BIOWELSH WORKSHEET FOR WJEC GCE A LEVEL BIOLOGY
UNIT 4 – VARIATION, INHERITANCE AND OPTIONS
TOPIC 4.3 INHERITANCE: WORKSHEET 1 (BW-A2-4.3-W1) MARK SCHEME

GENERAL INSTRUCTIONS

Recording of marks

Mark in red ink. One tick equals one mark, except in the extended response question, where a level of response scheme is used.

Write each question total in the box at the end of the question, and copy the totals onto the grid on the front cover of the worksheet. Add them to give the worksheet total out of 145.

Marking rules

Look at all of the work. Where the scheme says working is needed, the working must be seen. Mark crossed-out work if it has not been replaced. Give credit for correct, relevant answers that are not listed in the scheme.

Extended response question

Read the whole answer first. Decide which level descriptor fits the answer best, judging the overall quality. Then choose the mark within the level: the top mark when the answer matches both the content and the communication statements well, the middle mark when most of the content is there and the communication statement is partly met, and the bottom mark when only the content statements are matched.

Marking abbreviations

cao	=	correct answer only
ecf	=	error carried forward
bod	=	benefit of doubt
ORA	=	or reverse argument
owtte	=	or words to that effect

Notation: / separates alternatives; { } groups alternatives within a point; words in ( ) are not needed for the mark; underlined words are essential; (1) is one mark.

<table>
<tr><th colspan="4" rowspan="2">Question</th><th rowspan="2">Marking details</th><th colspan="6">Marks available</th></tr>
<tr><th>AO1</th><th>AO2</th><th>AO3</th><th>Total</th><th>Maths</th><th>Prac</th></tr>
<tr><td>1</td><td>(a)</td><td></td><td></td><td>X locus (of the body colour gene) / position of the gene / accept allele e (1)
Y centromere (1)
Z (homologous) chromosome / chromatid (1)</td><td>3</td><td></td><td></td><td>3</td><td></td><td></td></tr>
<tr><td></td><td>(b)</td><td></td><td></td><td>A different form / version of the same gene (found at the same locus) (1)</td><td>1</td><td></td><td></td><td>1</td><td></td><td></td></tr>
<tr><td></td><td>(c)</td><td></td><td></td><td>Ee heterozygous; NN homozygous (dominant); rr homozygous (recessive)
All three rows correct = 2 marks
Two rows correct = 1 mark
Example of a full-mark answer<table><tr><th>Gene</th><th>Genotype</th><th>Homozygous or heterozygous</th></tr><tr><td>body colour</td><td>Ee</td><td>heterozygous</td></tr><tr><td>gene N</td><td>NN</td><td>homozygous</td></tr><tr><td>gene R</td><td>rr</td><td>homozygous</td></tr></table></td><td>2</td><td></td><td></td><td>2</td><td></td><td></td></tr>
</table>

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
	(d)			Parental genotypes Ee × ee (1) Gametes E and e, and e (1) Offspring Ee grey and ee black in a ratio of 1 grey : 1 black (1) ecf from incorrect parental genotypes for the second and third marks **Example of a full-mark answer** **Parental phenotypes** grey body × black body **Parental genotypes** Ee × ee **Gametes** E, e × e **Offspring genotypes** Ee, ee **Offspring phenotypes** grey body, black body **Phenotype ratio** 1 grey : 1 black		3		3		
				Question 1 total	4	5	0	9	0	0

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
2	(a)			Both alleles are expressed in the heterozygote / neither allele is dominant (1) So a C^BC^W bird has a phenotype different from both homozygotes / shows features of both (1)	2			2		
	(b)			Parents $C^BC^W \times C^BC^W$ (1) Gametes C^B, C^W from each parent (1) Offspring C^BC^B black, C^BC^W blue, C^WC^W splash in a 1 : 2 : 1 ratio (1) **Example of a full-mark answer** **Parental phenotypes** blue × blue **Parental genotypes** $C^BC^W \times C^BC^W$ **Gametes** $C^B, C^W \times C^B, C^W$ Gametes / C^B / C^W **C^B** / C^BC^B black / C^BC^W blue **C^W** / C^BC^W blue / C^WC^W splash Phenotype ratio 1 black : 2 blue : 1 splash, which matches Table 2.1 (23 : 51 : 26).	1	2		3		
	(c)			1 : 2 : 1 (1) Accept 23 : 51 : 26 simplified to about 1 : 2.2 : 1.1		1		1	1	
	(d)			Blue birds are always heterozygous / C^BC^W (1) Each passes on either allele, so black and splash chicks (homozygotes) are always produced / only half the chicks are blue (1)		2		2		
	(e)			Black × splash / $C^BC^B \times C^WC^W$ (1) Every chick receives C^B from one parent and C^W from the other, so all are C^BC^W / blue (1)		1	1	2		
				Question 2 total	3	6	1	10	1	0

