Anglo-Chinese Junior College

JC2 Biology Preliminary Examination
Higher 2

A Methodist Institution
(Founded 1886)

BIOLOGY **9744/01**
Paper 1 Multiple Choice 10 September 2024
1 hour

Additional Materials: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, glue or correction fluid.
Write your Name and Index number in the Answer Sheet provided.

There are **thirty** questions in this section. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this Question Paper.
The use of an approved scientific calculator is expected, where appropriate.

1 Which statement is correct according to the principles of cell theory?

A All organisms originate from a single cell.

B Cells can carry out all necessary life processes independently.

C Cells are the fundamental units of structure and function in all living organisms.

D Multicellular organisms have cells that perform specialised functions.

2 Active transport is one of the key processes that occurs across the cell surface membrane. Without it, many other processes within the organism cannot occur.

Which statements accurately describe the features of active transport across a cell surface membrane?

1 It can move substances against their concentration gradients.

2 It relies solely on the diffusion process without any energy expenditure.

3 It involves the hydrolysis of ATP for energy.

4 It only occurs when the external concentration of the substance is higher than its internal concentration.

A 1, 2 and 3

B 1 and 3 only

C 2 and 4 only

D 3 and 4 only

3 Which statement can explain how viruses challenge the concepts of what is considered living?

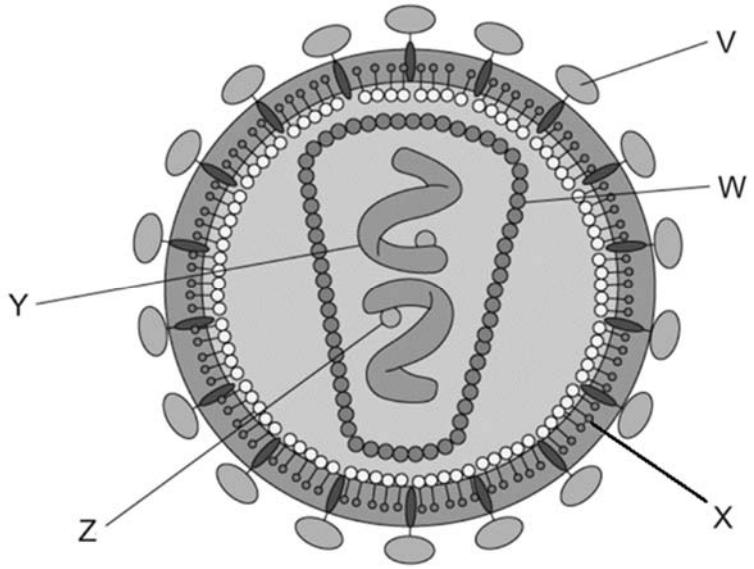
A They are much smaller than most cells.

B They can reproduce when they infect host cells.

C They have enzymes which are not active outside a host cell.

D They have their own genetic material which codes for viral proteins.

4 The diagram represents the structure of the human immunodeficiency virus (HIV).



Which statements are correct for components V, W, X, Y and Z in HIV?

1 V, W, X and Z are only made of amino acids while Y is made of ribonucleotides.

2 V and X are prevented from undergoing 3D conformational change when an inhibitor binds to CD4 receptor on host cell.

3 W protects the two identical positive-sense RNA molecules which will be reverse transcribed by Z.

4 Y contains genes which code for proteins in HIV, including one that cleaves polyproteins into individual functional proteins.

