Surname	Date	Tutor
First name(s)		

BioWelsh

GCE A LEVEL

BW-A2-4.4-W1

TOPIC WORKSHEET 1 – 4.4 VARIATION AND EVOLUTION

BIOLOGY – A2 unit 4

Variation, Inheritance and Options

Suggested time: 3 hours 20 minutes

For Tutor's use only

Question	Maximum Mark	Mark Awarded	Question	Maximum Mark	Mark Awarded
1.	11		9.	9	
2.	10		10.	9	
3.	9		11.	10	
4.	10		12.	9	
5.	11		13.	9	
6.	11		14.	14	
7.	10		15.	9	
8.	10		Total	151	

ADDITIONAL MATERIALS

In addition to this worksheet, you will require a calculator and a ruler.

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen. Do not use gel pen or correction fluid.

You may use a pencil for graphs and diagrams only.

Write your name and the date in the spaces at the top of this page.

Answer **all** questions.

Write your answers in the spaces provided in this booklet. If you are working on screen, write your answers on paper and number each one clearly.

INFORMATION FOR CANDIDATES

The number of marks is given in brackets at the end of each question or part-question. The worksheet is out of **151** marks.

The assessment of the quality of extended response (QER) will take place in question **15**.

The quality of written communication will affect the awarding of marks.

This worksheet is written by BioWelsh in the style of the WJEC A level Biology examination, following the WJEC specification (topic 4.4). It is not an official WJEC paper.

Tutor only

Answer **all** questions.

1. The two-spot ladybird, *Adalia bipunctata*, has two common colour forms. The red form is red with two black spots. The melanic form is black with red spots. Colour form is controlled by one gene, and the allele for the melanic form is dominant. Students counted the two forms at two sites in Wales. **Table 1.1** shows their results.

Table 1.1

Site	Number of red ladybirds	Number of melanic ladybirds
cool, cloudy upland site	58	42
sunny lowland site	91	9

(a) State the type of variation shown by colour form in the two-spot ladybird. Give a reason for your answer. [2]

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(b) Calculate the percentage of ladybirds at the upland site that were melanic. [1]

Percentage = ... %

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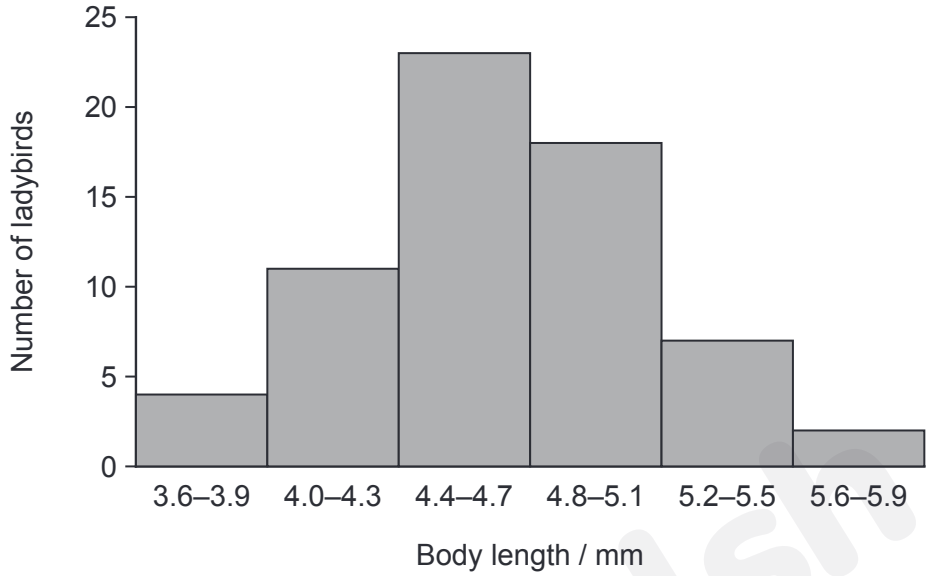
The students also measured the body length of 65 ladybirds. **Graph 1.2** shows their results.



