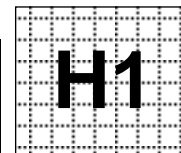


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| Civics Group | Index Number | Name (use BLOCK LETTERS) |
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ST. ANDREW'S JUNIOR COLLEGE
2015 Preliminary Examination

H1 BIOLOGY

8875/2

Paper 2: Core (Mark Scheme)

Wednesday

2 September 2015

2 hours

Additional Materials: Answer Paper
Cover Sheet for Section B

READ THESE INSTRUCTIONS FIRST

Write your name, civics group and index number on all the work you hand in.

Write in dark blue or black pen on both sides of the paper.

You may use a soft pencil for any diagram, graph or rough working.

Do not use staples, paper clips, highlighters, glue or correction fluid.

Section A

Answer **all** the questions.

Section B

Compulsory question to be answered on writing paper provided.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [] at the end of each question or part question.

| For Examiner's Use | |
|--------------------|------------|
| Section A | |
| 1 | /11 |
| 2 | /10 |
| 3 | /9 |
| 4 | /10 |
| Section B | |
| 5 or 6 | /20 |
| Total | /60 |

This document consists of **18** printed pages.

[Turn over

Section A

Answer **all** questions.

QUESTION 1

Amylase is an enzyme that catalyses the break down of starch into maltose. A student investigated the effect of increasing concentration of starch on the activity of amylase. He monitored the time taken for 2.0 cm^3 of starch solution to be completely hydrolysed for six different concentrations of starch solutions (1.0, 2.0, 3.0, 4.0, 5.0 and 6.0 moldm^{-3} respectively). He used his results to calculate the rate of starch digestion and tabulated it in Table 1.1.

Table 1.1

| Concentration of starch / moldm^{-3} | Rate of digestion / s^{-1} |
|---|-------------------------------------|
| 0.0 | 0 |
| 1.0 | 11 |
| 2.0 | 21 |
| 3.0 | 30 |
| 4.0 | 36 |
| 5.0 | 38 |
| 6.0 | 38 |

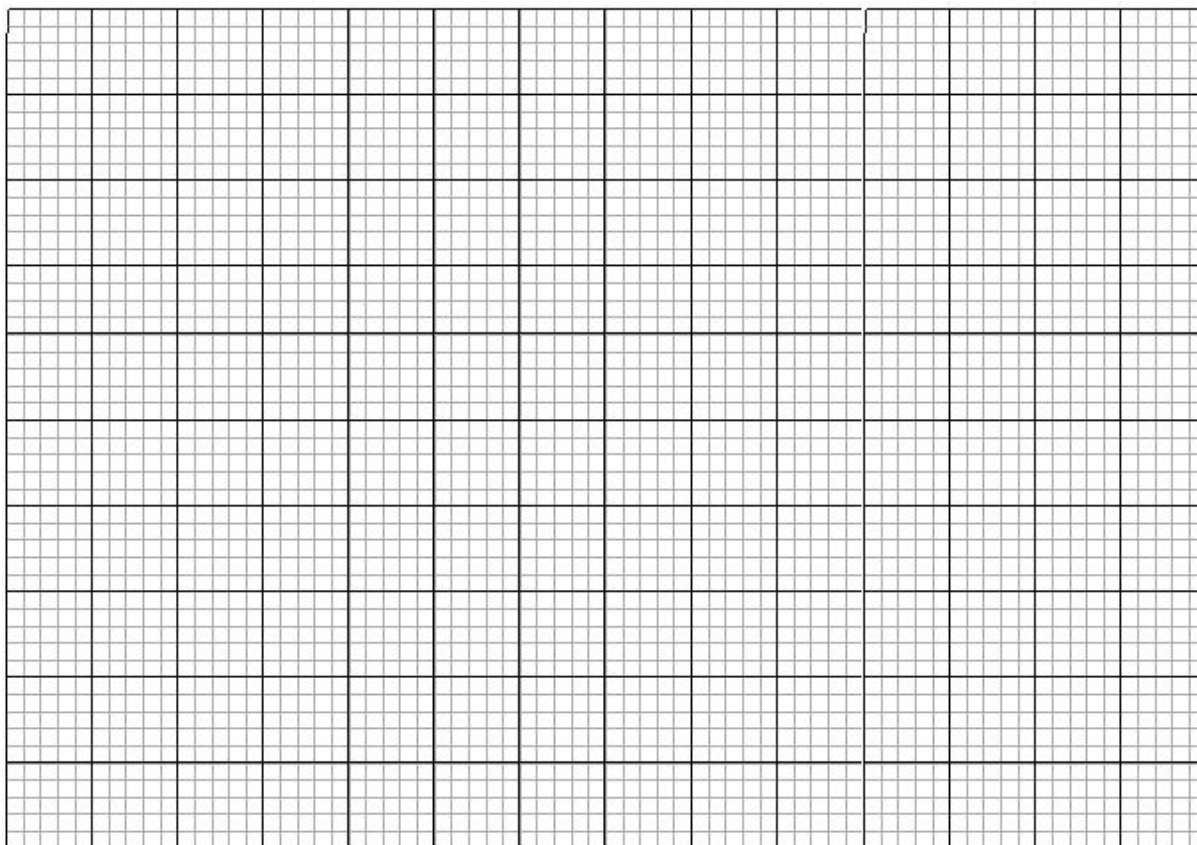
- (a) Suggest and explain one way the student could easily monitor the complete hydrolysis of starch in his experiments.

