CHOOSING an appropriate Statistical Test

1(a). An experiment was carried out where a student observed cells in different tissues under the microscope.

- The cells were undergoing mitosis.
- 200 cells were observed for each tissue.
- The number of cells in each stage of mitosis was recorded.

The results are shown in Table 2.2.

Tissue type	Number of cells in stage of mitosis				Total
	Prophase	Metaphase	Anaphase	Telophase	
V	65	55	7	73	200
W	85	59	6	50	200

The student had expected that the results observed for tissue type **W** would not be significantly different from those for tissue type **V**.

i. Identify the pieces of evidence in Table 2.2 that caused the student to suspect that the results for tissue type **W** might be **significantly** different from those for tissue type **V**.

[1]

ii. The student decided to analyse the data using a statistical test.

A friend suggested using Student's -test.

Why is Student's -test **not** suitable for dealing with this data?

[1]

(b). The chi-squared (x^2) test can be used to analyse the data.

i. Complete the rows for metaphase and telophase in the table below and calculate the $\mathbf{x}^2$ value for the data.

The $\mathbf{x}^2$ value is calculated using the following formula:

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

Cells	Observed (O)	Expected (E)	(O–E)	$(O–E)^2$	$\frac{(O-E)^2}{E}$
In prophase	85	65	20	400	6.154
In metaphase					
In anaphase	6	7	-1	1	0.143
In telophase					
Total	200	200			

x^2 = ... **[3]**

ii. The value of chi-squared (x^2) can be used to conclude whether the results for cells in tissue type **W** differ significantly from those for tissue type **V**.

The number of **degrees of freedom** determines which row of the $\mathbf{x}^2$ probability table is used.

The number of degrees of freedom is defined as:

the number of categories - 1

What will be the number of degrees of freedom used in this analysis?

[1]

iii. The student had expected that the results observed for tissue type **W** would not be significantly different from those for tissue type **V**.
Use your calculated value for $\mathbf{x}^2$ and the information from the $\mathbf{x}^2$ probability table below to conclude whether or not the results observed for tissue type **W** are significantly different from those for tissue type **V**.

Degrees of freedom	Probability (p)				
	0.99	**0.95**	**0.05**	**0.01**	**0.001**
1	0.00	0.00	3.84	6.64	10.83
2	0.02	0.10	5.99	9.21	13.82
3	0.11	0.35	7.82	11.35	16.27
4	0.30	0.71	9.49	13.28	18.47
5	0.55	1.15	11.07	15.09	20.52
6	0.84	1.64	12.59	16.81	22.46
7	1.24	2.17	14.07	18.48	24.32

Conclusion

.....

[2]

2. A scientist investigated the effect of different mineral solutions on root hair density on cress plants.

Cress plants were grown for seven days in two different mineral solutions, **A** and **B**.

The results are shown in the table below.

Cress plant	Root hair density (hairs mm^{-2})	
	Mineral solution A	**Mineral solution B**
1	42	25
2	53	41
3	60	32
4	52	34
5	38	58
6	48	27
Mean	48.8	
Standard deviation	8.0	

i. Calculate the standard deviation of root hair density for cress grown in mineral solution **B**.

Use the formula: $s = \sqrt{\frac{\Sigma(x-\bar{x})^2}{n-1}}$

[Write your answer in the table] **[3]**

ii. The scientist thought that mineral solution **B** might cause a reduction in root hair density.

Suggest an appropriate statistical test that the scientist could carry out in order to confirm their hypothesis.

[1]

3. Icefish live in very cold water.

Icefish contain biological molecules that allow them to tolerate cold temperatures.

A group of students investigated the effect of temperature on the activity of two forms of trypsin: human trypsin and icefish trypsin.

Part of their method is shown below:

- use 10 cm^3 of 5% trypsin solution for all trials
- measure enzyme activity at 10, 20, 30, 40 and 50 °C for both enzymes
- carry out each trial in the same pH buffer
- repeat the experiment 5 times at each temperature
- measure enzyme activity by recording the area of gelatine on a photographic film that is broken down over a set time period

- calculate the rate of enzyme activity at each temperature.

i. Suggest **and** explain two improvements that would increase the validity of the students' investigation.

