2027.M44S2

2027L025A1ES2

Coimisiún na Scrúduithe Stáit
State Examinations Commission

Leaving Certificate Examination
Sample 2

Biology

Higher Level

2 hours 30 minutes

300 marks

Examination Number

Date of Birth ☐☐/☐☐/☐☐ For example, 3rd February 2005 is entered as 03 02 05

Centre Stamp

Instructions

There are **seven** questions on this examination paper. Each question carries 50 marks.

Answer **Question 1** and any **five other** questions.

Write your Examination Number and your Day, Month and Year of Birth in the boxes on the front cover.

Write your answers in blue or black pen. You may use pencil for sketches, graphs and diagrams only.

This examination booklet will be scanned and your work will be presented to an examiner on screen. All of your work should be presented in the answer areas, or on the given graphs, or diagrams. Anything that you write outside of the answer areas may not be seen by the examiner.

You are not required to use all the space provided. There is space for extra work at the back of the booklet. If you need to use it, label any extra work clearly with the question number and part.

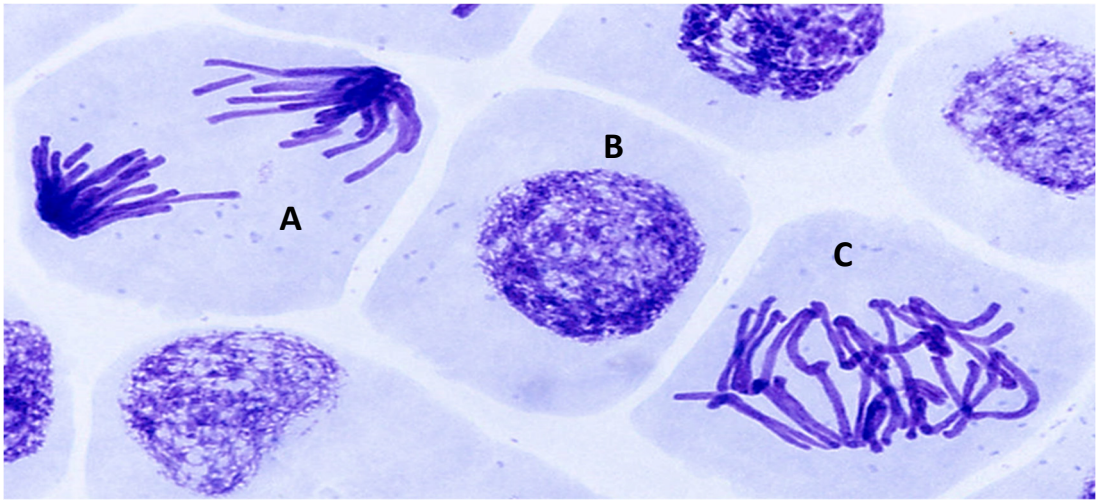
You may lose marks if your solutions do not include relevant supporting work.

You may lose marks if the appropriate units of measurement are not included, where relevant.

Question 1 is compulsory

Question 1 **50 marks**

(a) The light microscope image below is of cells in a garlic root tip at different stages in the cell cycle. Mitosis is one part of the cell cycle and is followed by cell division.
Analyse the image and answer the questions that follow.



(i) Identify **both** stages of **mitosis** that each of the cells labelled **A and C** are undergoing.

A:
C:

(ii) Identify the stage of the **cell cycle** that the cell labelled **B** is undergoing.

(iii) **On the image above**, write the letter **X** on the location of a cell membrane.

(iv) Uncontrolled cell division can lead to cancer.
Name **two** environmental risk factors that increase the chance of cancer development.

1.
2.

(b) The following experiment was carried out to investigate the effectiveness of a vaccine. Read the article and answer the questions that follow.

An international, placebo-controlled, double-blind trial was carried out to see if the vaccine was effective. A total of 43 448 people received injections: 21 720 with the vaccine and 21 728 with the placebo. Randomly assigned persons aged 16 years or older received two doses, 21 days apart, of either the placebo or the vaccine. Two doses of the vaccine gave 95% protection against the pathogen in persons 16 years of age or older.

Adapted from *Polack et al., 2020*.

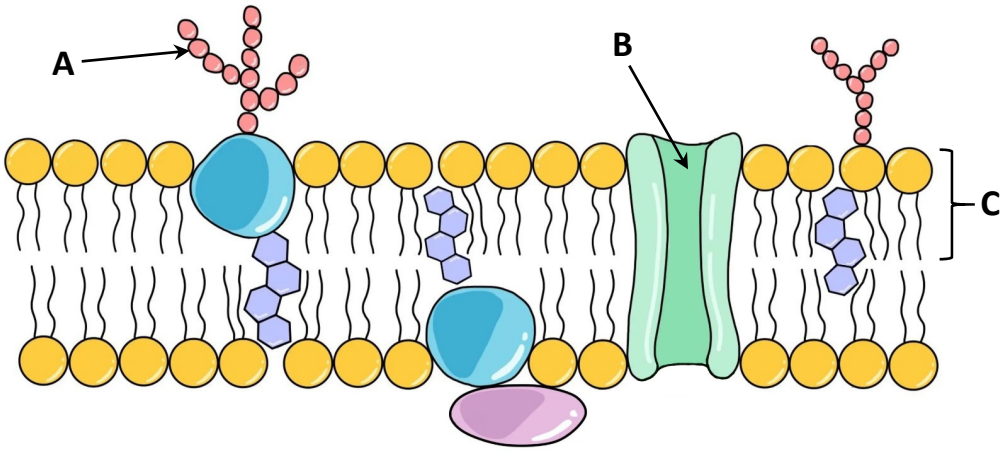
(i) Why was it important that the vaccine was tested in people from all around the world?

