2 A student investigated the effect of caffeine on human heart rate.

Three males of the same age were given cups of coffee containing caffeine. Their heart rates were measured 10 minutes after drinking the coffee.

Two hours later they were given cups of coffee with no caffeine and after 10 minutes their heart rates were measured.

The results are shown in the table.

Male	Heart rate / beats min^{-1}	
	Coffee containing caffeine	Coffee with no caffeine
1	75	72
2	78	71
3	70	70
Mean ± sd	74 ± 4	71 ± 1

(a) The student concluded that caffeine increases human heart rate.

Analyse the data to explain why these results may not support the conclusion.

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(b) Describe how this investigation could be improved.

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(Total for Question 2 = 6 marks)

12 A student carried out an investigation to compare the antibacterial effect of a garlic extract with that of three antibiotics, all at the same concentration.

(a) (i) To obtain the extract, a clove of garlic was cut into lots of small pieces and soaked in 0.1% ethanol for a long time.

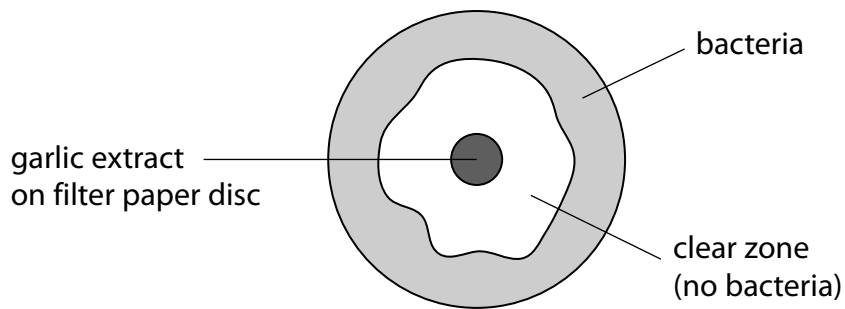Explain why this is an effective method of extraction.

(2)

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(ii) The diagram shows the effect of the garlic extract on bacteria growing on an agar plate.

The area of the clear zone was calculated by assuming it is a circle and estimating the diameter. The estimate made was 4.3 cm.

Calculate the estimated area of the clear zone.

(2)

Answer..

(b) The results of the investigation are shown in the table.

| Sample number | Estimated area of clear zone / mm² | | | Plant extract |
| | Antibiotics | | | |
	Chloramphenicol	Tetracycline	Streptomycin	Garlic
1	28	16	15	20
2	26	19	13	28
3	29	11	14	18
4	28	21	12	25
5	26	7	14	27
6	29	11	15	26
7	22	8	9	25
8	25	21	14	25
9	29	10	12	29
Mean	27	14	13	25
Standard deviation	2.37	5.54	1.90	3.60

These data were analysed using t-tests.

(i) Several statistical tests were available to the student to analyse these data, including the t-test, Chi squared and the correlation coefficient.

Explain why the t-test was chosen to analyse these data, rather than the other two tests.

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(ii) Calculate the *t* value for the data to compare garlic with chloramphenicol, using the formula:

$$t = \frac{\left| \overline{x}^1 - \overline{x}^2 \right|}{\sqrt{\left(\dfrac{\sigma_1^2}{n_1} + \dfrac{\sigma_2^2}{n_2} \right)}}$$

(3)

Answer...

(iii) The table shows the critical values of *t* with 16 degrees of freedom.

Significance level (p)	0.20	0.10	0.05	0.01	0.001
Critical value of *t*	1.34	1.75	2.12	2.92	4.02

Use your value of *t* to test the validity of a stated null hypothesis.

(4)

(c) The size of the clear zone depends on variables other than the antibacterial properties of the substances used, such as size and solubility of the antimicrobial molecules in the extract.

A new method was developed in which the minimum concentration of extract that causes inhibition of bacterial growth (Minimum Inhibitory Concentration, MIC), was found.

Samples of extract, bacteria (*E. coli*) and a respiration indicator were placed in a micro-titre tray.