<table>
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<tr><th>AO1</th><th>AO2</th><th>AO3</th><th>Total</th><th>Maths</th><th>Prac</th></tr>
<tr><td>3</td><td>(a)</td><td></td><td></td><td>Mm, because MM embryos die / Manx cats cannot be MM (1)</td><td></td><td>1</td><td></td><td>1</td><td></td><td></td></tr>
<tr><td></td><td>(b)</td><td></td><td></td><td>Parents Mm × Mm and gametes M, m from each (1)
Offspring genotypes MM, Mm, Mm, mm (1)
MM die, so 2 tailless : 1 tailed (1)
Example of a full-mark answer
Parental phenotypes Manx × Manx
Parental genotypes Mm × Mm
Gametes M, m × M, m
<table><tr><th>Gametes</th><th>M</th><th>m</th></tr><tr><td>M</td><td>MM dies as an embryo</td><td>Mm tailless</td></tr><tr><td>m</td><td>Mm tailless</td><td>mm tailed</td></tr></table>Kittens born: 2 tailless : 1 tailed.</td><td>1</td><td>2</td><td></td><td>3</td><td></td><td></td></tr>
<tr><td></td><td>(c)</td><td>(i)</td><td></td><td>4.59 (3)
Award 2 marks for $(O - E)^2 \div E$ values of 1.15 and 3.44
Award 1 mark for expected numbers of 66.75 and 22.25
Accept 4.6</td><td></td><td>3</td><td></td><td>3</td><td>3</td><td></td></tr>
<tr><td></td><td></td><td>(ii)</td><td></td><td>χ^2 is greater than 3.84, so the null hypothesis is rejected (1)
The difference between observed and expected is significant / not due to chance, so the results do not fit a 3 : 1 ratio (1)
ecf from (c)(i)</td><td></td><td></td><td>2</td><td>2</td><td></td><td>1</td></tr>
<tr><td></td><td></td><td>(iii)</td><td></td><td>58 : 31 is close to 2 : 1 (1.9 : 1), the ratio expected if MM kittens are missing (1)</td><td></td><td></td><td>1</td><td>1</td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td>Question 3 total</td><td>1</td><td>6</td><td>3</td><td>10</td><td>3</td><td>1</td></tr>
</table>

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
4	(a)			Metaphase I (1) Homologous chromosomes are in pairs / bivalents lined up on the equator (1)	1	1		2		
	(b)			P spindle pole / centriole; Q spindle fibre / microtubule; R chromosome / (one of a pair of) homologous chromosomes / two chromatids All three correct = 2 marks Two correct = 1 mark	2			2		
	(c)			Ab and aB (1) Both needed		1		1		
	(d)			Homologous pairs line up / orientate randomly and independently at the equator (1) In other cells the second pair is the other way round, giving AB and ab gametes (1) Both arrangements are equally likely, so AB, Ab, aB and ab are produced in equal numbers (1)	2	1		3		
	(e)			$16 / 2^4$ (1)		1		1	1	
				Question 4 total	5	4	0	9	1	0