(ii) What does "placebo-controlled" mean in the context of this experiment?

(iii) A total of 43 448 people aged 16 years or older took part in this experiment. Comment on the sample size used in relation to the reliability of the data.

(iv) Would it be correct to conclude that this vaccine works in children under the age of 16 years? Justify your answer.

(c) The simplified diagram shown below is of the fluid mosaic model of the cell membrane, proposed by Singer and Nicolson in 1972.



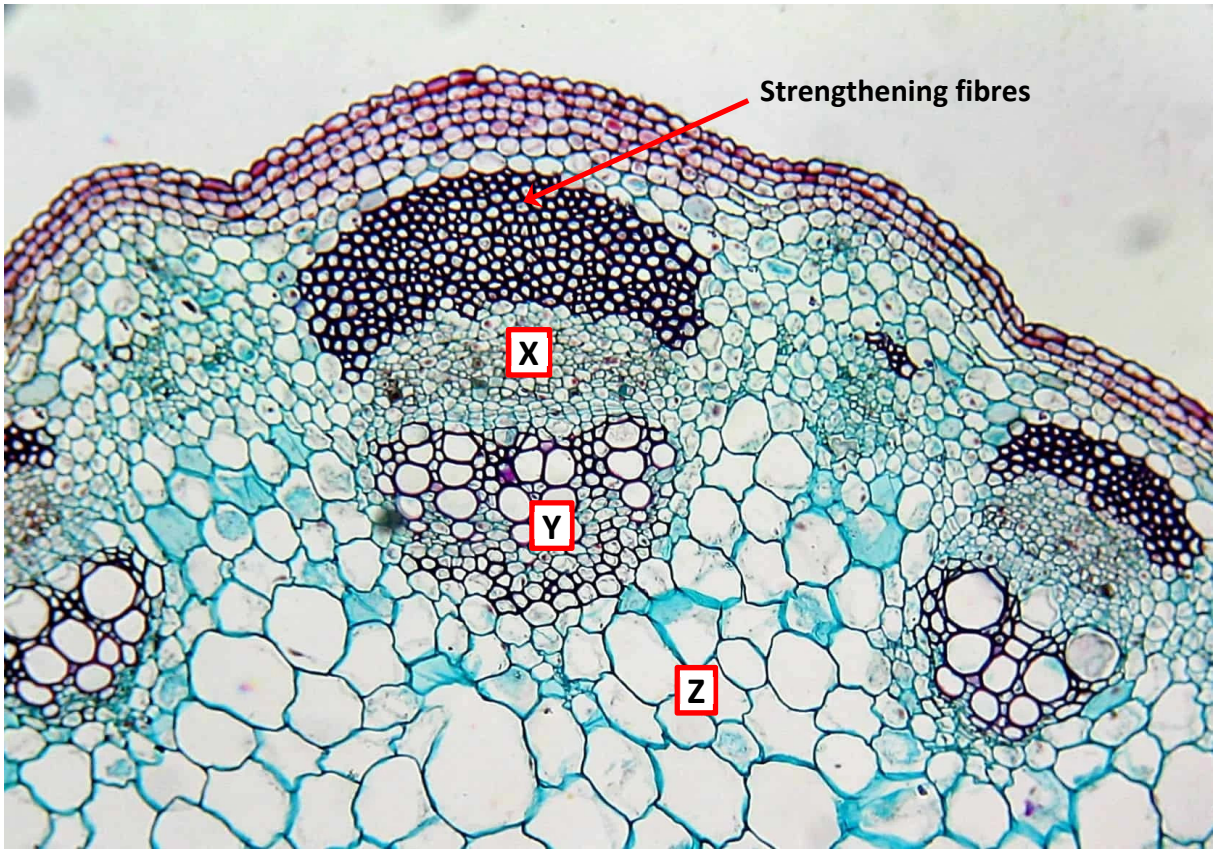
(i) Identify the part of the membrane labelled **C**.

(ii) Identify molecule **A**, which can be involved in cell signalling, such as in the immune system.

(iii) The discovery of molecule **B**, which spans the membrane, allowed Singer and Nicolson, and others to relate this molecule to an essential function of all membranes.
State this essential function.

(iv) State **one** technological development in microscopy, such as the one shown in the image that allowed for the development of the detailed structure of the cell membrane.

(d) The image below is of a plant stem as seen under a light microscope. Some of the cells in tissue **X** are involved in the movement of sucrose from the leaves towards the roots in plants.
Labels **Y and Z** also represent tissues.



(i) Name the types of tissue labelled **X**, **Y and Z**.

X:
Y:
Z:

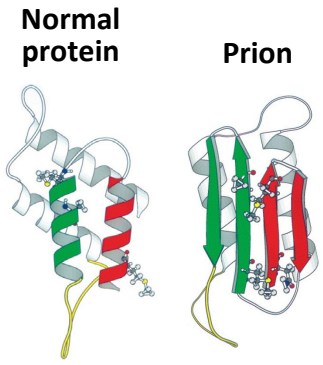
(ii) State a function of tissue **Y**.