1 = 4%
2 = 2%
3 = 1%
4 = 0.5%   concentration of
5 = 0.25%   extract
6 = 0.125%
7 = 0.0625%
8 = 0.0%
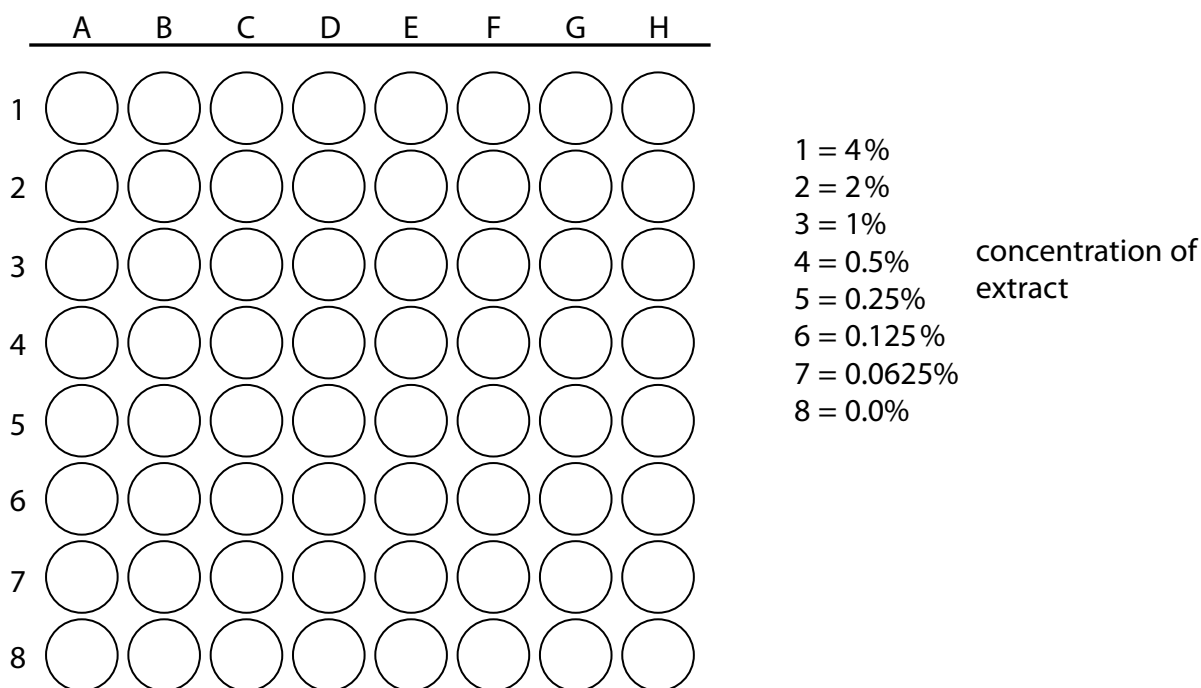
The diagrams show the results obtained. The tubes are black when respiration occurs and clear when no respiration occurs.

rosemary   geranium   garlic   cedar
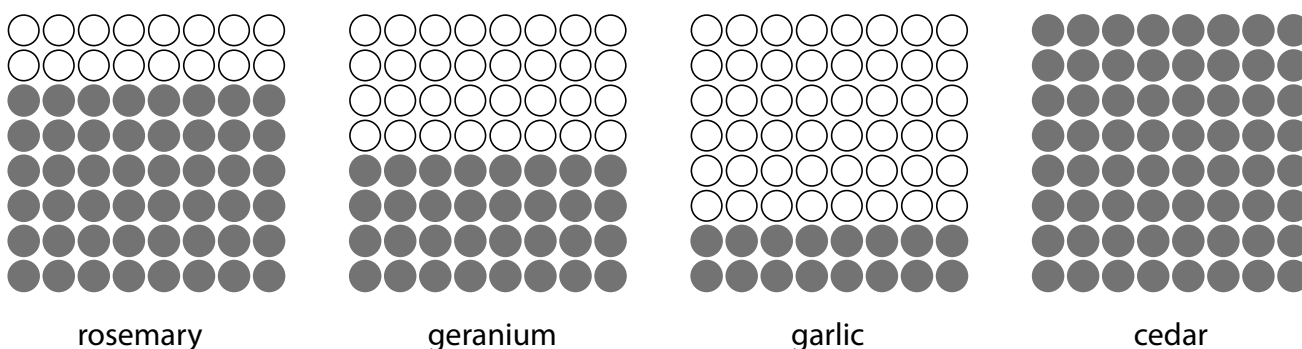
(i) Analyse the data to explain the results of this experiment.