Graph 1.2

(c) (i) State the modal class shown in **Graph 1.2**. [1]

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(ii) Explain why body length shows the pattern of variation seen in **Graph 1.2**. [3]

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(d) Melanic ladybirds absorb more heat from sunlight than red ladybirds, so they warm up and become active sooner in cool weather. Suggest why the melanic form is more common at the upland site. [2]

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Tutor only

(e) Name **two** processes during meiosis that produce genetic variation in the offspring of ladybirds. [2]

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2. A student investigated variation in the mass of seeds in two varieties of broad bean, *Vicia faba*. **Table 2.1** shows the mass of six seeds of variety X.

Table 2.1

Seed	1	2	3	4	5	6
Mass / g	1.8	2.1	2.4	2.0	2.6	2.3

(a) (i) Calculate the mean mass of the seeds. [1]

Mean = ... g

(ii) State the median mass of the seeds. [1]

Median = ... g

The standard deviation, s, is found using the formula:

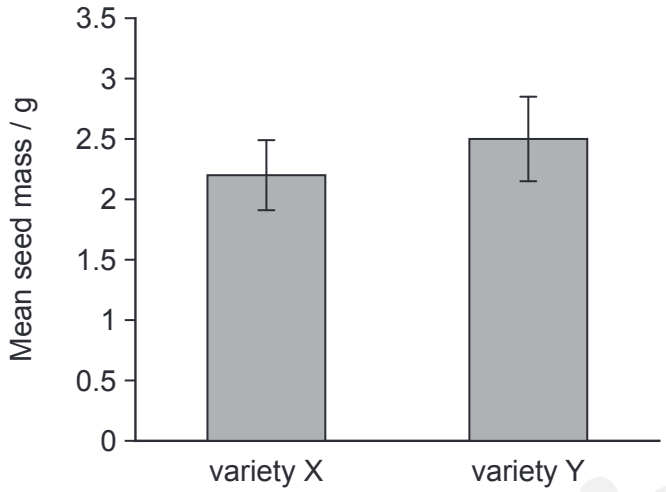
$$s = \sqrt{[\Sigma(x - \bar{x})^2 \div (n - 1)]}$$

(iii) Calculate the standard deviation of the seed masses. Give your answer to **2 decimal places**. [3]

s = ... g

Tutor only

The student then weighed six seeds of variety Y. **Graph 2.2** shows the mean mass of the seeds of each variety. The bars show one standard deviation above and below each mean.



Graph 2.2

(b) The student concluded that seeds of variety Y are heavier than seeds of variety X. Using **Graph 2.2**, explain why this conclusion may not be valid. [2]

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(c) Name the statistical test that should be used to find out whether the difference between the means is significant, and give a reason for your choice. [2]

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(d) Suggest **one** way the investigation should be changed before the test is used. [1]