.....[2]

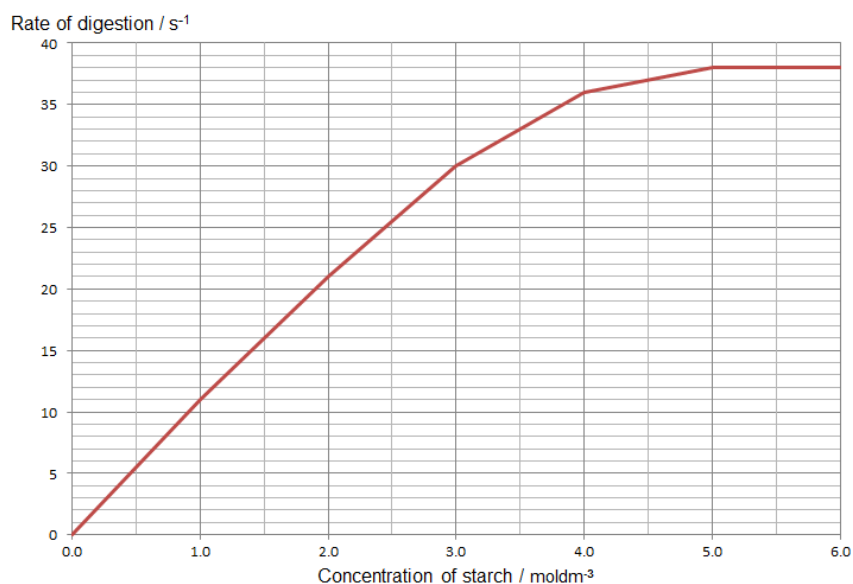
- 1 Add the same volume of iodine in KI solution to each test tube.
- 2 When starch is completely hydrolysed, the mixture will turn from blue black to yellowish brown.

- (b) Plot a graph of the data in Table 1.1.

.....[3]



- 1 Correctly labelled axes with units
- 2 Points are plotted with accuracy
- 3 Best fit line drawn



(c) Account for the shape of the graph drawn in (b).

-[4]
- 1 As starch concentration increased from 0 to 3.0 mol dm⁻³, the rate of digestion increased linearly from 0 to 30 s⁻¹.
 - 2 At low starch concentration, starch is the limiting factor.
 - 3 Increasing substrate concentration will increase the rate of effective collisions between starch and amylase to form enzyme-substrate complex.