(iii) State **one** adaptation of tissue **Y**, from the image **or** from your studies of plant structure, that allows the tissue to carry out its function.

(e) Read the following passage and answer the questions that follow.

Transmissible spongiform encephalopathies (TSEs) are a family of neurodegenerative disorders of the central nervous system (CNS) that include scrapie in sheep, bovine spongiform encephalopathy (BSE) in cattle and Creutzfeldt-Jakob disease (CJD) and variant CJD (vCJD) in humans (World Health Organisation, WHO, 2002). TSEs result from the misfolding of a particular protein called a prion, which is normally found on the nerve cell membranes in the brain.

Adapted from fsai.ie



(i) Explain why prions can be classified as pathogens.

(ii) BSE in cattle was first identified in the United Kingdom (UK) in the 1980s and the first cases of vCJD were reported in 1996.
Suggest a way in which this prion might have been transmitted from cattle to humans to cause disease.

(iii) Prions are an example of a misfolded protein.
Explain the importance of folding in proteins.

(iv) Name another non-cellular pathogen.

Answer any five questions from the following questions 2 to 7.
Each question carries 50 marks.

Question 2 **50 marks**

(a) The National Biodiversity Data Centre, as part of their Citizen Science programme, collects and records data on wild species received from members of the public. This helps to monitor the species diversity index in any given area. The data collected from County Cork (Jan - May 2024) on six different species of plants is shown in the table below.

Data from records.biodiversityireland.ie

Species name	Number recorded
Lesser Celandine (*Ficaria verna*)	46
Cuckooflower (*Cardamine pratensis*)	30
Primrose (*Primula vulgaris*)	27
Bluebell (*Hyacinthoides non-scripta*)	23
Foxglove (*Digitalis purpurea*)	10
Red Clover (*Trifolium pratense*)	9

(i) What is meant by the term *species*?

(ii) What is meant by the term *species diversity index*?

(iii) Using the data and formula, calculate the species diversity index for County Cork.

$$Species\ diversity\ index = \mathbf{1} - \frac{\mathbf{\Sigma\, n(n-1)}}{\mathbf{N(N-1)}}$$

N = Total number of organisms of all species
n = Total number of a particular species

(iv) Explain the significance of the diversity index number you calculated in part (iii).

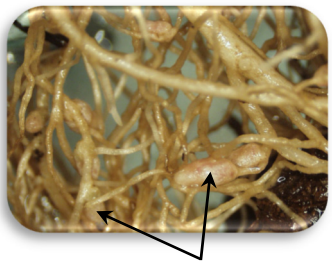
(v) A student stated that "*the number of each species recorded in the table from January to May 2024 in County Cork will not be the same if calculated over a year*".
Do you agree or disagree with this statement? Justify your answer.

(b) Read the passage below and answer the questions that follow.

Red clover is a plant that contains nodules on its roots. These nodules contain bacteria that live in a symbiotic relationship with the clover and which play an essential role in the process of nitrogen fixation during the nitrogen cycle. Farmers are encouraged to sow clovers with their grass as it helps towards environmental sustainability.

Adapted from teagasc.ie

Red clover plant



Root nodules

(i) Name the specific type of symbiotic relationship between red clover and the bacteria in the root nodules.

(ii) Name **one** other type of symbiotic relationship.

(iii) What is the significance of symbiotic relationships in nature?

(iv) Outline the importance of nutrient cycles such as the nitrogen cycle.

(v) Describe the process of nitrogen fixation during the nitrogen cycle.

(vi) Predict what you think may happen to the diversity of plants in a habitat if more clover was grown. Explain your answer.

Prediction:
Explain:

(vii) Suggest why sowing clover plants helps farmers move towards or improve environmental sustainability.

(c) Read the passage below and answer the questions that follow.

Systemic insecticides can be used in agriculture to target insects that damage commercial crops. These chemicals are often applied to the soil. They are water-soluble and can be absorbed and distributed throughout all plant tissues.

One group of insecticides called neonicotinoids are suspected of poisoning honeybees, bumblebees, and other beneficial insects. It has been shown that they interfere with insect nervous systems. These chemicals are found in the pollen and nectar that the bees collect.

Adapted from Fairbrother *et al.*, 2014.

(i) Name **two** plant organs that facilitate the absorption and transfer of insecticides from the soil water to the plant flowers.

1.
2.

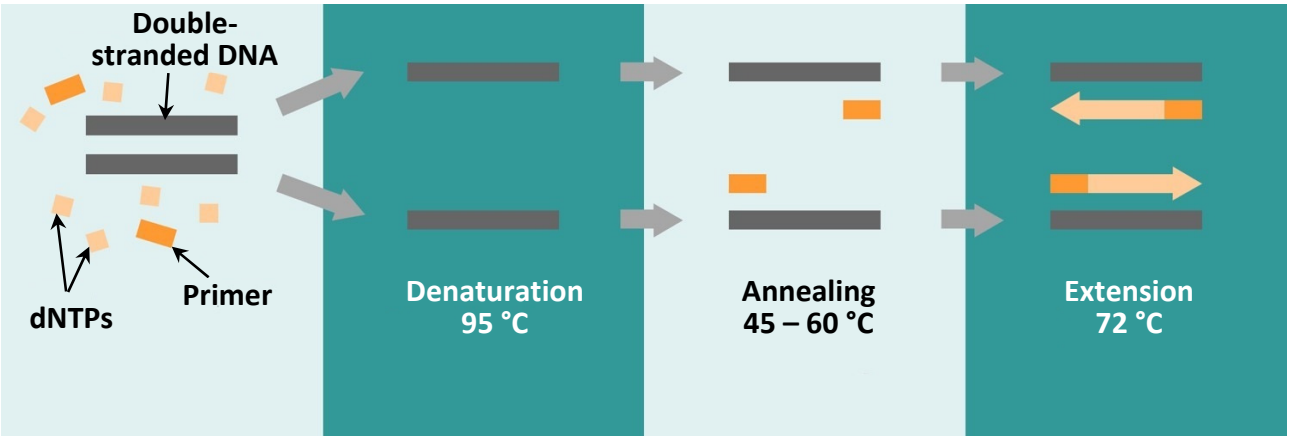
(ii) State **two** processes that allow for the uptake and transfer of water-soluble insecticides in plants.