(2)

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(ii) Give **two** changes that can be made to the procedure to get a more accurate measure of MIC.

(2)

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(iii) It was concluded that plant extracts inhibit respiration of bacteria. This conclusion may not be valid because the investigation has limitations.

Describe how the investigation could be modified to reduce the effect of two named limitations.

(2)

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(Total for Question 12 = 20 marks)

TOTAL FOR PAPER = 100 MARKS

6 The saiga antelope is found in the grasslands of Eurasia. In the 1970s its population was 1 250 000. The population has decreased due to loss of habitat and a disease outbreak in 2015.

Population estimates suggest as few as 50 000 individuals remain.

Conservation efforts aim to ensure that the population recovers to previous levels.

(a) The population may recover quickly as saiga antelopes usually produce twins.

(i) Even though both offspring are from the same father and the same mother, they may be genetically different.

Explain why the offspring may be genetically different.

(2)

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(ii) During fertilisation, only one sperm cell can fertilise an egg cell.

Explain why a second sperm cell cannot fertilise the egg cell.

(3)

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(b) Endangered animals are monitored to determine the diversity and viability of the population.

The height of 34 saiga antelopes is shown in the graph.
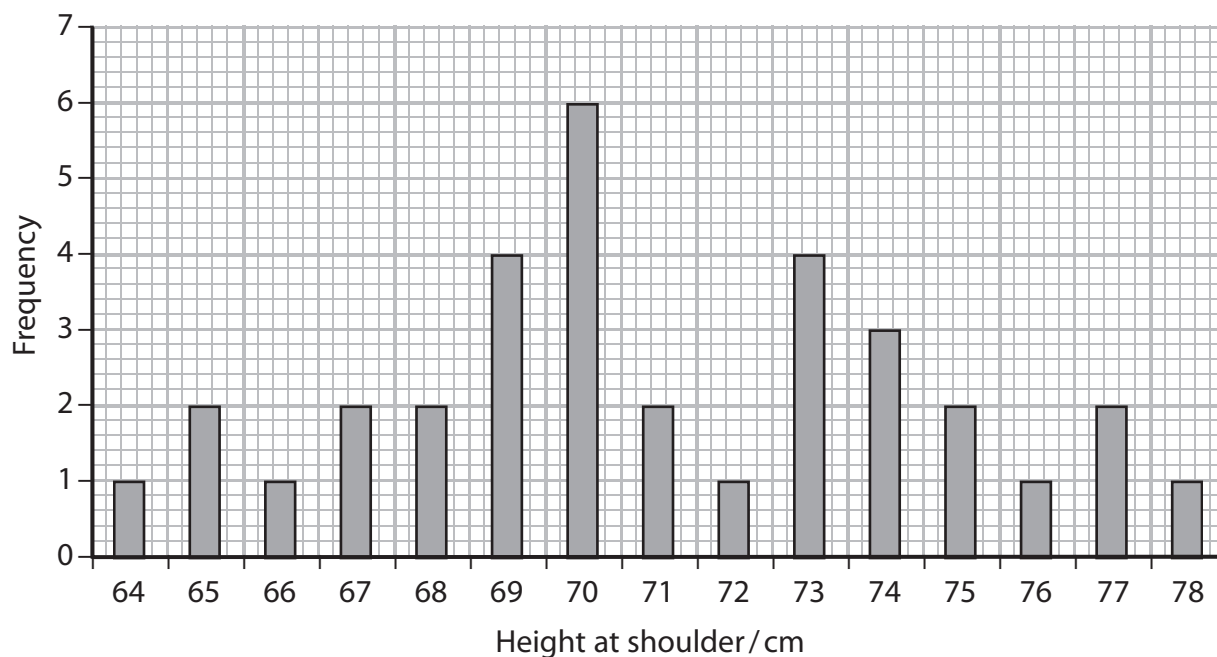
(i) State how the graph provides evidence that this characteristic shows polygenic inheritance.

(1)

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(ii) Height in animals is determined by polygenic inheritance.

Which is a description of polygenic inheritance of height?

(1)

- ☒ **A** controlled by a large number of alleles of one gene
- ☒ **B** controlled by more than one gene
- ☒ **C** controlled by one gene from each parent
- ☒ **D** controlled by one gene and the environment

(iii) State and justify the mode for height of the saiga antelope.