<table>
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<tr><th>AO1</th><th>AO2</th><th>AO3</th><th>Total</th><th>Maths</th><th>Prac</th></tr>
<tr><td>5</td><td>(a)</td><td></td><td></td><td>EV, Ev, eV and ev (1)
All four needed</td><td>1</td><td></td><td></td><td>1</td><td></td><td></td></tr>
<tr><td></td><td>(b)</td><td></td><td></td><td>9 : 3 : 3 : 1 (1)
Genes on different chromosomes assort independently, so the four gamete types are made in equal numbers and fuse at random (1)</td><td>2</td><td></td><td></td><td>2</td><td></td><td></td></tr>
<tr><td></td><td>(c)</td><td>(i)</td><td></td><td>Expected 97.5 and 32.5 (1)
$(O - E)^2 \div E$ values 0.31 and 0.62 (1)
$\chi^2 = 1.08$ (1)
Accept 1.1; ecf from the table
Example of a full-mark answer
<table>
<tr><th>Phenotype</th><th>Observed (O)</th><th>Expected (E)</th><th>$(O - E)^2 \div E$</th></tr>
<tr><td>grey, normal</td><td>290</td><td>292.5</td><td>0.02</td></tr>
<tr><td>grey, vestigial</td><td>101</td><td>97.5</td><td>0.13</td></tr>
<tr><td>ebony, normal</td><td>92</td><td>97.5</td><td>0.31</td></tr>
<tr><td>ebony, vestigial</td><td>37</td><td>32.5</td><td>0.62</td></tr>
<tr><td></td><td></td><td>$\chi^2 =$</td><td>1.08</td></tr>
</table></td><td></td><td>3</td><td></td><td>3</td><td>3</td><td>1</td></tr>
<tr><td></td><td></td><td>(ii)</td><td></td><td>3 degrees of freedom (1)
χ^2 (1.08) is less than the critical value of 7.82, so accept the null hypothesis (1)
Probability greater than 0.05 that the difference is due to chance / the difference is not significant / results fit 9 : 3 : 3 : 1 (1)
ecf from (c)(i)</td><td></td><td></td><td>3</td><td>3</td><td>1</td><td>1</td></tr>
<tr><td></td><td>(d)</td><td></td><td></td><td>Chance deviations have a smaller effect on the proportions / a large sample gives values closer to the true ratio (1)</td><td></td><td></td><td>1</td><td>1</td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td>Question 5 total</td><td>3</td><td>3</td><td>4</td><td>10</td><td>4</td><td>2</td></tr>
</table>

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
6	(a)			3910.5 / 3911 (1)		1		1	1	
	(b)			3 degrees of freedom (1) 3372 is much greater than 7.82, so reject the null hypothesis (1) The difference from 9 : 3 : 3 : 1 is significant / not due to chance (1)			3	3		
	(c)			The two genes are linked / on the same chromosome (1) In the parents P was on the same chromosome as L, and p with l, so these alleles were inherited together / did not assort independently (1) So most gametes were PL or pl (parental types) (1)		2	1	3		
	(d)			Crossing over / a chiasma formed between the two loci in prophase I (1) Producing a few recombinant gametes, Pl and pL (1)	2			2		
	(e)			The genes are close together, so crossing over between them is rare (1)			1	1		
				Question 6 total	2	3	5	10	1	0

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
7	(a)			Chlorophyll is only made / seedlings only turn green in the light (1) In the dark all seedlings would be pale, so green and albino could not be told apart (1)		2		2		2
	(b)			Any two (×1) from: • Volume of water / how damp the paper is (1) • Type of filter paper / substrate (1) • Number of seeds per dish (1) • Time before counting (1) • Seeds from the same parent plant (1)			2	2		2
	(c)			0.18 (3) Award 2 marks for 0.046 and 0.138 / 9 ÷ 195 and 9 ÷ 65 Award 1 mark for expected numbers 195 and 65		3		3	3	1
	(d)			χ^2 is less than 3.84 so the null hypothesis is accepted (1) The difference is due to chance / the results fit a 3 : 1 ratio, as expected for a monohybrid cross of two heterozygotes (1) ecf from (c)			2	2		1
	(e)			Albino seedlings cannot photosynthesise / have no chlorophyll (1) So they die once the food store in the seed has been used up (1)	1	1		2		
				Question 7 total	1	6	4	11	3	6

