VJC 2022 H2 Biology Prelim Paper 1 Answer

1	D		**11**	B		**21**	D
2	B		**12**	D		**22**	A
3	C		**13**	B		**23**	B
4	A		**14**	D		**24**	C
5	D		**15**	D		**25**	A
6	D		**16**	A		**26**	C
7	D		**17**	B		**27**	C
8	B		**18**	B		**28**	C
9	C		**19**	B		**29**	A
10	D		**20**	B		**30**	D

VJC 2022 H2 Biology Prelim Paper 2 Answer

Question 1

(a) (i) Identify organelles **A** and **B** and explain their roles in beta cells. [3]

Identifying organelles
- A – nucleolus, B – mitochondrion;

Role of nucleolus
- Produce ribosomes for protein synthesis of insulin;

Role of mitochondrion
- Produce ATP for synthesis and exocytosis of insulin;

(ii) With reference to Fig. 1.1 and 1.2, explain how the cell theory is supported. [2]

- Islet of Langerhans consists of many cells – living organelles consist of one or more cells;
- Cell contains organelles for ATP production, DNA for inheritance, etc. – cell is the most basic unit of life;

(iii) Outline the roles of the intermembrane system in the synthesis of insulin within beta cells. [3]

- Translation of insulin polypeptide at ribosomes on rough endoplasmic reticulum;
- Folding of insulin protein in cisternae of rough endoplasmic reticulum;
- Budding of transport vesicle to transport insulin from rough endoplasmic reticulum to Golgi apparatus;
- Biochemical modification of insulin in Golgi apparatus;

(iv) Describe how insulin is released by beta cells. [2]

- Insulin released via exocytosis;
- Insulin granules move to and fuse with cell surface membrane;

(b) With reference to Fig. 1.3, explain how the structure of insulin is significant to its role in the body. [3]

- Globular;
- Soluble in the blood to be transported to target cells;
- Specific 3D shape complementary to shape of insulin receptor;

Question 2

(a) Using a labelled diagram, show how a triglyceride molecule is hydrolysed. [3]

- Correct drawing and labels of triglyceride, glycerol and fatty acids;
- Correct labelling ester bonds and indication of hydrolysis sites;
- Correct label of hydrolysis and showing that 3 molecules of water are used;

(b) (i) Describe the structure of the fatty acid transporter and explain how it supports its role. [3]

- Ref. to amino acids with non-polar R groups forming hydrophobic interactions with hydrocarbon tails of phospholipids;
- Ref. to amino acids with polar R groups forming hydrogen bonds with hydrophilic phosphate heads and aqueous medium;
- Ref. to water-filled pore / channel for fatty acid to pass through;

(ii) Account for the number of ATP molecules produced for each acetyl CoA that enters the TCA (Krebs) cycle. [3]

- Ref. to 1 ATP, 3 NADH and 1 $FADH_2$ produced per acetyl CoA;
- Each NADH yields 2.5 ATP and each $FADH_2$ yields 1.5 ATP via the ETC;
- 1 + (3 x 2.5) + (1 x 1.5) = 10 ATP produced;

(iii) Explain why, for the same mass of glucose and triglyceride respired, a lot more ATP is produced from the triglyceride. [2]

- Ref. to long hydrocarbon tails in triglycerides which yield many acetyl CoA in beta-oxidation;
- Ref. to each glucose yielding only 2 acetyl CoA;

Question 3

(a) Briefly describe the role of DNA polymerase III in a eukaryotic cell. [2]

- Addition of deoxyribonucleotides to 3' OH via formation of phosphodiester bonds;
- Elongation from RNA primer to form daughter DNA strand;
- Ref. to proofreading;

(b) (i) With reference to their molecular structures, explain why the three polymerases have a different optimal pH. [2]

- They have different numbers of ionic bonds;
- Polymerases with more ionic bonds are more likely to denature as the pH changes;

OR

- They may have different R-groups;
- Polymerases with R-groups that can take up or release H^+ ions will be able to work well even under extreme pH;

(ii) Explain why P-Omega has a high percentage efficiency at 90 °C. [2]

- Has a higher proportion of disulfide linkages, does not denature at high temperatures;
- The higher kinetic energy at higher temperatures increases the rate of collision between enzyme and substrate and therefore increases the rate of reaction;
- Enzyme thus operates more efficiently;

(c) (i) Suggest which polymerase the researcher should choose to replicate his DNA. Explain the reasons behind your choice. [2]

- P-Beta;
- Works relatively efficiently in an alkaline medium;
- Shows some activity even at 90°C, thus it is not completely denatured at high temperature;

(ii) Fill up Table 3.2 below to indicate the types of polymerase from each of the sources. [1]

type of polymerase	origin of polymerase
P-Alpha	yeast
P-Beta	microbes from Bonneville Salt Flats
P-Omega	volcanic lake in New Zealand

Question 4

(a) Using your knowledge on DNA replication in cells, explain how the Hayflick limit occurs. [4]

- Ref. to end-replication problem;
- RNA primer removed at 5' end of daughter DNA strand;
- DNA polymerase cannot replace it with DNA nucleotides due to a lack of 3' OH;
- The telomeres shorten to the critical length that stops further cell division;

(b) (i) With reference to Fig. 4.1, describe how pHi becomes acidic. [3]

- Ref. to histone deacetylation by HDAC;
- Acetyl groups broken down into acetate and H^+;
- H^+ concentration increases in the cytoplasm thus decreasing pHi;

(ii) Suggest a role for such changes in histone acetylation other than transcriptional regulation. [1]

- Regulate / Maintain pHi;

(c) With reference to Fig 4.2, identify and describe the post-translational control of the amount of functional GPCRs. [4]

- Biochemical modification in the rough endoplasmic reticulum and Golgi apparatus;
- GPCR transported from rough endoplasmic reticulum to Golgi apparatus;
- Mature GPCR transported from Golgi apparatus to the cell surface membrane;
- Misfolded GPCR undergoes protein degradation by proteasome;
- Dimerisation of GPCR results in internalisation, placing the dimer into an endosome;
- Endosome (MVB) fuses with lysosome to digest the dimer;

Question 5

(a) Account for the difference between the cDNA obtained from the RT-PCR of a eukaryotic mRNA and the gene from which the mRNA was transcribed. [2]

- cDNA lack introns;
- cDNA is reverse transcribed from mature mRNA which had undergone splicing;

(b) (i) State which mutant has a phenotype consistent with a loss-of-function mutation in the *trpR* gene. Explain your answer. [3]

- Mutant 1;
- Loss-of-function mutation results in non-functional repressor produced;
- Unable to inhibit expression of *trp* operon regardless of the presence of tryptophan;

(ii) State the component of the *trp* operon in mutant 3 in which a loss-of-function mutation has occurred. Explain your answer. [2]

- Promoter;
- RNA polymerase cannot bind to initiate transcription;

(iii) If the phenotype of mutant 3 is caused by a mutation in the *trpR* gene, explain how this mutation would affect the structure and function of the repressor protein. [3]

- Ref. to a missense mutation;
- Change in 3D conformation of repressor produced, which is in the active conformation
- Able to bind to operator to inhibit expression of *trp* operon regardless of the presence of tryptophan

Question 6

(a) The M checkpoint occurs during mitosis of the cell cycle. Explain the significance of this checkpoint. [2]

- Checks for proper binding of spindle fibres to centromeres of chromosomes;
- Ensure proper separation of chromosomes / sister chromatids to prevent non-disjunction;

(b) With reference to Table 6.1, account for the differences in percentage distribution of cells at each stage. [2]

- Majority of the cells (87.3%) are in interphase stage;
- Interphase is the longest stage due to G1 checkpoint checking for presence of appropriate growth signals / time taken to carry out DNA replication;

(c) Using information from Table 6.1 and 6.2, explain the effect of oncogenes on cell division. [2]

- Fewer cells remain in interphase (42.9%) / More cells are in mitosis (57.1%) in the tumour;
- Oncogenes result in over-stimulation of cell division;

(d) Suggest why it is important to use percentage values when comparing data from the normal and tumour cell cultures. [1]

- The initial number of cells in each culture may not be the same;

Question 7

(a) (i) State the genotypes of the F1 male moth and the F2 female moth with white body and long antenna. [1]

- F1 male moth – $Z^{A}_{B}Z^{a}_{b}$, F2 female moth with white body and long antenna – $Z^{a}_{B}O$;

(ii) Explain how the F2 female moth with white body and long antenna is obtained. [3]

- Crossing over occurs in prophase I in the F1 male moth;
- Producing a gamete with the Z^{a}_{B} chromosome;
- Fertilisation of this gamete with a gamete with no Z chromosome from the female;

(b) In the space provided below, draw a genetic diagram of the above cross to show the expected phenotypic ratio of the offspring. [4]

You do not have to include gene **B** or antenna length in the diagram.