Improvement
Explanation

Improvement
Explanation

[4]

ii. Suggest appropriate units to use to represent the rate of enzyme activity in this investigation.

[1]

iii. The students recorded the temperature that produced the fastest reaction rate in each of the five replicates. These results are shown in Table 3.

Replicate	Temperature that produced the fastest reaction rate (°C)	
	Human trypsin	Icefish trypsin
1	40	20
2	10	10
3	30	20
4	40	30
5	40	30
Mean =	32.0	22.0
Mode =	40	20 and 30
Median =	40	20

Table 3

One of the students made the following statement:

I think the mean is a more accurate measure than the median or mode for these results.

Evaluate the student's statement.

[2]

iv. The students wanted to know whether there was a difference between the reaction rates of the two forms of trypsin at 30 °C.

They performed a statistical test on the mean of the five replicates for human trypsin and the five replicates for icefish trypsin.

Suggest the most appropriate statistical test for the students to use **and** explain why this test is appropriate.

[2]

4. Scientists self-pollinated some pea plants that were heterozygous for the gene controlling height.

They expected a 3:1 ratio of tall plants to short plants in the offspring.

1046 plants grew in the next generation. 798 were tall and 248 were short.

Which of the following, **A** to **D**, is a statistical test that could be used to determine if these numbers are significantly different from a 3:1 ratio?

A chi-squared
B Spearman's rank
C standard deviation
D Student's t-test

Your answer ☐ **[1]**

5. Students investigated the effect of light on the growth of garden cress seedlings.

- A total of 120 seedlings were divided into 2 groups of 60.
- Group A was grown in darkness for 2 days.
- Group B was grown for 1 day in darkness and then for 1 day in white light using the set-up shown in Fig. 3.1.

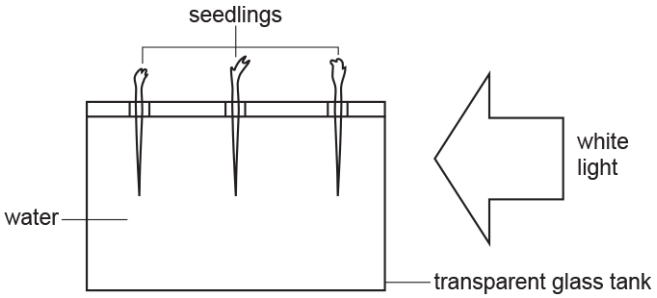

Fig. 3.1

The results of the students' experiment are shown in Tables 3.1 and 3.2.

Group	Mean length (mm)		Mean mass (µg)	
	stem	root	stem	root
A	13	18	102	60
B	25	23	160	120

Table 3.1

	Number of seedlings	
Direction of growth in Group B	stem	root
Away from light	2	29
Neither away from nor towards light	3	20
Towards light	55	11

Table 3.2

i. * Describe and explain the results shown in Tables 3.1 and 3.2.

[6]

ii. The students wanted to test whether there was a significant difference between the stem lengths of the seedlings in Group A and the seedlings in Group B.

State the name of the most appropriate statistical test for the students to use.

[1]

iii. Justify your choice of statistical test given in part **(ii)**.

[1]

iv. Table 3.2 records the direction of growth as:

- away from light
- neither away from nor towards light
- towards light.

The students used the chi-squared test to determine whether the direction of root growth was significantly different from their expectations.

Their null hypothesis was:

There is no difference between the expected direction of root growth and the observed direction of root growth.

The calculated chi-squared value was 8.10.

The students compared their chi-squared value of 8.10 to the values in Table 3.3.

Degrees of freedom	Probability (p)		
	0.10	**0.05**	**0.01**
1	2.71	3.84	6.64
2	4.60	5.99	9.21
3	6.25	7.82	11.34
4	7.78	9.49	13.28
5	9.24	11.07	15.09

Table 3.3

What can the students conclude about their results based on a chi-squared value of 8.10?

[3]

6. The pancreas produces digestive enzymes and is also involved in the regulation of blood glucose concentration.

Scientists investigated the effect of the drug nifedipine on the secretion of insulin from pancreas cells in culture.

Pancreas cells were first incubated with glucose at a concentration of 3 mmol dm^{-3}. The concentration of glucose was then increased to 20 mmol dm^{-3} in the presence or absence of nifedipine.