<table>
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<tr><th>AO1</th><th>AO2</th><th>AO3</th><th>Total</th><th>Maths</th><th>Prac</th></tr>
<tr><td>8</td><td>(a)</td><td></td><td></td><td>44 (1)</td><td>1</td><td></td><td></td><td>1</td><td></td><td></td></tr>
<tr><td></td><td>(b)</td><td></td><td></td><td>T is the X chromosome and U is the Y chromosome (1)
There is one X and one (smaller) Y instead of two X chromosomes (1)</td><td></td><td>2</td><td></td><td>2</td><td></td><td></td></tr>
<tr><td></td><td>(c)</td><td></td><td></td><td>Every egg / female gamete carries an X chromosome (1)
Half the sperm carry X and half carry Y, so the sperm decides whether the zygote is XX or XY (1)</td><td>2</td><td></td><td></td><td>2</td><td></td><td></td></tr>
<tr><td></td><td>(d)</td><td>(i)</td><td></td><td>She received her father's X chromosome, which carried X^b, but has normal vision so also has X^B (1)</td><td></td><td>1</td><td></td><td>1</td><td></td><td></td></tr>
<tr><td></td><td></td><td>(ii)</td><td></td><td>Parents $X^BX^b \times X^BY$ (1)
Offspring X^BX^B, X^BX^b, X^BY and X^bY (1)
Probability that a son is colour blind = 0.5 / 1 in 2 (1)
Example of a full-mark answer
Parental phenotypes carrier female × normal male
Parental genotypes $X^BX^b \times X^BY$
Gametes $X^B, X^b \times X^B, Y$
<table><tr><td>Gametes</td><td>X^B</td><td>Y</td></tr><tr><td>X^B</td><td>X^BX^B normal female</td><td>X^BY normal male</td></tr><tr><td>X^b</td><td>X^BX^b carrier female</td><td>X^bY colour blind male</td></tr></table>Sons: 1 normal : 1 colour blind, so the probability that a son is colour blind is 0.5.</td><td>1</td><td>2</td><td></td><td>3</td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td>Question 8 total</td><td>4</td><td>5</td><td>0</td><td>9</td><td>0</td><td>0</td></tr>
</table>

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
9	(a)			Males have only one X chromosome / the Y has no allele of the gene, so one recessive allele is expressed (1) Females need two recessive alleles / must inherit it from both parents, including an affected father, which is rare (1)	2			2		
	(b)			2 X^HX^h (1) 6 X^hY (1) 11 X^HX^h (1)		3		3		
	(c)			Her son 9 has haemophilia (1) He inherited his X chromosome / X^h from his mother, as his father 3 gave him a Y (1)			2	2		
	(d)			0.25 / 1 in 4 / 25 % (1)		1		1	1	
	(e)			She could be X^HX^H or X^HX^h (1) Her mother is a carrier, so she had a 1 in 2 chance of inheriting X^h, and she has no children to show it (1)			2	2		
				Question 9 total	2	4	4	10	1	0

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
10	(a)			Individuals 5 and 6 are not deaf but their daughter 10 is (1) So both parents carry the allele without expressing it / are heterozygous (1)			2	2		
	(b)			Individual 10 is an affected female with an unaffected father, 5 (1) If the allele were X-linked recessive, her father would pass his X to her and so would be affected / she must have received an allele from each parent (1)			2	2		
	(c)			5 Dd and 6 Dd (1) 10 dd (1)		2		2		
	(d)			2/3 / 0.67 (2) Award 1 mark for 1 DD : 2 Dd : 1 dd from Dd × Dd, or for 0.5		2		2	2	
	(e)			Individual 5 is Dd, and his d allele must have come from one of his parents (1)			1	1		
				Question 10 total	0	4	5	9	2	0