F1	phenotype	male with yellow body	x	female with white body				
	genotype	$Z^{A}Z^{a}dd$		$Z^{a}ODD$				1m
		meiosis						
	gametes	$Z^{A}d$ $Z^{a}d$		$Z^{a}D$ OD				1m
F2	genotype	$Z^{A}Z^{a}Dd$		$Z^{A}ODd$		$Z^{a}Z^{a}Dd$		$Z^{a}ODd$ 1m
	phenotype	male with brown body		female with brown body		male with white body		female with white body
	phenotypic ratio	1	:	1	:	1	:	1 1m
	observed numbers	48	:	51	:	50	:	51

Question 8

(a) With reference to Fig. 8.2, comment whether

(i) beak depth is an inherited characteristic. [2]

- Yes – as mean beak depth of parents increased from 7 to 11 mm, mean beak depth of offspring increased from 7.5 to 10 mm / mean beak depth of offspring are about the same as their parents;
- Parents with alleles coding for higher beak depths passed their alleles to their offspring;

(ii) more than one gene controls beak depth. [1]

- Yes – there is continuous variation in beak depth;

(b) (i) Explain why the range of beak depth of the medium ground finch on Isabela Island is different from those on Daphne Island. [5]

- Variation of beak depth within the populations on both islands exists due to mutations;
- Presence of smaller-sized seeds on Daphne Island;
- Those with smaller-sized beaks were selected for on Daphne Island as they were better able to feed on smaller-sized seeds;
- Those with selective advantage are more likely to survive, reproduce and pass on the alleles coding for beak size to their offspring;
- Frequency of alleles coding for smaller-sized beaks in the Daphne Island population increased over time and more individuals have smaller-sized beaks;

(ii) Outline how the medium ground finch on Daphne Island may evolve as a distinct species thousands of years in the future. [3]

- No gene flow between the two populations due to long distance between them;
- Natural selection continues within each population and mutations arise independently, such that over time, the two populations accumulate changes;
- They are classified as different species as they can no longer interbreed to form viable offspring;

(iii) Suggest why both species of finches are found on Isabela Island while only one is found on the other islands. [1]

Any one

- Medium ground finch may have originated on Daphne Island, small ground finch on Crossman Island and some members of both species migrated to Isabela Island;
- Both originated on Isabela and only one species happened to migrate to one of the other islands;
- Isabela Island is much bigger than the other two islands and likely have a variety of different-sized seeds to support both species;

Question 9

(a) Contrast between an antigen and an antibody. [2]

features	antigen	antibody
origin	found on / in a pathogen	produced by a plasma cell / found on cell surface membrane of B cell
composition	may be protein, carbohydrate, lipid in nature	protein
binding	has an epitope that binds to antigen binding site on antibody	contains antigen binding site for binding of antigen

(b) (i) Explain how the structure of the cell surface membrane of dendritic cell allows its role as an antigen presenting cell. [3]

- Ref. to the presence of receptors recognising a broad class of antigens;
- Ref. to weak hydrophobic interactions between fatty acid tails of phospholipids giving rise to the fluidity of cell surface membrane for phagocytosis;
- Ref. to the presence of MHC molecules for antigen-presentation;

(ii) Outline how immunological memory is developed after activation of specific helper T cells. [4]

- Activated helper T cells release cytokines;
- Specific B cell activated by cytokines to differentiate into memory B cells;
- Ref. to memory B cells recognising the same antigens found on the actual pathogens;
- Infection by the same pathogen activates the memory B cells to differentiate into plasma cells;
- Plasma cells release antibodies against the pathogen;

Question 10

(a) With reference to Fig 10.1 and 10.2, other than missing ice caps, predict how the natural landscape of the Swiss Alp would change in the next decade. [3]

- Ref. to increasing trend of temperature – temperature expected to continue increasing;

Any two
- New mountain lakes / rivers will appear as the ice melts away;
- Melting glaciers will contribute to sea level rising;
- New plants with higher heat tolerance will grow on the mountain tops;
- Presence of new habitats and warmer coonditios will encourage migration of animals uphill;
- Displacement of species living at the peak can lead to extinction;

(b) (i) State the optimal temperature for growth and development of the stone pine seedlings [1]

- 12 (accept 11-13) °C;

(ii) With reference to Fig 10.3, describe the change in rates between the gross and net photosynthesis before 35°C. [2]

- Both gross and net photosynthesis rates increase from -5 to 12°C;
- Gross photosynthesis rate continues to increase and plateaus around 35°C, net photosynthesis rate drops till it reaches zero at 35°C;

(iii) With your knowledge on photosynthesis, explain the change observed in **(bii)**. [3]

- From -5 to 12°C, increasing temperatures increased kinetic energy of enzymes in Calvin cycle, increasing the formation of enzyme-substrate complexes, thus increasing the gross and net photosynthesis rates;
- Beyond the optimal temperature of around 12°C, denaturation of the enzymes diminishes the gross photosynthesis rates;
- And net photosynthesis rate decreased rapidly as respiration rate increased;

VJC 2022 H2 Biology Prelim Paper 3 Answer

Question 1

(a) (i) State, as precisely as you can, where Rubisco is found in the plants. [1]

- Stroma of chloroplast;

(ii) Outline the significance of Rubisco to the plants. [3]

- Carbon fixation in Calvin cycle;
- Catalyse addition of carbon dioxide to ribulose bisphospate to form unstable 6C compound, which is then split into 2 molecules of glyerate-3-phosphate;
- Allows carbon dioxide to be incorporated into Calvin cycle to produce glucose;

With reference to Fig. 1.1,

(iii) of all the caffeine-producing plants, state the genus of the least related one. [1]

- *Theobroma*;

(iv) deduce if the evolution of caffeine in plants shows divergent evolution. Give a reason for your answer. [2]

- No – convergent evolution;
- Ref. to plants evolving caffeine independently – not inherited from a caffeine-producing common ancestor;

(v) Justify the claim of the scientist that the phylogenetic tree is reliable and suggest an improvement to the reliability. [2]

Reliability
- Quantitative, not ambiguous, objective;
- Many points of comparison;
- Present in all plants;

Improvement
- Compare more than 1 homologous genes;
- Compare Rubisco gene sequence instead – silent mutations;

(b) With reference to Fig. 1.2 and 1.3,

(i) calculate the rate of increase in global consumption of coffee between 2015 and 2019. Show your working below. [1]

There are 4 years between 2015 to 2019.
From graph, 2015 consumption is 149 million 60kg bags. In 2019 it was 157.5 million 60kg bags.
Rate of increase in global consumption is 157.5 – 149 = 8.5 million 60kg bags
In 4 years this will mean 8.5 / 4 = 2.125 million 60kg bags / year

(ii) state the region that contributed the most to the increase in the global consumption of coffee. Give a reason for your answer. [2]

- Asia & Oceania;
- Largest increase + Q.V.;

(c) With reference to the information provided,

(i) explain how the structure of adenosine aids in its movement across the synapse. [2]

- Small and polar / hydrophilic;
- Allows it to diffuse quickly across the synapse;

(ii) explain the significance of cAMP in adenosine signalling. [3]

- Second messenger;
- Binds to and activates protein kinase A via conformation change;
- Trigger phosphorylation cascade of nociceptive pathway;

(iii) explain how caffeine functions as a cognitive enhancer. [3]

- Structural resemblance to (nitrogenous base of) adenosine;
- Ref. to competitive inhibition;
- Competes with adenosine to bind to adenosine receptor;
- Lowers number of bound receptor thus decreasing / preventing the increase of drowsiness;

(iv) suggest two reasons for the need of repeated consumption of coffee throughout the day in order to prevent feeling of drowsiness. [2]

- High concentration of adenosine as the day progresses – outcompete caffeine to bind to adenosine receptor;
- Removal / Metabolism of caffeine by the body;

(d) (i) Outline the symbiotic relationship between coffee berry borer and its gut bacteria. [3]

- Gut bacteria breaks down caffeine – allows coffee berry borer to consume coffee fruits and leaves as food source without adverse effect;
- Less competition for food with other herbivores which cannot consume coffee plants;
- Protection / Optimal environment for gut bacteria;
- Stable supply of caffeine as food source when coffee berry borer feeds on coffee fruits and leaves;

(ii) Explain how coffee berry borer may be classified as a distinct species. [2]

- Ref. to ecological species concept;
- Ref. to exploiting a new niche;

OR

- Ref. to biological species concept;
- Ref. to no interbreeding with other beetles to form fertile, viable offspring;

OR

- Ref. to morphological species concept;
- Ref. to longer gut;

Question 2

(a) (i) Outline how cancer cells can be 'stem cell-like'. [2]

- Cancer cells are undifferentiated cells with no tissue-specific structures or functions;
- Cancer cells have the ability to carry out cell division indefinitely / long-term;
- Cancer cells express the telomerase gene / have active telomerase;

(ii) Describe the differences that can be seen in cancer cells compared with normal germ line cells. [3]

feature	cancer cell	normal germ line cell
type of cell division	mitosis	mitosis and meiosis
exhibit contact inhibition	no	yes
need for growth factor	no	yes
cell cycle checkpoints	non-functional	functional
cell cycle arrest for DNA repair or to trigger apoptosis	continue to divide to accumulate mutations	cannot proceed with cell cycle when mutation / DNA damage is detected for repair or to trigger apoptosis
mutations in genes controlling cell cycle	yes	no
ability to induce angiogenesis and metastasis	yes	no

