER 2020

**LIFE SCIENCES: PAPER I**

Time: 3 hours

200 marks

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**PLEASE READ THE FOLLOWING INSTRUCTIONS CAREFULLY**

1. This question paper consists of 15 pages and a yellow Answer Booklet of 16 pages (i–xvi). Please check that your question paper is complete. Detach the yellow Answer Booklet from the middle of the question paper. Remember to write your examination number in the blocks provided.
  2. This question paper consists of four questions.
  3. Question 1 must be answered in the yellow Answer Booklet provided.
  4. Questions 2, 3 and 4 must be answered in your Answer Book.
  5. Start **each question** on a **new** page.
  6. Read the questions carefully.
  7. Number the answers exactly as the questions are numbered.
  8. Use the total marks that can be awarded for each of Questions 1, 2, 3 and 4 as an indication of the detail required.
  9. It is in your own interest to write legibly and to present your work neatly.
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**QUESTION 2**

2.1 Haemoglobin molecules are made during the process of protein synthesis. The genetic code for making haemoglobin is stored in the DNA of cells.

2.1.1 State TWO differences in structure between DNA and RNA. (2)

2.1.2 Name the process in a cell which results in the formation of mRNA. (1)

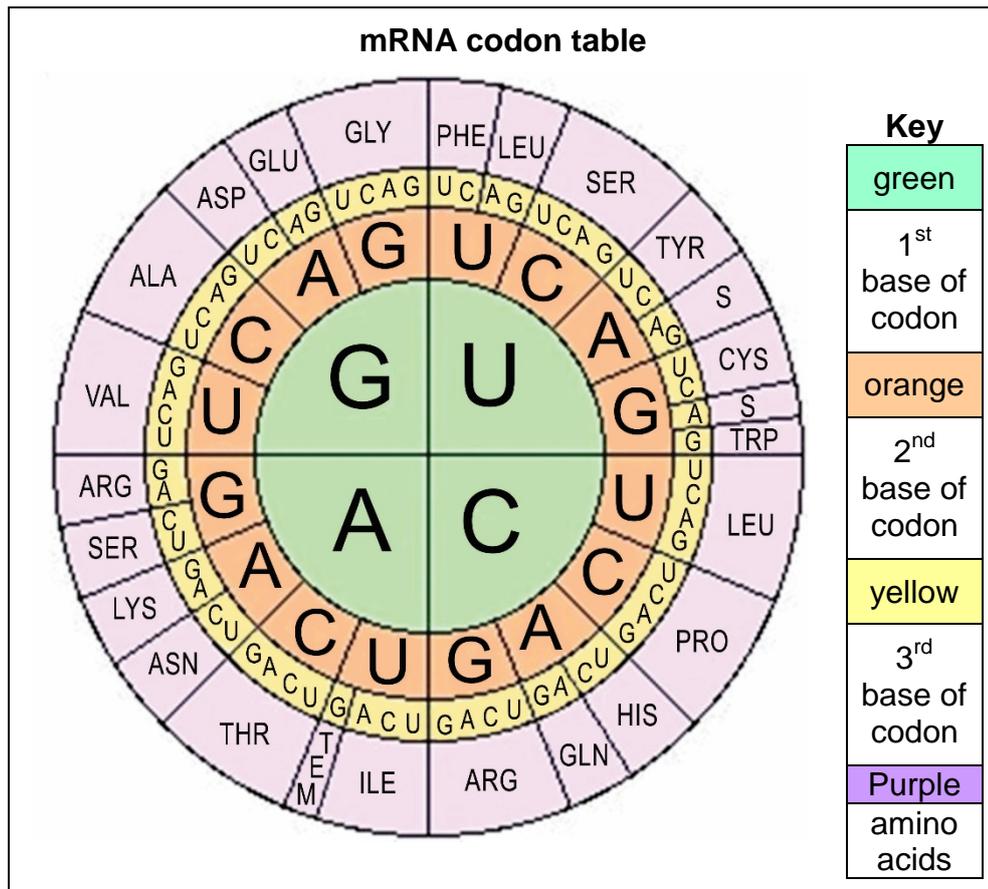
2.1.3 Name the location in the cell where mRNA would be made. (1)

2.1.4 (a) The following sequence of nitrogen bases is part of the DNA template that makes part of the haemoglobin molecule.

**ACA CCT GAG**

Use the above template strand of DNA to write the corresponding **mRNA** nucleotide sequence. (3)

(b) Use the mRNA codon table below to write down the amino acids coded for by the mRNA in the correct order.