The scientists then measured the amount of insulin secreted by the cells. They recorded their results as a percentage of the total insulin content of the cells. Each experiment was repeated seven times.

The results are shown in the table.

Condition	Mean insulin secreted (%)
Without nifedipine	7.8 ± 0.78
With nifedipine	0.8 ± 0.15

i. Name the cells that secrete insulin.

[1]

ii. Explain why it was necessary to increase the concentration of glucose surrounding the cells before they measured insulin secretion.

[2]

iii. Suggest and explain which statistical test the researchers would have used to analyse their data.

[2]

iv. The statistical test gave a value of $p < 0.001$. Use the words 'chance' and 'probability' to draw a conclusion from the result of the statistical test.

[2]

v. Nifedipine blocks Ca^{2+}-channels.

Explain how blocking calcium channels could inhibit insulin secretion.

[2]

7. A student carried out an investigation to see the effect of changing the concentration of the enzyme maltase. They used two different maltase concentrations (concentration **P** and **Q**) to break down the disaccharide maltose for 10 minutes. The student carried out the reducing sugar test and recorded the percentage absorbance of each solution using a colorimeter.

Their results are shown in the table.

Absorbance (arbitrary units)	
Maltase concentration P	**Maltase concentration Q**
0.235	0.452

0.253	0.523
0.436	0.541
0.258	0.361
0.224	0.256
0.236	0.236

Which statistical test would be used to determine if there was a significant difference between the mean glucose concentration produced by maltase concentration **P** and maltase concentration **Q**?

A Chi-squared test
B Spearman's rank correlation coefficient
C *t* -test – paired
D *t* -test – unpaired

Your answer ☐ **[1]**

8. A class compared the number of chloroplasts in the leaves taken from plants of the same species growing in two areas. One area had a high light intensity, the other had a low light intensity.

Which option is the correct procedure for statistical analysis of the data collected by the class?

A Calculate the mean number of chloroplasts per cell in the high and low light intensity areas and use a paired t-test.
B Calculate the mean number of chloroplasts per cell in the high and low light intensity areas and use an unpaired t-test.
C Calculate the median number of chloroplasts per cell in the high and low light intensity areas and calculate Spearman's rank correlation coefficient.
D Calculate the median number of chloroplasts per cell in the high and low light intensity areas and use a chi-squared test.

Your answer ☐ **[1]**

END OF QUESTION PAPER

Mark scheme

Question			Answer/Indicative content	Marks	Guidance
1	a	i	***W*** */ it, has* (many) more cells in prophase **and** (far) fewer cells in telophase ✓	1	**CREDIT** correct ref to the relative numbers of cells in both phases **CREDIT** stated correctly calculated differences e.g. 'W has 20 more cells in prophase and 23 less in telophase' 'W has 20 more cells in prophase and V has 23 more cells intelophase' 'a difference of 20 in prophase and 23 in telophase' **ACCEPT** answers referring to speed rather than no. of cells (i.e. W spends longer in prophase but less time in telophase etc) **DO NOT CREDIT** if Metaphase and/or Anaphase are suggested **Examiner's Comments** This question tested candidates' ability to scan a set of data and select the significant differences. The mark was not awarded if only one of prophase or telophase was discussed. The difference neededto be qualified as more in prophase and less in telophase for cell W, or calculated figure differences for both stages needed to be given.
		ii	t-test compares two (or more) means **or** *idea that this* data does not include mean(s) **or** cannot calculate mean from this data **or** cannot calculate SD from this data ✓	1	**CREDIT** ref to not being a normal distribution / is not continuous data / is discrete data **ACCEPT** the idea that there are more than 2 categories **IGNORE** ref to 'average' instead of 'mean' **Examiner's Comments** There was wide variation in candidates' familiarity with the Student's t-test. Most correct answers referred to the need for comparing or calculating means for this test. Some stated that the test could only be used for calculations relating to biodiversity, as this had presumably been the context in which it had been taught.
	b	i	*calculation* $\mathbf{X}^2$ = 13.835 **or** 13.833 **or** 13.834 ✓ ✓ ✓	3	**Correct value of x^2 = 3 marks** **Answer should be to 3 dp to be consistent with the rest of the table. If answer unrounded or over-rounded but otherwise correct, max 2**

