



Rewarding Learning

ADVANCED
General Certificate of Education
2023

Centre Number

--	--	--	--	--

Candidate Number

--	--	--	--	--

Biology

StemUp Model Solution

Assessment Unit A2 2

assessing

Biochemistry, Genetics and
Evolutionary Trends



[ABY21]

ABY21

FRIDAY 16 JUNE, MORNING

TIME

2 hours 15 minutes.

INSTRUCTIONS TO CANDIDATES

Write your Centre Number and Candidate Number in the spaces provided at the top of this page.

You must answer the questions in the spaces provided.

Do not write outside the boxed area on each page or on blank pages.

Complete in black ink only. **Do not write with a gel pen.**

Answer **all nine** questions.

INFORMATION FOR CANDIDATES

The total mark for this paper is 100. Section A carries 82 marks. Section B carries 18 marks. Figures in brackets printed down the right-hand side of pages indicate the marks awarded to each question or part question.

You are reminded of the need for good English and clear presentation in your answers.

Use accurate scientific terminology in all answers.

You should spend approximately **25 minutes** on Section B.

You are expected to answer Section B in continuous prose.

Quality of written communication will be assessed in Section B.

Statistics Sheets are provided for use with this paper.

13899



BLANK PAGE
DO NOT WRITE ON THIS PAGE

13899



Section A

- 1 Complete the table below, containing terms which relate to inheritance.

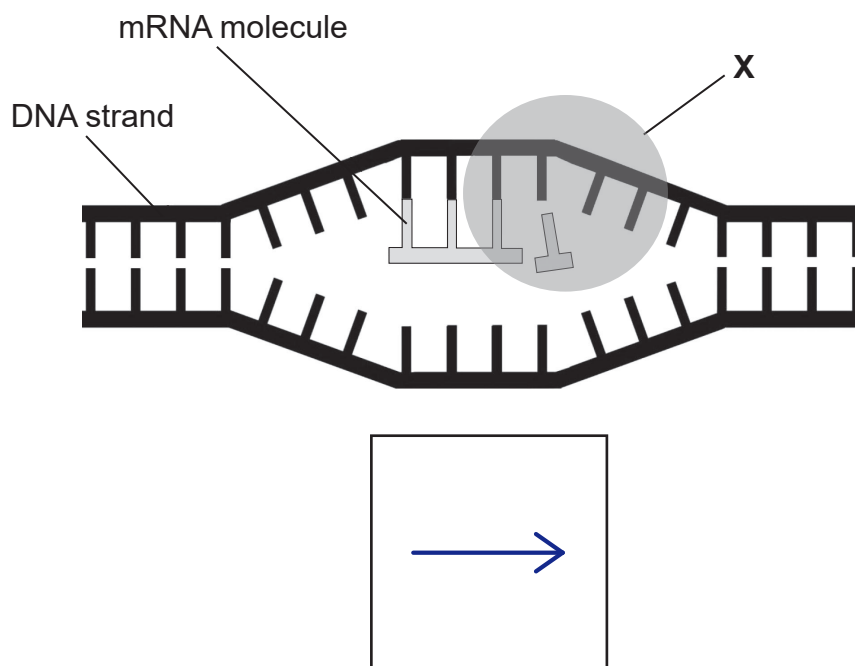
Term	Definition
Gene	<i>A length of DNA (on a chromosome) that codes for a polypeptide / protein.</i>
Allele	<i>An alternative form of the same gene, found at the same locus.</i>
<i>Homozygous</i>	Having alleles of a gene which are both the same
<i>Locus</i>	The position of a gene on a chromosome
Phenotype	<i>The expression of the genotype (the observable characteristics), in association with the environment.</i>

[5]

[Turn over



- 2 Protein synthesis involves several stages, including transcription and translation. The diagram below represents transcription.



Source: Principal Examiner

- (a) (i) State the name of the enzyme labelled X.

RNA polymerase

[1]

- (ii) In the box on the diagram, draw an arrow clearly indicating the direction of movement of the enzyme along the strand of DNA.

[1]



- (iii) Use the information provided and your knowledge to describe the process of transcription.

RNA polymerase binds to the DNA and breaks the hydrogen bonds between complementary bases, so the two strands separate (unwind) and one strand acts as the template.

Free (activated) RNA nucleotides (ribonucleotides) line up opposite the exposed bases on the template strand by complementary base pairing (A with U, T with A, C with G).

Adjacent ribonucleotides are joined by phosphodiester bonds (condensation), catalysed by RNA polymerase as it moves along the DNA, forming mRNA.

Behind the enzyme the hydrogen bonds between the DNA strands reform and the mRNA is released.

[4]

- (b) Following the process of transcription, the mRNA molecule is released from the transcription site. The mRNA then undergoes further changes before translation takes place. Describe the changes that occur in the mRNA molecule.

Introns (non-coding sequences) are removed / excised from the pre-mRNA.

The remaining exons (coding sequences) are spliced / joined together to form mature mRNA.

[2]

[Turn over]



- 3 The polymerase chain reaction (PCR) is used to amplify (make many copies of) small samples of DNA. The amount of DNA doubles every cycle.

(a) (i) State **one** use of PCR.

Amplifying DNA from a crime scene for genetic fingerprinting, or for
paternity testing or diagnosis of an infection.

[1]

- (ii) A PCR machine can complete 40 PCR cycles in one hour. Calculate the number of cycles which will be completed if the PCR machine runs for 75 minutes.