- 4 Increasing starch concentration from 3.0 to 6.0 mol dm⁻³ increases the rate of digestion from 30 to a maximum of 38 s⁻¹.
- 5 Starch is no longer a limiting factor, amylase active sites are fully saturated.

(d) Relate one structural feature of starch to its function in plants.

-[2]
- 1 Hydroxyl groups project into the interior of the helix, unable to interact with water / makes starch insoluble
 - 2 able to store in large quantities without altering osmotic potential of plant cells.
- OR
- 3 Hydroxyl groups project into the interior of the helix, do not form cross linkages between starch molecules
 - 4 easily hydrolysed into monomers when needed.
- OR
- 5 $\alpha(1\rightarrow6)$ glycosidic bonds present causing amylopectin to be highly branched
 - 6 Makes starch a compact molecule, can store large amounts of glucose in the limited space of the cells.

[Total : 11]

QUESTION 2

The shape of domestic pigs' tails is controlled by a single gene with two alleles.

Three possible phenotypes exist: corkscrew (Fig. 2.1), single-loop (Fig. 2.2) and unlooped (Fig. 2.3).



Fig. 2.1



Fig. 2.2



Fig. 2.3

When a sow with single-loop tail is mated with the same male with unlooped tail for multiple breeding seasons, they produced the following offspring:

25 single-loop tail

27 unlooped tail

(a) Using the letters **T** and **t**, draw a genetic diagram to show the results of the cross.
.....[5]

T – allele for corkscrew tail

t – allele for unlooped tail

| | | | |
|----------------------------------|------------------|---|---------------|
| Parental phenotypes: | Single-loop tail | x | Unlooped tail |
| Parental genotypes: | Tt | x | tt |
| Parental gametes: | (T) (T) | x | (t) |
| F ₁ genotypes: | Tt | | tt |
| F ₁ phenotypes: | Single-loop tail | | Unlooped tail |
| F ₁ phenotypic ratio: | 1 | : | 1 |

Mark scheme

- 1 Presentation: appropriate symbols (for incomplete dominance), gametes circled
- 2 Parental genotype
- 3 Parental gametes
- 4 F₁ genotypes / Punnett square
- 5 F₁ genotypes correspond to phenotypes
- 6 F₁ phenotypic ratio

(b) Warthogs also have tails that exhibit the corkscrew, single-loop and unlooped phenotypes. Unlike the cross in (a), however, when a female warthog with single-loop tail is mated with a male warthog with unlooped tail, they produced offspring

in the ratio of 1 cockscrew tail : 1 single-loop tail : 2 unlooped tail. Suggest and explain a reason for this difference between the inheritance of 'tail curliness' in pigs and warthogs.

.....[2]

- 1 The alleles controlling tail curliness is sex-linked / present on the X chromosome.
- 2 When the female warthog with genotype $X^C X^c$ is mated with male warthog with genotype $X^c Y$, the 1:1:2 phenotypic ratio is observed.

(c) Identical twins develop from two genetically identical zygotic stem cells. With reference to a named environmental factor, describe how each twin could have a different phenotype.

.....[3]

- 1 Diet can result in one twin developing late-onset diabetes while the other twin doesn't
- 2 The twin who overeats / has high-sugar diet will secrete high levels of insulin for long period of time
- 3 Resulting in repeated exposure of target cells (to large amounts of insulin) /desensitises the target cells' responsiveness to insulin; result in the target cells failing to regulate glucose levels in the blood.

[Total : 10]

QUESTION 3

Astyanax mexicanus is a single species of tetra fish consisting of a sighted surface-dwelling form (surfacefish) and many blind cave-dwelling forms (cavefish) from different caves. The cavefish have small eyes that do not work, but are able to navigate in the complete darkness of the caves by emitting pressure waves with their mouths. It was found that the surfacefish were more heavily parasitized by a bacteria which infected the eyes as they do not have a thick layer of scale-like tissue covering their eyes, which is present in the cavefish.

It was thought that the ancestral morph of *Astyanax mexicanus*, which lived some 1.2 million years ago, had functional eyes. They were slowly displaced from their river habitats by large predatory fish into smaller streams that flowed through caves.