1.
2.

(iii) **In the box below**, draw a labelled diagram of the internal structure of a flower that would be visited by a bumblebee.

Question 3 **50 marks**

(a) The diagram below shows three stages in a technique used in molecular genetics called polymerase chain reaction (PCR).



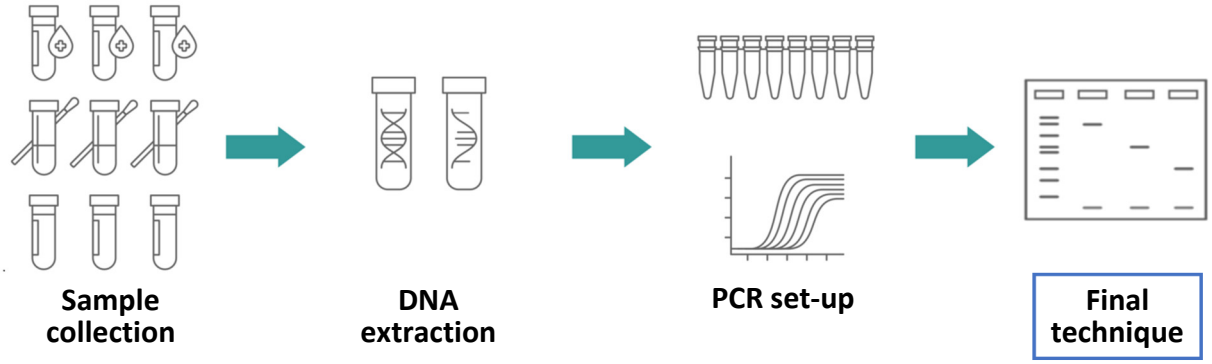
(i) Analyse the diagram and explain what is happening to the double-stranded DNA template during the denaturation or first stage of polymerase chain reaction (PCR).

Some components of PCR **shown in the diagram** include: a DNA template (double-stranded DNA), nucleotides (dNTPs), and primers (short, single-stranded sections of DNA that bind to the template DNA either side of the DNA sequence of interest).
Some components **not shown in the diagram** include: Taq polymerase (a type of DNA polymerase), pH buffer, magnesium chloride and a thermocycler machine.

(ii) **On the diagram above**, draw a circle around the temperature at which you think Taq polymerase works optimally.

(iii) A student states that: "*a pH buffer is not a necessary component for PCR*".
Do you agree or disagree with this statement?
Justify your answer.

(b) Polymerase chain reaction (PCR) is a technique used to amplify small amounts of a DNA sequence of interest, into larger more detectable quantities. The DNA must first be extracted from a sample before PCR can be carried out and the results analysed.
The main stages of this process are shown in the diagram below.

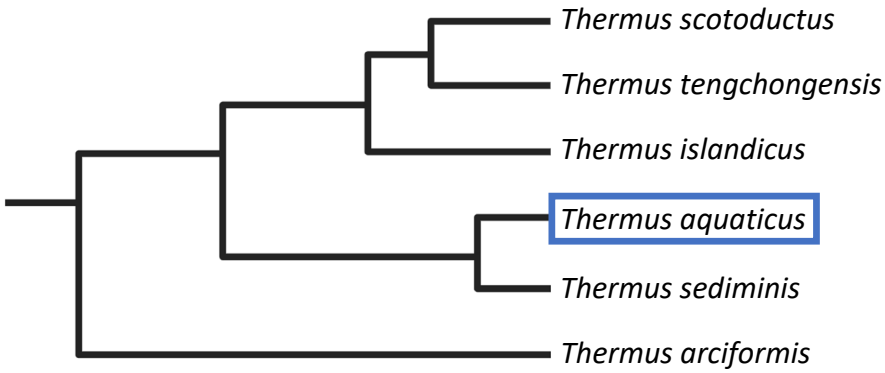


(i) Name the **final technique** shown in the diagram above that is used to separate DNA fragments.

(ii) Describe how the technique you have named at (i) above is used to separate DNA fragments.

(iii) During the **sample collection** stage, it is important to follow good laboratory practices, which always includes wearing laboratory gloves.
Suggest why the wearing of laboratory gloves is mandatory given the two steps that follow sample collection.

