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General Certificate of Education
2025

Centre Number

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Candidate Number

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Biology

Assessment Unit A2 2

assessing

Biochemistry, Genetics and
Evolutionary Trends



[ABY21]

ABY21

FRIDAY 13 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 questions in black ink and use a dark HB pencil for drawings and graphs.

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 may use a scientific calculator.

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.

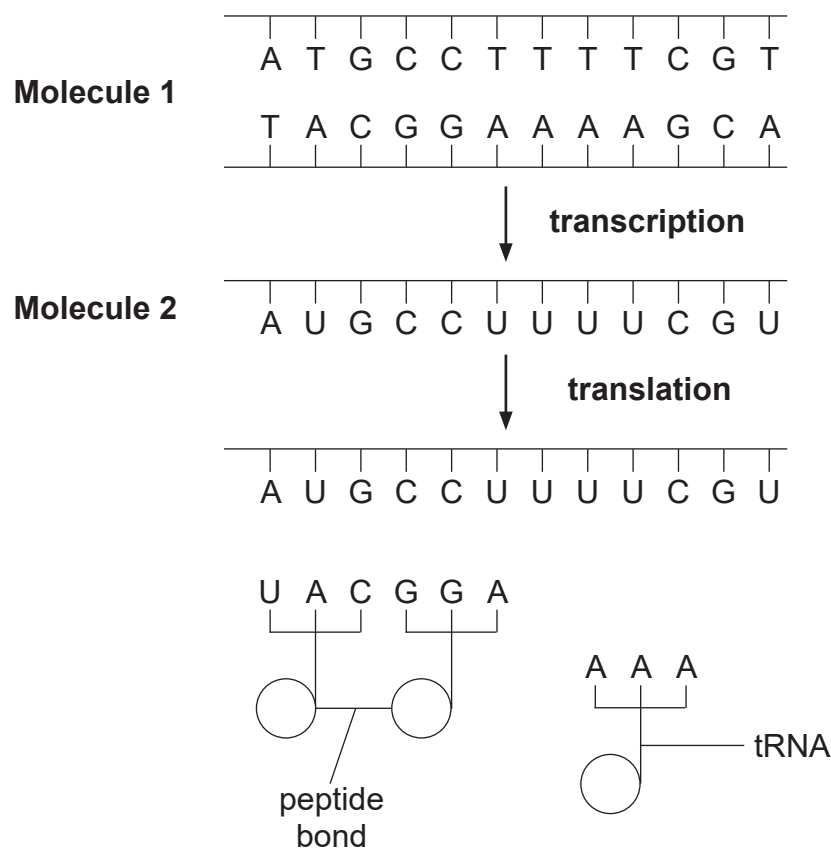
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36ABY2101

Section A

1 (a) Some stages in the synthesis of a protein are represented in the diagram below.



Source: Principal Examiner

(i) Identify **molecules 1 and 2** in the above diagram.

Molecule 1: _____

Molecule 2: _____

[2]

(ii) Name **one** enzyme involved in the process of transcription.

_____ [1]



(b) Some codons and the amino acids for which they code are shown in the table below.

Codon	Amino acid
UUU	Phe
AUG	Met
CGU	Arg
CGG	Arg
CCU	Pro
UGA	No amino acid

(i) Explain what is meant by a triplet code.

_____ [1]

(ii) Suggest the role of the codon UGA in protein synthesis.

_____ [1]

The codons CGU and CGG both code for the amino acid Arg.

(iii) State the term used to describe this feature of the genetic code.