(a) Explain how natural selection could have resulted in the evolutionary change demonstrated here.

.....[5]

- 1 Genetic variation in eye development is present in the ancestral morph due to mutation.
- 2 When they were displaced into the smaller streams in caves, sight is no longer important.
/ Eyes became vestigial structures in the cavefish.
- 3 The selection pressure is parasitism by bacteria
- 4 Fish with thicker scale-like tissue covering their eyes were at a selective advantage, as they were less parasitized (accept converse argument)
- 5 Thus, better able to survive to reproductive age and produce more offspring, passing down their alleles (which determines the development of their eyes) to their offspring.
- 6 After many generations, natural selection will lead to change in frequency of alleles responsible for eye development.

(b) The evolution of the *Astyanax mexicanus* was demonstrated by anatomical homology. Using a named example, discuss another type of homology evidence supporting natural selection.

.....[4]

- 1 Embryological homology
/ Comparison of early developmental stages of organisms revealed that embryos from different species retain similarities during their development.
- 2 Such similarities/homology suggests inheritance from a common ancestor
- 3 which can later develop into homologous structures with very different functions, implying on descent with modification.
- 4 E.g. presence of a tail and pharyngeal pouches in all vertebrate embryos, which later develop gill slits in fishes and parts of ears and throat in humans.

OR

- 1 Molecular homology
/ Comparison between organisms at the molecular level revealed similarities
- 2 Such similarities/homology suggests inheritance from a common ancestor
- 3 As descendents of the same species evolved independently, more and more differences are accumulated in their DNA.
- 4 E.g. similarities in the sequence of DNA, RNA and amino acids of different organisms of common genes.

QUESTION 4

Patients suffering from Life-threatening Multiple Thrombosis (LMT) are unable to synthesise sufficient amounts of platelet factor IV (PF4), which are released by activated platelets at sites of injury to promote blood coagulation. Recent advances in genetic engineering has seen preliminary success in cloning human PF4 gene into bacteria for the mass production of PF4 to be used in clinical treatments of LMT.

Fig. 4.1 shows the simplified map of the plasmid, pYH29, used in the cloning of PF4 gene. The selectable markers used are genes that confer resistance to two antibiotics: Kanamycin (Kan^R) and Clindamycin (Cln^R).

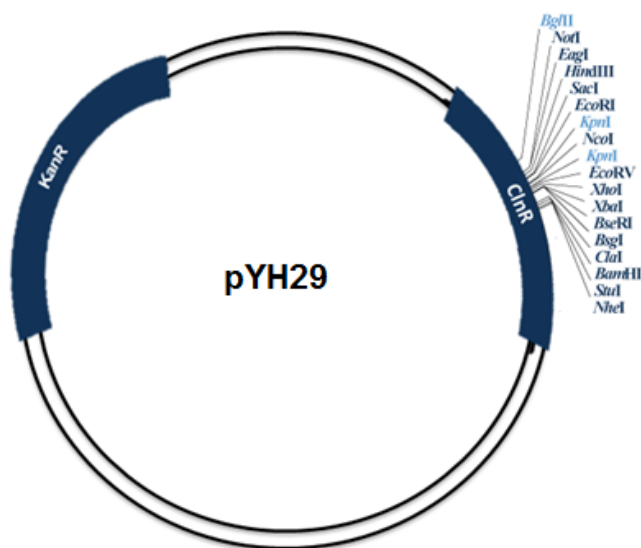


Fig. 4.1

- (a) The amount of PF4 gene inserts obtained from reverse transcription of extracted mRNA is normally too little for successful cloning. Suggest one way to increase the amount of the PF4 gene inserts.

.....[1]
1 Perform PCR to amplify the PF4 gene inserts.

- (b) The PF4 gene insert was obtained from reverse transcribing extracted mRNA and cut it with *Hind*III (restriction enzyme). Describe and explain the subsequent procedures for cloning the PF4 gene into *E. coli* cells.