(c) Taq DNA polymerase was originally isolated from the bacterium *Thermus aquaticus* which was first discovered in a hot spring in Yellowstone National Park in North America in the 1960s. This enzyme can resist the high temperatures necessary in PCR.
The chart below is of a phylogenetic tree showing the evolutionary relationship between the different types of DNA polymerase from various bacterial species when compared to Taq DNA polymerase.



Adapted from Saghatelyan et al., 2021, Microbiology Open, wiley.com

(i) Name a bacterial species that is most closely related to *Thermus aquaticus*, in terms of the structure of its DNA polymerase. Explain your answer.
Note: *Thermus aquaticus* is highlighted in the chart.

Name:
Explain:

(ii) Suggest **two** ways by which the gene that codes for DNA polymerase might have evolved in the genus, *Thermus*.

1.
2.

(iii) State **two** sources of evidence, other than phylogeny, that support evolution by natural selection.

1.
2.

(d) Genome databases can be used to obtain information on genetic diseases.
The table shows an extract of information from a genome database.

Phenotype	Location of gene (chromosome)	Inheritance
Sickle cell disease	11	Autosomal recessive
Red-green colour blindness	X	X-linked
Haemophilia	X	X-linked

Sourced from www.ncbi.nlm.nih.gov

(i) Explain the term *inheritance*.

(ii) What does 'X-linked' mean?

(iii) What chromosome number is the sickle cell disease allele present on?

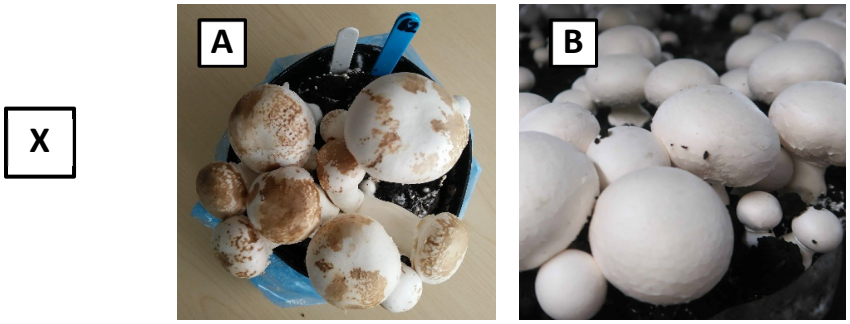
(iv) Name a sector of society that could make use of the genetic data access that genome databases provide **and** suggest how access to this data is of use to this sector of society.

Name:
Suggest:

(v) Discuss **one** possible ethical issue in relation to advancements in genetic technologies.

Question 4 **50 marks**

(a) Image **A** shows the interaction between the bacterium *Pseudomonas fluorescens* and the button mushroom *Agaricus bisporus*. The bacterium causes blotches on the mushrooms. Image **B** shows unaffected button mushrooms.



(i) **On the image above**, draw an arrow from the letter **X** to the location of the bacteria growing on the button mushroom in image **A**.

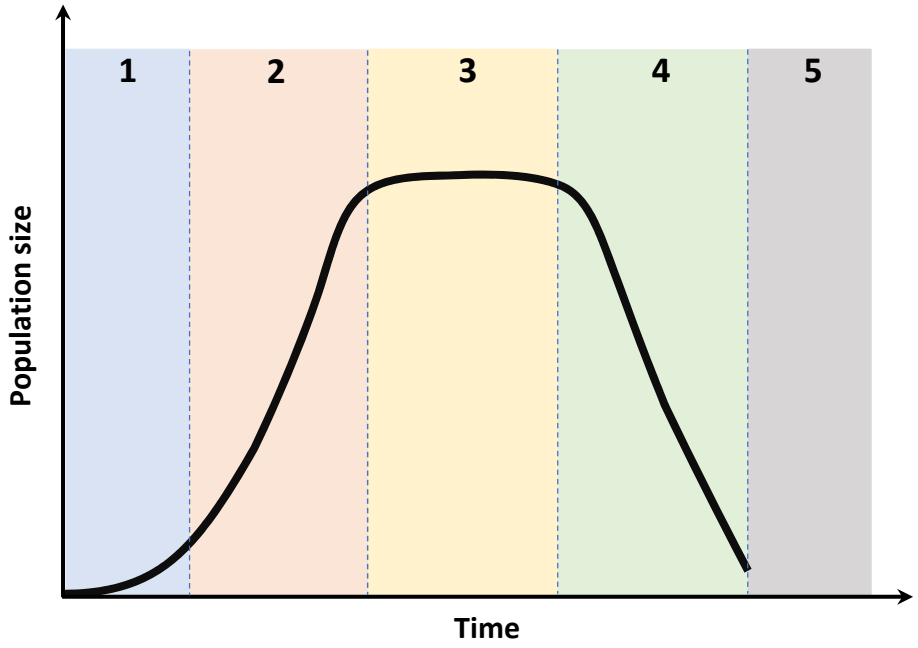
(ii) Draw a labelled diagram of a bacterial cell in the box below.

Labelled diagram:

(iii) Distinguish briefly between bacteria **and** fungi in terms of cellular nature **and** nutrition.

Organism	Cellular nature	Nutrition
Bacteria		
Fungi		

(b) The graph below shows a growth curve for one species of bacteria grown in a bioreactor. The majority of bacteria follow this growth curve, but some species can enter a fifth phase, not shown on the graph.



(i) Identify the **four** phases (**1**, **2**, **3 and 4**) of the bacterial growth curve shown on the graph above.