(Show your working.)

$$75 \text{ minutes} = 75 \div 60 = 1.25 \text{ hours}$$

$$\text{number of cycles} = 1.25 \times 40 = 50$$

50 cycles

[2]



In 1987, an enzyme called Taq DNA polymerase was isolated from the thermophilic (heat-loving) bacterium *Thermus aquaticus*. This enzyme was later used to replace the standard DNA polymerase enzyme that had been in use previously.

- (b) Explain how the use of Taq DNA polymerase enzyme helped to improve the PCR process.

Taq polymerase is thermostable: it comes from a thermophilic bacterium

so it is not denatured at the high temperature (about 95 °C) used to

separate the DNA strands.

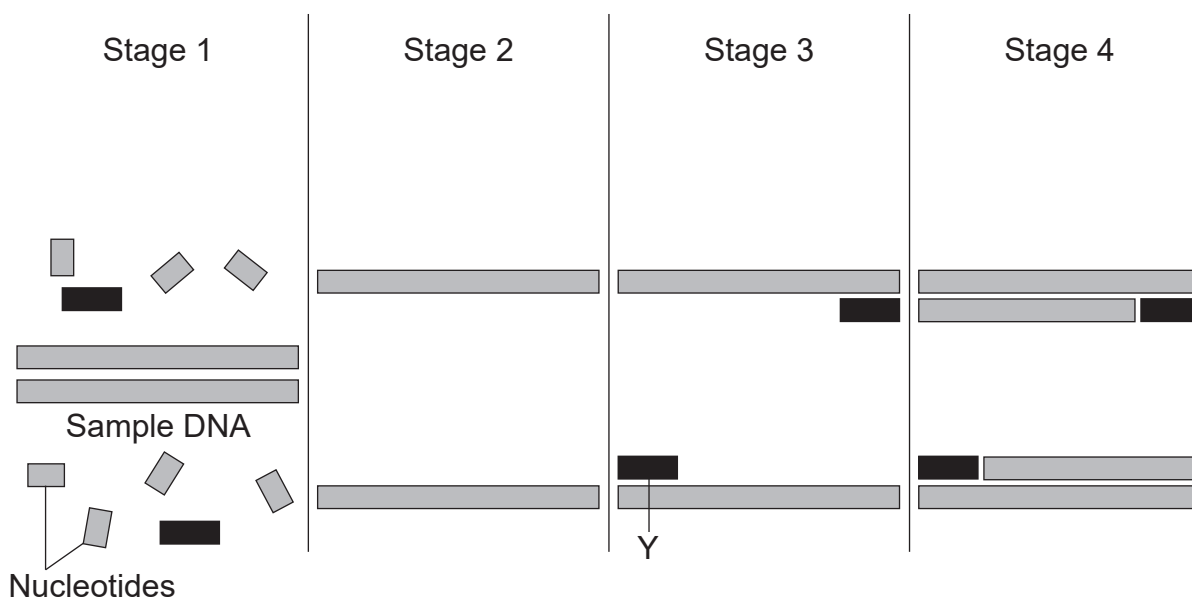
Therefore it does not need to be replaced (fresh enzyme added) at the end of each cycle.

So the complete process is faster, can be automated and is more cost efficient.

[3]



(c) The diagram below represents some stages of the PCR cycle.



Source: Principal Examiner

(i) Identify the molecule labelled Y.

Primer

[1]

(ii) Describe **two** functions of molecule Y.

1. Prevents the separated DNA strands from re-annealing (rejoining).

2. Provides a double-stranded start point for DNA polymerase to begin replication / brackets the DNA section to be copied.

[2]



4 Respiration is a cellular process which produces ATP. The ATP generated can be used in energy-requiring processes such as muscle contraction.

(a) (i) Explain the benefit of using ATP as an immediate energy store in cells.

Hydrolysis of ATP is a single reaction, so energy is released

immediately when it is needed.

It releases a small, manageable amount of energy, so little is wasted

as heat, and ATP is soluble and easily transported within the cell.

[2]

(ii) Cyanide inhibits the enzyme cytochrome oxidase. Using your knowledge of the electron transport chain, explain how cyanide prevents ATP production.

Cyanide inhibits cytochrome oxidase, so electrons / hydrogen cannot be

passed to oxygen (the final acceptor) to form water.

The electron / hydrogen carriers therefore remain reduced and the

chain stops, so ATP formation by oxidative phosphorylation is

prevented.

[2]

(b) Muscle contraction occurs via the sliding filament theory. State precisely which step of muscle contraction uses ATP.

Release (detachment) of the myosin head from the actin binding site, so

it can reorientate.

[1]

[Turn over]