					<table><tr><th>Cells</th><th>O</th><th>E</th><th>(O – E)</th><th>(O – E)²</th><th>(O – E)²/E</th></tr><tr><td>In prophase</td><td>85</td><td>65</td><td>20</td><td>400</td><td>6.154</td></tr><tr><td>In metaphase</td><td>59</td><td>55</td><td>4</td><td>16</td><td>0.291</td></tr><tr><td>In anaphase</td><td>6</td><td>7</td><td>-1</td><td>1</td><td>0.143</td></tr><tr><td>In telophase</td><td>50</td><td>73</td><td>- 23</td><td>529</td><td>7.247</td></tr><tr><td>Total</td><td>200</td><td>200</td><td></td><td></td><td>13.835</td></tr></table> **Award 1 mark per correct row** (whether rounded or not) **plus 1 mark for x^2** **Only penalise the same type of error once.ALLOW** ecf for x^2 from incorrect row value(s) **Examiner's Comments** The chi-squared test was well done by a great many candidates, who were clearly well-prepared for the calculation aspect of the test. It was clear, however, that some candidates had not encountered chi-squared before [ref. the mathematical requirements in the AS Specification]. The scaffolding provided in the question, however, assisted them in completing the calculation. In this question as sample figures in the last column were given to three decimal places, answers should also have been given to three decimal places. The common errors were in rounding figures incorrectly or thinking that the square of -23 is also a negative number.
		ii	3 (degrees of freedom) ✓	1	**Examiner's Comments** Most candidates followed the instructions given and correctly identified the degrees of freedom as 3.
		iii	**Any statement(s) made must be correct for the candidate's responses to (i)and (ii).** *two from*1 calculated value is, > / greater than, 7.82 / the critical value at p = 0.05 / the value for (p =) 0.05 **or** 7.82 / the critical value at p = 0.05 / the value for (p =) 0.05, is, less than / <, 13.835 ✓ 2 (difference / deviation) is, significant / not due to chance ✓ 3 95% certain that the results are not due to chance **or** difference would only occur by chance 5% of	2	**ALLOW** ecf from candidate's calculated x^2value in **(i)** using the number of degrees of freedom theystated in **(ii)**. <table><tr><th rowspan="2">Degrees of freedom</th><th colspan="5">Probability (p)</th></tr><tr><th>0.99</th><th>0.95</th><th>0.05</th><th>0.01</th><th>0.001</th></tr><tr><td>1</td><td>0.00</td><td>0.00</td><td>3.84</td><td>6.64</td><td>10.83</td></tr><tr><td>2</td><td>0.02</td><td>0.10</td><td>5.99</td><td>9.21</td><td>13.82</td></tr><tr><td>3</td><td>0.11</td><td>0.35</td><td>7.82</td><td>11.35</td><td>16.27</td></tr><tr><td>4</td><td>0.30</td><td>0.71</td><td>9.49</td><td>13.28</td><td>18.47</td></tr><tr><td>5</td><td>0.55</td><td>1.15</td><td>11.07</td><td>15.09</td><td>20.52</td></tr><tr><td>6</td><td>0.84</td><td>1.64</td><td>12.59</td><td>16.81</td><td>22.46</td></tr><tr><td>7</td><td>1.24</td><td>2.17</td><td>14.07</td><td>18.48</td><td>24.32</td></tr></table> For incorrect x^2 and degrees of freedom values, apply mark points 1 to 5 to correspond to their