_____ [1]

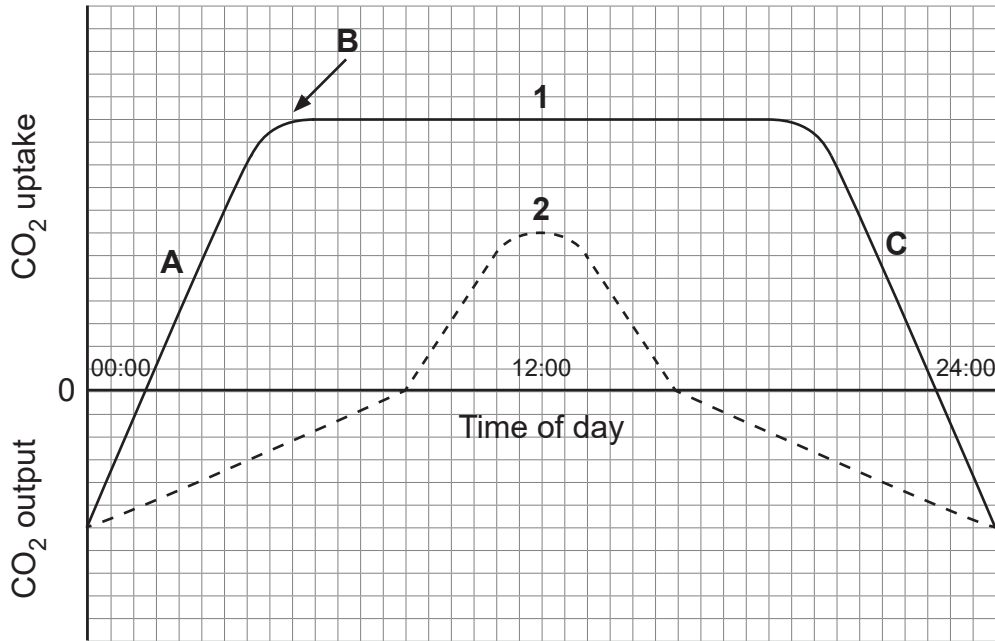
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2 Plants photosynthesise and respire during the daytime.

Lines 1 and 2 on the graph below represent measurements of carbon dioxide (CO_2) taken over a 24-hour period.

The graph shows data from the same plant in two different seasons (line 1 = summer, line 2 = winter).



Source: Principal Examiner

(a) The region labelled **A** on graph line 1 is due to the effect of increasing light intensity on photosynthesis. However, both light intensity and temperature increase up to 12:00 noon.

(i) Account for the constant CO_2 uptake after point **B** on graph line 1.

[1]



- (ii) Using your understanding of the light-dependent and light-independent stages of photosynthesis, explain why the rate of CO₂ uptake decreases at C in graph 1.

[2]

- (iii) Explain the evidence from the graph that indicates that net photosynthesis rather than gross photosynthesis is represented by the data.

[2]

The line labelled **2** represents measurements taken during winter.

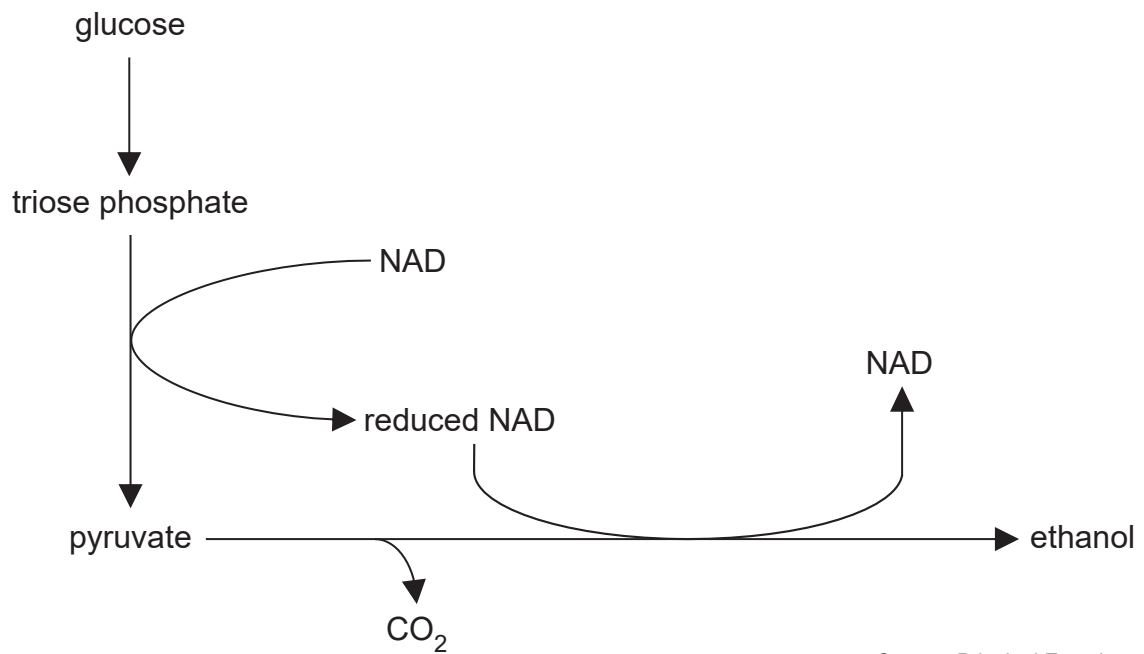
- (b) Using only the information provided, explain why a farmer would expect a greater yield from a crop plant grown in summer than in winter.