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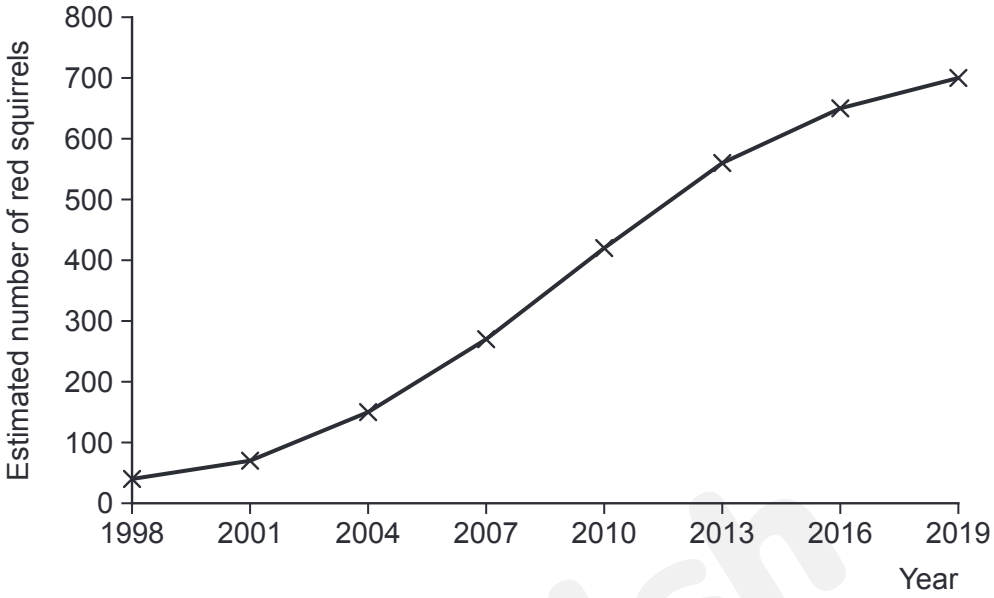
3. Red squirrels are native to Britain. Grey squirrels were introduced from North America in the nineteenth century. Grey squirrels eat acorns and other seeds more efficiently than red squirrels, and they carry a virus that kills red squirrels. On the island of Anglesey, grey squirrels were removed from 1998 onwards. **Graph 3.1** shows the estimated number of red squirrels on the island.



Graph 3.1

(a) State the type of competition that occurs between red and grey squirrels. [1]

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(b) Suggest **two** resources for which red and grey squirrels compete. [2]

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(c) Describe the change in the number of red squirrels shown in **Graph 3.1**. [2]

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Tutor only

(d) Explain how the removal of grey squirrels affected the survival and breeding success of red squirrels. [2]

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(e) Suggest why the rate of increase in the red squirrel population slowed after 2013. [2]

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4. Snowshoe hares, *Lepus americanus*, live in the forests of North America. In most areas they moult each autumn from a brown coat into a white coat, as shown in **Image 4.1**. In some regions, snow now lies on the ground for several weeks less each year than it did fifty years ago, so white hares are often seen on brown ground.

Image 4.1

(a) Name the selective agency acting on white hares when there is no snow. [1]

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Researchers fitted hares with radio collars and recorded how many survived. **Table 4.2** shows the results of the study.

Table 4.2

Colour of hare compared with the ground	Probability of surviving a 4-week period
coat matches the ground	0.93
coat does not match the ground	0.80

(b) Calculate the percentage decrease in the probability of survival for hares whose coats do not match the ground. [2]

Percentage decrease = ... %

(c) In a few areas with little snow, some hares stay brown all winter. This is caused by a different allele of one gene. Explain how the frequency of this allele could change in regions where the snow cover is becoming shorter. [4]

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Tutor only

(d) Suggest why the white-coat allele still gives an advantage to hares in the far north of their range. [1]

(e) Name **two** selective agencies, other than predation, that could affect the survival of snowshoe hares. [2]