(b) (i) Suggest a reason why doctors remove the patient's stem cells from their blood or bone marrow before the cancer treatment begins. [1]

- To prevent cancer treatment from killing / causing mutations in the stem cells;

(ii) With reference to Fig 2.1, give a conclusion for the effectiveness of the two treatment methods for breast cancer in women. Justify your answer. [3]

- Both treatment methods show a decrease in effectiveness over time;
- Before 60 months, conventional-dose chemotherapy is more effective than high-dose chemotherapy plus stem-cell transplantation before 60 months – it takes around 60 months for probability of survival to decrease to 0.1 for conventional-dose chemotherapy, which is slower than the 55 months for high-dose chemotherapy plus stem-cell transplantation;
- After around 60 months, both methods are equally (in)effective;

Question 3

(a) With reference to Fig. 3.1, contrast the structure of SARS-CoV-2 with that of HIV. [2]

feature	SARS-CoV-2	HIV
type of glycoprotein on viral envelope	spike protein (S)	gp120 and gp41
no. of single strands RNA	one	two copies
presence of capsid coat	absent	present
presence of viral enzymes	no viral enzymes	contains reverse transcriptase and integrase

(b) Describe three ways in which the structure of antibodies contributes to their functions. [3]

- Specific antigen binding sites that are complementary in shape to specific antigens – allow binding to antigens;
- 2 antigen binding sites – allow binding to 2 antigens;
- Fc region – binds to specific Fc receptor on specific immune cells for effector functions;
- Disulfide bonds – maintain specific 3D conformation;

(c) With reference to Fig. 3.2, explain how variability at the DNA level result in variability in the antigen-binding sites of antibodies. [3]

- Ref. to somatic recombination;
- Results in random combinations of VJ gene segments in the light-chain loci and VDJ gene segments in the heavy-chain locus;
- Ref. to expression of the VJ gene segment in either the λ light-chain locus on chromosome 22 or κ light-chain locus on chromosome 2;
- Expression of one particular VJ gene segment and one particular VDJ gene segment results in one particular light chain variable domain and one particular heavy chain variable domain respectively, which together form an antigen binding site of a particular shape and specificity;

(d) Explain how the vaccine triggers the production of antibodies and how the antibodies confer protection against the virus. [5]

<u>How vaccine triggers production of antibodies (4 max.)</u>

- Ref. to antigen presentation by antigen presenting cells;
- Specific helper T cell activated to release cytokines;
- Specific naïve B cell activated, aided by cytokines released by helper T cell;
- Activated B cells undergo clonal expansion and differentiation into plasma cells that release antibodies specific to the spike proteins;

<u>How antibodies confer protection against the virus</u>

- Antibodies bind to the spike proteins on SARs-CoV-2 to block attachment to specific receptor on host cells, thus preventing infection / facilitate phagocytosis of by macrophages;

(e) Suggest why scientists have not been able to create an effective vaccine against HIV. [1]

- There is high mutation rate in the HIV RNA genome due to the high error rate and lack of proofreading in HIV reverse transcriptase;

Question 4

(a) Epigenetics is the study of changes in organisms that are caused by modifications of gene expression rather than alteration of the genetic code. Describe how such modifications can be achieved. [15]

Chromatin remodelling

1. The packaging of **DNA with histones into nucleosomes/chromatin** can allow for **chromatin remodeling** which can modify gene expression
2. **Histones acetylation** at the **free lysine residues at the N terminus**
3. by **histone acetylase** (accept if histones deacetylation is mentioned instead)
4. result in **decreased net positive charge of histones**
5. **lowering the affinity of histones** to **negatively charged DNA**
6. to form **euchromatin/become less condensed**
7. This allows for **greater accessibility of general transcription factors and RNA polymerase** at the promoter to **increase transcription** (and specific transcription factors at control elements, to be covered in the second portion of answer)
8. **Histone deacetylation** will result in **chromatin becoming more condense and reduce transcription**
9. **DNA methylation** adds methyl groups to **DNA sequences rich in cytosine** / CpG-rich sites
10. catalysed by **DNA methyltransferase**
11. Many transcription factors bind to DNA at CpG-rich sites, thus methylation of these sites **interferes with transcription factors binding**, resulting in the **suppression of the initiation of transcription**.
12. It also induces **histones deacetylation** as **histones deacetylase** recognizes and **bind to the methylated DNA**

Increase accessibility to specific transcription factors

13. Each gene has a **specific/unique combinations** of **control elements** like **enhancers or silencers.**
14. The presence of **appropriate** combination **of activators or repressors proteins** in a particular cell types at a precise time can determine the expression of the genes
15. **Activators** can bind to the **enhancer** to **upregulate** the RNA polymerase activity/transcription
16. **Repressors** can bind to the **silencer** to **downregulate** the RNA polymerase activity/transcription
17. the binding of specific transcription factors to the control elements will trigger a **DNA looping mechanism aided by DNA bending proteins**
18. to bring the **specific transcription factors close** to the promoter to **interact with the transcription initiation complex.**

QWC – cover 2 aspects of chromatin remodelling (DNA methylation and histones acetylation)

(b) Using relevant examples, discuss the significance of regulating gene expression. [10]

Introduction:

1. Regulation of gene expression is the process which controls the type, timing (temporal), location (spatial) and amount of genes expressed in a cell;

Prevent wastage of energy/resources

2. Allow prokaryotes to **synthesise only enzymes/proteins that are required** and thus **prevent wastage of energy and resources**
3. (prokaryotes) Using trp operon as an example, in the presence of excess tryptophan, trp operon is switched off;
4. As tryptophan is in excess, no need to express enzymes involved in tryptophan synthesis;
5. Relevant detail for explanation e.g. trp acts as co-repressor, activates trp repressor, binds to operator, block RNA polymerase from binding
   OR
6. Or lac operon is only expressed **in the absence of glucose and presence of lactose**;

7. As bacteria prefer to use glucose as respiratory substrate, there is no need to express enzymes required for lactose metabolism when glucose is present;
8. Relevant detail to explain catabolite repression e.g. in the presence of glucose, cAMP levels are low → no active cAMP-CAP complex → lac operon is switched off

Allows for cell differentiation

9. (Almost) all cells (except gametes) of a multicellular organism have the same set of genes but different cells switch on different genes to express only the proteins required for their specialized functions
10. For example beta cells of islet of Langerhans express genes for insulin and switch off genes for glucagon / vice versa for alpha cells
    OR neuron cells express genes for neurotransmitters but beta cells of islet of Langerhans switch those genes off
    OR as blood stem cells differentiate into red blood cells, genes expressing haemoglobin are switched on
    OR as activated B cell differentiate into plasma cells, genes expressing antibodies are upregulated (Accept another valid examples)

Response to environment / maintenance of homeostasis

11. Cells divide in response to growth factors
12. When growth factors bind to their receptors, cell signalling pathway(s) is set off, which activate certain transcription factors
13. Which activate the expression of genes controlling/promoting cell division
    OR
14. Antigen binding activates T helper cells and upregulate expression of cytokines
15. Activated B cell in response to cytokines differentiate into plasma cells upregulating expression of antibodies to be secreted
    OR
16. Liver/muscle cells' response to insulin/glucagon (high/low blood glucose concentration)
17. When named hormone bind to their receptors, cell signalling pathway(s) is set off, which activate phosphorylation cascade / phosphorylation of named enzymes of the signal transduction pathway
18. Which activate named enzymes which catalyse specific reactions (cellular response) to restore normal blood glucose concentration

Development

19. (multicellular organisms) express the genes only at required times of their developmental process
20. Example globin genes are expressed at different time and in different amounts in human development, i.e. foetal Hb is different from adult Hb due to expression different globin genes (or any other relevant examples)
21. Stem cells express telomerase to allow indefinite self-renewal while differentiated cells silenced telomerase gene
22. Honey bee queen and worker bees have the same set of genes but differences in the DNA methylation profile of the queen and worker larvae result in different genes being activated and hence different phenotypes being produced
23. Queen larvae are fed with royal jelly which results in increased expression of genes in ovary development
24. Royal jelly activates pathways associated with the catabolism of proteins, carbohydrates and fats → increased growth rates seen in queen larvae relative to worker larvae

Regulation of cell cycle to prevent cancer

25. Expression of cell cycle checkpoint proteins is regulated to ensure cell divides in a controlled manner without accumulating mutations
26. Regulation of Ras protein activity by GTP – example of post-translational modification / expression of Ras gene is regulated to prevent overexpression
27. Prevent overstimulation of cell division – prevents uncontrolled division

28. Regulation of p53 expression – only expressed in response to appropriate signals e.g. detection of DNA damage

QWC – cover at least 2 categories with relevant examples;

Question 5

(a) Respiration produces ATP. Describe the role of ATP in living organisms. [15]

Introduction

1. Brief outline of ATP structure – **adenine nitrogenous base + ribose sugar + 3 phosphate groups**
2. **Small, water-soluble energy carrier** molecule
3. **Hydrolysis of ATP** / cleavage of phosphate group **releases energy** to drive **cellular / metabolic / endergonic (energy-requiring) reactions**