[2]

[Turn over



3 The diagram below represents a respiratory pathway in a plant.



Source: Principal Examiner

(a) (i) State the name of the metabolic pathway that converts glucose to pyruvate.

_____ [1]

(ii) Identify the type of respiration shown above, using evidence from the diagram to support your answer.

_____ [2]



(iii) The pathway shown occurs in plant roots, particularly in waterlogged soil.

Suggest how the pathway shown is an adaptation in this environment.

[2]

There is a net gain of 2 ATP molecules in the metabolic pathway from glucose to pyruvate.

(b) Account for this net ATP production.

[1]



(c) The respiratory quotient (RQ) value can be used to determine both the type of respiration occurring in tissue and the respiratory substrate being respired.

In an investigation, some plant tissue was found to have a RQ value of 1.0.

(i) Identify the substrate being respired.

[1]

(ii) State the equation used to calculate the RQ value.

[1]

(iii) During the investigation, the tissue used 50 mm^3 of oxygen.

Using the equation in (c)(ii) and the information provided, calculate the volume of carbon dioxide produced by the tissue.

Show your working out.

_____ mm^3 [2]



- 4 The phylum Arthropoda consists of several classes, including Insecta (insects) and Arachnida (arachnids).

The photographs below show an insect and an arachnid.



Source: J. Napier



Source: Principal Examiner

- (a) (i) Identify **one** feature visible in the photographs which confirms that both animals are arthropods.

_____ [1]

- (ii) Identify **one** feature visible in the photographs which suggests these animals belong to different classes.

_____ [1]

Arthropods show bilateral symmetry.

- (iii) Define the term bilateral symmetry.

_____ [2]

[Turn over



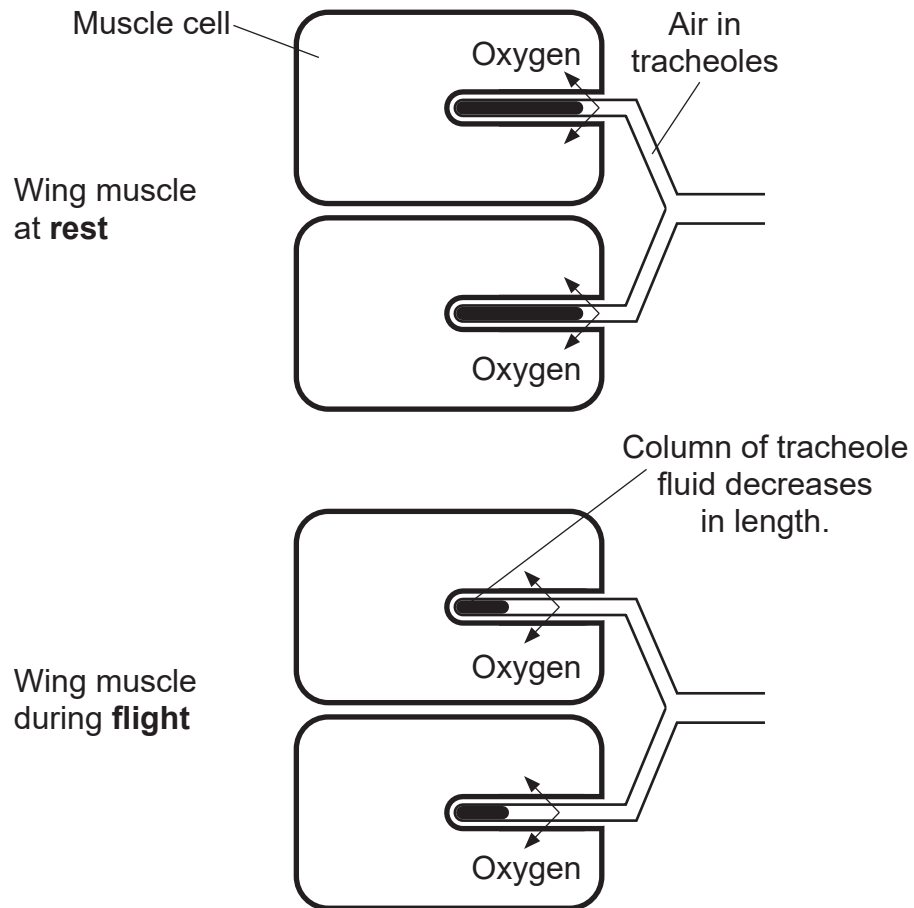
Insects are the most successful animal group on Earth. This is due in part to the ability to fly.