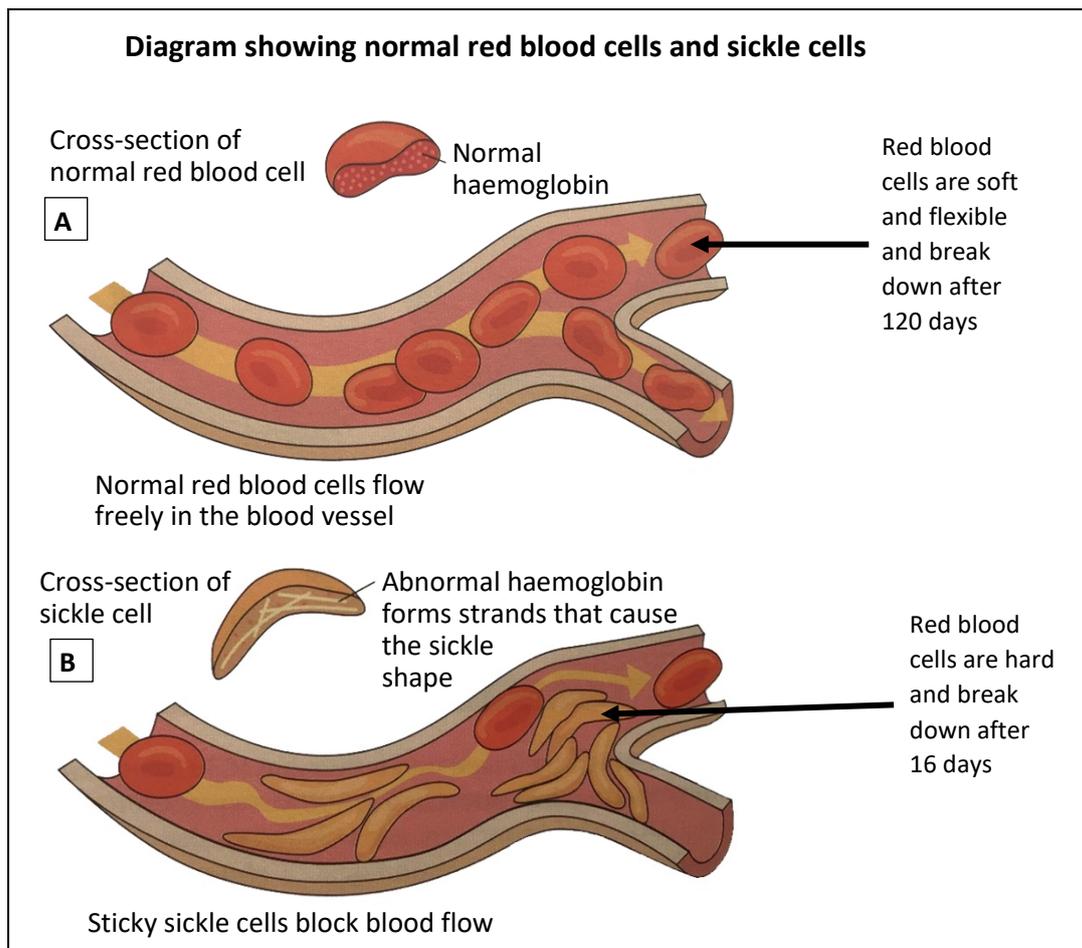
[Adapted: <https://slideplayer.com>]

(3)

2.1.5 Draw a flow diagram to represent the steps in the synthesis of a protein (such as the haemoglobin molecule) in the cytoplasm of the cell. (6)

2.1.6 Haemoglobin is a single chain of 147 amino acids. Calculate the number of nucleotides that would code for this protein molecule. Show all working. (2)

2.2 Haemoglobin molecules are protein molecules found in the red blood cells of humans. Haemoglobin molecules serve as the oxygen carriers in the blood. A mutation in the gene coding for haemoglobin can cause a serious condition known as sickle-cell anaemia, where the red blood cells have an abnormal sickle cell shape. Individuals with this disease suffer from anaemia, periodic episodes of pain, swollen hands and feet and frequent infections.



[Adapted: <Biological Sciences Review>]

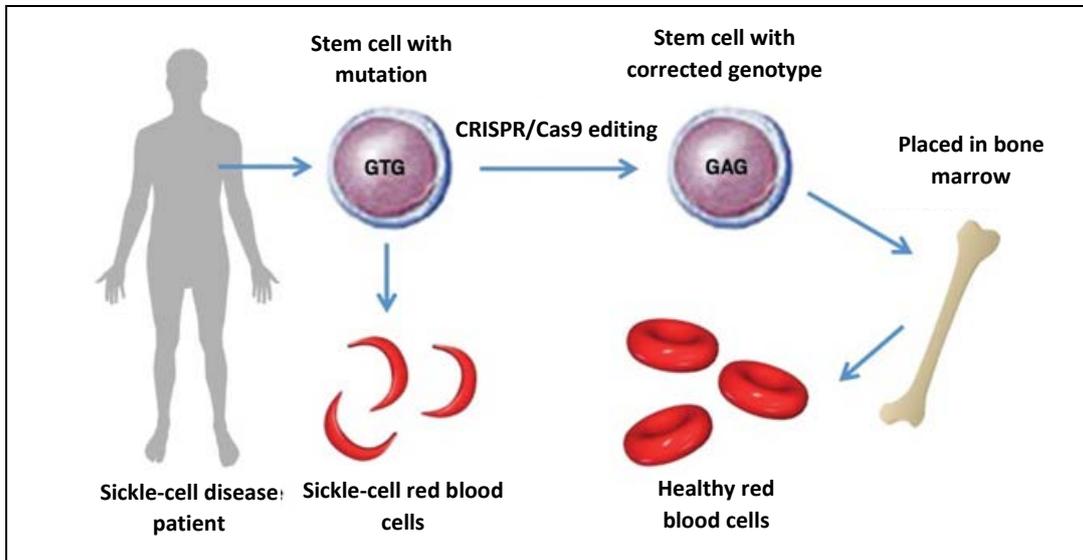
2.2.1 Use the information given in the diagram to tabulate THREE differences between a normal red blood cell and a sickle cell. (5)