.....[4]

- 1 Plasmid pYH29 is cut with HindIII to **generate complementary sticky ends**.
- 2 Plasmid and PF4 gene insert are mixed, anneal with each other by forming hydrogen bonds between complementary sticky ends
- 3 DNA ligase added to seal the nicks by formation of phosphodiester bonds between adjacent nucleotides (on the sugar phosphate backbone)
- 4 *E. coli* cells made competent by addition of Ca²⁺; transformation is carried out via heat shock treatment.

- (c) Using both antibiotics, explain how the researchers ensure that only colonies which contain the PF4 gene insert are cultured in large quantities.

-[5]
- 1 Plated bacteria on **LB/Kan plate** to select for **transformed bacteria/bacteria that have taken up the plasmid**;
 - 2 Replica plated on **LB/Cln** plate; comparison of bacterial colonies on LB/Kan plate and LB/Cln plate.
 - 3 Colonies that cannot survive on LB/Cln plate contain recombinant plasmid; Insertion of PF4 gene disrupts ClnR gene;
 - 4 Perform **gene probing** using DNA probes that is **complementary to PF4 gene**.
 - 5 Ref. X-ray autoradiography

[Total : 10]

Section B

Answer one question.

Your answers should be illustrated by large, clearly labelled diagrams, where appropriate.

Your answers must be in continuous prose, where appropriate.

Your answers must be set out in sections (a), (b) etc., as indicated in the question.

- 5 (a) Discuss the role of proteins in eukaryotic transcription. [6]
(b) Describe the process of translation. [8]
(c) Discuss the roles of mRNA, tRNA and rRNA in protein synthesis. [6]

[Total: 20]

OR

- 6 (a) Compare substrate level phosphorylation and oxidative phosphorylation. [6]
- (b) Explain the small yield of ATP under anaerobic conditions in both yeast and mammals. [8]
- (c) State the similarities between ATP production in mitochondria and chloroplasts and suggest why these similarities exist. [6]

5(a) Discuss the role of proteins in transcription. [6]

- 1 A transcription factor search for and attach to the TATA box / promoter
- 2 This binding attracts general transcription factors and RNA polymerase II to bind to the promoter, forming the transcription initiation complex.
- 3 RNA polymerase II moves along the DNA to unwind and unzip the double helix, (exposing 10 to 20 DNA bases at a time)
- 4 RNA polymerase II adds complementary ribonucleotides to the 3' end of the growing RNA chain.
- 5 RNA polymerase II catalyses formation of phosphodiester bonds between adjacent ribonucleotides, forming a continuous mRNA chain..
- 6 RNA polymerase II transcribes a DNA sequence which codes for the polyadenylation signal (AAUAAA) in the RNA transcript;
- 7 10 to 35 nucleotides downstream from this signal, pre-mRNA is cleaved by proteins and released from the growing RNA chain (while RNA polymerase II continues to transcribe the DNA)

5(b) Describe the process of translation. [8]

Amino acid activation

- 1 attachment of an amino acid to its specific tRNA (amino acid activation) catalysed by aminoacyl tRNA synthetases

Initiation

- 2 initiator tRNA with anticodon UAC carrying methionine associates with the small ribosomal subunit
- 3 (initiator tRNA-small ribosomal subunit) binds to the 5' cap of the mRNA, then moves downstream along the mRNA until it reaches the start codon/AUG,
- 4 binds with the start codon/AUG (through complementary base-pairing) at P site of large ribosomal subunit
- 5 formation of translation initiation complex
/ assembly of ribosome + mRNA + translation initiation factors (TIFs)

Elongation

- 6 complementary base pairing between anti-codon of incoming aminoacyl- tRNA binds to codon on mRNA at A site of large ribosomal subunit
- 7 peptide bonds formed between adjacent amino acids catalysed by peptidyl transferase;
- 8 ribosomes translocates one codon / 3 nucleotides along the mRNA in the 5' to 3' direction, exposing codon at A site of ribosome to receive another aminoacyl-tRNA
- 9 initial tRNA is relocated to E site and ejected from ribosome, tRNA carrying the growing polypeptide chain is repositioned to P site