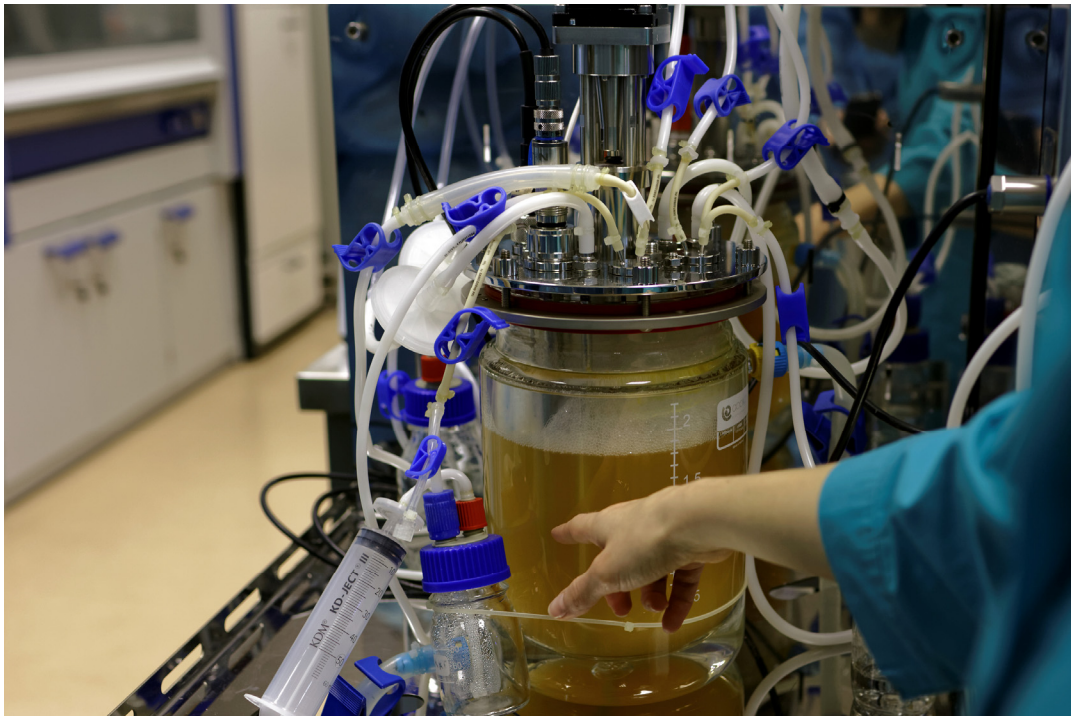
1.
2.
3.
4.

(ii) **By drawing on the growth curve above**, complete the line showing the fifth phase that some species of bacteria can enter.

(iii) State the name given to this fifth phase of the growth curve.

(iv) What structure forms in bacteria that allows them to enter the fifth phase of the growth curve?

(c) The image below is of a bioreactor that can be used in bioprocessing with microorganisms in the pharmaceutical industry.



(i) There are sensor probes in the bioreactor that detect and measure factors that influence the growth of microorganisms.
State any **two** factors that influence the growth of microorganisms.

1.
2.

(ii) Explain how **one** of the factors you have given at (i) above affects the growth of microorganisms.

(iii) **Other than the pharmaceutical industry**, identify **two** industries where microorganisms are used to produce substances of use to humans.

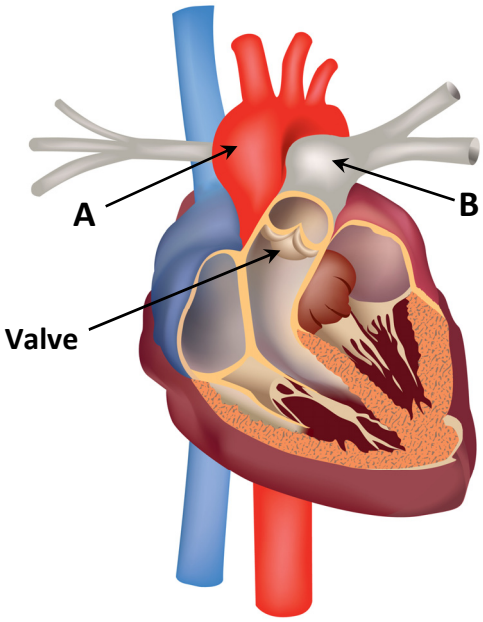
1.
2.

(d) Describe an activity you carried out in the laboratory to investigate **one** factor that affects the growth of microorganisms. You may use a labelled diagram if you wish.

Labelled diagram:

Question 5 **50 marks**

(a) The diagram shows the internal structure of the human heart.



(i) Identify the blood vessels labelled **A** and **B**.

A:
B:

(ii) What happens to the valve labelled in the diagram when the ventricles contract?

(iii) **On the diagram**, draw an **X** where the pacemaker is located.

(iv) Describe how the carbon dioxide concentration in blood plasma varies between blood vessels **A** and **B**.

(v) **In the space below**, model **one** structural difference between an artery **and** a vein, by describing the difference **and/or** drawing a labelled diagram.

Labelled diagram:

(b) The transport of materials within humans is carried out using a two-circuit circulatory system.

(i) Identify **both** circuits.

1.
2.