Protein synthesis

4. **Amino acid activation** / attachment of amino acid to tRNA

Transport across membrane

5. ATP is required for **active transport** to transport substances **against concentration gradient**
6. E.g. ATP binds to and phosphorylates sodium-potassium pump, causing it to change conformation so that sodium leaves while potassium binds (or any other valid example)
7. ATP is required for **bulk transport** like **exocytosis or endocytosis**
8. E.g. ATP required for movement of (any named) vesicles / motor proteins that drag the vesicles

RNA monomer

9. **Monomer of ribonucleic acid (RNA)**
10. The **2 terminal phosphate groups of each ATP are hydrolysed** and the nucleoside monophosphate is **incorporated into the RNA strand** / forms phosphodiester with another nucleotide

Cell signaling

11. Involved in **phosphorylation cascade** of a cell signaling pathway,
12. ATP is used to **activate proteins by phosphorylating them** / each **kinase catalyzes the addition of phosphate groups from ATP** to a **protein**
13. **cAMP, a second messenger** molecule involved in relaying signals, is synthesized **from ATP, catalysed by adenylyl cyclase**

Respiration

14. ATP used to **phosphorylate glucose in glycolysis**
15. **Activate / raise energy level / increase reactivity of glucose** at the start of
16. Makes sugar molecule **negatively-charged and unable to diffuse** out of the cell
17. **Maintains a steep concentration gradient** for glucose to enter the cell

Photosynthesis

18a. ATP is used in Calvin cycle to reduce **3-phosphoglycerate to triose phosphate**
18b. It is also used to **regenerate ribulose bisphosphate**

Prokaryotes

19. In prokaryotes, **ATP can be converted to cAMP** by adenylyl cyclase to bind to **catabolite activator protein (CAP)**
20. **cAMP-CAP complex** can bind to **CAP binding site** to enhance RNA polymerase binding to promoter to **upregulate expression of lac operon.**

QWC (1 mark): Cover at least 2 areas for the role of ATP

(b) Using relevant examples, discuss the significance of complementarity in the production of ATP. [10]

Introduction

1 Complementarity refers to the interaction between two molecules that allows them to **bind** together / are **complementary in terms of shape/size/charge/orientation**.

Significance in substrate level phosphorylation

1 ATP is produced via **substrate-level phosphorylation** in **glycolysis and Krebs cycle**
2 which is the **direct enzymatic transfer of a phosphate group from a substrate to ADP** to form **ATP**
3 enzyme **active site** must be **complementary in shape, (size, charge and orientation) to substrate**
4 Named enzyme, substrate and products of any one SLP reaction

Significance in oxidative phosphorylation

5 ATP also produced via **oxidative phosphorylation / chemiosmosis**
6 electron transport chain proteins **has specific binding site** – complementary in **shape to reduced NAD and FAD** to receive electrons carried on them
7 Some **ETC complexes come into contact with each other** as they pass electrons – idea of complementarity
8 Also have **specific channels for H ions/protons** (idea than channel must be complementary in shape and size to H ions)
9 to **pump H ions /protons across the membrane / ref to active transport of H ions/protons to maintain proton gradient**
10 ATP **synthase catalyse formation of ATP from ADP and Pi**
11 **ATP synthase has specific active site** – complementary in **shape to its substrates ADP and Pi**
12 And **specific channel for H ion/protons to pass through via facilitated diffusion**
13 **Proton flow** provides energy required for **ATP synthesis**

Significance in anaerobic respiration

14 In anaerobic respiration, **enzyme (lactate dehydrogenase/alcohol dehydrogenase)** has **specific active sites to substrate to regenerate NAD for continual ATP production**

QWC (1 mark): At least two correct examples mentioned.

YISHUN INNOVA JUNIOR COLLEGE
JC2 PRELIMINARY EXAMINATION
Higher 2

CANDIDATE NAME

CG

INDEX NO

BIOLOGY

9744/01

Paper 1 Multiple Choice

16 Sep 2022

1 hour

Additional Materials: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

Do not use staples, paper clips, glue or correction fluid/tape.
Write your name, index no. and CG on this cover page and OTAS provided unless this has been done for you.

There are **thirty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.

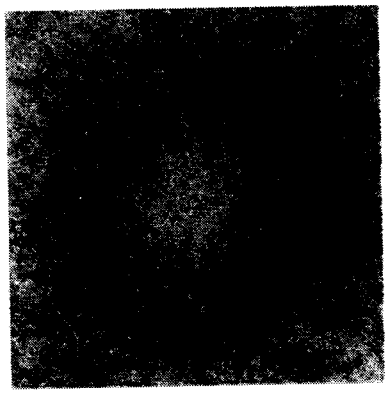
Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

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 booklet.
The use of an approved scientific calculator is expected, where appropriate.

This document consists of **21** printed pages and **1** blank page.

1 The electron micrograph shows a structure found in the cytoplasm of an animal cell.



What is this cell structure?

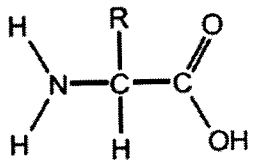
A centriole

B lysosome

C ribosome

D vesicle

2 The diagram represents an amino acid.



R represents a variable side chain.

Which of the following is **not** a possible side chain?

A CH_3

B $CH_2CH_2SCH_3$

C CH_2CONH_2

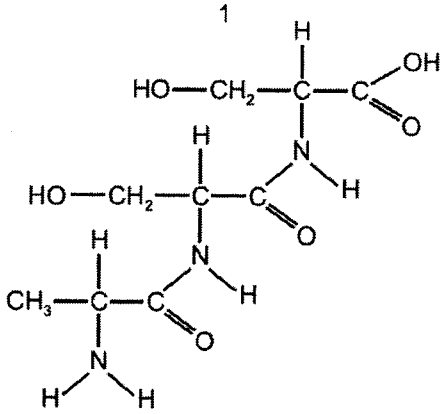
D $HOCH_2CH(OH)CH_2OH$

3 A student carried out four tests for biological molecules on a solution. The results are shown in the table.

test for biological molecule	observation
iodine solution	orange
biuret	blue
Benedict's	orange
emulsion	clear

Which molecules are present in this solution?

1



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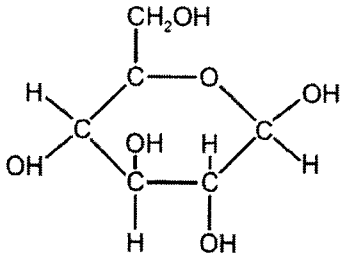

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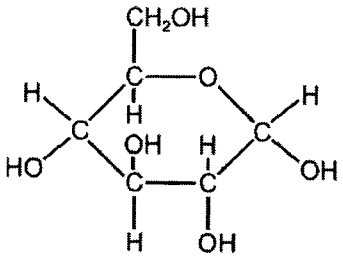
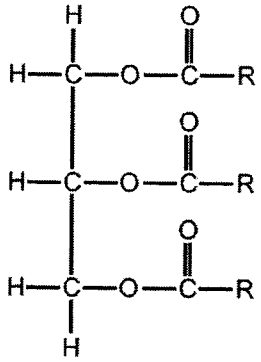


4



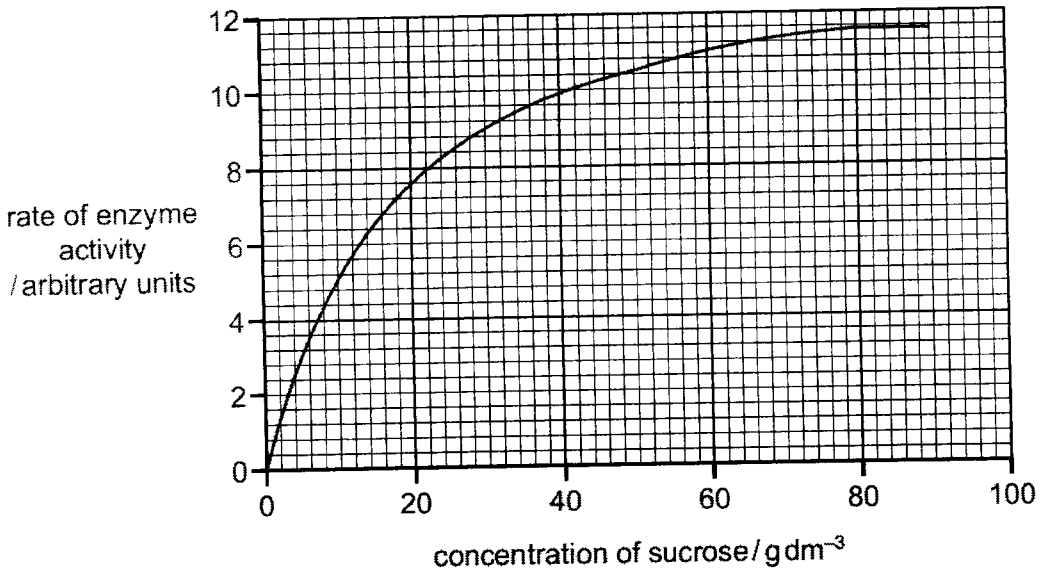
A 1 and 3

B 1 and 4

C 2 and 3

D 3 and 4

4 The graph shows the rate of activity of the enzyme sucrase plotted against the concentration of sucrose.



Why does the rate of enzyme activity remain constant from 80 – 90 g dm^{-3}.