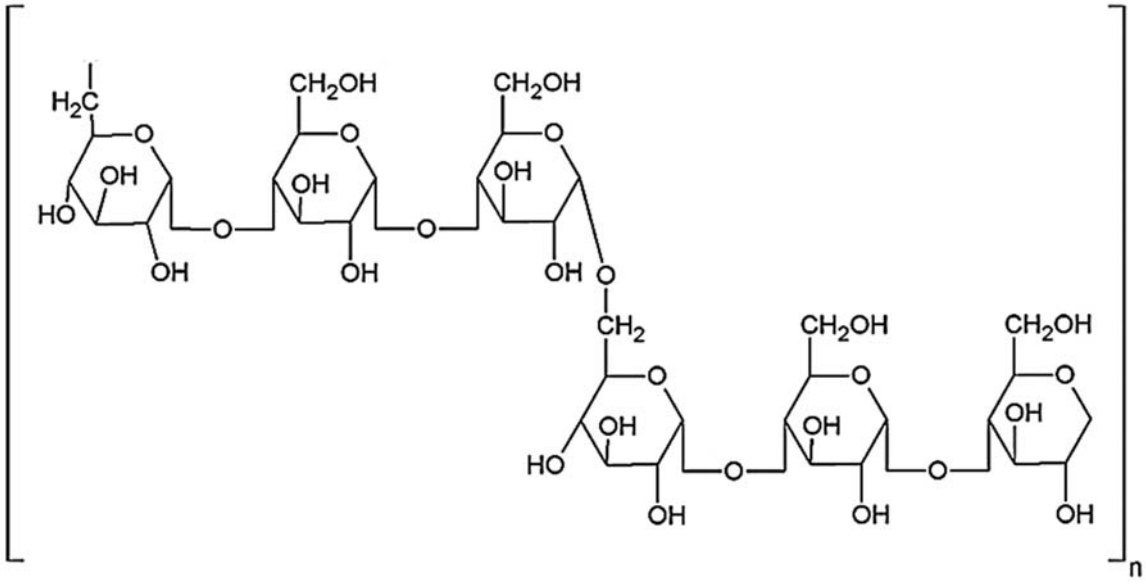
A 1, 3 and 4

B 1 and 2 only

C 2 and 3 only

D 3 and 4 only

5 Pullulan is a polysaccharide. The diagram shows the repeating unit present in pullulan.



Which row correctly identifies characteristics that are present in molecules of pullulan?

	OH group attached to the anomeric carbon is below the plane of the ring	presence of 1,6 glycosidic bond
A	✓	✓
B	×	×
C	×	✓
D	✓	×

key

✓ = true

× = **not** true

6 Reelin is a glycoprotein that plays a critical role in the development of the nervous system. Its structure and function can be influenced by various factors, including temperature and pH. The structural integrity of reelin is essential for its interaction with its receptors and subsequent signalling pathways.

Which statements describe the effects of temperature or pH on reelin?

1 Increasing the temperature can cause partial unfolding of reelin, exposing hydrophobic regions that can lead to aggregation and loss of function.

2 Decreasing the pH can result in protonation of amino acid side chains, disrupting ionic interactions and causing a conformational change in reelin.

3 Significant increases in temperature above the optimum can improve the ability of reelin to interact with receptors by transiently exposing binding sites.

4 Changes in pH can lead to the ionisation of groups on the oligosaccharides of reelin, thereby altering its stability and receptor binding affinity.

A 1 and 2

B 1 and 4

C 2 and 3

D 3 and 4

7 An enzyme is known for its ability to cleave peptide bonds in proteins. A specific region of this enzyme contains specific amino acid residues that interact with the peptide bonds in other proteins, allowing for precise cleavage.

Which statement describes how other proteins bind to the enzyme for them to undergo precise cleavage?

A Hydrophobic interactions between non-polar residues at the active site of the enzyme promote enzyme-substrate binding, altering the overall energy change of the reaction.

