Rewarding Learning

ADVANCED
General Certificate of Education
2023

Centre Number

Candidate Number

Biology

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.

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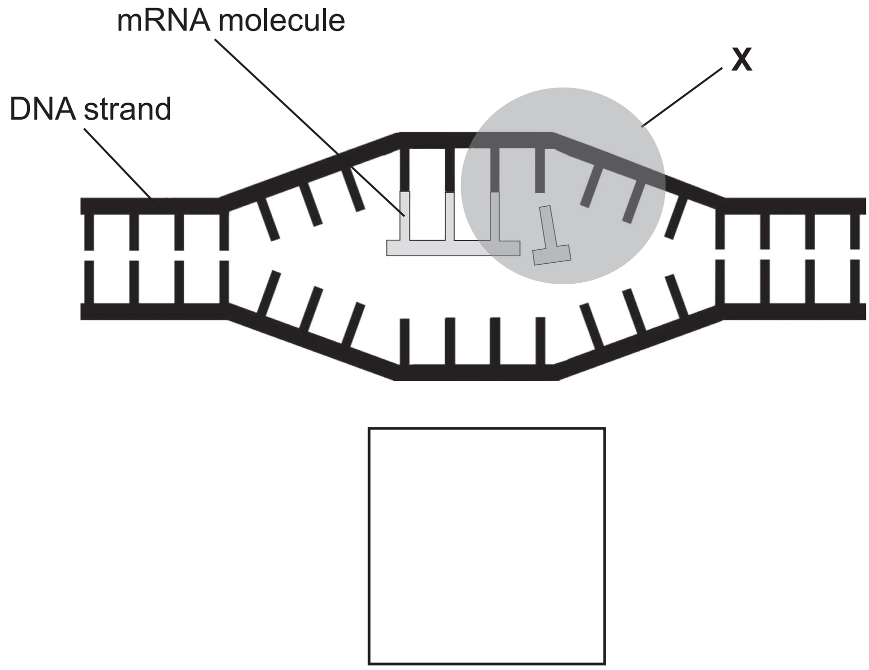
Section A

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

Term	Definition
Gene	
Allele	
	Having alleles of a gene which are both the same
	The position of a gene on a chromosome
Phenotype	

[5]

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**.

______________________________ [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.

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____ [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.

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____ [2]

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.

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____ [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.)

____________________ [2]

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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.

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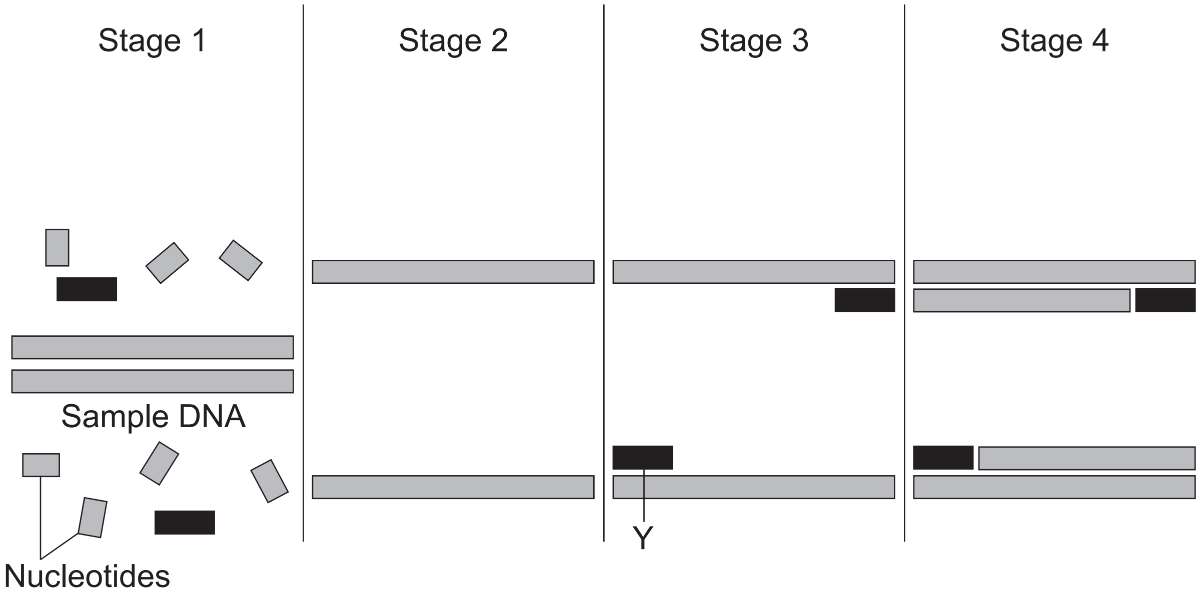
(c) The diagram below represents some stages of the PCR cycle.