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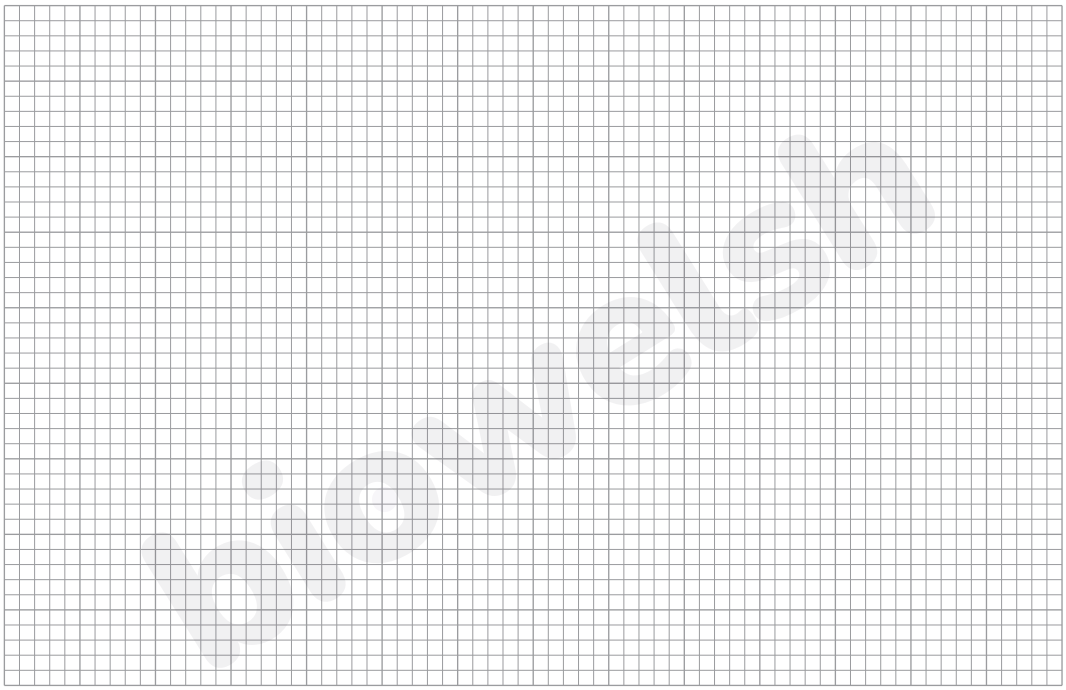
5. Warfarin is a poison used to kill brown rats, *Rattus norvegicus*. It stops the recycling of vitamin K, so the blood of the rat cannot clot. Some rats carry an allele of the gene for the enzyme that warfarin acts on, which makes them resistant to warfarin. **Table 5.1** shows the percentage of rats that were resistant in one farming area after warfarin was first used there.

Table 5.1

Time since warfarin was first used / years	0	2	4	6	8	10	12	14
Rats resistant to warfarin / %	2	3	8	22	46	67	78	82

(a) Plot a graph of the data in **Table 5.1** on the grid below. Join the points with straight lines. [4]



(b) Use your knowledge of natural selection to explain the change in the percentage of resistant rats. [4]

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(c) Resistant rats need much more vitamin K in their diet than other rats. When farmers changed to a different poison, the percentage of resistant rats fell. Explain why. [2]

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(d) Name the type of selection that occurred while warfarin was being used. [1]

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Tutor only

6. The medium ground finch, *Geospiza fortis*, lives on the Galápagos Islands and feeds mainly on seeds. **Image 6.1** shows the head of one of these finches. Birds with deeper beaks can crack larger, harder seeds.

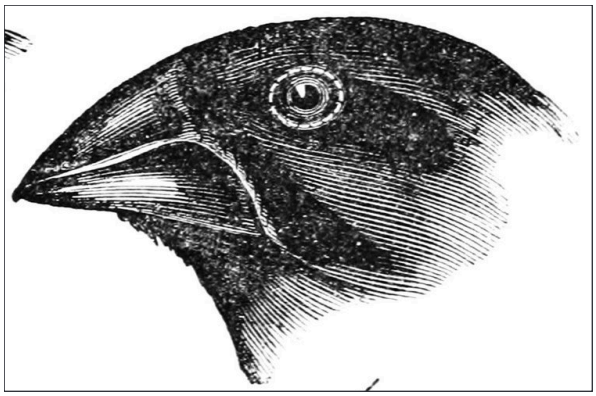

Image 6.1

During a severe drought on one small island, the plants produced few seeds. The small, soft seeds were eaten first, and most of the seeds left were large and hard. Most of the finches on the island died.