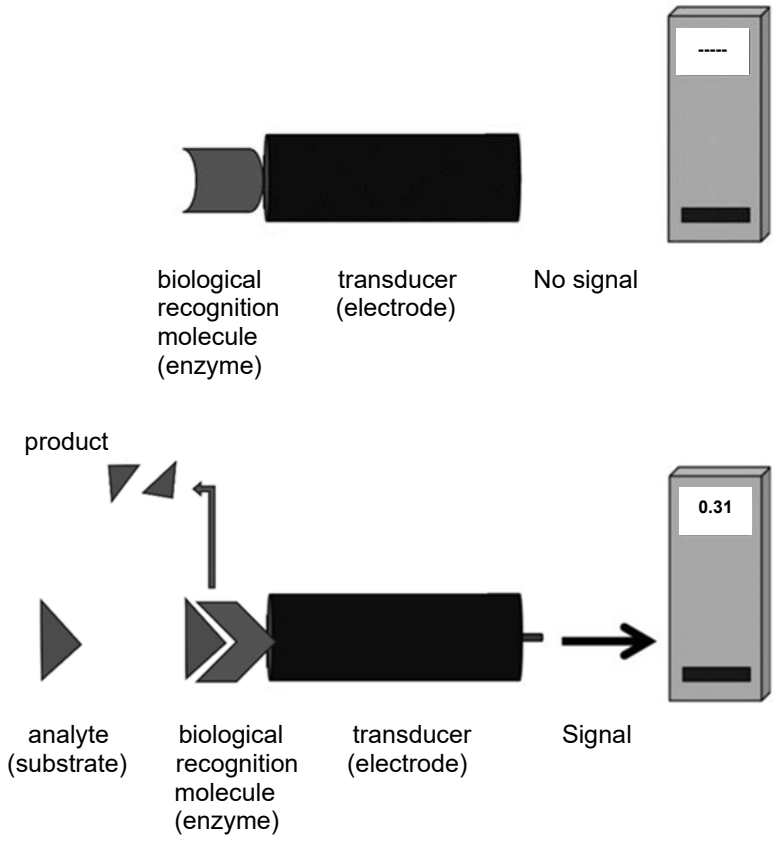
B Ionic interactions between polar residues at the active site of the enzyme and the protein substrate increase the rate of enzyme-substrate complex formation.

C The protein substrate undergoes a change in 3D conformation, leading to an induced-fit that adjusts the conformation of the active site of the enzyme.

D The active site of the enzyme forms a complementary conformation that specifically accommodates the peptide bonds of the protein substrate.

8 Enzyme-based biosensors in the food industry are used to analyse nutrients and detect natural toxins. They can also be used to determine the level of pesticides, proteins and fatty acids found in food. In a biosensor, enzymes are immobilised on the transducer. The products of the reaction will detach from the biosensor.

The diagram shows how an enzyme molecule interacts with its substrate (the analyte) in a biosensor.



Which statement is consistent with the above information?

A The enzymes can be reused before the products are removed.

B The enzymes undergo a 3D conformational change that stimulates the transducer.

C The substrates interact directly with the transducer and interfere with the reading.

D The transducer detects the change in the concentration of the products.

9 Which statement is a common feature of rRNA, tRNA and mRNA?

A They are made up of ribose sugars, nitrogenous bases and phosphate groups.

B They are products of transcription and used as templates in translation.

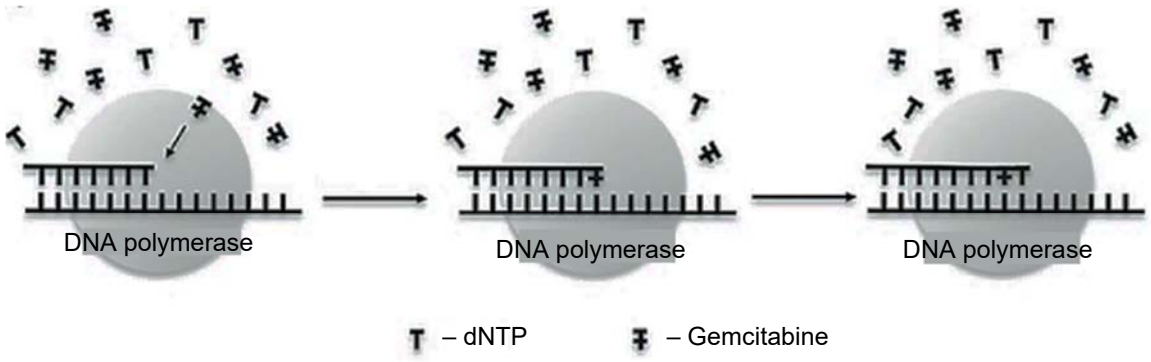
C They can form phosphodiester bonds between complementary bases.

D They each have a 1:1 ratio of pyrimidine and purine bases.

10 Gemcitabine is a chemotherapy drug used in the treatment of cancer, such as bladder and breast cancer.

Gemcitabine is structurally similar to deoxycytidine, which has cytosine attached to the deoxyribose sugar via a glycosidic bond. When Gemcitabine is incorporated into DNA during DNA replication, a single deoxyribonucleotide is added next. This non-terminal position of Gemcitabine makes DNA polymerases unable to proceed, terminating DNA replication. The addition of an extra nucleotide hides the incorporated Gemcitabine from enzymes that could excise Gemcitabine from DNA to reverse its effect on DNA synthesis.