2.2.2 The mutant allele for sickle-cell anaemia is recessive. Draw a genetic cross/Punnett square to determine the probability of parents who are both heterozygous for sickle-cell having a child with sickle-cell anaemia. Show the ratios of all the phenotypes arising from the cross.

Use the following key:

**N** – normal                      **n** – sickle-cell (6)

2.3 One possible strategy to cure sickle-cell disease uses CRISPR/Cas9 technology to edit a mutant gene in the stem cells that give rise to other blood cells of patients. The healthy cells are then placed back into the patient's red bone marrow. The image below depicts this process.



[Adapted: <<https://cen.acs.org>>]

2.3.1 State whether the following statements regarding the information shown in the above diagram are TRUE or FALSE.

- (a) CRISPR/Cas9 can be used to edit parts of the human genome. (1)
- (b) The mutation in the stem cell is a substitution point mutation. (1)
- (c) CRISPR/Cas9 technology will correct the mutation in every cell of the patient. (1)
- (d) The process shown in the diagram is a form of gene therapy. (1)

2.3.2 Clinical trials using this process to treat sickle-cell anaemia are underway. Suggest TWO important reasons why clinical trials should be carried out before making this technique available to all sickle-cell anaemia patients. (2)

2.4 Read the information in the textbox below.

Carriers of the sickle-cell mutation are heterozygous for the condition and are resistant to malaria infections. Malaria is a life-threatening disease caused by a parasite that invades red blood cells.

The map below shows areas in Africa where there is a high incidence of malaria (B) and people who are carriers of the sickle-cell mutation (A).

**A**
**B**

Carriers of sickle-cell mutation
 

 Malaria

[Adapted: <<https://slideplayer.com>>]

Refer to the theory of natural selection to explain how sickle-cell carriers became more widespread in areas of Africa where there was a high incidence of malaria.

(5)  
[40]

**QUESTION 3**

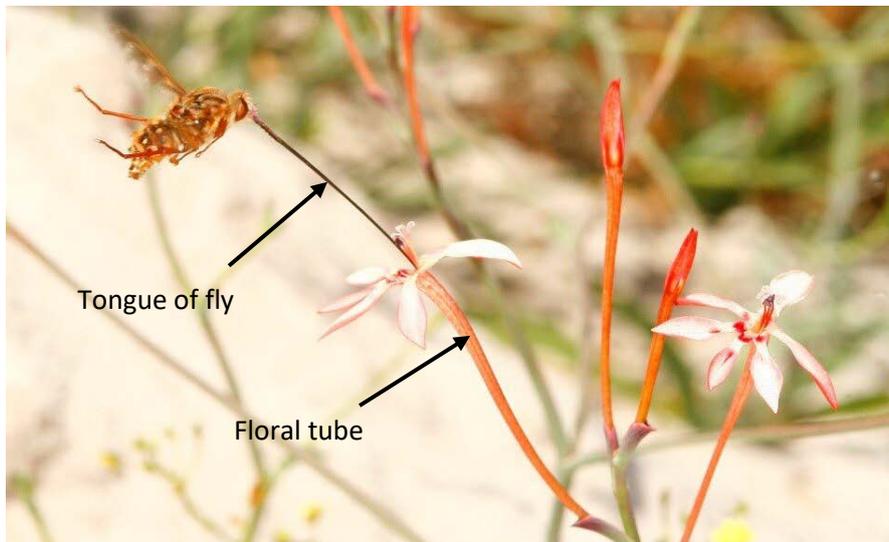
3.1 Read the article below. Use the information in the text and your own knowledge to answer the questions that follow:

**Speciation in the long-tubed iris plant**

Evolutionary ecologists have succeeded in observing the process of speciation in a plant, the **long-tubed iris**. For the past 15 years they have been visiting the sand-plain fynbos on South Africa's West Coast to monitor the process in these plants.

The ecologists noted that some plants had short floral tubes and others had long floral tubes. However, very few plants had tubes of intermediate (in-between) length. The population of plants was only visited by one pollinator, the long-tongued fly.