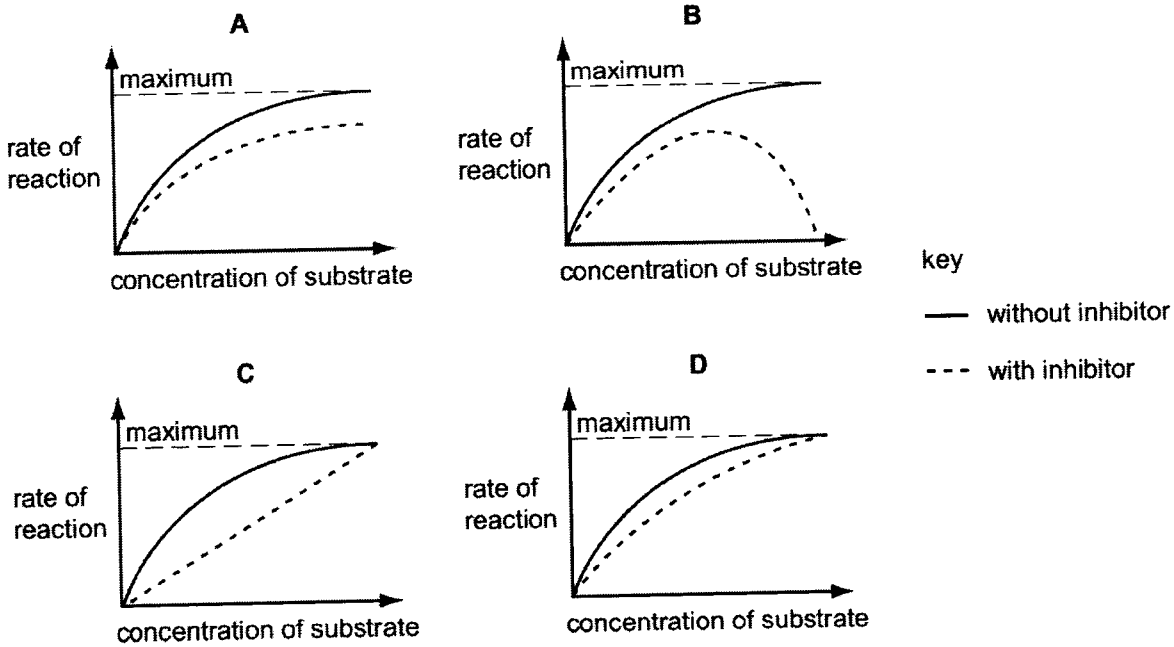
A All the enzyme has been inhibited.

B All the substrate has been used up.

C The concentration of the enzyme is limiting the rate.

D The concentration of the substrate is limiting the rate.

5 Which graph represents the action of a non-competitive inhibitor?



6 The following are all observations about cell surface membranes.

1 Phospholipids labelled with radioactive phosphate groups change position over time.

2 Proteins labelled with fluorescent dyes change position over time.

3 Lectins are proteins that bind to polysaccharides. Lectins only attach to the outside of cell surface membranes.

4 Electron microscope images of membranes fractured by freezing shows a large number of regularly arranged particles interrupted by larger particles.

5 Some proteins can easily be removed from the membrane by changing the ionic balance.

6 Some proteins can only be separated from the membrane by disrupting the membrane with detergent.

Which observations provide evidence for the fluid mosaic model of cell surface membranes?

A 1, 2 and 4

B 1, 2 and 6

C 3, 4 and 5

D 3, 5 and 6

7 Some stem cells divide and give rise to phagocytes.

Where in the human body do these stem cells divide?

1 blood

2 bone marrow

3 lymph nodes

A 1, 2 and 3

B 1 and 3 only

C 2 only

D 3 only

8 Which statement(s) about RNA is / are correct?

1 It is less stable than DNA as it contains a ribose sugar that lacks a 2' OH group.

2 It is a single stranded polymer of purine and pyrimidine joined by phosphodiester bonds.

3 It is synthesised in the 5' to 3' direction where the 5'-phosphate group of the growing RNA strand is joined to the 3'-hydroxyl group of an incoming nucleotide.

4 The function of ribosomal RNA is to catalyse the formation of peptide bonds.

A 4 only

B 1 and 3 only

C 2 and 3 only

D 1, 3 and 4 only

9 The following statements list the processes that occur during translation.

1 The large subunit of the ribosome binds and forms the translation initiation complex.

2 The second amino acyl-tRNA complex now binds to mRNA at the "A" site of the ribosome.

3 The small ribosomal subunit, with initiator tRNA bound, binds to the 5' cap of the mRNA and scans for the first start codon.

4 Soluble protein called release factor recognises the stop codon and binds at the "A" site.

5 Formation of a peptide bond between the first and the second amino acids by peptidyl transferase.

6 The second amino acyl-tRNA complex moves from the "A" site to the "P" site.

Using the information provided above, deduce the order in which these processes occur.

A 1 → 3 → 2 → 5 → 6 → 4

B 1 → 3 → 2 → 6 → 5 → 4

C 3 → 1 → 2 → 5 → 6 → 4

D 3 → 1 → 2 → 6 → 5 → 4

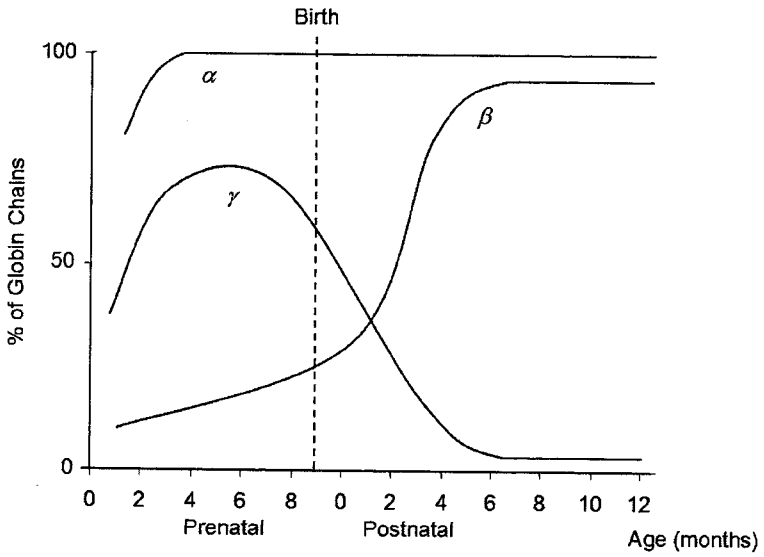
10 The non-template strand of part of a DNA molecule has the sequence 5' GAATTA 3'.

Which row is correct for this part of the corresponding template and tRNA strands?

	the sequence of the template strand	the anticodons of tRNA used in translation
A	5' CTTAAT 3'	5' CUU 3' and 5' AAU 3'
B	5' CTTAAT 3'	5' UAA 3' and 5' UUC 3'
C	5' TAATTC 3'	5' CUU 3' and 5' AAU 3'
D	5' TAATTC 3'	5' UAA 3' and 5' UUC 3'

11 The globin gene family in humans consists of α, β and γ genes. These genes code for the globin chains that make up haemoglobin and are expressed at different levels during different developmental stages.

The graph shows the expression of the various globin chains during the prenatal (fetal) and postnatal (after birth) periods.



Which statement **cannot** account for the differences in the levels of expression of globin chains?

A A growth factor triggers the expression of a transcription factor that increases the rate of β-globin gene expression during the postnatal period.

B Alternative splicing occurs in the mRNA of the α-globin and β-globin genes, resulting in differences in the rate of expression of globin chains during the prenatal period.

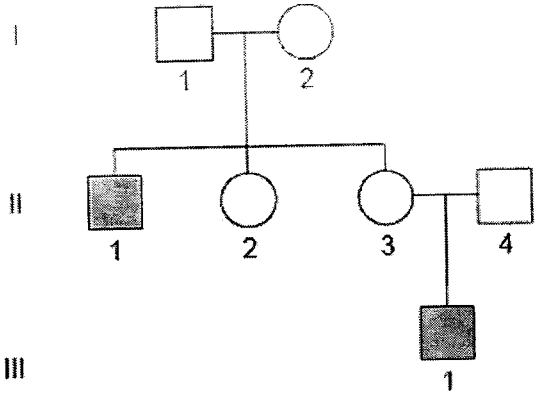
C Methyl groups are added to regulatory sequences of γ-globin genes during the prenatal period, allowing for some proteins to bind.

D The shortening of poly(A) tail in the mRNA of γ-globin genes reduces its stability, resulting in a decrease in the rate of expression of γ-globin chains during the prenatal period.