The diagram shows the mechanism of action of Gemcitabine.



Which statement about Gemcitabine is correct?

A It binds to and inhibits the action of DNA repair enzymes.

B It is hydrophilic and does not readily cross the cell membrane by simple diffusion.

C It is structurally similar to a purine.

D It results in cell cycle arrest at M phase and programmed cell death.

11 Translation did not occur successfully in a eukaryotic organism. The structures in the cell are analysed and the results are shown in the table.

structure	presence
free floating aminoacyl-tRNAs	yes
complex of mRNA and small ribosomal subunit	yes
initiator tRNA based paired with AUG codon on mRNA in the P-site of large ribosomal subunit	yes
second aminoacyl-tRNA in the A-site of large ribosomal subunit	yes
free polypeptide chain	no

How many statements are possible explanations for these observations?

1 Aminoacyl-tRNA synthetases are non-functional.

2 mRNA fails to align at the ribosome.

3 Peptidyl transferase is non-functional.

4 Release factor protein fails to hydrolyse polypeptide chain from the mRNA.

A 1 **B** 2 **C** 3 **D** 4

12 Transformation is the process by which foreign DNA is introduced into a cell. Transformation occurs naturally in some species of bacteria.

The five events of this process are listed. The events are not listed in the correct sequence.

1 The double-stranded DNA is converted to single-stranded DNA as it passes through the bacterial cell surface membrane.

2 The DNA replaces a corresponding region of the chromosome via homologous recombination in the recipient cell.

3 A donor bacterium undergoes cell death and releases its DNA into the surroundings.

4 The DNA binds to a channel protein on the surface of the recipient bacterial cell.

5 The DNA is bound by proteins that protect it from nucleases in the cytoplasm.

What is the correct sequence of steps for this transformation process in bacteria?

A 1 → 3 → 5 → 4 → 2

B 1 → 4 → 5 → 2 → 3

C 3 → 4 → 1 → 5 → 2

D 3 → 5 → 4 → 2 → 1

13 DNA samples were taken from five individuals and analysed using gel electrophoresis to produce a DNA profile. The diagram shows the DNA profile for one gene.

What may be concluded from these results?

A 60% of the individuals are homozygous for the gene locus.

B For individual 5, the DNA fragment nearer to the positive electrode was inherited maternally.

C Individuals 1 and 2 exhibit the homozygous dominant phenotype for this gene.

D The DNA in the two bands of individual 3 has the same number of bases.

14 Which statements about control elements are correct?

1 All control elements are located upstream of the transcription start site.

2 Regulatory proteins can bind to control elements, resulting in changes in the expression of genes in the cell.

3 Control elements are non-coding DNA and exist as heterochromatin in the cell.

4 General transcription factors are the only proteins that can bind to control elements to regulate gene expression.

A 1, 2 and 4

B 1 and 3 only

C 3 and 4 only

D 2 only

15 eIF2α is a eukaryotic initiation factor which plays a crucial role in the initiation of translation. It is part of the eIF2 complex, which is responsible for delivering the initiator methionyl-tRNA to the ribosome, thereby enabling the assembly of the translation initiation complex. Under normal conditions in the cell, eIF2α protein kinase is inactive.

When cells experience stress conditions such as the accumulation of misfolded proteins in the rough endoplasmic reticulum, eIF2α protein kinase is activated. Active eIF2α protein kinase will add a phosphate group to eIF2α.

The phosphorylated eIF2α forms a complex with eIF2B and inhibits its function. eIF2B normally catalyses the exchange of GDP bound to eIF2 for GTP. This exchange is crucial as only the GTP-bound form of eIF2 can participate in the initiation of translation to deliver the initiator methionyl-tRNA to the ribosome.

Which statement is consistent with this information?