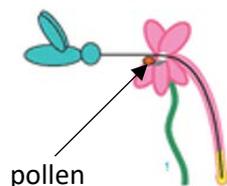
**Long-tubed iris being pollinated by the long-tongued fly**



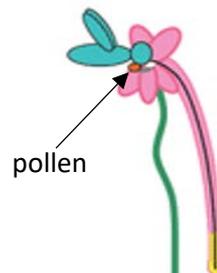
[Adapted: <<https://phys.org/news>>]

The ecologists were able to conclusively show that the long-tubed and short-tubed flowers place and receive pollen on different parts of the fly's body.

**Pollen is placed midway on the tongue when visiting short-tubed flowers**



**Pollen is placed on the head or on the tongue closer to the head when visiting long-tubed flowers**



[Source:< <https://www.researchgate.net>>]

Consequently, pollen is rarely transferred between the long-tubed and short-tubed flowers.

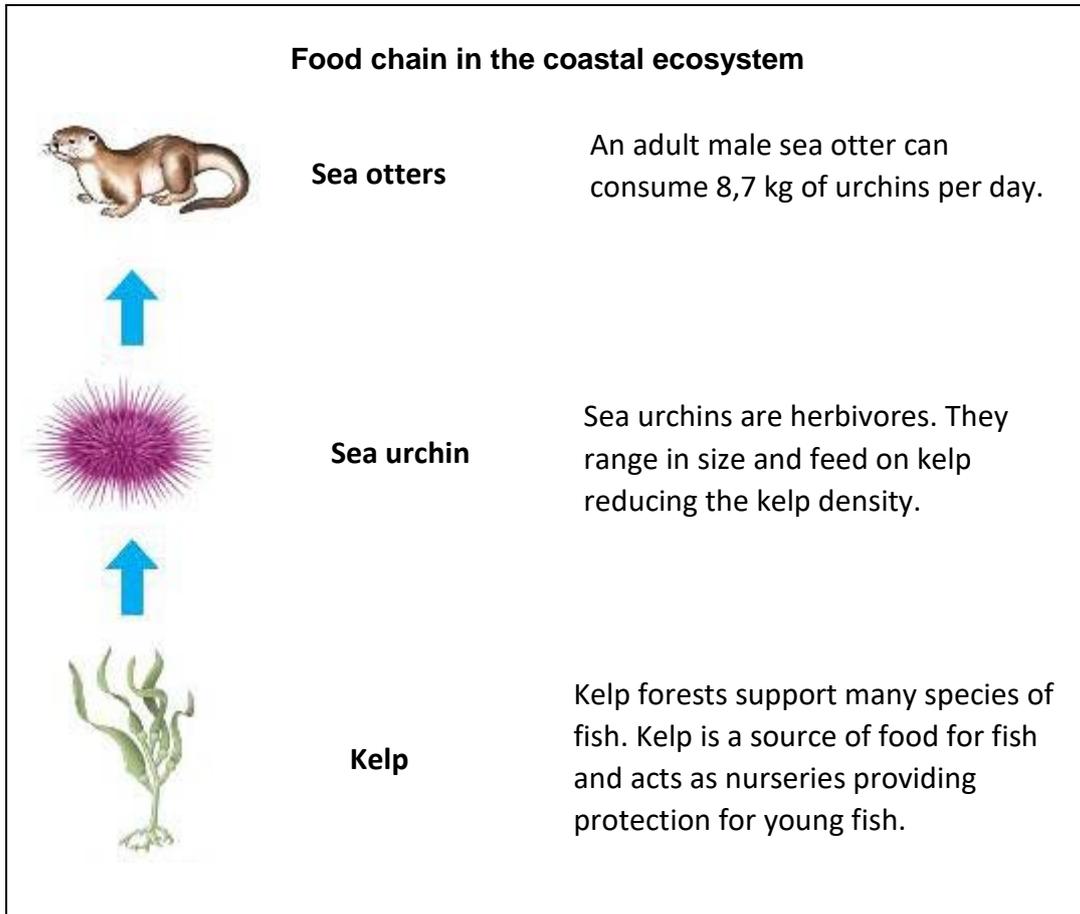
[Adapted: <<https://phys.org/news>>]

- 3.1.1 Explain the meaning of the term *species*. (3)
- 3.1.2 State whether this is an example of sympatric or allopatric speciation and provide a reason for your answer. (2)
- 3.1.3 Explain why the two forms of the iris plant, those with short floral tubes and those with long floral tubes, are reproductively isolated. (3)
- 3.1.4 Suggest why this example is a form of microevolution. (2)
- 3.1.5 The ecologist wanted to estimate the number of dung beetles found in the area. She set up traps and caught 677. She marked each dung beetle on the base of the abdomen with non-toxic paint and released them back into the area. Two days later she set up the trap again. Five hundred and sixty (560) beetles were caught of which 35 had been marked.

The ecologist repeated this procedure of estimating the dung beetle population size several times over a period of five years and received similar results. She also noted a variation in the sizes and ages of the dung beetles as well as an availability of dung beetle food sources.