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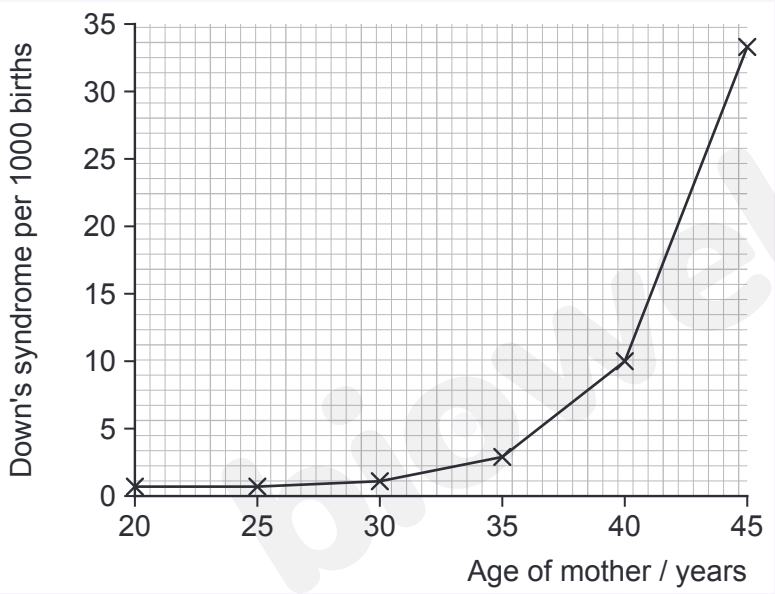
<tr><td>11</td><td>(a)</td><td></td><td></td><td>S sickle(-shaped) red blood cell / erythrocyte (1)
W white blood cell / leucocyte / neutrophil (1)</td><td>2</td><td></td><td></td><td>2</td><td></td><td></td></tr>
<tr><td></td><td>(b)</td><td>(i)</td><td></td><td>mRNA GAG and GUG (1)
Glutamic acid and valine (1)
Example of a full-mark answer<table><tr><th></th><th>Hb^A</th><th>Hb^S</th></tr><tr><td>DNA coding strand</td><td>GAG</td><td>GTG</td></tr><tr><td>mRNA codon</td><td>GAG</td><td>GUG</td></tr><tr><td>Amino acid</td><td>glutamic acid</td><td>valine</td></tr></table></td><td></td><td>2</td><td></td><td>2</td><td></td><td></td></tr>
<tr><td></td><td></td><td>(ii)</td><td></td><td>(Base) substitution / point mutation (1)</td><td>1</td><td></td><td></td><td>1</td><td></td><td></td></tr>
<tr><td></td><td>(c)</td><td></td><td></td><td>Valine is non-polar / hydrophobic, replacing charged / hydrophilic glutamic acid (1)
At low oxygen concentration the haemoglobin molecules stick together / form long fibres (1)
Which distorts the red blood cell into a rigid sickle shape (1)</td><td>1</td><td>2</td><td></td><td>3</td><td></td><td></td></tr>
<tr><td></td><td>(d)</td><td></td><td></td><td>Both normal and sickle haemoglobin are made (1)
Enough normal haemoglobin is made that cells only sickle at very low oxygen concentrations / oxygen transport is nearly normal (1)</td><td></td><td>1</td><td>1</td><td>2</td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td>Question 11 total</td><td>4</td><td>5</td><td>1</td><td>10</td><td>0</td><td>0</td></tr>
</table>

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
12	(a)			474 is a multiple of 3 / 474 ÷ 3 = 158, so whole triplets are removed (1) The reading frame is kept, so later triplets are read correctly; the protein only lacks 158 amino acids (1)		2		2	1	
	(b)			176 is not a multiple of 3 (1) Causing a frame shift, so every triplet after the deletion is read differently (1) Different amino acids / an early stop codon, so the protein is not made or cannot function (1)	1	2		3		
	(c)			Boy Q makes a shorter dystrophin (1) Which still partly works / still stabilises the muscle fibre membranes to some extent (1)			2	2		
	(d)			The genetic code is degenerate, so the new triplet codes for the same amino acid / the change is in an intron (1)	1			1		
	(e)			A girl would need a recessive allele on both X chromosomes, so her father would have to be affected (and affected boys rarely have children) (1)	1			1		
				Question 12 total	3	4	2	9	1	0

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
13	(a)			Non-disjunction (1) Anaphase I / meiosis I: the homologous chromosomes did not separate (1)	1	1		2		
	(b)			K 24 (1) L 22 (1)		2		2	1	
	(c)			K is fertilised by a normal sperm with 23 chromosomes / one chromosome 21 (1) The zygote has three copies of chromosome 21 / trisomy 21 / 47 chromosomes (1)	2			2		

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
	(d)			Axes correct way round, labelled with units: x = age of mother / years; y = babies with Down's syndrome per 1000 births (1) Suitable linear scales using more than half of the grid (1) All points plotted correctly ± half a small square (1) Points joined with ruled straight lines (1) **Example of a full-mark answer**  		2	2	4	4	2
	(e)			Oocytes are held paused in prophase I from before birth until ovulation, so older oocytes have been waiting longer / more time for damage to the spindle or chromosomes (1)		1		1		
				Question 13 total	3	6	2	11	5	2