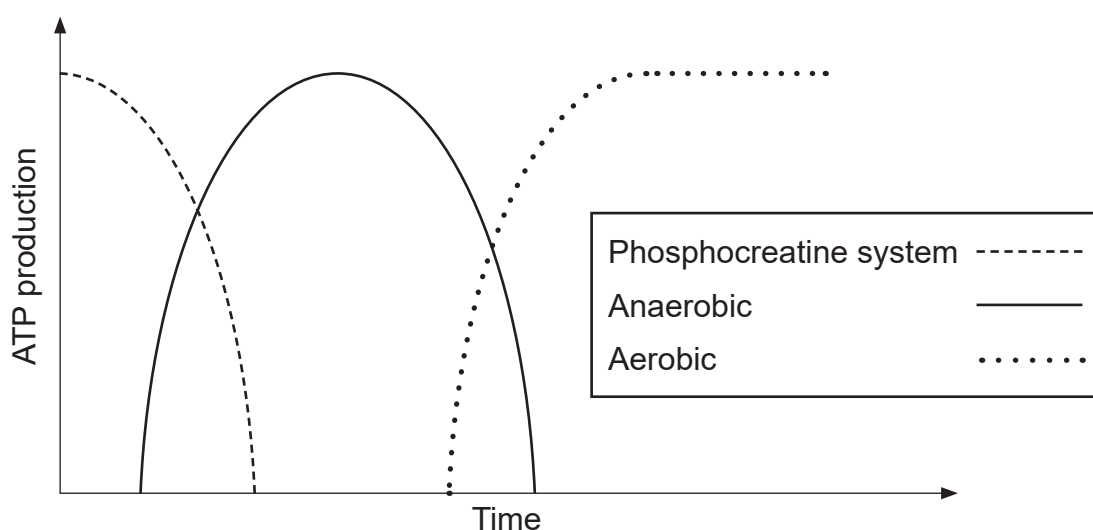
(c) Muscle contraction uses ATP produced from three cellular processes:

- glycolysis (anaerobic respiration)
- aerobic respiration
- the phosphocreatine system

The phosphocreatine system uses creatine phosphate, a small amount of which is stored in muscle cells. This can make ATP very quickly.

The contribution which each of these processes makes to muscle contraction was investigated. The graph below summarises the results of the investigation.

The subjects involved began with intense exercise that decreased in intensity over time.



(i) Describe the trends shown by the results.

At the start of exercise most ATP is supplied by the phosphocreatine system, which peaks quickly then falls.

Anaerobic respiration then supplies most ATP, rising to a peak as the phosphocreatine supply decreases, and then falling.

Aerobic respiration increases later and then supplies ATP for a sustained period (levels off) as exercise continues.

[3]



- (ii) Suggest explanations for the trends shown in ATP production during the period of exercise **before** aerobic respiration becomes dominant.

The phosphocreatine system produces ATP very rapidly, but the small store of creatine phosphate in muscle cells is quickly used up.

Anaerobic respiration then dominates as oxygen availability is limited during intense exercise; glycolysis is a shorter pathway so produces ATP faster.

[2]

- (d) Anaerobic respiration of glucose involves glycolysis followed by further reactions. Explain the importance of these further reactions.

The further reactions (pyruvate to lactate, using reduced NAD) allow the regeneration / reoxidation of NAD.

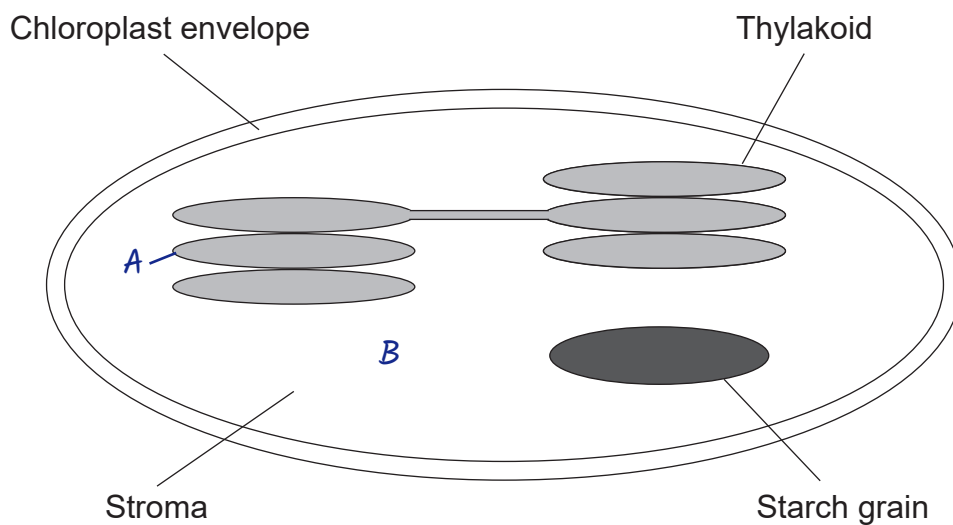
So NAD is available for the dehydrogenation reactions of glycolysis to continue, producing a small yield of ATP.

[2]

[Turn over]



- 5 (a) Chloroplasts are the site of the light-dependent and light-independent stages of photosynthesis. The diagram below represents a chloroplast.



Source: Principal Examiner

- (i) Label the diagram with **A** and **B** to indicate where the following processes take place:

A Light-dependent stage

B Light-independent stage

[2]

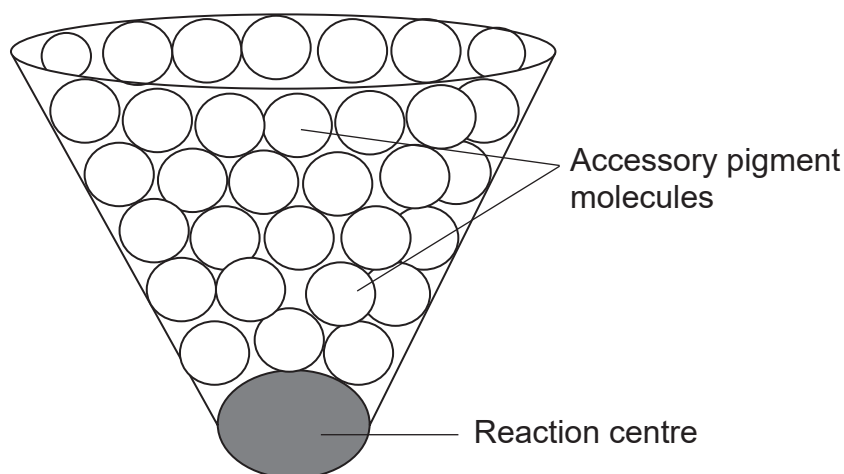
- (ii) Explain precisely what is meant by the term 'chloroplast envelope'.