			the time ✓ 4 (difference / deviation) also significant at p = 0.01 value **or** 99% certain that the results are not due to chance **or** difference would only occur by chance 1% of the time **or** value is, > / greater than, p = 0.01 / 11.35 **or** probability is, < / less than, 0.01 **or** probability is between 0.01 and 0.001 **or** probability is not significant at p = 0.001 ✓ 5 the null hypothesis can be rejected✓		results. **Examiner's Comments** As might be expected, this part of the question proved to be the most challenging. Comparing the calculated value of chi-squared with a statistical table to draw a conclusion was the weakest step in the mental processing. There are many ways of expressing the conclusion that can be drawn from a chi-squared procedure and the mark scheme gives an exhaustive list of examples for use in teaching. Candidates who got parts (e)(i) and / or (e)(ii) wrong were not disadvantaged at this stage, as conclusions were marked based on their figures. The crucial piece of understanding that was missing from wrong answers is that the probability in the column headings is the probability of this amount of deviation (difference) occurring by chance. The use of p = 0.05 as the critical value is central to the interpretation. It may also help to explain to students that the smaller the chi-squared value, the better the fit of the two sets of data.
			Total	**8**	
2		i	12.1 ✓ ✓ ✓	3	*Max 2 if answer not given to 1 decimal place.* If answer is incorrect **ALLOW** 1 mark for evidence of correct mean calculation: 36 or 36.2 **Examiner's Comments** Most candidates gained 1 mark for correctly calculating the mean at 36.2. Many were also able to use the formula to calculate the standard deviation correctly although a significant number of candidates gave up after calculating the mean. In common with other calculations on this examination paper the most frequent reason for loss of marks was incorrect rounding. Candidates should be reminded to round their final answer rather than rounding earlier in the calculation. All processed data is recorded to up to one significant figure more than the raw data. **OCR support** The maths skills handbook is provided on the OCR website: https:/www.ocr.org.uk/Images/294471-biology-mathematical-skills-handbook.pdf
		ii	(students) (unpaired) t-test ✓	1	**DO NOT ALLOW** paired t-test **Examiner's Comments**

					Judging by the number of crossed-out alternatives seen on scripts, candidates were unprepared for selecting appropriate statistical tests. Only a few candidates gave the correct response. The most common incorrect answers were chi-squared or Spearman's rank correlation and some candidates referred to 'calculate a mean'. **OCR support** The Mathematical skills statistics booklet is provided on the OCR website: https:/www.ocr.org.uk/Images/338621-mathematical-skills-statistics-booklet.doc
			Total	**4**	
3		i	*I*: another named control variable (not mentioned in text) ✓ *E*: *idea of* prevent other factors (other than temperature) affecting results ✓ *I*: *idea of* standardised method ✓ *E*: minimises experimental error ✓ *I*: temperature intervals closer together ✓ *E*: (gives a more) accurate estimate of optimum temperature ✓ *I*: control group / tube with no trypsin / tube with boiled trypsin ✓ *E*: to see if gelatine breaks down without trypsin (at different temperatures) / to allow comparison (with experimental data) ✓	4 max (AO3.4)	*Read as prose as improvement mark could be found in explanation e.g. 'I; substrate concentration E; should be kept constant' gets I mp* *Marks for explanation can be awarded if the linked improvement mark is attempted but not given* e.g. area of film / volume of pH buffer / source of trypsin thickness / volume / concentration, of, gelatine / substrate **IGNORE** amount e.g. thickness may affect rate of breakdown of gelatine e.g. film is placed in the solution in the same way each time / measure time for set volume of gelatine to be broken down / use a thermostatically controlled water bath **ALLOW** improves, accuracy / reproducibility/ repeatability / precision **IGNORE** improves reliability **ALLOW** extend temperature range below 10°C **ALLOW** shows the optimum / best temperature (for trypsin) **ALLOW** improves precision **DO NOT ALLOW** improves, reproducibility/reliability **ALLOW** to show trypsin is needed to break down gelatine **ALLOW** to see if heat breaks down gelatine **Examiner's Comments**

					Candidates did not gain marks for describing improvement aspects of the experiment that were already in place on the exam paper (e.g. controlling pH using a buffer) or variants of this (e.g. saying that the set time period should be stated exactly). The most common correct answers concerned controlling another variable such as the thickness, volume or concentration of the gelatine substrate. Not all could match this improvement with the explanation that variation in this variable would affect the rate being measured. Candidates also sometimes attempted to describe a way of standardising the method, such as using a thermostatically-controlled water bath, although again correct explanations relating to improved precision and reproducibility or repeatability were not always forthcoming. Few candidates considered running a control experiment. Candidates who realised that accuracy could be improved by testing at more temperatures often did not state 'within the range' or to make clear that the more temperature intervals they suggested would be smaller intervals between 10°C and 50°C. Some students did not understand that this question was about practical measurement and talked about improvements relating to calculations and statistical analysis. Correct use of terms such as accuracy, precision, reproducibility and repeatability were important in answering this question. Many candidates justified their suggested improvements by simply repeating the term 'validity' from the question.  **AfL** The word 'amount' is not specific enough and should be avoided by candidates.  **OCR support** Appendix 4 of the Practical Skills Handbook, provides information on terms used in measurement and conventions for recording and processing experimental measurements. This is in line with the 'The Language of measurement' booklet: https:/www.ocr.org.uk/Images/294468-biology-practical-skills-handbook.pdf