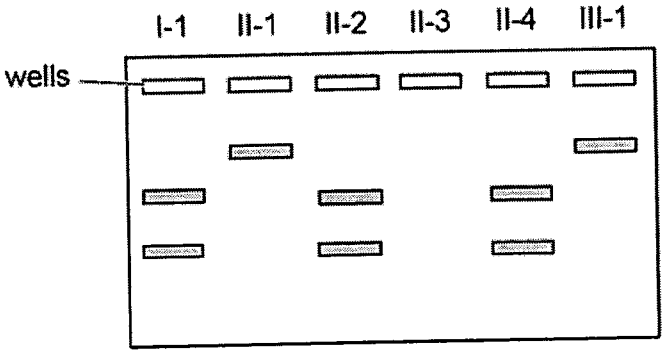
12 Menkes' Disease in humans is characterised by sparse and wiry hair, growth failure and deterioration of the nervous system. Onset of the Menkes' syndrome usually occurs during infancy.

Restriction digestion was carried out on DNA samples taken from a family in which this X-linked disorder was present. The DNA fragments obtained were subjected to gel electrophoresis.

The family pedigree is shown below.



The figure below shows the results obtained after gel electrophoresis.



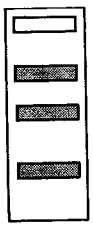
What would be the band pattern of individual II-3?

A

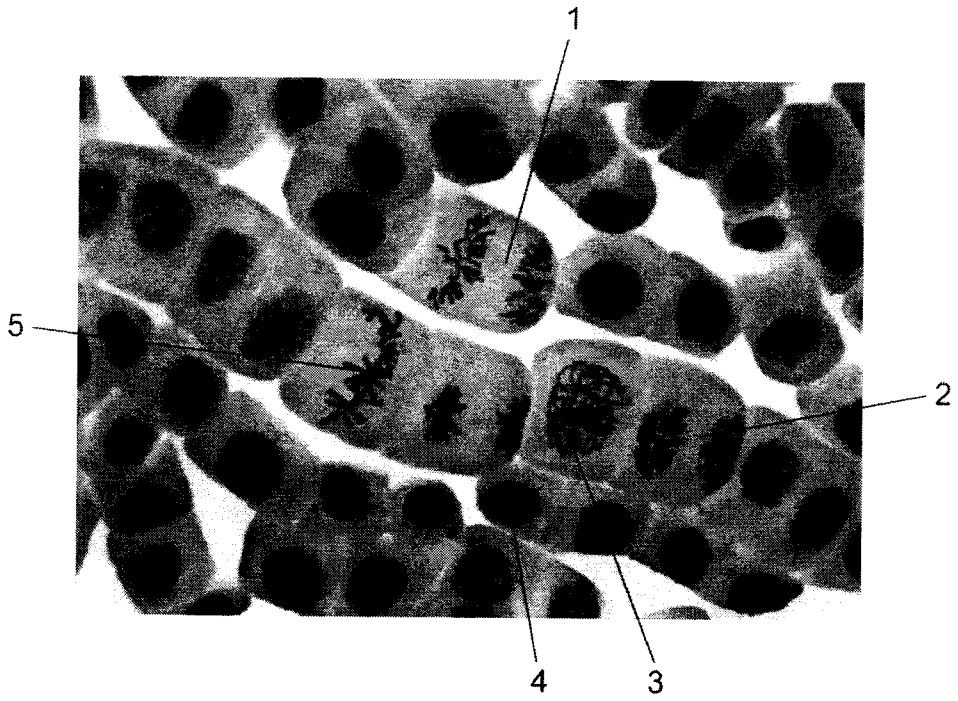
B

C

D



13 The photomicrograph shows cells in different stages of mitosis.



In which order do these stages occur?

A 3 → 1 → 5 → 2 → 4

B 3 → 5 → 2 → 1 → 4

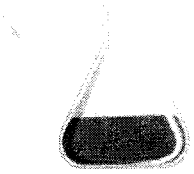
C 4 → 3 → 5 → 1 → 2

D 4 → 5 → 1 → 2 → 3

14 Essential amino acids e.g. methionine (met), biotin (bio), leucine (leu), threonine (thr) and arginine (arg) are critical for the bacteria cells to survive and replicate. Some bacteria carried the genes required for the synthesis of the amino acid (indicated by "+") while others with the genes (indicated by "-") will take up these amino acids from the culture medium.

An experiment involving two strains of bacteria were conducted to investigate gene transfer.

strain A (met^- bio^- leu^- thr^+ arg^+) strain B (met^+ bio^+ leu^+ thr^- arg^-)



grown together in the presence of methionine, biotin, leucine, threonine, and arginine

↓

grown in agar plates with different amino acids present

The results of the investigation are summarised in the table below.

flask	bacterial srain grown	amino acid present in agar plate					presence of bacteria colonies
		met	bio	leu	thr	arg	
1	A	✓	✗	✓	✗	✗	no
2	B	✗	✗	✗	✓	✓	yes
3	A + B	✗	✗	✗	✗	✗	yes

Which of the following process(es) could explain the results in flask 3?

1 Conjugation
2 Transduction
3 Transformation

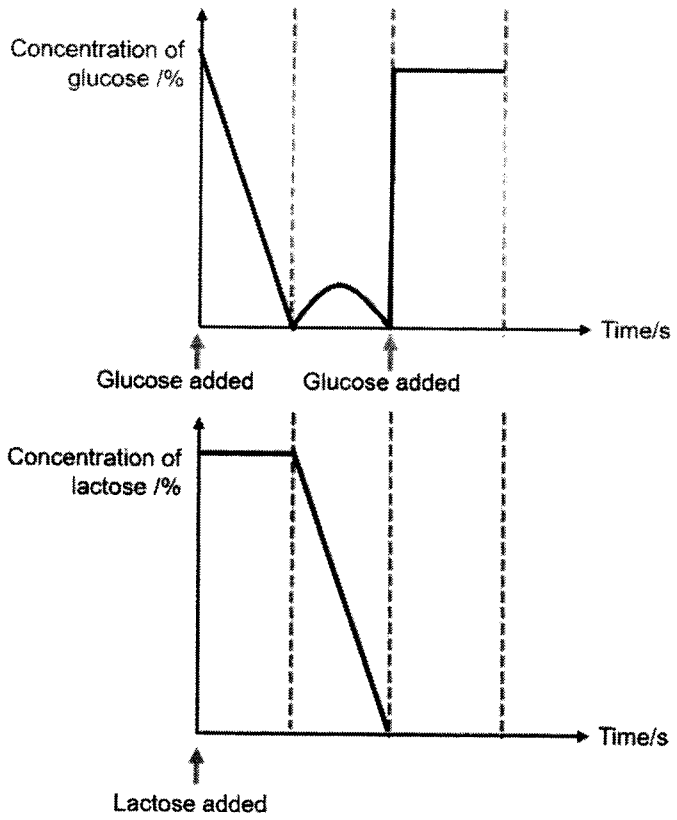
A 3 only

B 1 and 2

C 1 and 3

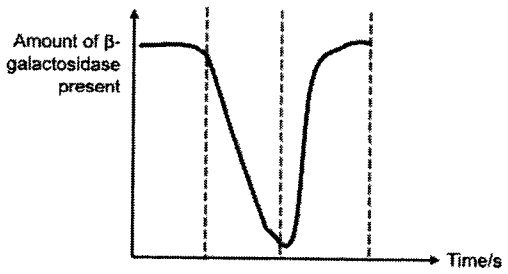
D 1, 2 and 3

15 *Escherichia coli* are able to metabolise both glucose and lactose for their energy requirement. In an experiment, researchers added glucose and lactose into the *E. coli* culture at different time points and measured the amount of β-galactosidase, glucose and lactose levels at regular time intervals. The arrows in the diagram indicate the addition of the respective metabolite into the culture.

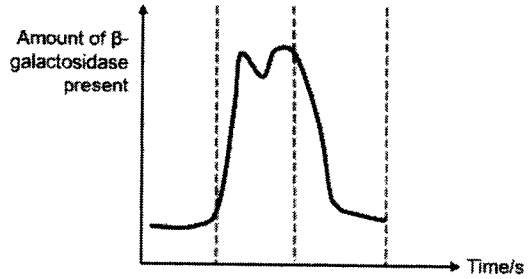


Which graph correctly shows the corresponding amount of β-galactosidase present in the culture?

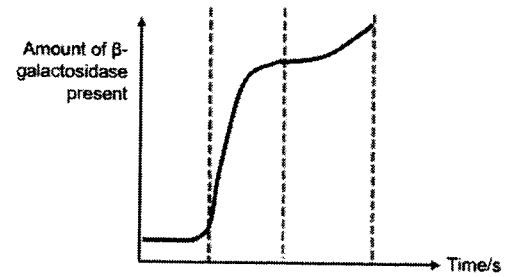
A



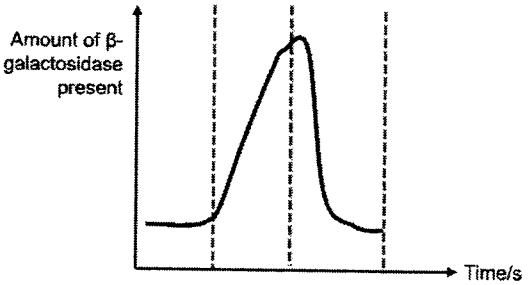
B



C



D



16 Which of the following statement(s) concerning *trp* operon is / are true?

1 A mutation of the regulatory gene leads to constitutive production of tryptophan.

2 There is one start and one stop codon in the mRNA of *trp* operon.

3 The repressor is inactive in the presence of excess tryptophan.

4 The mRNA codes for multiple polypeptides involved in the synthesis of tryptophan.

A 1 only

B 1 and 4

C 2 and 3

D 1, 2 and 4

17 A tall, green-stemmed plant with the genotype TTrr was crossed to a short, red-stemmed plant with the genotype ttRR. The F1 plants were allowed to self-fertilise. A χ^2 test was carried out on the results obtained for the F2 generation.