The double membrane (inner and outer membranes) surrounding the chloroplast.

[1]



The diagram below represents an 'antenna complex'. This is made up of a reaction centre chlorophyll molecule, arranged with several hundred other accessory pigment molecules.



Source: Principal Examiner

- (b) (i) Using the diagram and your knowledge, suggest how an antenna complex is an adaptation for light harvesting.

It contains large numbers of accessory pigment molecules (e.g. chlorophyll b, carotenoids) which absorb light over a wide range of wavelengths.

The pigments are tightly packed in an ordered arrangement on the thylakoid membrane (funnel shape), so absorbed energy is passed from pigment to pigment by resonance energy transfer to the reaction centre chlorophyll a.

[3]

[Turn over



- (ii) Light energy causes the production of ATP by photophosphorylation. Describe concisely the steps involved in this process.

Light energy absorbed by the reaction centre causes photoactivation: electrons are excited to a higher energy level and emitted from the chlorophyll.

The electrons are passed to an electron acceptor molecule.

They then pass down a chain of electron carriers, releasing energy which is used to make ATP from ADP and P_i (photophosphorylation).

[3]

- (iii) Describe how the electrons lost from photosystems I and II are replaced.

PSI *Electrons emitted from PSII (passed along the electron carrier chain) replace those lost from PSI.*

PSII *Photolysis of water ($2H_2O \rightarrow 4H^+ + 4e^- + O_2$) supplies electrons to replace those lost from PSII.*

[2]



Plants growing in habitats with low light intensity often have much greater numbers of the accessory pigments associated with light harvesting.

(c) Suggest an advantage of this to the growth of the plant.

More accessory pigments harvest more of the available light, reducing the impact of low light intensity as a limiting factor.

So the light-dependent reaction proceeds faster, giving more ATP and reduced NADP, so more glucose / organic molecules are made for growth.

[2]

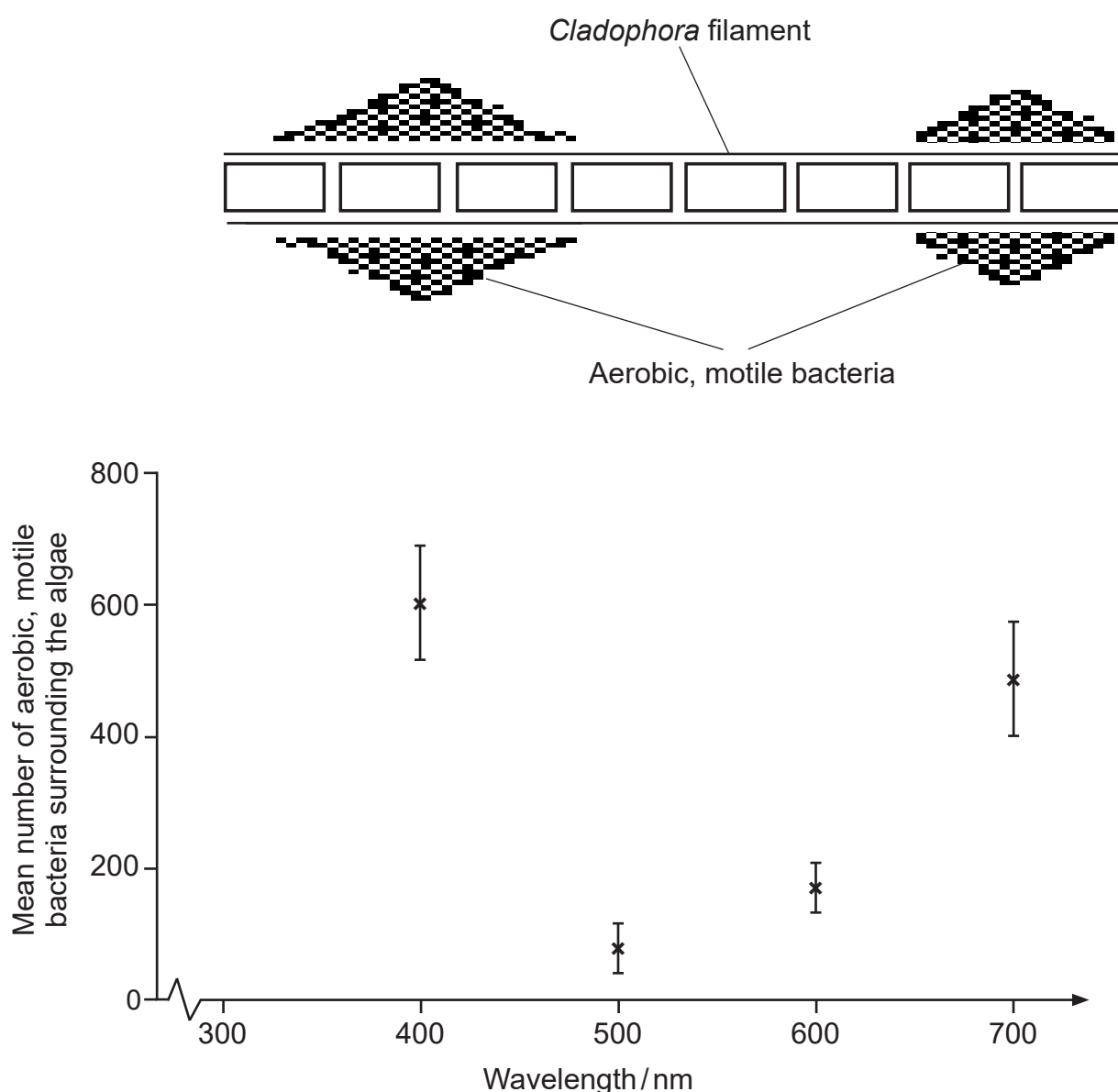
[Turn over]