		ii	mm^2 / cm^2 **and** s^{-1} / min^{-1} ✓	1 (AO2.4)	**ALLOW** /s /min **DO NOT ALLOW** 'per' or 'sec' or 'minute' **Examiner's Comments** A few answers provided correct units for area per unit time such as mm^2 s^{-1} or cm^2 / min. Errors included giving measures of volume (mm^3 and cm^3), combining two conventions such as using a slash and '$^{-1}$' after the time term, and writing in the format of area unit 'per' the time unit. Correct abbreviations of units were needed as opposed to words like 'minutes' or 'sec'.
		iii	*I agree / yes, because…* two mode values exist (for icefish trypsin) ✓ *I disagree / no, because…* outlier / anomaly, included in the mean (for human trypsin) ✓ median / mode, not / less, affected by outliers ✓	2 max (AO3.2)	**IGNORE** references to decimal places **Examiner's Comments** Many candidates provided descriptions of the terms mean, mode and median, but these gained no marks, as they were not related to the question. Some candidates showed awareness that the mean calculation included an outlier though not all reasoned that, as a result the student's statement was incorrect. Similarly not all considered that a strength of the median or mode is that they are unaffected by outliers. Very few noticed that the existence of two values for the mode for icefish trypsin was a problem. Some candidates are demonstrating their understanding of the command term 'evaluate' by trying to provide a balanced answer, in this year's exams.
		iv	(Student's)(unpaired) t-test ✓ (they are) comparing **means** (of two data sets) / AW ✓	2 (AO3.1)	**IGNORE** standard deviation **DO NOT ALLOW** paired / dependent / related, t-test e.g. 'finding the difference between 2 means' **ALLOW** 'compare averages of 2 data sets' **Examiner's Comments** Many candidates referred to the correct answer which was t-test. . However, most candidates scored only one mark as they did not explain that this allows comparison of two means (they often just stated two data sets, which is too vague). Some candidates showed extended knowledge of the application of statistics to experimental design with the use of terms like unpaired, unrelated and independent. Incorrect answers included the χ^2 test, standard deviation and Spearman's rank correlation.

					OCR support 'Mathematical skills statistics booklet' can help to develop the correct use of statistical tests: https:/www.ocr.org.uk/Images/338621-mathematical-skills-statistics-booklet.doc
			Total	**9**	
4			A ✓	1 AO2.2	
			Total	**1**	
5		i	***Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question.*** ***In summary:*** *Read through the whole answer. (Be prepared to recognise and credit unexpected approaches where they show relevance.)* *Using a 'best-fit' approach based on the science content of the answer, first decide which of the level descriptors,* ***Level 1****,* ***Level 2*** *or* ***Level 3****, best describes the overall quality of the answer.* *Then, award the higher or lower mark within the level, according to the Communication Statement (shown in italics):* o *award the higher mark where the Communication Statement has been met.* o *award the lower mark where aspects of the* ***Communication Statement*** *have been missed.* ● *The science content determines the level.* ● *The Communication Statement determines the mark within a level.* **Level 3 (5-6 marks)** Detailed description **and** linked explanation of results for **both** tables. *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3-4 marks)** Describes results for **both** tables with some explanation of at least **one** table. *There is a line of reasoning with some structure. The information presented is*	6 (AO2.3) (AO2.4) (AO3.1)	**Indicative scientific points may include (but are not limited to):** *AO2.3 and 2.4 Apply knowledge and understanding of scientific ideas and techniques in a practical context when handling qualitative and quantitative data.* *Descriptions:* <u>Table 3.1</u>: ● light increases length and mass of both roots and stems ● group A has less growth than group B <u>Table 3.2</u>: ● stems grow towards the light (with a few exceptions) ● (almost) half the roots grow away from light ● some appear unaffected by light or grow towards light *AO3.1 Analyse scientific information to make judgements and reach conclusions* *Explanations:* <u>Table 3.1</u>: ● more carbohydrates produced during photosynthesis ● light may trigger growth and germination (through phytochromes) <u>Table 3.2</u>: ● details of phototropism (e.g. auxins produced in shoot tip moves to side away from light / auxins cause more cell elongation on side away from light) ● light allows photosynthesis ● positive phototropism in stems