Source: Principal Examiner

(i) Identify the molecule labelled **Y**.

______________________________ [1]

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

1. ____

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2. ____

____ [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.

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____ [2]

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

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____ [2]

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

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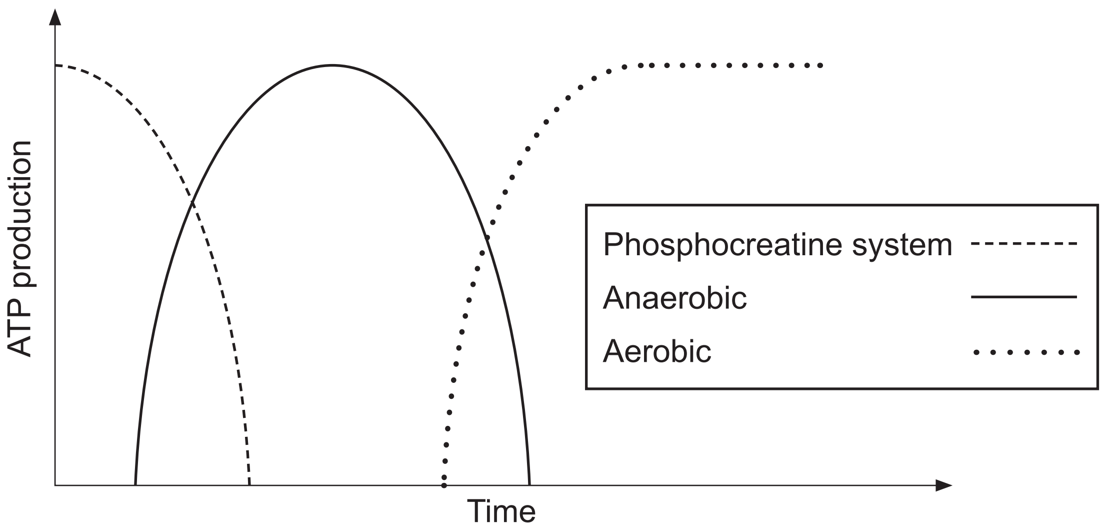
____ [1]

(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.

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____ [3]

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

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

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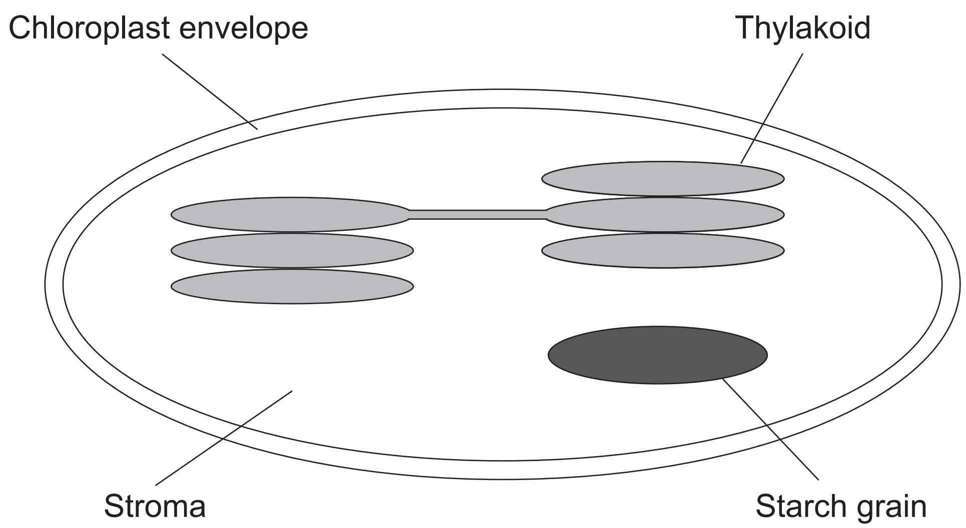
5 **(a)** Chloroplasts are the site of the light-dependent and light-independent stages of photosynthesis. The diagram below represents a chloroplast.



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'.

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____ [1]

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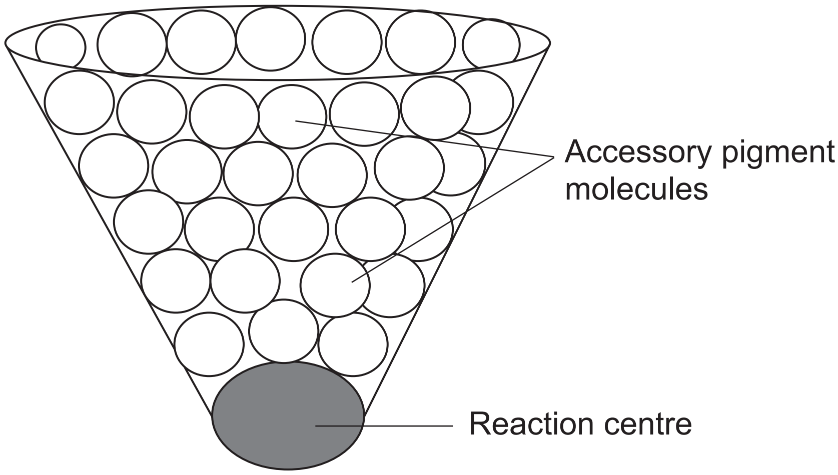
The diagram below represents an 'antenna complex'. This is made up of a reaction centre chlorophyll molecule, arranged with several hundred other accessory pigment molecules.