- 6 (a) A scientist called Engelmann investigated the relationship between wavelength of light and rate of photosynthesis.

His experiments used two organisms: the filamentous alga *Cladophora* and a species of aerobic bacterium, *Bacillus termo*, which is motile (capable of movement). The numbers of bacteria observed close to the algal filament at different wavelengths of light were used to estimate relative photosynthesis rate.

The diagram and graph below summarise the experiment and his results. The graph shows mean numbers of bacteria with associated 95% confidence limits.



Source: Principal Examiner



- (i) Explain why Engelmann used bacteria that were aerobic and motile as indicators of photosynthesis.

Aerobic Oxygen is produced as a by-product of photosynthesis, and
aerobic bacteria need oxygen for respiration.

Motile The bacteria move to and accumulate in regions of higher
oxygen concentration, i.e. where photosynthesis is fastest.

[2]

- (ii) Engelmann's results correspond to an 'action spectrum' for photosynthesis. Explain the term 'action spectrum'.

A graph showing the rate of photosynthesis,
which occurs at different wavelengths of light.

[2]

- (iii) Engelmann concluded that there was no significant difference in the mean numbers of bacterium at 400nm and 700nm. Identify the evidence for this conclusion.

The 95% confidence limits (error bars) at 400 nm and 700 nm
overlap.

[1]

[Turn over]



(b) Explain how 95% confidence limits are used to assess the reliability of data.

Wide 95% confidence limits indicate lower reliability; narrow limits indicate higher reliability.

This is because wide limits show the results are more variable, with a larger standard deviation / standard error.

[2]



- 7 (a) One technique in gene technology involves gene transfer, for example the human insulin gene into a host bacterial cell.

The enzyme reverse transcriptase can be used to produce a copy of a desired gene.

- (i) Describe how reverse transcriptase is used to produce a copy of a desired gene.

(Mature) mRNA for the desired gene is extracted from the tissue.

Reverse transcriptase uses the mRNA as a template to make a

complementary single strand of cDNA.

The single strand of cDNA is converted to a double-stranded

molecule by DNA polymerase.

[3]

- (ii) Suggest and explain why cells from the pancreas are required for the technique described above when producing a copy of the insulin gene.

Pancreas (β) cells produce insulin, so the insulin gene is being expressed.

This means there is a high copy number of insulin mRNA to extract.

[2]

- (iii) A desired gene can also be obtained from chromosomal DNA, using restriction enzymes. Describe the action of restriction enzymes.

They cut DNA at a specific base sequence (recognition site),

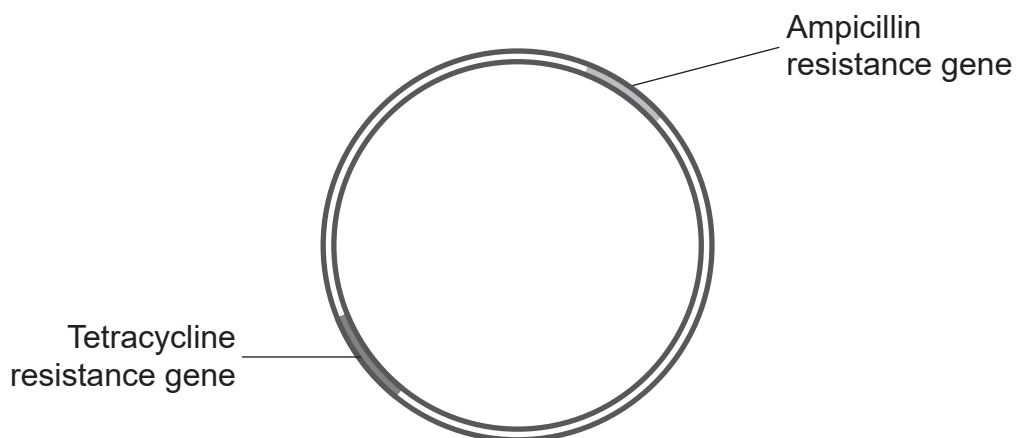
producing staggered (sticky) ends or blunt ends.