(2)

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(c) Saiga antelopes are related to a wide range of other species of antelope.

The diagram shows the phylogenetic relationships between some antelopes.
This diagram was produced using data from analysis of a protein.
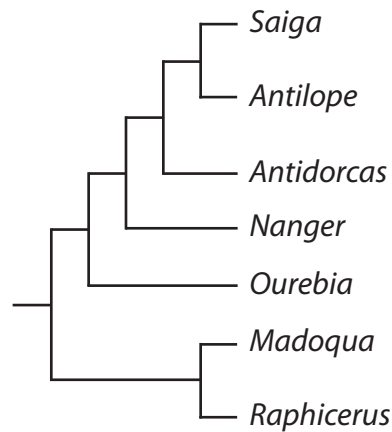
(i) Explain how this diagram indicates that saiga antelopes are more closely related to *Antilope* than to *Antidorcas*.

(2)

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(ii) This is a more recent classification diagram based on a study of the mitochondrial genomes of antelopes.

Gazella
Nanger
Eudorcas
Antilope
Litocranius
Antidorcas
Saiga
Ourebia
Raphicerus
Madoqua
Dorcatragus
Procapra

Deduce how this study led to different opinions about the relationship between *Saiga* and *Antilope*.

(3)

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(Total for Question 6 = 14 marks)

2   Blowfly larvae can be used by a forensic scientist to help determine the time of death of a body.

The diagram shows a Petri dish used by a student to investigate whether young and old blowfly larvae show a preference for light or dark conditions.
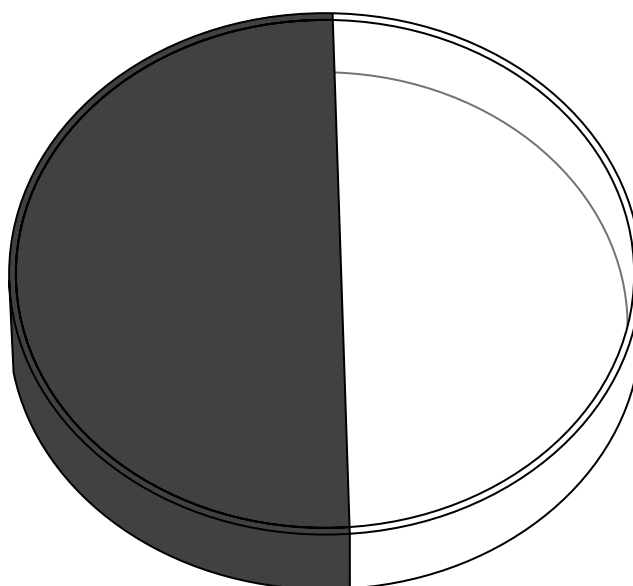
In the first trial, the left side was dark and the right side was light.

Five blowfly larvae were added to each side of the chamber.

After five minutes, the number of larvae on each side of the Petri dish was recorded.

In the second trial, the same experiment was repeated but this time the right side was dark and the left side was light.

The table shows the results of the trials.

Trial	Number of young blowfly larvae		Number of old blowfly larvae	
	Left side dark	Right side light	Left side dark	Right side light
1	9	1	2	8
2	2	8	9	1

(a) Give a null hypothesis for this investigation.

(1)

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(b) The Chi squared test can be used to determine whether the results of this investigation indicate a significant difference in the distribution of young larvae between the light and the dark side.

(i) Use the formula to calculate the Chi-squared value for young larvae.

(3)

$$\chi^2 = \sum \frac{(\text{Observed} - \text{Expected})^2}{\text{Expected}}$$

Answer ....

(ii) The table below gives some critical values for Chi-squared.

p value			
0.15	0.1	0.05	0.025
2.07	2.71	3.84	5.02

Use your calculated value to determine whether the difference between the observed and expected results is significant.

(1)

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(c) Forensic scientists measure the length of larvae found in the tissues of a dead person to help them determine time of death. Older larvae are longer than younger larvae.

The growth of insect larvae can be affected by a number of factors including toxins.

Explain a procedure that you could use to find out if the presence of a toxin in a sample of dead tissue could affect the accuracy of estimating time of death.