Source: Principal Examiner

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

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____ [3]

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

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____ [3]

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

PSI ____

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PSII ____

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____ [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.

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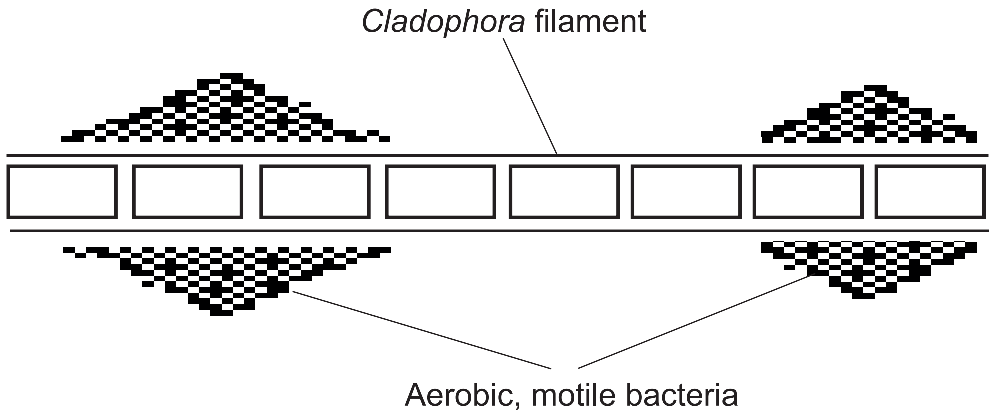
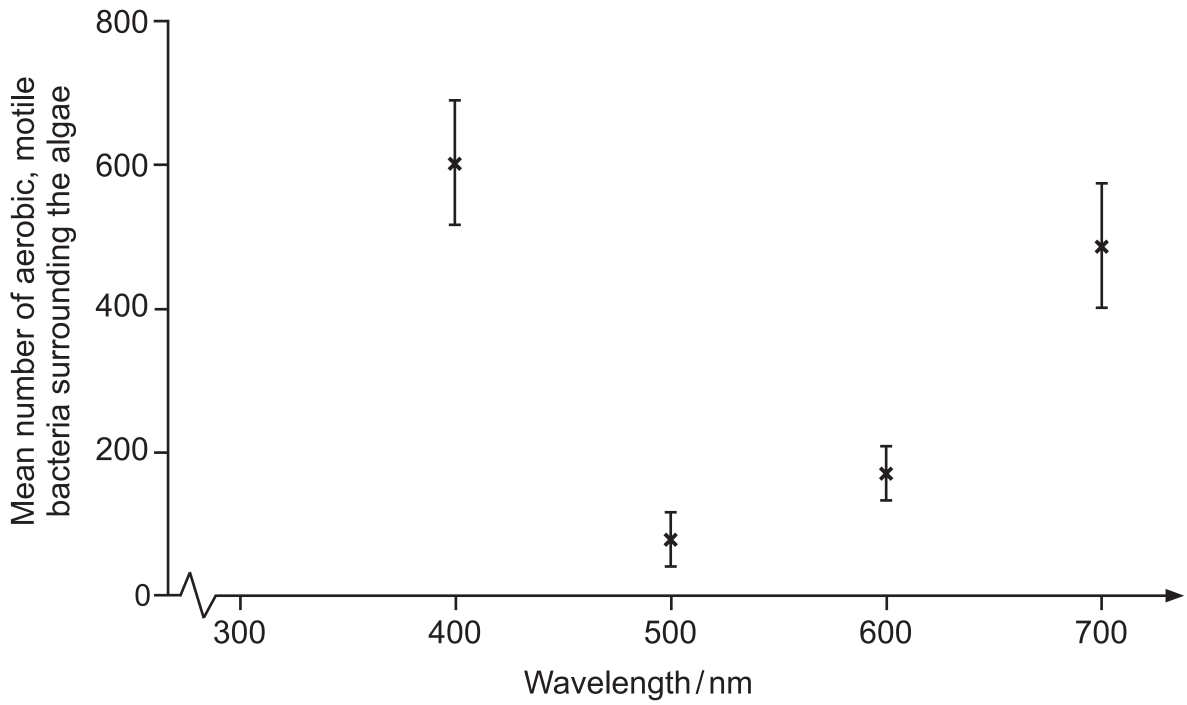
____ [2]

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

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

Aerobic ____

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Motile ____

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____ [2]

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

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____ [2]

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

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

[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.