[2]

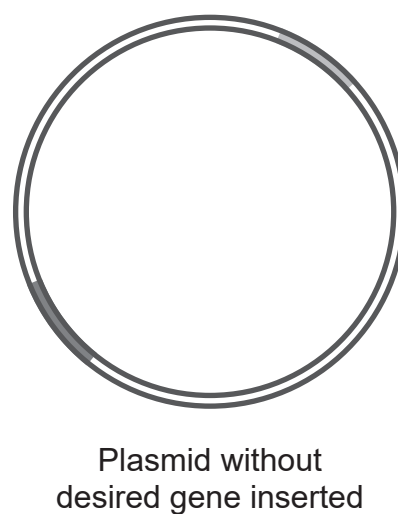
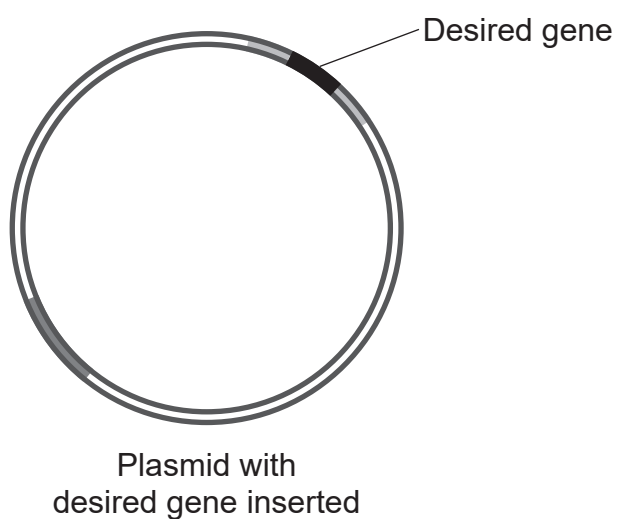
[Turn over]



- (b) Plasmids are small loops of DNA, which may be used to transfer a desired gene into the host bacterial cell. A typical plasmid is shown below.



The diagram below shows two possible outcomes when attempting to insert a desired gene into this plasmid.



Source: Principal Examiner



- (i) State the term used to describe the role of the plasmid in this process.

Vector

[1]

- (ii) Describe how uptake of the plasmid by bacterial cells can be brought about.

Heat (thermal) shock in the presence of calcium ions.

[1]

- (iii) In this process, antibiotic resistance genes are referred to as 'marker' genes. Describe and explain how these could be used to identify bacterial cells that have taken up the plasmid with the desired gene inserted.

Grow the bacteria on agar containing tetracycline: only bacteria that have taken up a plasmid survive, as they are resistant to tetracycline (the gene is intact).

Then replica plate the colonies onto agar containing ampicillin.

Bacteria whose plasmid has the insulin gene inserted cannot grow on ampicillin, because the insert interrupts the ampicillin resistance gene; so colonies that grow on tetracycline but not on ampicillin have the desired gene.

[3]

[Turn over]



- 8 (a) Distinguish between the terms 'dominance' and 'epistasis'.

Dominance is an allelic interaction: one allele of a gene masks the expression of the other allele of the same gene.

Epistasis is a gene interaction: one gene masks / affects the expression of a different gene.

[2]

- (b) In squash plants (*Cucurbita*) fruit colour is determined by two genes, A/a and B/b. The dominant allele A prevents the production of pigment in the fruit, resulting in white fruit. The genotype aa allows the production of pigment, so the fruit will be coloured. The dominant B allele results in production of yellow fruit, while the b allele results in production of green fruit.

Complete a genetic diagram to show the outcome of a cross between squash plants heterozygous for both genes.

Parental phenotype: white × white

Parental genotype: AaBb × AaBb

Gametes: AB Ab aB ab × AB Ab aB ab

	AB	Ab	aB	ab
AB	AABB	AABb	AaBB	AaBb
Ab	AABb	AAbb	AaBb	Aabb
aB	AaBB	AaBb	aaBB	aaBb
ab	AaBb	Aabb	aaBb	aabb

F1 phenotypes	Ratio
White (A_ _ _)	12
Yellow (aaB_)	3
Green (aabb)	1

[5]



- (c) A χ^2 goodness-of-fit test was used to confirm if the expected epistatic ratios existed in this genetic cross.

The colour of samples of fruit from 3400 plants produced from repeated crosses in part (b) was recorded.

The table below shows the numbers of different colours of fruit recorded. Also shown is the partial calculation of the χ^2 value.

- (i) Complete the table and calculate the χ^2 value.

Phenotype	Observed (O)	Expected (E)	O – E	(O – E) ²	$\frac{(O - E)^2}{E}$
White	2560	2550	10.00	100	0.039
Yellow	620	637.5	– 17.5	306.25	0.480
Green	220	212.5	7.5	56.25	0.265
					$\chi^2 = 0.784$

[4]

- (ii) State the appropriate degrees of freedom for this χ^2 test.

2

[1]

- (iii) State the p-value for your calculated χ^2 value.

0.90 > p > 0.50

[1]

- (iv) State an appropriate null hypothesis for this χ^2 test.

There is no significant difference between the observed and expected numbers of each squash fruit colour (12 : 3 : 1).

[1]

[Turn over]



(v) State your decision regarding the null hypothesis.

The null hypothesis is accepted.

[1]

(vi) Explain what this suggests about the relationship between the two genes.

The results fit the expected 12 : 3 : 1 ratio, suggesting genes A and

B show an epistatic interaction (A masks the effect of B).

[1]



Section B

Quality of written communication will be assessed in this section.

- 9 Evolution in the kingdom Animalia has involved changes in body form and support, as well as changes in gut structure and function.

Describe the features occurring in the **five** animal phyla listed below, with regard to body form, support, and gut structure and function. [18]

Cnidaria

Cnidarians (e.g. Hydra) show radial symmetry: the body can be divided into similar halves along many planes through the central axis. This allows feeding in all directions, as tentacles with stinging cells capture prey arriving from any side; many are filter feeders.