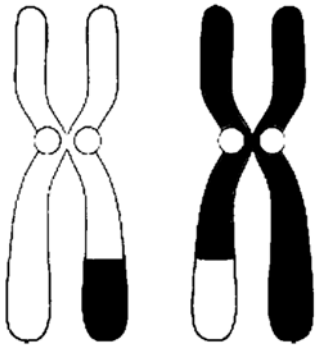
A Initiator methionyl-tRNA is not delivered to the ribosome under normal conditions in the cell.

B Phosphorylated eIF2α binds to eIF2B, preventing the phosphorylation of GDP to GTP on eIF2 and this reduces the rate of mRNA translation in the cell.

C The eIF2α-eIF2B complex is recognised by proteasomes for degradation as it has been tagged by the phosphate group.

D Rate of mRNA translation is low under stress conditions as the eIF2α-eIF2B complex is present in the cell.

16 The diagram shows a pair of homologous chromosomes.



Which events could explain the presence of these chromosomes in a cell?

1 Semi-conservative DNA replication at S phase

2 Replication of centrioles during G_2 phase

3 Crossing-over between non-sister chromatids of homologous chromosomes at prophase I

4 Independent assortment of homologous chromosomes at metaphase I

A 1, 2, 3 and 4

B 1, 3 and 4 only

C 1 and 3 only

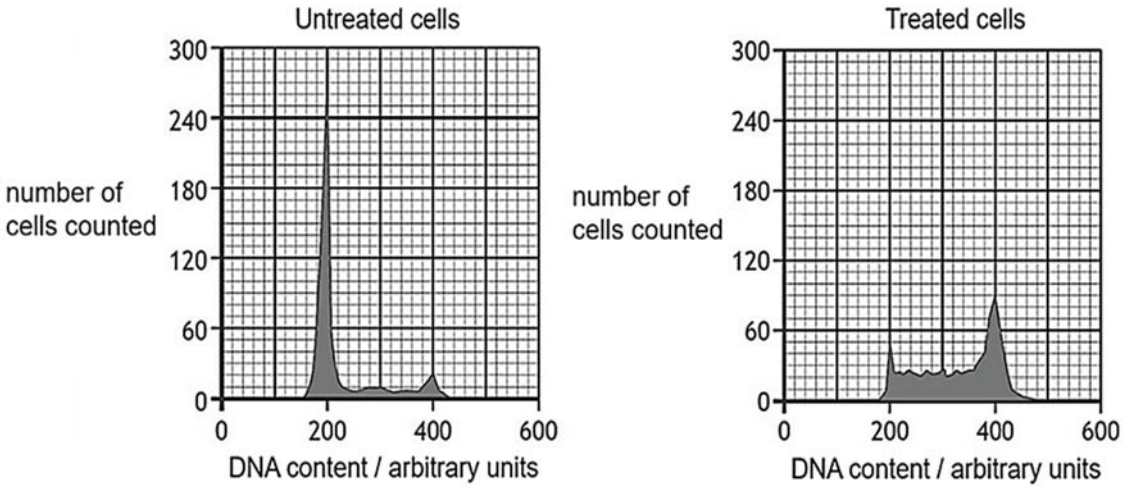
D 3 and 4 only

17 A study was carried out to investigate the effect of wild ginger extract on initiating apoptosis in colon cancer cells. The distribution of the cancer cells across the different phases of the cell cycle was then investigated by measuring the DNA content of the cells.

- Cultures of cells were treated with 10 μg cm^{-3} ginger extract or left untreated for 24 hours as a control.

- A DNA content of 200 arbitrary units represents that of a non-dividing diploid cell.

The graphs show the results for untreated and treated cells.



Which conclusion is consistent with the results?

A Cells treated with wild ginger extract are arrested at the G_2 checkpoint.

B Apoptosis is not initiated in treated cells as the DNA damage is not significant enough.

C Untreated cells show an increased number of cells in the S phase compared to treated cells.

D Untreated cells did not divide at all.

18 In one variety of cucumber plant, two different genes control the shape of the leaves and the number of spines on the fruit respectively. Allele H results in normal leaves and allele h results in heart-shaped leaves. Allele F results in few spines on the fruit and allele f results in many spines on the fruit.