[3]

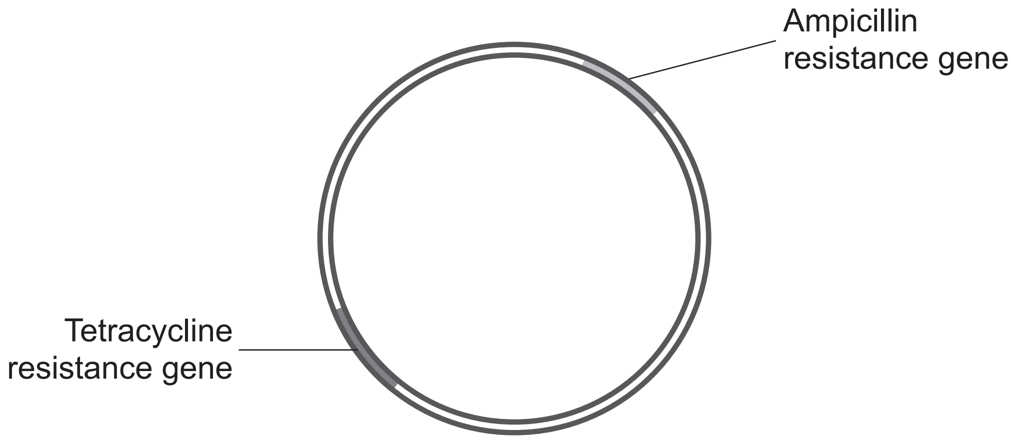
(ii) Suggest and explain why cells from the pancreas are required for the technique described above when producing a copy of the insulin gene.

[2]

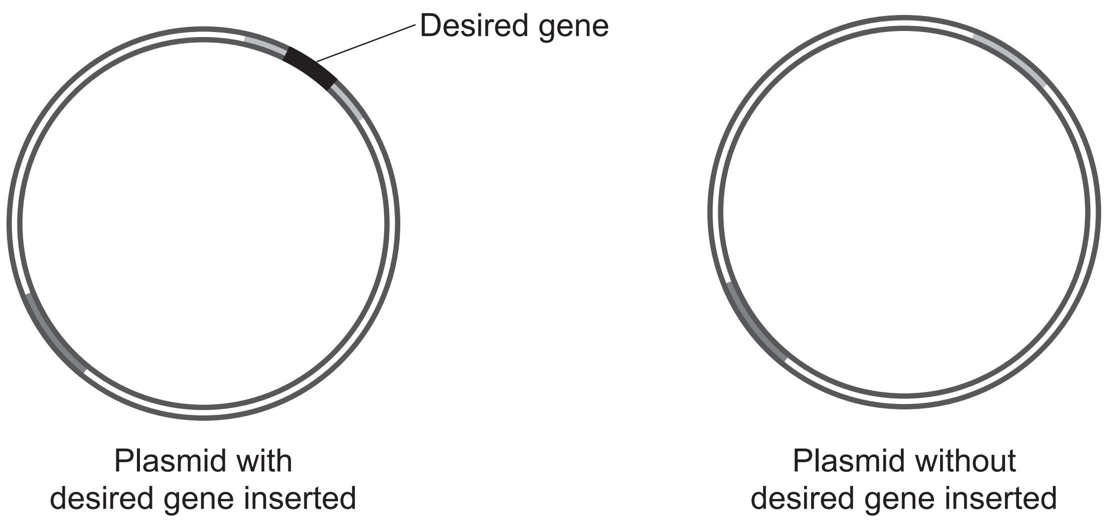
(iii) A desired gene can also be obtained from chromosomal DNA, using restriction enzymes. Describe the action of restriction enzymes.

[2]

(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.

_______________________________ [1]

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

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_______________________________ [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.

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_______________________________ [3]

[Turn over

8 **(a)** Distinguish between the terms ‘dominance’ and ‘epistasis’.

[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

[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		–17.5		
Green	220	212.5	7.5	56.25	0.265
					χ^2 =

[4]

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

_______________________________ [1]

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

_______________________________ [1]

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

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_______________________________ [1]

(v) State your decision regarding the null hypothesis.

____ [1]

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

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____ [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

Platyhelminthes

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Annelida

[Turn over

Arthropoda

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Chordata

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For Examiner's use only	
Question Number	**Marks**
1	
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Total Marks	

Examiner Number

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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

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	33.56	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

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