(5)

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(Total for Question 2 = 10 marks)

3 Blowflies are found in many parts of the world, including Africa.

The diagram shows the life cycle of one species of blowfly (species A) found in Africa.
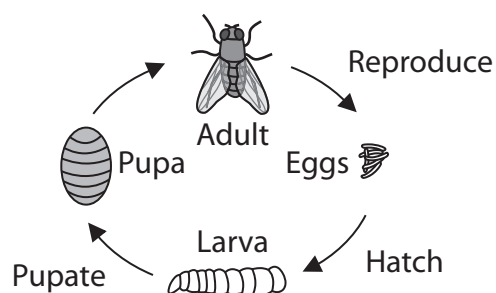
An investigation was carried out to find the temperature at which 50% of the larvae of this species survive. This investigation was repeated for a further six species of African blowfly larvae, B to G. All other variables were kept constant.

In another investigation, the temperature of sand that the larvae selected when ready to pupate was recorded.

(a) A student used the data from these investigations to find out if there is a statistically significant correlation between the two sets of temperatures.

To do so, a Spearman's rank correlation coefficient can be calculated.

(i) Complete the table to rank all the data and to calculate d and d^2 for species E to G.

(3)

Blowfly species	Mean temperature at which 50% of larvae survive / °C	Rank for mean temperature for 50% larvae survival	Mean temperature of sand selected / °C	Rank for mean temperature of sand selected	Difference in rank (d)	Difference in rank squared (d^2)
A	49.0	5	26.1	7	−2	4
B	47.5	2	23.2	3	−1	1
C	48.5	3	24.7	6	−3	9
D	42.9	1	16.6	1	0	0
E	48.8		23.6			
F	50.1		24.2			
G	49.2		23.1			

(ii) Calculate the Spearman's rank correlation coefficient (r_s) using the equation:

(3)

$$r_s = 1 - \frac{6\sum d^2}{n(n^2 - 1)}$$

where $\sum d^2 = 34$ and n is the number of blowfly species.

Answer..

(iii) The table shows critical values for r_s.

n	Probability		
	0.10	**0.05**	**0.01**
5	0.900	1.000	1.000
6	0.829	0.886	1.000
7	0.714	0.786	0.929
8	0.643	0.738	0.881
9	0.600	0.683	0.833

Deduce whether the data showed a statistically significant correlation.

(2)

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(b) A number of observations were made about a dead rhinoceros:

- adults of all seven species of blowfly (A to G) were observed near the rhinoceros
- large numbers of living larvae of species F were present inside the rhinoceros
- mean temperature in this group of larvae was $49 \pm 1.1\,°C$
- mean temperature of the air surrounding the rhinoceros was $33 \pm 3.0\,°C$.

(i) Determine how the mean temperature of 49 °C was found.

(2)

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(ii) It was observed that all the living larvae in the rhinoceros belonged to species F.

The metabolic activity of the larvae of species F increases the temperature within the dead rhinoceros.

Explain the advantages for this species of blowfly of increasing the temperature within the dead rhinoceros.

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(Total for Question 3 = 13 marks)

5 Pickling is a technique used to preserve food. Onions can be pickled by immersing them in a solution of sodium chloride.

A student investigated the effects of changing the concentration of sodium chloride solution on the mass of onion tissue. Small onions were peeled, had their tops and bottoms cut off and were weighed. The onions were then placed into covered beakers containing different concentrations of sodium chloride solution.

Six beakers were set up as shown in the diagram.

| 0% sodium chloride solution | 2.5% sodium chloride solution | 5% sodium chloride solution | 10% sodium chloride solution | 15% sodium chloride solution | 20% sodium chloride solution |
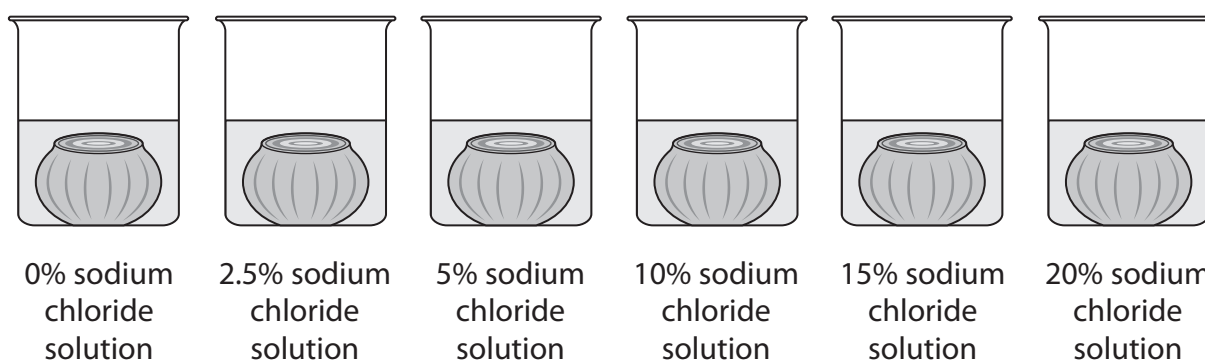
The beakers were left for two days. The onions were removed, blotted dry and reweighed. The investigation was repeated two more times.