- (a) Calculate the number of dung beetles found in the area. Show all working. (3)
- (b) State TWO ways the ecologist carried out this procedure to ensure a reliable result. (2)
- (c) Give TWO reasons why this method used by the ecologist is an indirect method of calculating population size. (2)
- (d) Evaluate whether the ecologist could use the data she has collected as well as her observations to determine whether the dung beetle population was at carrying capacity in this area of fynbos. Give reasons for your answer. (3)

3.2 Study the image below of a food chain in a coastal area. Use the information provided and your own knowledge to answer the questions that follow:



[Adapted: <<https://bio1152.nicerweb.com>> ; <<http://seaotterconservation.blogspot.com>>]

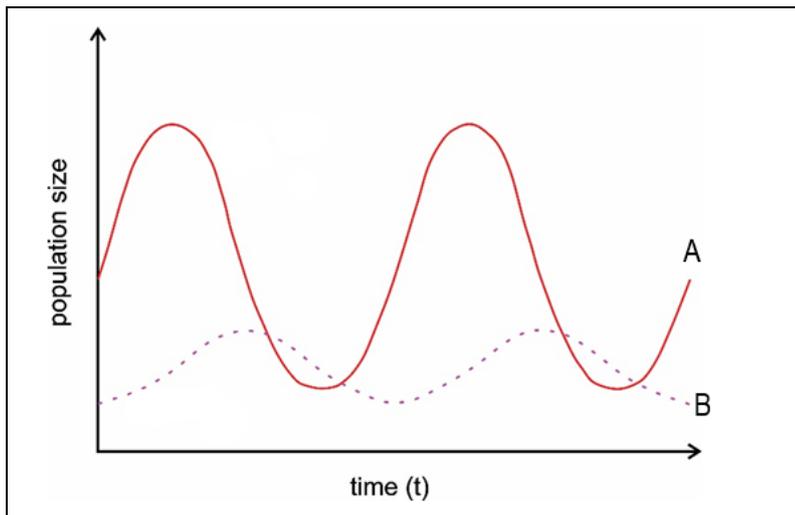
3.2.1 Explain the meaning of the following terms:

- (a) Ecosystem (2)
- (b) Population (2)

3.2.2 State TWO roles played by the kelp forests in the coastal ecosystem. (2)

3.2.3 State any THREE density dependent factors that would limit the size of the sea otter population. (3)

3.2.4 Study the predator-prey graph shown below.



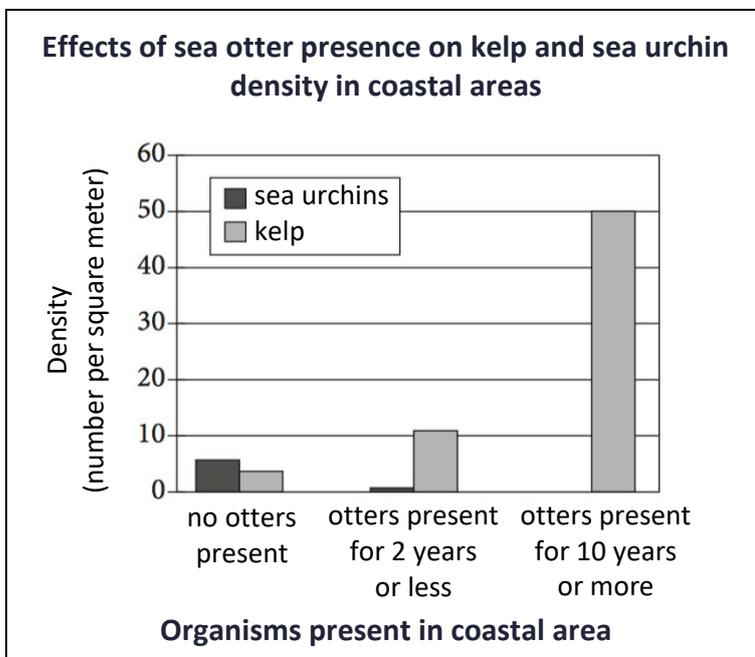
[Adapted: <<http://ealbiologytasis.blogspot.com>>]

Select the animal from the food chain on the previous page that would best be represented by:

(a) Line A (1)

(b) Line B (1)