The gut is a simple sac-like gut (the enteron) with only one opening, which acts as both mouth and anus, so there is no one-way flow and no regional specialisation.

Support is by a hydrostatic skeleton: the fluid-filled enteron, together with the surrounding aqueous medium, gives the body shape and something for contractile cells to act against.

[Turn over]



Platyhelminthes

Flatworms (e.g. planarians) show bilateral symmetry: the body can be divided into two mirror-image halves by only one plane. This allows the development of a head region (cephalisation), with sense organs at the front, so the animal moves forward actively to find food.

The gut is a tube-like, branched gut, but still with only one opening.

Although there is some specialisation, the body is a dense mass of metabolic tissue with no body cavity.

Dorso-ventral flattening increases the surface area to volume ratio, keeping diffusion distances short. Support is mainly by the body tissues themselves, as a skeletal system is absent.



Annelida

Annelids (e.g. the earthworm) are bilaterally symmetrical with a head end, and metamerically segmented: the body is a series of repeated segments separated by septa.

Support is provided by a hydrostatic skeleton of fluid-filled, segmented body cavities (coelom). Circular and longitudinal muscles act against this fluid, and segmentation lets each part change shape independently, e.g. for burrowing.

A one-way gut has developed, with a separate mouth and anus, so food moves in one direction. This allows regional specialisation of the gut, e.g. a crop for storage, a muscular gizzard for grinding and an intestine for digestion and absorption.

[Turn over



Arthropoda

Arthropods (e.g. insects) are bilaterally symmetrical and segmented, with segments fused into regions such as head, thorax and abdomen. Support is by a hard chitin exoskeleton with jointed limbs, which also protects the body and reduces water loss.

They possess a one-way gut showing regional specialisation (foregut, midgut, hindgut). The basic body plan is suited to many feeding niches, with a range of mouthpart types, e.g. chewing mandibles in locusts and piercing, sucking mouthparts in aphids.

Often the larval form has different food sources from the adults of the same species (caterpillars eat leaves, butterflies feed on nectar), reducing competition.



Chordata

Chordates (e.g. mammals) are bilaterally symmetrical with a distinct head.

Support is by an internal, jointed, calcified skeleton (endoskeleton) of bone and cartilage, which grows with the animal.

A spinal (vertebral) column supports the body and protects the spinal cord, with segmented muscle blocks attached along it for powerful movement.

They possess a one-way gut with a much greater degree of regional specialisation than other phyla (mouth, oesophagus, stomach, duodenum, ileum, colon). Associated systems, e.g. the circulatory system, allow mass flow transport of absorbed nutrients.

THIS IS THE END OF THE QUESTION PAPER



BLANK PAGE
DO NOT WRITE ON THIS PAGE

13899





BLANK PAGE
DO NOT WRITE ON THIS PAGE

13899



DO NOT WRITE ON THIS PAGE

For Examiner's use only	
Question Number	Marks
1	
2	
3	
4	
5	
6	
7	
8	
9	

Total Marks	
--------------------	--

Examiner Number

Permission to reproduce all copyright material has been applied for.
In some cases, efforts to contact copyright holders may have been unsuccessful and CCEA will be happy to rectify any omissions of acknowledgement in future if notified.





ADVANCED
General Certificate of Education

Biology

Statistical Formulae and Tables

Statistics Sheets

Statistical Formulae and Tables

1 Definition of Symbols

n = sample size

$\bar{x}$ = sample mean

$\hat{\sigma}$ = estimate of the standard deviation

These parameters are obtained using a calculator with statistical functions, remembering to use the function for $\hat{\sigma}$ – which may be designated a different symbol on the calculator – with $(n - 1)$ denominator.

2 Practical Formulae

2.1 *Estimation of the standard deviation (error) of the mean ($\hat{\sigma}_{\bar{x}}$)*

$$\hat{\sigma}_{\bar{x}} = \sqrt{\frac{\hat{\sigma}^2}{n}}$$

2.2 *Confidence limits for population mean*

$$\bar{x} \pm t \sqrt{\frac{\hat{\sigma}^2}{n}}$$

which can be rewritten, in terms of $\hat{\sigma}_{\bar{x}}$, as

$$\bar{x} \pm t(\hat{\sigma}_{\bar{x}})$$

where t is taken from t tables for the appropriate probability and $n - 1$ degrees of freedom.

3 Tests of significance

3.1 Student's t test

Different samples are denoted by subscripts; thus, for example, $\bar{x}_1$ and $\bar{x}_2$ are the sample means of sample 1 and sample 2 respectively.

The following formula for t is that to be used:

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{\hat{\sigma}_1^2}{n_1} + \frac{\hat{\sigma}_2^2}{n_2}}}$$

which can be rewritten, in terms of $\hat{\sigma}_{\bar{x}}$, as

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\hat{\sigma}_{\bar{x}_1}^2 + \hat{\sigma}_{\bar{x}_2}^2}}$$

with $n_1 + n_2 - 2$ degrees of freedom.

3.2 Chi squared test

Using the symbols O = observed frequency, E = expected frequency and Σ = the sum of

$$\chi^2 = \Sigma \frac{(O - E)^2}{E}$$

with $n - 1$ degrees of freedom (where n is the number of categories).