The mean percentage change in mass was calculated.

The results of the investigation are shown in the table.

Sodium chloride solution (%)	Percentage change in mass (%)				SD
	1	**2**	**3**	**Mean**	
0.0	7.3	7.1	7.9	7.4	0.4
2.5	3.2	4.7	5.8	4.6	
5.0	−1.3	−0.9	−1.2	−1.1	0.2
10.0	0.6	−0.8	−1.9	−0.7	1.3
15.0	−2.1	−1.8	−2.9	−2.3	0.6
20.0	−2.2	−2.4	−1.9	−2.2	0.3

(a) (i) Explain **one** way in which this investigation could be improved.

(2)

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(ii) Standard deviation can be calculated using the formula shown.

$$S = \sqrt{\frac{\sum(x - \bar{x})^2}{n - 1}}$$

Calculate the standard deviation for the 2.5% sodium chloride solution.

(2)

Answer ....

(iii) Deduce the effect of increasing the concentration of sodium chloride on the change in mass of the onion tissue.

(3)

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(b) A method for pickling red onions is to immerse them in wine vinegar. This vinegar contains ethanoic acid. The vinegar causes anthocyanin pigments to leave the onion cells, entering the solution.

Explain why pickling in vinegar would result in anthocyanin pigments leaving the onion cells.

(3)

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(Total for Question 5 = 10 marks)

Question Number	Acceptable Answer	Additional guidance	Mark
2(a)	An explanation that makes reference to the following: • male 3 had same heart rate in both conditions so suggests no effect (1) • standard deviations overlap so difference may be chance (1) • caffeine concentration unknown / sample size small so may be unrepresentative (1)		**(3)**

Question Number	Acceptable Answer	Additional guidance	Mark
2(b)	A description that makes reference to three of the following: • take into account resting heart rate (1) • include females in the sample (1) • have a range of ages in the sample (1) • take into account previous coffee drinking habits (1) • as heart rate is affected by exercise, need to take this into account (1)		**(3)**

(Total for Question 2 = 6 marks)

Question Number	Acceptable Answer	Additional guidance	Mark
12(a)(i)	An explanation that makes reference to the following: • (small pieces) provides large surface area to volume ratio (1) • (use of ethanol for a long time means) the antibacterial substance is soluble in ethanol and more will be extracted (1)		**(2)**

Question Number	Acceptable Answer	Additional guidance	Mark
12(a)(ii)	$\pi 2.15^2$ (1) 14.5 cm^2 (1)		**(2)**

Question Number	Acceptable Answer	Additional guidance	Mark
12(b)(i)	An explanation that makes reference to the following: • the t-test assess the significance of the difference between the means of the two treatments (1) • Chi squared not appropriate because there are no expected values (1) • correlation coefficient not appropriate because the independent variable is discontinuous / not continuous (1)		**(3)**

Question Number	Acceptable Answer	Additional guidance	Mark
12(b)(ii)	$2.37^2 \div 9 = 0.62$ and $3.60^2 \div 9 = 1.44$ (1) $\sqrt{(0.62 + 1.44)} = 1.44$ (1) $(27 - 25) \div 1.44 = t = 1.39$ (1)	Correct answer gains full marks	**(3)**

Question Number	Acceptable Answer	Additional guidance	Mark
12(b)(iii)	An answer that makes reference to the following: • there is no significant difference between the clear area caused by garlic compared with that caused by chloramphenicol (1) • $p > 0.05$ (1) • difference due to chance (1) • therefore accept null hypothesis (1)	Allow marking points for the calculated value of t from the candidate	**(4)**