3.3 The graph below shows how the numbers of sea otters affect sea urchin and kelp density in coastal areas.



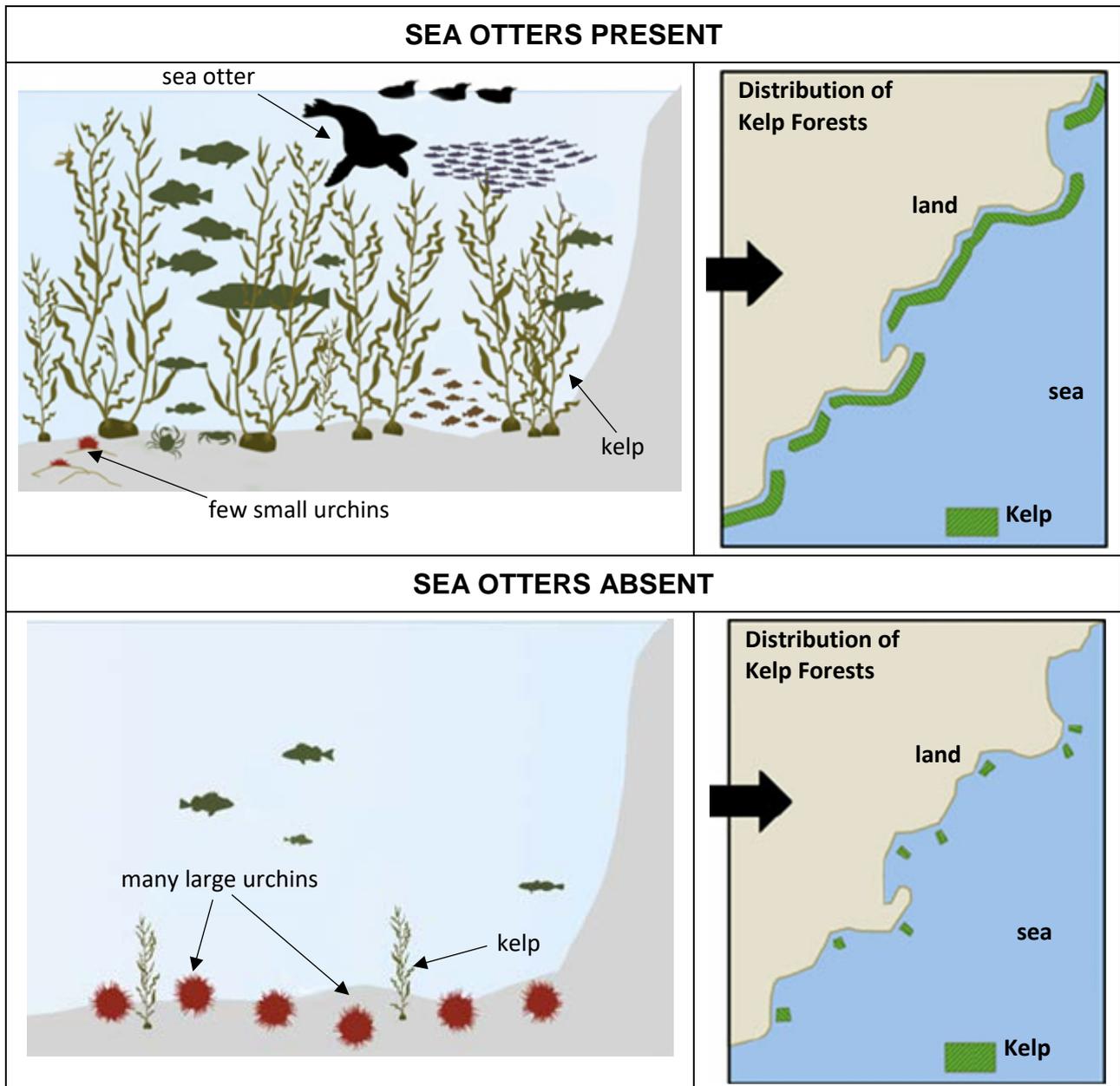
[Source: <<https://www.testbig.com>>]

3.3.1 From the graph determine the number of sea urchins present in an ecosystem when there are no sea otters present. (2)

3.3.2 Explain the reason for high kelp density when otters have been present in an area for 10 years or more. In your answer refer to all the organisms present in the food chain on page 8. (3)

3.4 In a study done in Alaska, scientists wanted to investigate if otters are a *keystone species*. Keystone species are important to the health of an ecosystem and without them the biodiversity of an ecosystem would decrease.

Refer to the images below taken from the study to evaluate whether sea otters can be regarded as a keystone species. Give well explained reasons for your decision.



[Adapted: <<https://www.researchgate.net>>]

(4)  
[40]

**QUESTION 4**

4.1 Read the article below. Use the information in the text and your own knowledge to answer the questions that follow:

**Mendel and his research on the mechanisms of inheritance**



Gregor Johan Mendel worked with pea plants in the gardens of the monastery. The focus of his research was to investigate the mechanism of inheritance.

Mendel's garden produced a large volume of data to analyse:

- Twenty eight thousand pea plants
- Forty thousand flowers
- Four hundred thousand seeds

[Source: <<https://www.britannica.com>>]

The table below shows some of the results of his monohybrid crosses of pea plants.