A farmer collected two cucumber plants, 1 and 2, which were produced from crosses between different pure-breeding plants in his garden. Both have normal leaves and fruits with few spines. He conducted a test cross on each plant. The table shows the results of these crosses.

phenotype	observed numbers	
	cross with plant 1	cross with plant 2
heart-shaped leaves and many spines	122	2
normal-shaped leaves and many spines	6	82
heart-shaped leaves and few spines	4	85
normal-shaped leaves and few spines	124	4

Which statement can be supported by these results?

A The two genes are found on different chromosomes.

B The two genes in plant 2 assort independently during meiosis.

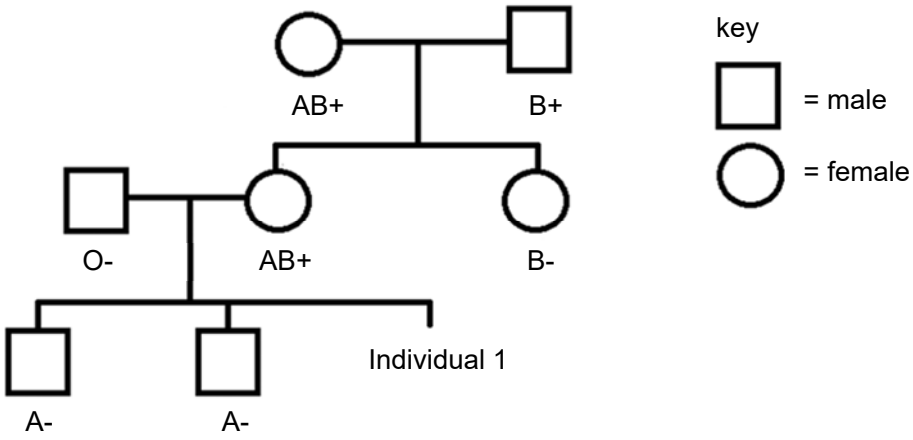
C The two genes are linked and they are located far apart on the chromosome.

D In plant 1, the dominant alleles H and F are linked on one chromosome and the recessive alleles h and f are linked on the other chromosome.

[Turn over

19 The diagram shows the inheritance of blood types at two different autosomal gene loci, the ABO blood group and the Rhesus blood group, in a family.

An individual denoted AB+ has AB blood type and is Rhesus positive, while an individual denoted B- has B blood type and is Rhesus negative.



What is the probability that Individual 1 will be a girl with blood group A and is Rhesus positive?

A 1 in 2

B 1 in 4

C 1 in 8

D 1 in 16

20 Genetic variations are classified either as continuous or discontinuous.

Which statement explains why there is a range of phenotypes for continuous variation?

A Continuous variation results in the population displaying a normal distribution.

B Expression of the phenotypes is relatively unaffected by environmental factors.

C The differences between individuals of a species are quantitative.

D The range typically results from the combined effects of multiple genes, each having two or more alleles.

21 Which statements about limiting factors in photosynthesis are correct?

1 With lower concentrations of chlorophyll, less light is absorbed by the photosystems, leading to lower rate of photophosphorylation.