Part of the table of values for χ^2 is shown.

degree of freedom	probability				
	0.5	0.1	0.05	0.01	0.001
1	0.46	2.71	3.84	6.64	10.83
2	1.39	4.6	5.99	9.21	13.82
3	2.37	6.25	7.82	11.34	16.27
4	3.36	7.78	9.49	13.28	18.46

The value of χ^2 in this investigation was 7.6.

What is the probability of this value of χ^2 value?

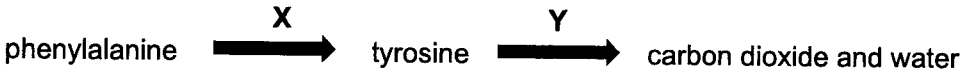
A between 0.001 and 0.01

B between 0.01 and 0.05

C between 0.05 and 0.1

D less than 0.05

18 The following reaction sequence occurs in humans.



Genetic disease **P** is caused by an enzyme deficiency in step **X** and genetic disease **Q** is caused by an enzyme deficiency in step **Y.** Both conditions are rare and are caused by recessive alleles.

A person with genetic disease **P** marries a person with genetic disease **Q**.

Which phenotypes would be expected for their children?

A All have neither genetic disease

B All have genetic disease **P** only

C All have genetic disease **Q** only

D All have both genetic diseases

19 A tall, pink-flowered plant is self-fertilised and produces the offspring shown.

	flower colour		
	red	pink	white
tall plants	73	157	67
dwarf plants	21	53	25

When self-fertilised, which type of plant will only produce identical offspring?

A dwarf, pink-flowered

B dwarf, red-flowered

C tall, red-flowered

D tall, white-flowered

20 Mammalian liver cells were homogenised, and the resulting homogenate centrifuged. Portions containing only mitochondria and cytosol (residual cytoplasm) were each isolated. Samples of each portion, and of the complete homogenate, were incubated in four ways:

1 with glucose

2 with pyruvate

3 with glucose plus cyanide

4 with pyruvate plus cyanide

Cyanide inhibits carriers in the electron transport chain. After incubation, the presence or absence of carbon dioxide and lactate in each sample was determined. The results are summarised in the table below.

Tube	samples of homogenate					
	complete		mitochondria only		cytosol	
	carbon dioxide	lactate	carbon dioxide	lactate	carbon dioxide	lactate
1	✓	✓	✗	✗	✗	✓
2	✓	✓	✓	✗	✗	✓
3	✗	✓	✗	✗	✗	✓
4	✗	✓	✗	✗	✗	✓

✗ = absent, ✓ = present

Which statement can be concluded from the table?

A Both aerobic and anaerobic respiration were occurring in tube 3.

B Carbon dioxide was not formed when mitochondria were incubated with glucose as there was no oxygen present.

C Lactate formation in mitochondria was inhibited by the presence of cyanide.

D The action of cyanide would be similar to that of a cell experiencing anaerobic respiration.

21 Which statement about respiration under anaerobic conditions in yeast and mammalian muscle tissue is correct?

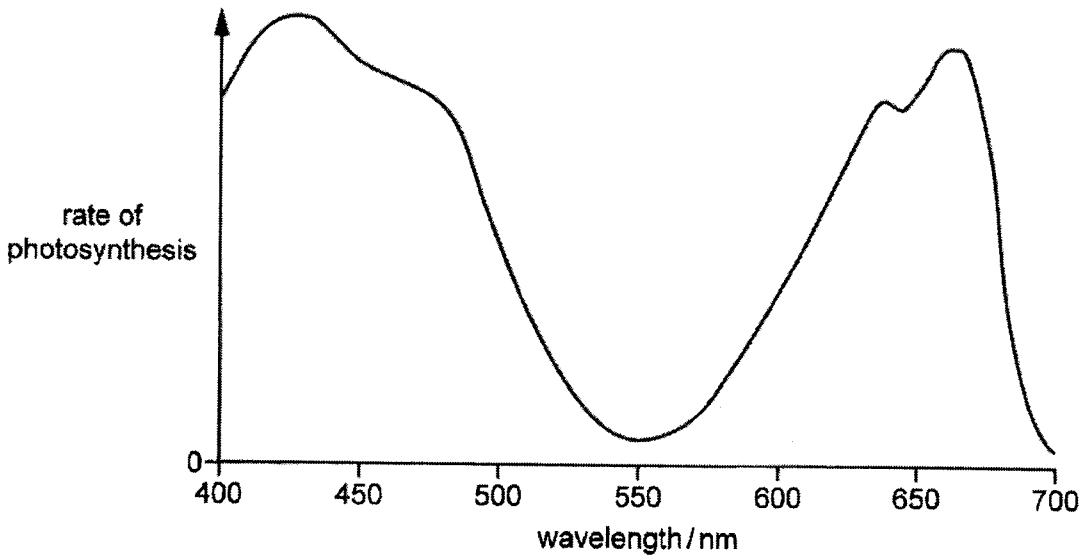
A During respiration under anaerobic conditions, only a small proportion of the energy in the initial reactants is used for ATP production.

B Under anaerobic conditions, ethanol production releases fewer carbon dioxide molecules than lactate production for the same yield of ATP.

C The amount of energy yielded from lactate production and ethanol production cannot be compared since the initial reactants are different.

D The continued production of ATP depends on respiration of ethanol in yeast and respiration of lactate in mammalian tissue.

22 The graph below shows the action spectrum for photosynthesis of a particular plant.



Which of the following explains the rate of photosynthesis for this plant at wavelengths of light between 525 nm and 575 nm?

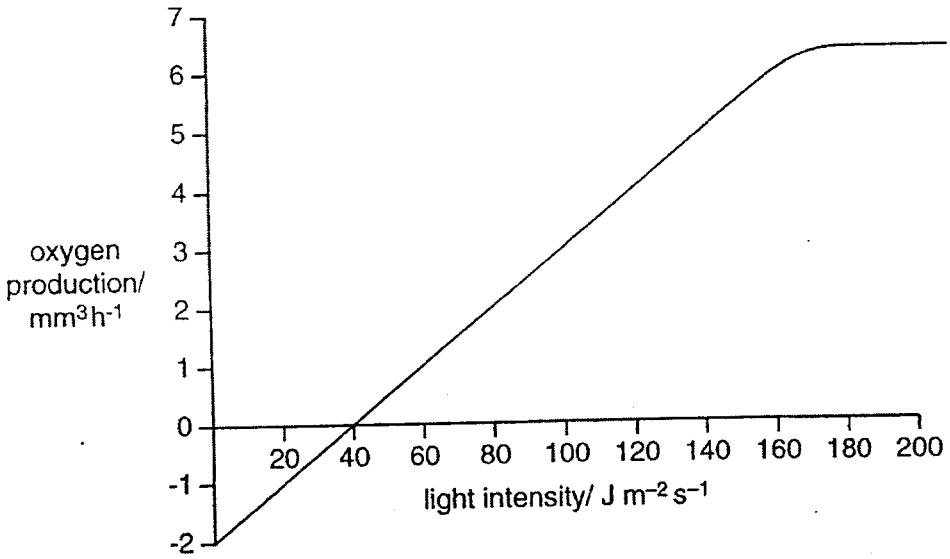
A Chlorophyll a is unable to undergo photoactivation between this wavelength.

B Energy level of light between this wavelength is low.

C The plant does not have pigments that absorb green light.

D The plant lacks carotenoid and xanthophyll pigments.

23 The graph shows the relationship between oxygen production in photosynthesis and light intensity for a unicellular green organism in 0.02% sodium hydrogencarbonate solution.



The most likely explanation of the fact that the graph levels off at 180 J m^2 s^{-1} is that the system is

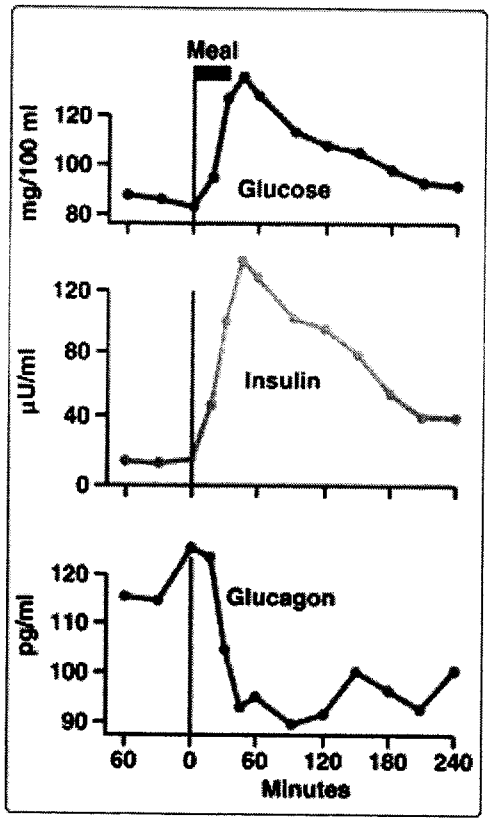
A light limited and carbon dioxide saturated.