(b) (i) Suggest how their ability to fly has contributed to the success of insects.

[1]

Flying puts a high respiratory demand on the insect, so an efficient mechanism for the delivery of oxygen to wing muscles is essential.

The diagram below represents the system of tubes called tracheoles which deliver oxygen directly to the wing muscle cells from the air outside.



Source: Principal Examiner



(ii) Using the diagram, suggest how a decrease in the length of tracheole fluid allows wing muscles to maintain higher rates of respiration.

[2]

(iii) Describe the role of oxygen in aerobic respiration.

[2]

[Turn over



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36ABY2112



5 Plant leaves can have different adaptations allowing them to maximise growth.

For example, so-called 'sun' and 'shade' leaves are adapted for different light conditions.

One adaptation is the increased thickness of sun leaves compared to shade leaves. Researchers studied some other leaf adaptations in the common nettle (*Urtica dioica*) growing in different light conditions.

Their observations are shown in the table below.

Leaf feature	Sun leaves	Shade leaves
Colour	Light green	Dark green
Mean length / cm	4.70	7.90
Mean width / cm	4.69	7.67
Mean mass per unit area / g cm ⁻²	0.52	0.13

Source: Adapted from Science and Plants for Schools, Field Studies Council

- (a) (i) Identify **one** similarity and **one** difference in the data for mean length and mean width shown by the two types of leaves.

Similarity _____

Difference _____
_____ [2]

- (ii) Suggest how the darker green colour is achieved in shade leaves and explain the benefit of this.

_____ [2]

[Turn over



(b) A t-test can be used to determine if there is a significant difference between the mean leaf masses per unit area of the sun and shade leaves.

(i) State an appropriate null hypothesis.

[1]

(ii) Use the data in the table below to complete the t-test.

	Sun leaves	Shade leaves
Number in sample (n)	32	30
Mean leaf mass per unit area / g cm^{-2} (\bar{x})	0.52	0.13
Standard deviation (error) of the mean ($\hat{\sigma}_{\bar{x}}$)	0.03	0.04

Source: Adapted from *Science and Plants for Schools*, Field Studies Council

Show your working out.

$t =$ _____ [3]



(iii) State the number of degrees of freedom.

[1]

(iv) State the probability of the t-value you have calculated and comment on what this means.

_____ [2]

(v) State the decision regarding the null hypothesis.

Explain your reasoning.

_____ [2]

[Turn over





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(Questions continue overleaf)



- 6 The human genome consists of about 3 billion base pairs. However, only around 10% of this is coding DNA.

The CFTR gene is 200 kilobases (kb) long, of which 6.5kb are coding.

- (a) Calculate the percentage of the CFTR gene which is **non-coding**.

Show your working out.

_____ % [2]

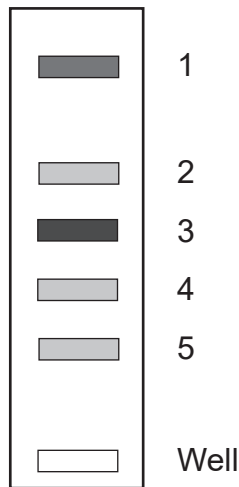
Areas within non-coding regions of DNA can have many repeated base sequences. A repeated sequence of 9–100 base pairs is called a 'minisatellite'.

- (b) Suggest why mutations in the minisatellite region will have little or no effect on the individual.

_____ [1]



(d) The diagram below represents a DNA fingerprint obtained from an individual.