Question Number	Acceptable Answer	Additional guidance	Mark
12(c)(i)	An explanation that makes reference to the following: • suggests cedar wood oil has no anti-microbial effect on *E. coli* and all other oils do (1) • quoting at least two values from: rosemary 2%, geranium 0.5%, garlic 0.125% / manipulation of data to show relative effects (1)		**(2)**

Question Number	Acceptable Answer	Additional guidance	Mark
12(c)(ii)	An answer that makes reference to the following: • for cedar wood oil try concentrations above 4% (1) • for all the others, try concentrations below 0.0625% (1)		**(2)**

Question Number	Acceptable Answer	Additional guidance	Mark
12(c)(iii)	A description that makes reference to the following: • only one tray per species – need repeated measurements (1) • species – only used one species of bacteria / only used extracts from four plant species (1)		**(2)**

(Total for Question 12 = 20 marks)

Question Number	Answer	Additional Guidance	Mark
6(a)(i)	An explanation which makes reference to two of the following: • (each zygote is formed) from different gametes / random fertilisation (1) • each gamete contains different combinations of alleles (1) • (different combination of alleles due to) { independent assortment / crossing over } (during meiosis) (1)	ALLOW not monozygotic twins	**(2)**

Question Number	Answer	Additional Guidance	Mark
6(a)(ii)	An explanation which makes reference to the following: • cortical reaction / fusion of cortical granules with egg cell (surface) membrane (1) • resulting in { thickening / hardening } of the zona pellucida (1) • therefore (other) sperm cells cannot reach egg cell (surface) membrane (1)		**(3)**

Question Number	Answer	Additional Guidance	Mark
6(b)(i)	• (range of heights) show continuous variation (1)	ALLOW continuous data	(1)

Question Number	Answer	Mark
6(b)(ii)	**B** - controlled by more than one gene *The only correct answer is B* *A is not correct because a polygenic trait is not controlled by a large number of alleles of one gene* *C is not correct because a polygenic trait is not controlled by one gene from each parent* *D is not correct because a polygenic trait is not controlled by one gene and the environment*	(1)

Question Number	Answer	Additional Guidance	Mark
6(b)(iii)	An answer which makes reference to the following: • 70 cm (1) • the highest frequency (of antelopes) (1)	ALLOW 'most common' height	(2)

Question Number	Answer	Additional Guidance	Mark
6(c)(i)	An explanation which makes reference to the following: • (*Saiga* more closely related to *Antilope*) because they shared a common ancestor more recently (1) • there are more similarities in the protein (1)	e.g. similar sequences of amino acids in the protein	**(2)**

Question Number	Answer	Additional Guidance	Mark
6(c)(ii)	An answer which makes reference to the following: • they are less closely related (1) • DNA { profiling / analysis / comparison } (1) • (detected) more differences in the mitochondrial genome (1)		**(3)**

Question Number	Acceptable Answer	Additional guidance	Mark
2(a)	larvae show no significant preference for light over dark side (1)	Allow vice versa Must have NO in hypothesis.	**(1)**

Question Number	Acceptable Answer	Additional guidance	Mark
2(b)(i)	calculation of expected frequency 10 and 10 (1) $(O-E)^2$/E for both light and dark sides 49 ÷ 10 = 4.9 (1) sum = 9.8 (1)		**(3)**

Question Number	Acceptable Answer	Additional guidance	Mark
2(b)(ii)	An answer that makes reference to the following: • higher than 3.84 therefore Chi square value as high as 9.8 arise by chance alone less than 1 in 20 / 0.05 therefore there is a significant difference (1)	allow ECF for incorrect value of Chi allow converse if calculated of Chi is lower than 3.84	**(1)**

Question Number	Acceptable Answer	Additional guidance	Mark
2(c)	An explanation that makes reference to five of the following: • use of dead tissue containing toxin and dead tissue not containing tissue so valid comparison can be made (1) • {young larvae of same length / fly eggs} allowed access to both types of dead tissue so they have same potential for growth (1) • reference to time scale before growth of larvae measured to allow time for growth to occur (1) • length measured for several larvae to ensure reliability (1) • control of {temperature / type of tissue / age of tissue / species of larvae} because these factors affect growth (1) • recognition that comparison of results may show under or over estimate of time of death (1)		**(5)**