(a) State the type of competition that took place between the medium ground finches during the drought. [1]

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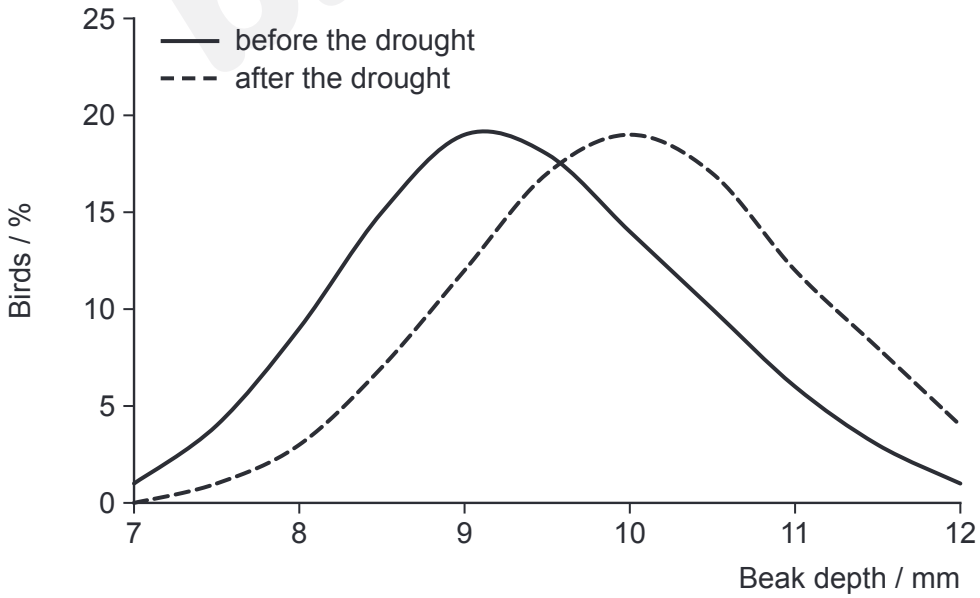
Graph 6.2 shows the beak depth of the finches on the island before the drought and of the birds that survived it.



Graph 6.2

Tutor only

(b) (i) Describe the change in the distribution of beak depth shown in **Graph 6.2**. [2]

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(ii) The mean beak depth increased from 9.4 mm to 10.0 mm. Calculate the percentage increase in the mean beak depth. [2]

Percentage increase = ... %

(c) Explain how the drought led to this change in beak depth. [3]

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(d) Name the type of selection shown. [1]

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(e) Different islands have different species of ground finch, each with a beak suited to the food on its island. Explain how this supports Darwin's theory of evolution. [2]

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Tutor only

7. Pingelap is a small, isolated atoll in the Pacific Ocean. In about 1775 a typhoon killed most of its people, leaving about 20 survivors. One of the survivors carried a recessive allele that causes achromatopsia, a condition in which people see no colours at all. The present population is descended mainly from these survivors. **Table 7.1** shows the frequency of achromatopsia.

Table 7.1

Population	Frequency of achromatopsia
Pingelap	about 1 in 10
worldwide	about 1 in 30 000

(a) Define the term **gene pool**. [1]

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(b) Name the effect on a gene pool when a population is suddenly reduced to a few individuals. [1]

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The Hardy-Weinberg equations are:

$$p + q = 1 \quad p^2 + 2pq + q^2 = 1$$

(c) Assuming the population of Pingelap is in Hardy-Weinberg equilibrium, calculate the frequency of carriers of the achromatopsia allele. Show your working. [3]

Frequency of carriers = ...

(d) Explain why achromatopsia is so much more common on Pingelap than worldwide. [3]

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Tutor only

(e) Suggest **two** reasons why the Hardy-Weinberg equation may not give an accurate estimate of the frequency of carriers on Pingelap. [2]

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Tutor only

8. The ability to taste a bitter chemical, phenylthiocarbamide (PTC), is controlled by one gene. The allele for tasting, **T**, is dominant to the allele for non-tasting, **t**. **Table 8.1** shows the results of a survey of 1000 students.

Table 8.1

Phenotype	Number of students
taster	804
non-taster	196

(a) Explain why the frequency of allele **t** is calculated from the number of non-tasters and not from the number of tasters. [1]

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(b) Calculate the frequency of allele **t**. [2]

Frequency of t = ...

(c) Calculate the number of heterozygous students expected in the survey. [2]

Number of heterozygous students = ...