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
14	(a)			As the number of severe sunburns increases, the risk of melanoma increases / positive correlation (1) From 1.0 with no sunburns to 3.0 with 10 / the risk triples (1)			2	2		
	(b)			110 (%) (2) Award 1 mark for (2.1 – 1.0) ÷ 1.0 × 100		2		2	2	
	(c)			UV is a mutagen / damages DNA, causing mutations (1) In a proto-oncogene, making an oncogene, or in a tumour suppressor gene such as TP53, switching it off (1) So cell division / mitosis becomes uncontrolled and a tumour forms (1)	2	1		3		
	(d)			They show a correlation, not a causal link (1) Other factors could be involved, for example skin type / total time in the sun / inherited alleles / people who burn more may differ in other ways (1)			2	2		
				Question 14 total	2	3	4	9	2	0

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
15				**Indicative content**	3	3	3	9		
				A Epigenetics and how it controls gene expression A1 Epigenetics is the control of gene expression by factors other than changes to the DNA base sequence A2 Methyl groups are added to cytosine, especially in the promoter of a gene A3 A heavily methylated promoter stops RNA polymerase / transcription factors binding, so the gene is not transcribed / is switched off A4 Acetylation of histones loosens the packing of DNA, so the gene can be transcribed A5 Removing acetyl groups makes the DNA wind tightly round the histones, so the gene is switched off A6 Epigenetic tags are copied when cells divide by mitosis						
				B The results in Graph 15.1 B1 The difference in methylation increases with age B2 From 1.1 % at 3 years to 4.6 % at 50 years, about four times greater B3 Twins share a base sequence, so the differences are epigenetic B4 Twins experience different environments as they grow up, for example diet, smoking, stress or illness, which change methylation B5 Small random errors in copying methylation build up with each cell division over a lifetime						

Question	Marking details	Marks available					
		AO1	AO2	AO3	Total	Maths	Prac
	C How epigenetic changes could lead to cancer in one twin C1 Methylation of the promoter of a tumour suppressor gene switches it off C2 So damaged cells are no longer stopped from dividing / apoptosis is not triggered C3 Loss of methylation / histone changes could switch on a proto-oncogene, increasing cell division C4 Uncontrolled mitosis leads to a tumour C5 Environmental factors such as carcinogens in one twin's lifestyle can also cause mutations, adding to the epigenetic changes						
	7-9 marks Indicative content of this level is detailed information from all three lists. The candidate constructs an articulate, integrated account, correctly linking relevant points in a logical sequence. The answer fully addresses the question with no irrelevant inclusions or significant omissions. Scientific conventions and vocabulary are used appropriately and accurately.						
	4-6 marks Indicative content of this level is detailed information from two of the lists, or less detail from all three. The candidate constructs an account correctly linking some relevant points, showing some reasoning. The answer addresses the question with some omissions. Scientific conventions and vocabulary are usually used appropriately and accurately.						
	1-3 marks Indicative content of this level is some information from at least one of the lists, or a little information from more than one. The candidate makes some relevant points, showing limited reasoning. The answer addresses the question with significant omissions. Use of scientific conventions and vocabulary is limited.						

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
				0 marks The candidate does not make any attempt or give a relevant answer worthy of credit.						
				Question 15 total	3	3	3	9	0	0

UNIT 4: VARIATION, INHERITANCE AND OPTIONS, TOPIC 4.3

SUMMARY OF MARKS ALLOCATED TO ASSESSMENT OBJECTIVES

Question	AO1	AO2	AO3	TOTAL MARK	MATHS	PRAC
1	4	5	0	9	0	0
2	3	6	1	10	1	0
3	1	6	3	10	3	1
4	5	4	0	9	1	0
5	3	3	4	10	4	2
6	2	3	5	10	1	0
7	1	6	4	11	3	6
8	4	5	0	9	0	0
9	2	4	4	10	1	0
10	0	4	5	9	2	0
11	4	5	1	10	0	0
12	3	4	2	9	1	0
13	3	6	2	11	5	2
14	2	3	4	9	2	0
15	3	3	3	9	0	0
TOTAL	**40**	**67**	**38**	**145**	**24**	**11**

A Tutor Meets Tutee project

BioWelsh mark scheme BW-A2-4.3-W1 (MS). Not an official WJEC mark scheme.