			relevant and supported by some evidence. **Level 1 (1-2 marks)** Offers some description for both tables **or** describes and explains one table. *The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.* **0 marks** No response or no response worthy of credit.		• geotropism more important than phototropism in roots • (some) negative phototropism in roots • other reasons for varied data, e.g. conditions not natural / measurement error / shading of stems / stems heavier than roots so tips
		ii	(unpaired) t-test ✓	1 (AO2.8)	**ALLOW** unrelated t-test **DO NOT ALLOW** paired/related, t-test
		iii	*idea of* comparing two means ✓	1 (AO3.3)	
		iv	8.10 is greater than 5.99 (at 2 degrees of freedom) ✓ (therefore) significant (difference) at (p =) 0.05 ✓ not significant at (p =)0.01 ✓ (indicates greater than 95% probability that) difference is not due to chance ✓ null hypothesis can be rejected (at p = 0.05) ✓	3 max (AO3.2)	**ALLOW ECF for mp2 ,4 and 5 if 9.49 or 11.07 value used from table for max 2 marks** **ALLOW** 'students chi-squared value greater than critical value for 2 degrees of freedom' **ALLOW** 'there is a significant difference between the observed and expected results' **ALLOW** 'less than 5% probability that difference is due to chance'
			Total	**11**	
6		i	beta / β (cells) ✓	1 (AO1.1)	
		ii	glucose (concentration) causes release of insulin / AW ✓ change in insulin secretion is high enough to be measured / AW ✓	2 (AO3.3 AO2.3)	**IGNORE** synthesis or production of insulin **ALLOW** amount of insulin (secreted by the cells) was high enough to measure
		iii	(unpaired) t-test ✓ because they are comparing <u>means</u> ✓	2 (AO3.3 AO2.3)	**DO NOT ALLOW** paired t-test **IGNORE** reference to tailed **IGNORE** standard deviation **IGNORE** reference to null hypothesis
		iv	<u>probability</u> is, less than / <, 0.1% / 0.001 ✓ (so) results / differences between means, were due to <u>chance</u> ✓	2 (AO2.4 AO3.1)	**ALLOW for 2 marks** e.g. there is less than 1 in 1000 <u>probability</u> that the results are due to <u>chance</u> **OR ora** e.g. there is greater than 99.9% <u>probability</u> that results are not due to <u>chance</u>
		v	Ca^{2+} / calcium ions, do not enter (cells) ✓ less / no, exocytosis ✓	2 (AO2.4)	**ALLOW** for **1 max** description of what happens without the inhibitor

					ALLOW less / no, movement of vesicles towards membrane **ALLOW** less / no, vesicles fuse with membrane **DO NOT ALLOW** vesicles not secreted
			Total	**9**	
7			**D ✓**	1	**Examiner's Comments** Many candidates recognised that the t-test was the most appropriate test to compare two mean values. However, fewer were able to select between paired and unpaired tests correctly. **OCR support** The use of paired and unpaired t-tests is described in the Mathematical Skills Handbook available at: https:/www.ocr.org.uk/Images/294471-biology-mathematical-skills-handbook.pdf OCR has also additional support on statistics: https:/www.ocr.org.uk/Images/346170-graphs-tables-and-drawings-student-checklists.doc https:/www.ocr.org.uk/subjects/science/maths-for-biology/handling-data/
			Total	**1**	
8			**B**	1 (AO2.8)	**Examiner's Comments** Use of mathematical skills and data analysis is a requirement of A level Biology, although statistical analysis remains challenging for some candidates. Many candidates demonstrated their knowledge by choosing the unpaired *t*-test in option B as the appropriate statistical test to use in this context. Distinguishing between a paired and an unpaired *t*-test proved the biggest challenge with option A being the most common incorrect response.
			Total	**1**	