2 At low light intensity, the rate of photosynthesis increases linearly with increasing light intensity.

3 Carbon dioxide is a limiting factor only when the rate of photosynthesis increases after its concentration changes.

4 Limiting factors such as temperature can only be increased to affect the rate of photosynthesis.

A 1, 2, 3 and 4

B 1, 2 and 3 only

C 1 and 2 only

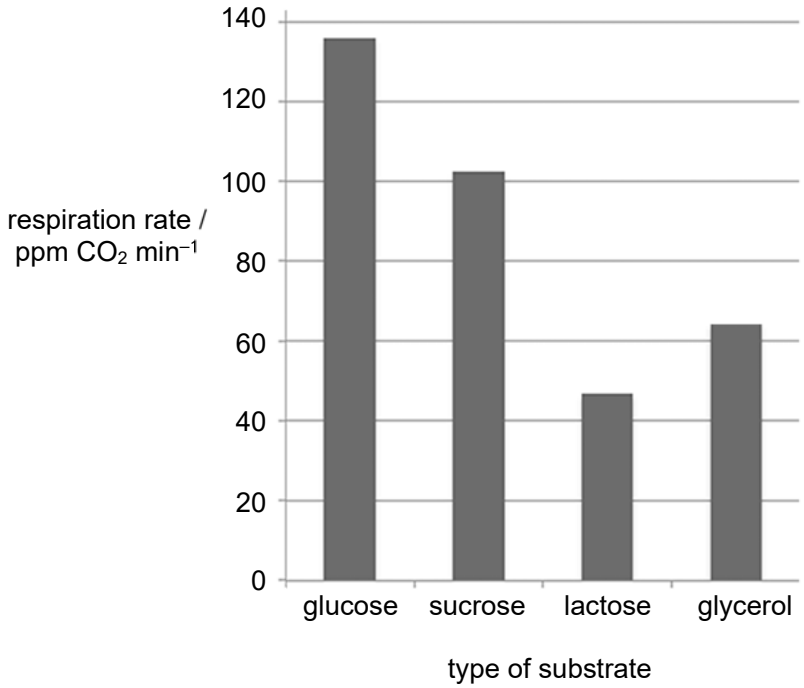
D 3 and 4 only

22 Anaerobic respiration comprises glycolysis and fermentation. Depending on the organism, either alcoholic or lactate fermentation can occur during anaerobic respiration.

Which row correctly identifies molecules that are produced during each stage of anaerobic respiration?

	glycolysis	alcoholic fermentation	lactate fermentation
A	glucose	ethanal	lactic acid
B	pyruvate	reduced NAD	lactic acid
C	ATP	NAD	reduced NAD
D	reduced NAD	ethanol	NAD

23 The graph shows the rate of respiration in yeast when different substrates are added to the culture media.



Which statement can be concluded from the data in the graph?

A The respiration rate in yeast cells is 1.4 times higher when glycerol is used instead of lactose.

B If glycerol and lactose were added together, the respiration rate will be comparable to when only sucrose is added.

C The respiration rate is lower when lactose is added as compared to sucrose because yeast cells do not metabolise lactose.

D If both glucose and sucrose were to be added simultaneously, the respiration rate will be 238 ppm CO_2 min^{-1}.

24 Which statement about G-protein linked receptors is correct?

A G-protein linked receptors in the human body have the same 3D conformation.

B Mutation in the gene coding for G-protein linked receptor may result in G-protein not binding to the intracellular region of the receptor.

C Seven different polypeptides aggregate to form the seven transmembrane alpha helices of the G-protein linked receptor.

D Upon binding to a ligand, an activated G-protein linked receptor can act as a transcription factor and bind to DNA to regulate gene expression.

25 Which statement is true for all examples of microevolution?

A Microevolutionary changes are beneficial to a species.

B Microevolutionary changes occur over many generations.

C Natural selection leads to microevolutionary changes.

D The percentage of individuals carrying a particular allele changes.

26 A study was conducted to investigate the effect of radiation on biodiversity after the 1986 Chernobyl nuclear power plant explosion. A total of 189 adult male Eastern tree frogs were collected from the affected region. Some of the frogs were collected from different locations within the exclusion zone, which has the highest radiation levels in the world, and it forms a circle around the power plant with a radius of approximately 30 kilometers. Some of the frogs were collected from outside the exclusion zone which has no radioactive pollution.

The collected frogs were brought back to the laboratory and their colours were determined based on luminance. Luminance describes the perceived brightness of an object. The higher the luminance, the lighter in colour the frog. A frog with 0% luminance would be black, and a frog with 100% luminance would be white. Frogs with darker skin coloration contained high levels of melanin. The scientists observed that frogs within the exclusion zone had skin luminance ranging from 4.2% to 45.6% whereas those outside the zone had luminance ranging from 22.4% to 63.9%.

What can be concluded from this study?

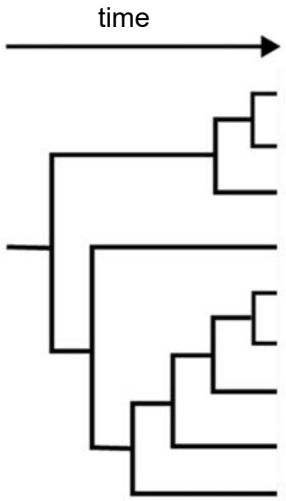
A The melanin protected the darker frogs in the exclusion zone from the high levels of radiation.