**Table showing three of Mendel's monohybrid crosses of pea plants**

Characteristic	Offspring of F <sub>1</sub>	Offspring of F <sub>2</sub> (numbers)	Ratio of F <sub>2</sub>
Height: Tall x dwarf	all tall	787 tall, 277 dwarf	2,84 : 1
Seed pod colour: Green x yellow	all green	428 green, 152 yellow	2,82 : 1
Seed shape: Round x wrinkled	all round	5475 round, 1850 wrinkled	2,96 : 1

[Adapted: Mukherjee, S. 2016. The Gene. Page 52; Clegg, C.H. & Mackean, D.G. 1994. Advanced Biology pg. 615]

- 4.1.1 Explain your understanding of *monohybrid inheritance*. (2)
- 4.1.2 Differentiate between the terms *dominant* and *recessive*. In your explanation refer to one example from the table above. (4)
- 4.1.3 Provide THREE well-explained reasons why Mendel's experiments are regarded as an example of good scientific practice. (6)

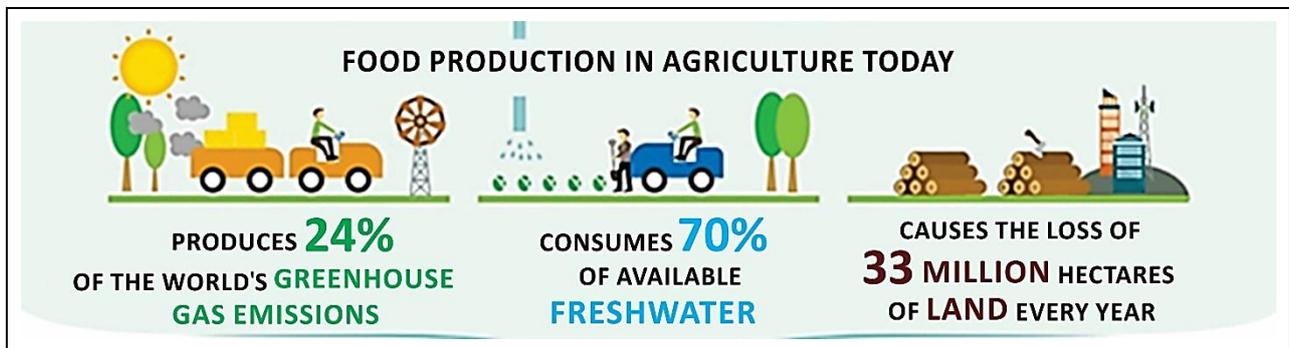
4.1.4 Read the following extract and answer the questions that follow:

On February 8, 1865 Mendel presented his work to the acclaimed Brunn Society for Natural Science. His paper, "Experiments on Plant Hybridisation," was published the following year. However, none of the scientists at the time seemed to understand the importance of this new scientific knowledge. This was because Mendel's work was very different to the current popular beliefs about inheritance. Scientists also did not use and understand the type of numerical data used by Mendel. It was only 30 years later when scientists were accustomed to keeping numerical records and analysing them statistically that Mendel's work was recognised.

[Adapted: <<https://www.nature.com>> ; Gasking, E. Journal of the History of Ideas Vol. 20, No. 1 (Jan., 1959), pp. 60–84]

- (a) Provide TWO reasons why Mendel's work was not initially accepted by the scientific community. (2)
- (b) What does this information in the extract above suggest about the way in which new scientific knowledge is accepted by scientists? (2)

4.2 The image below shows the impact of agriculture on the environment.



[Adapted: <<https://www.forum-csr.net>>]

- 4.2.1 State THREE ways in which the production of food contributes to the ecological footprint of people. (3)
- 4.2.2 Suggest why food production in more-developed countries would result in a larger ecological footprint. (2)

4.2.3 Agricultural production will need to increase by 70% by 2050 to feed a growing global population. Do you think this level of food production is sustainable? Use information from the image below and on the previous page (Question 4.2) to support your answer.

### Contribution of GMO crops

**INCREASES CROP PRODUCTIVITY**  
**MORE AFFORDABLE FOOD**  
REDUCES PRODUCTION COSTS

**CONSERVES BIODIVERSITY**  
**IMPORTANCE TO ENVIRONMENT**  
PREVENTS DEFORESTATION




**REDUCES AGRICULTURE'S ECO-FOOTPRINT**  
**LOWERS PESTICIDE USE**  
DECREASES CO<sub>2</sub> EMISSIONS

HELPS COUNTERACT CLIMATE CHANGE  
**REDUCES GREENHOUSE GASES**



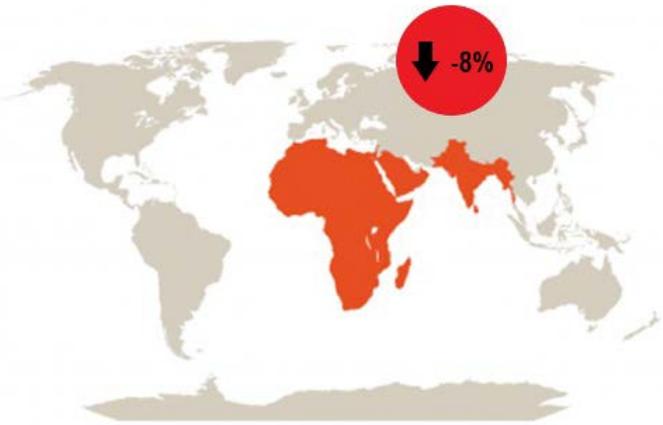
**CONTRIBUTES TO ALLEVIATION OF POVERTY AND HUNGER**  
**BETTER LIVELIHOODS FROM HIGHER YIELDS**