Source: Principal Examiner

(i) Name the type of enzyme used to prepare DNA for this process and explain its role.

[2]

(ii) Using the diagram above, identify the band containing the longest DNA fragments and explain your answer.

Band _____

Explanation _____

[2]



Various methods can be used to make DNA fragments visible. In this case, a dye was used to stain the DNA.

(iii) Band **3** is more darkly stained than the other bands.

Suggest what this indicates about band **3**.

[1]

[Turn over



- 7 Two genes involved in determining eye colour in humans are denoted **B/b** and **G/g**. Both the **B** and **G** alleles code for the production of the dark pigment melanin in the iris of the eye, and are dominant to the recessive alleles which will result in the absence of melanin.

When two heterozygous individuals (**BbGg**) reproduce, five phenotypic classes of eye colour are possible in the offspring.

BBGG will result in dark-brown eyes, while **bbgg** will result in blue eyes. The other three phenotypes in order of decreasing darkness (mid-brown, light-brown and hazel) are dependent on the overall number of dominant alleles in the genotype.

- (a) (i) Complete the following genetic diagram to show the cross between two heterozygous individuals with light-brown eyes.

Parental phenotypes: light-brown eyes × light-brown eyes

Parental genotypes: **BbGg** × **BbGg**

Gametes:

Offspring phenotype	Dark-brown	Mid-brown	Light-brown	Hazel	Blue
Expected ratio					

[5]



(ii) Explain why the observed ratio may differ from the expected ratio.

[1]

Polygenic inheritance arises from the control of an organism's phenotype by several interacting genes. The greater the number of interacting genes, the greater the number of phenotypes produced.

(b) State the type of variation most likely to involve polygenic inheritance.

[1]



- 8 (a) Lactase is an enzyme which digests lactose, the sugar found in milk. Babies must produce lactase to consume a milk-based diet.

Following the introduction of solid food (weaning), some children produce less lactase due to reduced activity of the lactase-producing gene. However, other children exhibit 'lactase persistence', since the gene responsible remains fully active and produces lactase.

- (i) Suggest why there is reduced activity of the lactase-producing gene as some children get older.

[1]

The mutation resulting in lactase persistence occurred in humans around 8000 to 10000 years ago. This is around the time that human groups began farming animals such as cattle.

- (ii) Suggest why the occurrence of this mutation was of benefit to those humans who began farming.

[2]



Gene sequencing has shown that those with lactase persistence have a single base difference in their genome.

(iii) The single base difference that causes lactase persistence is an example of a SNP (single nucleotide polymorphism).

State **two** differences between an epigenetic change and a SNP.

1. _____

2. _____

_____ [2]



- (b) Researchers have studied lactase persistence in ancient and modern human populations. They analysed DNA from human remains of both ancient and modern human populations.

The table below summarises some of their findings. The lactase persistence allele is dominant (M).

Estimated age of samples	Number of individuals	Genotype frequency			Lactase persistence phenotype frequency
		mm	Mm	MM	
8500–7500 years	8	1.00	0.00	0.00	0.00
1000–800 years	18	0.28	0.44	0.28	0.72
Modern humans	450	0.15	0.48	0.37	0.85

Source: Ancient DNA Analysis Reveals High Frequency of European Lactase Persistence Allele (T-13910) in Medieval Central Europe | PLOS One
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- (i) Suggest why only eight samples were analysed for humans who lived 8500–7500 years ago.

[1]

- (ii) PCR was used before analysis of the DNA took place.

Suggest why this was necessary.

[1]



- (c) (i) Using your knowledge of the Hardy-Weinberg equation, calculate the frequency of the recessive allele (m) in the sample of the modern humans.

Show your working out.

_____ [2]

- (ii) Calculate the number of heterozygous individuals in the sample of modern humans.

Show your working out.

_____ [2]

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(iii) Using the information provided, suggest an explanation for the increase in the frequency of the lactase persistence phenotype over time.

[2]

(iv) Suggest why the data provided for modern humans is the most likely to meet the requirements of Hardy-Weinberg calculations.

[1]



(b) Variation in a population allows for selection.

State how such variation may arise and discuss how directional selection may result in speciation.





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For Examiner's use only	
Question Number	Marks
1	
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Total Marks	
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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.	<i>p</i> = 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

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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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