B Frogs found within the exclusion zone have a higher level of melanin than frogs found outside the exclusion zone.

C The selection pressure within the exclusion zone is the high levels of radiation.

D Frogs in other areas affected by radiation will also have higher levels of melanin.

27 The diagram shows a phylogenetic tree for various closely related species that share a common ancestor.



How many speciation events are shown in the phylogenetic tree?

A 6 **B** 7 **C** 8 **D** 9

28 Singapore's National Childhood Immunisation Schedule (NCIS) recommends all healthy children who are aged 6 months until 59 months to get yearly influenza vaccines.

The flu vaccine is formulated each influenza season as the virus that causes influenza often undergoes mutation in the gene coding for its antigenic protein.

Which statement explains why a child who has taken an outdated vaccine is susceptible to a mutated influenza virus?

A He will not have a primary immune response to the mutated antigen.

B He will not have a secondary immune response to the mutated antigen.

C His innate immune response is not specific to the mutated antigen.

D His adaptive immune response is not activated by the mutated antigen.

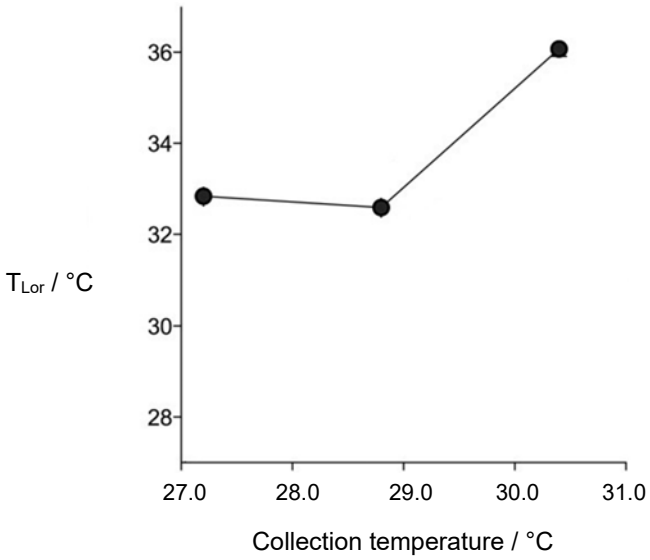
29 Which row correctly matches the mechanisms of generating antibody diversity?

	somatic recombination	somatic hyper-mutation
A	occurs in immature B cells in the thymus	occurs in mature B cells in the bone marrow
B	changes the V and C regions of antibodies	changes the V regions of antibodies
C	involves rearrangements of the different V, D or J segments in the immunoglobulin genes	involves point mutations of the segments in the immunoglobulin genes
D	affects only the light chains of the antibodies	affects both light and heavy chains of the antibodies

30 The long-spined sea urchin, *Diadema antillarum*, is a significant reef grazer essential for the healthy functioning of coral reefs. They feed on algae and prevent them from overgrowing and suffocating the corals. Given the importance of coral reefs as nursery habitats for edible marine species and concerns about global climate change, the thermal tolerance of *Diadema antillarum* was investigated in a study.

The temperature at which *Diadema antillarum* could no longer hold itself upright in water (T_{Lor}) is used as an indicator of thermal tolerance. This is the temperature at which the neuromuscular system of the animal no longer has sufficient integrity to hold itself upright. The thermal tolerance was measured over three collection temperatures (27.2 °C in winter, 28.8 °C in spring, 30.4 °C in summer) to determine if they acclimatised to changes in environmental water temperatures.

The results of the investigation are shown in the graph.



Which statements are supported by the information?

1 Eradication of sea urchin due to climate change will have a significant impact on global food supply.

2 *Diadema antillarum* has the capacity to acclimatise to different seasonal temperatures.

3 As tropical sea temperatures increase by as much as 4.8 °C by the end of this century, *Diadema antillarum* will be able to adapt to these higher temperatures.

4 Other stressors such as ocean acidification and infectious diseases are likely to have deleterious effects on tropical marine ecosystem.

A 1, 2 and 3

B 1, 3 and 4

C 1 and 2 only

D 2 and 4 only

End of paper