Table 1 Student's t values

d.f.	$p = 0.1$	0.05	0.02	0.01	0.002	0.001
1	6.314	12.706	31.821	63.657	318.31	636.62
2	2.920	4.303	6.965	9.925	22.327	31.598
3	2.353	3.182	4.541	5.841	10.214	12.924
4	2.132	2.776	3.747	4.604	7.173	8.610
5	2.015	2.571	3.365	4.032	5.893	6.869
6	1.943	2.447	3.143	3.707	5.208	5.959
7	1.895	2.365	2.998	3.499	4.785	5.408
8	1.860	2.306	2.896	3.355	4.501	5.041
9	1.833	2.262	2.821	3.250	4.297	4.781
10	1.812	2.228	2.764	3.169	4.144	4.587
11	1.796	2.201	2.718	3.106	4.025	4.437
12	1.782	2.179	2.681	3.055	3.930	4.318
13	1.771	2.160	2.650	3.012	3.852	4.221
14	1.761	2.145	2.624	2.977	3.787	4.140
15	1.753	2.131	2.602	2.947	3.733	4.073
16	1.746	2.120	2.583	2.921	3.686	4.015
17	1.740	2.110	2.567	2.898	3.646	3.965
18	1.734	2.101	2.552	2.878	3.610	3.922
19	1.729	2.093	2.539	2.861	3.579	3.883
20	1.725	2.086	2.528	2.845	3.552	3.850
21	1.721	2.080	2.518	2.831	3.527	3.819
22	1.717	2.074	2.508	2.819	3.505	3.792
23	1.714	2.069	2.500	2.807	3.485	3.767
24	1.711	2.064	2.492	2.797	3.467	3.745
25	1.708	2.060	2.485	2.787	3.450	3.725
26	1.706	2.056	2.479	2.779	3.435	3.707
27	1.703	2.052	2.473	2.771	3.421	3.690
28	1.701	2.048	2.467	2.763	3.408	3.674
29	1.699	2.045	2.462	2.756	3.396	3.659
30	1.697	2.042	2.457	2.750	3.385	3.646
40	1.684	2.021	2.423	2.704	3.307	3.551
60	1.671	2.000	2.390	2.660	3.232	3.460
120	1.658	1.980	2.358	2.617	3.160	3.373
∞	1.645	1.960	2.326	2.576	3.090	3.291

Reproduced from R E Parker: Introductory Statistics for Biology second edition Studies in Biology No 43 by permission of Edward Arnold (Publishers) Ltd

Table 2 χ^2 values

d.f.	$p = 0.900$	0.500	0.100	0.050	0.010	0.001
1	0.016	0.455	2.71	3.84	6.63	10.83
2	0.211	1.39	4.61	5.99	9.21	13.82
3	0.584	2.37	6.25	7.81	11.34	16.27
4	1.06	3.36	7.78	9.49	13.28	18.47
5	1.61	4.35	9.24	11.07	15.09	20.52
6	2.20	5.35	10.64	12.59	16.81	22.46
7	2.83	6.35	12.02	14.07	18.48	24.32
8	3.49	7.34	13.36	15.51	20.09	26.13
9	4.17	8.34	14.68	16.92	21.67	27.88
10	4.87	9.34	15.99	18.31	23.21	29.59
11	5.58	10.34	17.28	19.68	24.73	31.26
12	6.30	11.34	18.55	21.03	26.22	32.91
13	7.04	12.34	19.81	22.36	27.69	34.53
14	7.79	13.34	21.06	23.68	29.14	36.12
15	8.55	14.34	22.31	25.00	30.58	37.70
16	9.31	15.34	23.54	26.30	32.00	39.25
17	10.09	16.34	24.77	27.59	33.41	40.79
18	10.86	17.34	25.99	28.87	34.81	42.31
19	11.65	18.34	27.20	30.14	36.19	43.82
20	12.44	19.34	28.41	31.41	37.57	45.32
21	13.24	20.34	29.62	32.67	38.93	46.80
22	14.04	21.34	30.81	33.92	40.29	48.27
23	14.85	22.34	32.01	35.17	41.64	49.73
24	15.66	23.34	33.20	36.42	42.98	51.18
25	16.47	24.34	34.38	37.65	44.31	52.62
26	17.29	25.34	35.56	38.89	45.64	54.05
27	18.11	26.34	36.74	40.11	46.96	55.48
28	18.94	27.34	37.92	41.34	48.28	56.89
29	19.77	28.34	39.09	42.56	49.59	58.30
30	20.60	29.34	40.26	43.77	50.89	59.70
40	29.05	39.34	51.81	55.76	63.69	73.40
50	37.69	49.33	63.17	67.50	76.15	86.66
60	46.46	59.33	74.40	79.08	88.38	99.61
70	55.33	69.33	85.53	90.53	100.43	112.32
80	64.28	79.33	96.58	101.88	112.33	124.84
90	73.29	89.33	107.57	113.15	124.12	137.21
100	82.36	99.33	118.50	123.34	135.81	149.45

Reproduced from R E Parker: Introductory Statistics for Biology second edition Studies in Biology No 43 by permission of Edward Arnold (Publishers) Ltd



COUNCIL FOR THE CURRICULUM EXAMINATIONS AND ASSESSMENT

29 Clarendon Road, Clarendon Dock, Belfast BT1 3BG

☎ +44 (0)28 9026 1200

☎ +44 (0)28 9026 1234

☎ +44 (0)28 9024 2063

✉ info@ccea.org.uk

🌐 www.ccea.org.uk

stemup.co.uk

Rewarding Learning