(Total for Question 2 = 10 marks)

Question Number	Answer	Additional Guidance	Mark
3(a)(i)	An answer that makes reference to the following: • correct ranking for both columns (1) • correct difference in rank (1) • correct difference squared (1)		

E	48.8	**4**	23.6	**4**	**0**	**0**
F	50.1	**7**	24.2	**5**	**2**	**4**
G	49.2	**6**	23.1	**2**	**4**	**16**

-2 and -4 are incorrect differences in rank

(3)

Question Number	Answer	Additional Guidance	Mark
3(a)(ii)	• numerator (top line of formula) correctly calculated (1) • denominator (bottom line of formula) correctly calculated (1) • correct answer (1)	<u>Example of calculation</u> 6 x 34 or 204 7 x 48 or 336 0.3929 / 0.393 / 0.39 Correct answer with no working scores full marks	**(3)**

Question Number	Answer	Additional Guidance	Mark
3(a)(iii)	An answer that makes reference to the following: • no (significant) correlation (1) • as the calculated figure is less than { 0.786 / the critical value for p= 0.05 } (1)	 ALLOW not statistically significant ECF - ALLOW significant correlation if the value calculated for 3aii is greater than { cv for 0.05 / 0.786 } ALLOW 5% FOR 0.05 ECF- ALLOW calculated value is greater than the cv if the value calculated for 3aii is greater than 0.786	**(2)**

Question Number	Answer	Additional Guidance	Mark
3(b)(i)	An answer that makes reference to the following: • measure temperature from { several readings / random positions } (within the group of larvae) (1) • description of how mean calculated (1)	ALLOW stated number of measurements e.g. readings summated and answer divided by number of readings taken ALLOW 'average' for mean	**(2)**

Question Number	Answer	Additional Guidance	Mark
3(b)(ii)	An explanation that makes reference to the following: • increases enzyme activity for (larvae / species F) (1) • high temperature { kills / denatures enzymes of } other species (1) • (high temperature) increases food availability by { reducing competition from other species / increasing rate of decomposition of rhino } (1)	ALLOW description of increase in activity including maximizes rate of growth/digestion, shorter lifecycle IGNORE ref to metabolic activity unqualified ALLOW outcompetes other {species / larvae} for food	**(3)**

Question Number	Answer	Additional Guidance	Mark
5(a)(i)	An explanation that makes reference to the following: • same {age / type} of onion (1) • increases {repeatability / validity} (1) OR • smaller concentration intervals (1) • increasing {confidence in / validity of} conclusion (1) OR • same {temperature / surface area of onion} (1) • due to effect on osmosis (1)		**(2)**

Question Number	Answer	Additional Guidance	Mark
5(a)(ii)	• correct calculation of numerator (1) • correct calculation of standard deviation (1)	Example of calculation $$\sum(x - \bar{x})^2 = 3.41$$ $(3.2 - 4.6)^2 + (4.7 - 4.6)^2 + (5.8 - 4.6)^2$ $$\sqrt{\frac{3.41}{2}} =$$ 1.3 / 1.31 / 1.306 / 1.3057 Correct answer no working scores full marks ALLOW ECF if number other than 3.41 calculated	**(2)**

Question Number	Answer	Additional Guidance	Mark
5(a)(iii)	An answer which makes reference to three of the following: • 2.5% (sodium chloride solution) resulted in an increase in mass (1) • an increase (in sodium chloride solution) from 5% to {15% / 20%} resulted in a loss in mass (1) • because of the movement of water by osmosis (1) • (SD) values overlap for {5% and 10% / 10% and 15% / 10% and 20% / 15% and 20%} (sodium chloride solution) therefore no (significant) difference (1)		**(3)**

Question Number	Answer	Additional Guidance	Mark
5(b)	An explanation which includes the following: • increased permeability of (cell surface) membrane (1) plus two of the following • the low pH would {change the shape of / denature} proteins (in cell surface membrane) (1) • (as vinegar) affects bonds (in protein) (1) • (vinegar / ethanoic acid) could dissolve lipids (in the cell membrane) (1)	ALLOW tonoplast ALLOW change in pH / acidic conditions would {change the shape of / denature} proteins	**(3)**