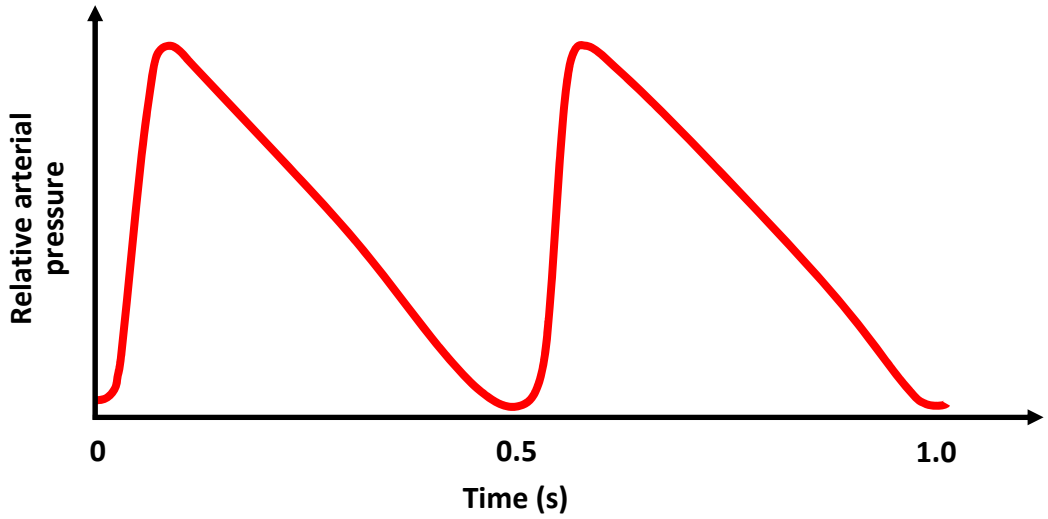
(ii) Describe the pathway of blood circulation in **one** of these circuits.

Named pathway:

(iii) Describe what may happen to the heart when a coronary artery becomes completely blocked.

(iv) Explain the term *blood pressure*.

(c) The graph below shows the change in arterial blood pressure of an athlete over two consecutive heartbeats.
Analyse the graph and answer the questions that follow.



(i) **On the graph above**, write the letter **X** to indicate a point in time during which the left ventricle is contracting.

(ii) Using the information given on the graph above, calculate the heart rate in beats per minute (bpm) of the athlete.

Calculation:

(iii) Does the graph shown above represent an athlete at rest? Justify your answer.

(d) **(i)** Explain why cardiac muscle cells have large numbers of mitochondria.

(ii) **In the space below**, model how an antagonistic muscle pair functions in the movement of a synovial joint by providing a description **and**/**or** drawing a labelled diagram.

Labelled diagram:

Question 6 **50 marks**

(a) Read the passage below and answer the questions that follow.

The Venus flytrap (*Dionaea muscipula*) is a plant that catches and digests insects. It is native to North and South Carolina in America, where it is common in damp mossy and boggy areas.

Venus flytraps do not rely on digesting insects for energy, but rather use the nitrogen-rich animal proteins to enable their survival in poor soil conditions.

The plant's leaves have spiny 'teeth' along their edges and can fold together and enclose an insect landing inside. This action is triggered by pressure on sensitive hairs in each leaf. Glands on the leaf surface then secrete a red sap that digests the insect's body.

Adapted from National Wildlife Federation, nwf.org

(i) Suggest a reason why the Venus flytrap must consume insects.

(ii) Why do you think Venus flytraps do not rely on insects for energy?

(iii) Identify a structural adaptation that allows the Venus flytrap to survive in its habitat.

(iv) State a biotic factor that can influence the population size of the Venus flytrap.

(v) Do you think that climate warming will endanger this plant population? Justify your answer.

Yes		No	

(vi) Bogs, where the Venus flytrap can be found, are one example of a carbon sink. List **two** other examples of carbon sinks.

1.

2.

(vii) Draw a labelled diagram of the **carbon cycle**.

Labelled diagram:

(b) Light intensity is one factor that can affect the rate of photosynthesis. The table below shows the results from a student's investigation into the effect of light intensity on the rate of photosynthesis of an aquatic plant. The light intensity was varied by placing a desk lamp at various distances away from the plant.

Distance (d) of lamp from plant in metres	1	0.8	0.6	0.4	0.2
Light intensity ($1/d^2$)					25
Rate of photosynthesis (Number of bubbles of gas counted per min)	10	15	18	25	25

(i) Complete the table of results to show all the light intensities.

Calculations:

(ii) **In the space below**, draw a **line** graph of the student's results.

(iii) Analyse the data and state a conclusion for the investigation.

(iv) Identify **one** variable that would need to be controlled in this investigation to increase the reliability of the data.

(c) Describe the **non-cyclic pathway** of the light dependent reactions of photosynthesis.
You may use a labelled diagram if you wish.

Labelled diagram:

Question 7 **50 marks**

(a) Three types of biomolecule include lipids, carbohydrates and proteins.

(i) **Complete the table below**, by writing **Lipid or Carbohydrate or Protein** into **each** box to match the molecular formula to its corresponding biomolecule.

A	B	C
$C_9H_{14}N_4O_3$	$CH_3(CH_2)_n COOH$	$C_6H_{12}O_6$

(ii) State a reason to support your answers in (i) above.

Reason for A:
Reason for B:
Reason for C:

(iii) Identify **two** nutritional sources of lipids.

1.
2.

(iv) Proteins are used by cells to carry out certain metabolic reactions.
State **two** examples of proteins that have roles in metabolic reactions.