Termination

- 10 chain termination occurs when stop codon (UAG, UGA, UAA) in A site;
- 11 a protein called release factor binds directly to the stop codon in the 'A' site, addition of water instead of amino acid to release polypeptide chain;

5(c) Discuss the roles of mRNA, tRNA and rRNA in protein synthesis. [6]

Role of mRNA

- 1 messenger molecule that conveys information from DNA in nucleus to protein synthesis in cytoplasm;
- 2 codons in mRNA specify the order and sequence in which amino acids are positioned to form a polypeptide.

tRNA roles

- 3 Transports amino acids to the ribosome for use in building the polypeptides
- 4 Ensures correct position and sequence of each amino acids on the elongating polypeptide chain (based on complementary base-pairing between anticodon on tRNA and codon on mRNA).

rRNA roles

- 5 rRNA assembled with proteins to form ribosomal subunits in nucleolus (ribosomal subunits are then exported via nuclear pores to the cytoplasm)
- 6 rRNA in ribosomes hold tRNA and mRNA in close proximity
- 7 position new amino acid to the growing polypeptide chain and catalyse formation of peptide bond during translation

6(a) Compare substrate level phosphorylation and oxidative phosphorylation.

[6]

| Features | Substrate level phosphorylation | Oxidative phosphorylation |
|--|---|---|
| 1 Definition | Synthesis of ATP occurs when an enzyme transfers a phosphate group from a substrate molecule to ADP. | Synthesis of ATP occurs as electrons are transferred from NADH or FADH ₂ to oxygen by an electron transport chain. The energy coupling occurs through a <u>proton gradient</u> . |
| 2 Location | The <u>cytosol</u> and the <u>mitochondrial matrix</u> . | On the <u>inner membrane</u> of mitochondrion. |
| 3 Reactions | In glycolysis, from 1,3-diphosphoglycerate to 3-phosphoglycerate to pyruvate. In Krebs cycle, from succinyl CoA to succinate. | Involves a series of <u>redox reactions</u> via a series of electron carriers in the the electron transport chain. |
| 4 Involvement of electron transport chain | No | Yes |
| 5 Involvement of oxidation | No | Yes |
| 6 Number of ATP molecules formed per glucose molecule oxidised | 4 | 34 |

6(b) Explain the small yield of ATP under anaerobic conditions in both yeast and mammals. [8]

- Under anaerobic conditions, oxygen is no longer available as the final electron and proton acceptor in the ETC
- Electron carriers remain reduced (as NADH and FADH₂)
- Oxidative phosphorylation, Krebs cycle, link reaction stopped (due to the lack of electron carriers NAD⁺ and FAD)
- Pyruvate is reduced by NADH (in cytoplasm at the end of glycolysis)
- Forming ethanol + CO₂ in yeast
- and lactate in mammals
- NAD⁺ regenerated for use in glycolysis
- only glycolysis would occur resulting in two molecules of ATP
- produced via substrate level phosphorylation

6(c) State the similarities between ATP production in mitochondria and chloroplasts and suggest why these similarities exist. [6]

Similarities

- 1 Both have electron carriers embedded in membranes - inner membrane of mitochondrion and thylakoid membrane of chloroplast
- 2 Both involve electrons being passed down a series of electron carriers with increasing electronegativity and in order of decreasing energy levels
- 3 Energy released from electron transport chain is used to generate a proton gradient
- 4 Both involves diffusion of protons down a concentration gradient through ATP synthase / ref. chemiosmosis;
- 5 potential energy of the proton gradient is used for the synthesis of ATP from ADP and P_i

Why these similarities exist

- 6 Both processes of ATP production are similar in the organelles because of the endosymbiont theory / endosymbiosis
- 7 mitochondria and chloroplasts originated as prokaryotic organisms which were taken inside a eukaryotic cell

- END OF PAPER -