### The future of food and farming: 2050s

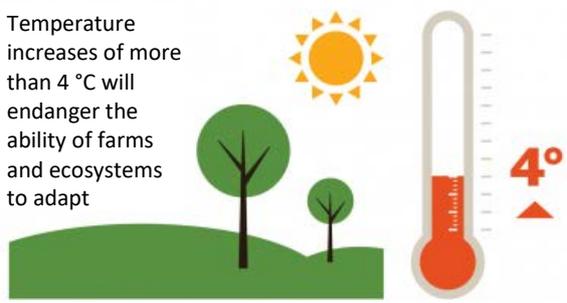
#### Widespread impact on food and farming are highly likely

Average decline in yields for eight major crops across Africa and South Asia



#### Heat and water may pass critical thresholds

Temperature increases of more than 4 °C will endanger the ability of farms and ecosystems to adapt



Water cycles will be very different and less predictable



Changes in intensity, frequency, and seasonality of rain



Sea level rises and melting glaciers

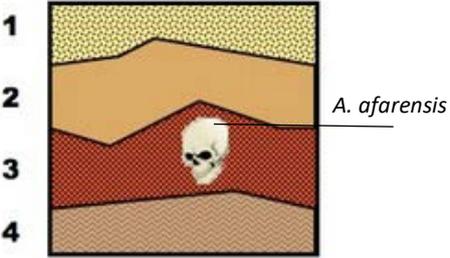
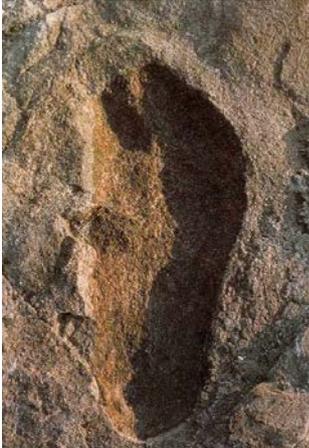


Changes in groundwater and river flows

[Adapted: <<https://www.forum-csr.net>> ; <<http://world-media-group.com>>]

(5)

4.3 Read the article below and use the information in the text and your own knowledge to answer the questions that follow:

<b>The Laetoli footprints</b>	
<p>Around 3,6 million years ago in Laetoli, Tanzania, three hominids walked through wet volcanic ash. When the nearby volcano erupted again, layers of ash covered and preserved the oldest known footprints of early hominids.</p> <p>The Laetoli footprints were most likely made by <i>Australopithecus afarensis</i>, a hominid whose fossils were found in the same sediment layer. The entire footprint trail is almost 27 metres long and includes impressions of about 70 hominid footprints.</p>	
<p style="text-align: center;"><b>Image of Laetoli footprints</b></p>  <p style="text-align: center; font-size: small;">[Source: &lt;https://www.getty.edu&gt;]</p>	<p style="text-align: center;"><b>Layers of rock</b></p> <p>Age (m.y.a.)</p>  <p style="text-align: center; font-size: small;">[Adapted: &lt;http://www.vce.bioninja.com.au&gt;]</p>
<p style="text-align: center;"><b>Close up of footprint</b></p>  <p style="text-align: center; font-size: small;">[Source: &lt;https://za.pinterest.com&gt;]</p>	

[Adapted: <http://humanorigins.si.edu>]

- 4.3.1 Suggest TWO pieces of evidence from the sources that scientists could use to determine that the Laetoli footprints were made by *Australopithecus afarensis*. (2)
- 4.3.2 Discuss how the position of the big toe in the footprint could indicate whether the foot of the individual was more human-like or more ape-like. (2)
- 4.3.3 Justify why the Tanzanian government should preserve and protect the site of the Laetoli footprints. (2)

4.4 Read the article below regarding a scientific investigation carried out by scientists on the Laetoli footprints.

An investigation was conducted by scientists at the University of Arizona to see if the individuals who made the Laetoli footprints walked using a human-like bipedalism or a more ape-like movement (bent-knee, bent-hip).

- The depth that the toes pressed into the ash of the preserved Laetoli footprints was measured and recorded.
- Eight human subjects were asked to walk through sand and the toe depth of their footprints was measured and recorded.
- The human subjects were then asked to mimic the walk of the apes by using a "bent-knee, bent-hip" ape-like movement through the sand. The toe depth of their footprints was measured and recorded.

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

**Graph showing toe depth of different footprints**

Type of footprint	Toe depth (cm)
Bent-knee, bent-hip walk by human	6
Normal walk by human	2.2
Laetoli	1.1

[Adapted: <<https://journals.plos.org>>]

- 4.4.1 Suggest a possible aim for this investigation. (2)
- 4.4.2 Identify the dependent variable of the investigation. (1)
- 4.4.3 Do the results of the investigation suggest that the hominids that left the Laetoli footprints were bipedal? Use data from the graph to support your answer. (3)
- 4.4.4 Do you think this investigation is a realistic way to determine the relationship between bipedalism and footprint appearance? Explain your answer. (2)

[40]

**Total: 200 marks**