B light limited and the temperature is below optimum.

C light saturated and carbon dioxide limited.

D light saturated and the temperature is above optimum.

24 The figure shows the levels of glucose, insulin and glucagon found in blood, before and after a carbohydrate-containing meal was ingested.



Which row correctly identifies the events occurring at the respective timings?

	Timing	Events
A	60 minutes before meal	Glucagon results in the activation of glycogen phosphorylase, leading to increased rates of glycogenolysis in liver cells and an increase in blood glucose levels.
B	30 minutes before meal	Glucagon binds to G protein-linked receptors, leading to the activation of G proteins due to the phosphorylation of GDP molecules. Cellular responses lead to the maintenance of blood glucose levels.
C	At the start of meal (0 minutes)	Insulin binds to tyrosine kinase receptors, resulting in the cross-phosphorylation of tyrosine residues. Cellular responses lead to a decrease in blood glucose levels.
D	60 minutes after meal	Insulin results in the translocation of glucose transporters to the cell surface, leading to increased rates of glucose uptake in muscle cells and a decrease in blood glucose levels.

25 Which statements are correct interpretations of Darwinian evolutionary theory?

1 Advantageous behaviour acquired during the lifetime of an individual is likely to be inherited.

2 In competition for survival, the more aggressive animals are more likely to survive.

3 Species living in a stable environment will not evolve any further.

4 Variation between individuals of a species is essential for evolutionary change.

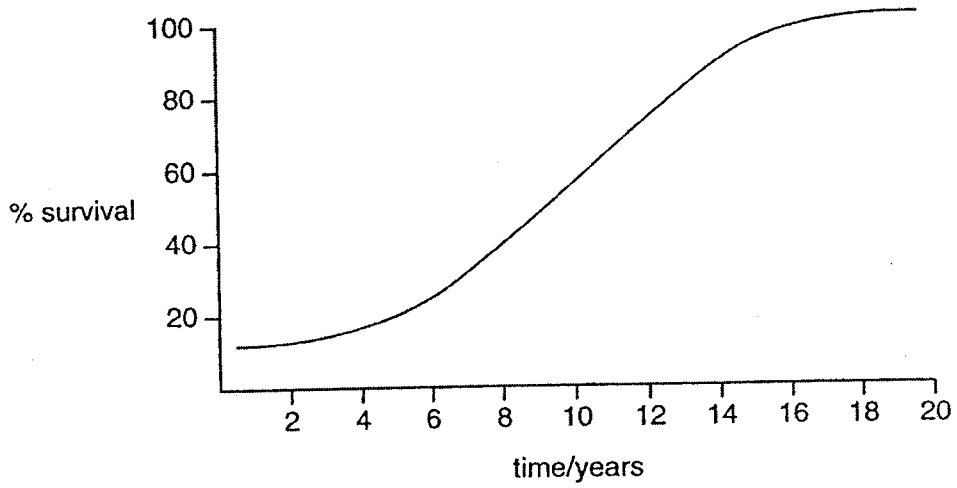
A 1, 2 and 4 only

B 2 and 3 only

C 3 and 4 only

D 4 only

26 The graph shows the effect of pesticide treatment on houseflies over a number of years. A standard amount of pesticide was used each year in summer.



How is the effect of the pesticide best explained?

A A few resistant flies reproduced more successfully, and the resistance allele increased in frequency.

B At every generation an increasing proportion of flies mutated to become resistant.

C Repeated exposure to the pesticide caused the flies to become more resistant.

D The allele for resistance mutated from the recessive form to the dominant form.

27 Reproduction in seahorses, *Hippocampus* , is unusual as it is the male rather than the female that becomes pregnant. The male has a brood pouch located on its tail. The larger the male the larger the pouch. The female transfers unfertilised eggs into the pouch. The larger the female the more eggs are produced that can be transferred to the brood pouch. The male releases sperm onto the eggs and they are fertilised. The male carries the developing brood for a period of several weeks until he finally gives birth.

Research into seahorse populations has revealed the following.

- They are monogamous. A male and female remain together for the whole mating season.
- Within a population, mates are selected by size. Large females mate with large males and small females mate with small males.
- Few intermediate sized individuals are produced and they have a low survival rate.

Which of the following conclusions **cannot** be drawn from the above information?

A Disruptive selection has occurred.

B Intermediate sized individuals are selected against.

C There is phenotypic variation in tail size in males.

D Monogamy results in lower selection pressure as males and females remain together the whole mating season.

28 An antibody is a protein complex secreted by plasma B cells. Which of the following statements regarding the mechanisms of generating antibody diversity is true?

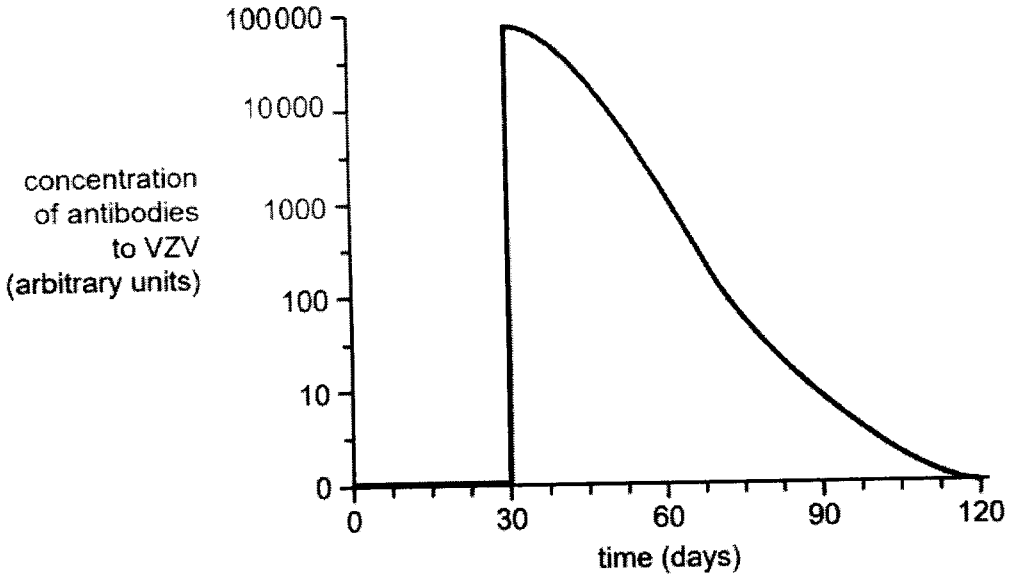
A An antibody changes its affinity upon binding to the antigen through a process known as somatic hypermutation.

B Class switching occurs to produce antibodies with different constant regions in B cells undergoing differentiation in the bone marrow.

C DNA rearrangement during somatic recombination generates a wide repertoire of B cells with different B cell receptors.

D During clonal expansion, rearrangement of the V, D and J segments give rise to antibodies with different variable regions.

29 Chickenpox (varicella) is a highly contagious viral disease caused by the varicella-zoster virus (VZV). A laboratory technician measured the concentration of antibodies to VZV in a person's blood over a 120-day period. An event occurred on day 30 that significantly altered the concentration of antibodies. The concentration of antibodies over the 120 days is displayed in the graph below.



Which one of the following events could have occurred on day 30?

A a booster vaccination against VZV for the person

B an exposure of the person to VZV

C an injection of antibodies to VZV into the person

D an oral dose of antibiotics was given to the person

30 Investigations into the possible current and future impacts of climate change need to be put into the context of the well-documented and on-going impacts of other drivers of change, such as population growth. The statements below are effects of climate change and population growth.

1 More intensive land use results in degradation of soils and more rainfall run-off

2 Food and feed shortages

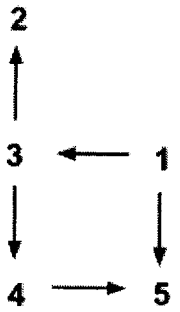
3 Greater frequency of water deficit in soil for crops and pasture growth

4 More frequent dry years experienced

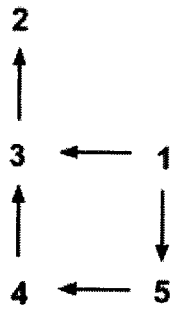
5 Increase food demand and competition for pastures

Which of the following diagram correctly illustrates the relationship between climate change and population growth?

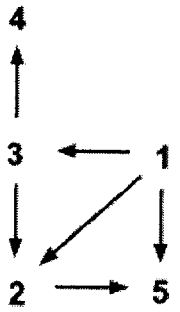
A



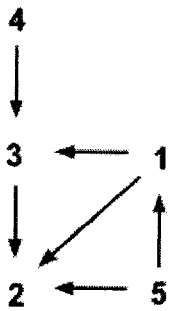
B



C



D



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