1.
2.

(b) A fizzy drink (red lemonade) containing **2 %** (2 g/100 cm^3) glucose solution was used to prepare different concentrations of glucose solutions as shown in the table below.

% glucose concentration	2	1	0.5	0.25	0.125	0
Colour of red lemonade in cups						

Students were given these solutions in **unmarked cups** and asked to use glucose test strips to quantitatively investigate the level of glucose in the unknown samples.

The colour chart for glucose on the test strip bottle used by the students is shown in the table below.

Analyse the data and answer the questions that follow.

% glucose concentration	0	0.1	0.25	0.5	1	2
Test strip bottle colour						
Colour	Blue green	Light green	Mint green	Olive brown	Medium brown	Dark brown

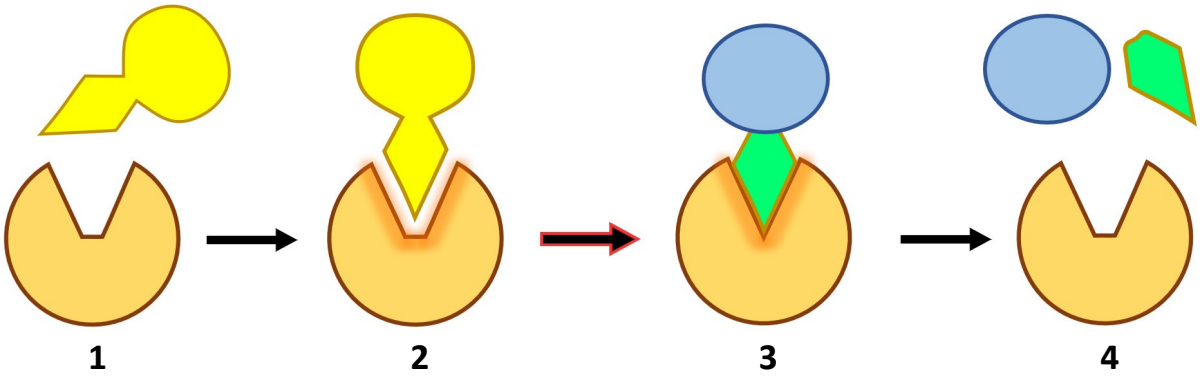
(i) How would a student know if a sample they tested contained **1 %** glucose solution?

(ii) Would a student be able to accurately identify a **0.375 %** glucose solution using this technique? Justify your answer.

(c) Draw a labelled diagram of the human digestive system.

Labelled diagram:

(d) The human body uses enzymes to chemically digest food.
The diagram below illustrates a model of how enzymes function.



(i) Enzymes can be referred to as '*selective catalysts*'.
Explain this term based on your knowledge of enzymes.

(ii) Using the diagram above, explain how enzymes function in catalysing biochemical reactions.
In your answer refer to the events that take place at **each** numbered stage in the diagram above.

Additional writing space.
Label all work clearly with the question number and part.

Additional writing space.
Label all work clearly with the question number and part.

Additional graph paper.
Label all work clearly with the question number and part.

Acknowledgements:

Images/graphs/diagrams:

Image on page 3:	Adapted from Josef Reischig, wikimedia.org
Image on page 4:	alamy.com
Diagram on page 5:	Adapted from bioninja.com.au
Image on page 5:	dreamstime.com
Image on page 6:	© Ross E. Koning, *Morphology and Anatomy of Plants*
Diagram on page 7:	Huang *et al*., 1995, Current Biology Ltd - https://tinyurl.com/3z7w7suw
Images on page 8:	dreamstime.com
Images on page 9:	Valeriy Shevtsov via istockphoto.com; Michael W. Clayton via wisc.edu
Image on page 11:	shutterstock.com
Diagram on page 12:	integra-biosciences.com
Diagram on page 13:	integra-biosciences.com
Diagram on page 14:	Adapted from Saghatelyan *et al*., 2021. Characteristics of DNA polymerase I from an extreme thermophile, *Thermus scotoductus* strain K1. Microbiology Open, wiley.com.
Images on page 16:	mycelia.be; horticulture.ahdb.org.uk
Graph on page 17:	State Examinations Commission
Image on page 18:	dreamstime.com
Diagram page 20:	dreamstime.com
Graph on page 22:	State Examinations Commission
Image on page 24:	Dugeot via pixabay.com
Images on page 29:	State Examinations Commission; dreamstime.com
Diagram on page 31:	State Examinations Commission

Texts/data:

Text on page 4:	Adapted from Polack *et al*., 2020, Safety and Efficacy of the BNT162b2 mRNA Covid-19 Vaccine, New England Journal of Medicine.
Text on page 7:	Adapted from fsai.ie
Data on page 8:	records.biodiversityireland.ie
Text on page 9:	teagasc.ie
Text on page 11:	Fairbrother *et al*., 2014, Risks of neonicotinoid insecticides to honeybees, Environmental Toxicology and Chemistry.
Data on page 15:	National Library of Medicine, National Center for Biotechnology Information, https://www.ncbi.nlm.nih.gov/
Text on page 24:	Adapted from National Wildlife Federation, nwf.org

Material may have been adapted, for the purpose of assessment, without the authors' prior consent.

Do not write on this page

Leaving Certificate Examination – Higher Level

Biology

Sample 2

2 hours 30 minutes