In shorthorn cattle the alleles for red coat, C^R, and white coat, C^W, are codominant. C^RC^W cattle have a mixture of red and white hairs and are called roan. **Table 8.2** shows the coat colours in a herd of 1000 cattle.

(d) (i) Calculate the frequency of allele C^R in the herd. [2]

Frequency of C^R = ...

Tutor only

(ii) Complete **Table 8.2** to show the number of cattle of each colour expected if the herd were in Hardy-Weinberg equilibrium. [2]

Table 8.2

Coat colour	Genotype	Observed number	Expected number
red	C^RC^R	350	.....
roan	C^RC^W	500	.....
white	C^WC^W	150	.....

(iii) State whether the herd appears to be in Hardy-Weinberg equilibrium for coat colour. Explain your answer. [1]

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Tutor only

9. The Scottish wildcat, *Felis silvestris*, lives in a few remote areas of the Highlands. The wild population is small, and wildcats often mate with domestic cats, *Felis catus*, producing hybrids that can breed. Researchers caught 60 cats that looked like wildcats and found their genotypes for one gene with two alleles, **G1** and **G2**. **Table 9.1** shows the results.

Table 9.1

Genotype	G1G1	G1G2	G2G2
Number of cats	30	12	18

(a) State **three** conditions that must be met for the Hardy-Weinberg principle to apply to a population. [3]

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(b) Calculate the frequency of allele **G1** in the cats caught. [2]

Frequency of G1 = ...

(c) Calculate the number of heterozygous cats expected in the sample if the population were in Hardy-Weinberg equilibrium. [2]

Expected number = ...

(d) Using the information given, suggest **two** reasons why the number of heterozygous cats is much lower than expected. [2]

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Tutor only

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Tutor only

10. About 3 million years ago, the Isthmus of Panama formed a land bridge between North and South America, separating the Caribbean Sea from the Pacific Ocean. Several species of snapping shrimp, *Alpheus*, exist as pairs that look almost identical, one member of each pair on each side of the isthmus. Researchers placed a male and a female shrimp together and recorded whether they formed a mating pair or fought. **Table 10.1** shows the results.

Table 10.1

Origin of the male and female	Percentage that formed a mating pair
both from the same ocean	64
one from each ocean	8

(a) Name the type of isolation that first separated the two populations of shrimps. [1]

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(b) Explain how the two populations could have become separate species. [4]

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(c) Use **Table 10.1** to identify the type of reproductive isolation that now keeps the shrimps apart. Explain your answer. [2]

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(d) Explain why the results in **Table 10.1** alone do not show that the shrimps on the two sides are separate species. [2]

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Tutor only

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Tutor only

11. The apple maggot fly, *Rhagoletis pomonella*, lays its eggs in the fruit of hawthorn trees in North America. About 150 years ago, some flies began to lay eggs in apples instead. The flies mate on the fruit of the type of tree they hatched from. Apple and hawthorn trees grow together in the same areas. **Table 11.1** shows information about the two groups of flies.

Table 11.1

Group of flies	Fruit ripens	Adults most active
apple flies	August	early August
hawthorn flies	September to October	early September

(a) Using **Table 11.1**, suggest **two** reasons why apple flies and hawthorn flies rarely mate with each other. [2]

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(b) State whether this is an example of allopatric or sympatric speciation. Give a reason for your answer. [1]

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(c) Explain how this situation could lead to the formation of two species. [3]

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Tutor only

(d) Complete **Table 11.2** by naming the isolating mechanism in each example and stating whether it is pre-zygotic or post-zygotic. [4]

Table 11.2

Example	Isolating mechanism	Pre-zygotic or post-zygotic
two frog species with different mating calls	.....	.....
sea urchin sperm cannot bind to the eggs of another species	.....	.....
hybrid embryos of two toad species die before hatching	.....	.....
two orchids whose flowers only fit pollinating insects of different sizes	.....	.....

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Tutor only

12. Radish, *Raphanus sativus*, and cabbage, *Brassica oleracea*, both have 18 chromosomes in their body cells. **Image 12.1** shows what happened when a plant breeder crossed them.

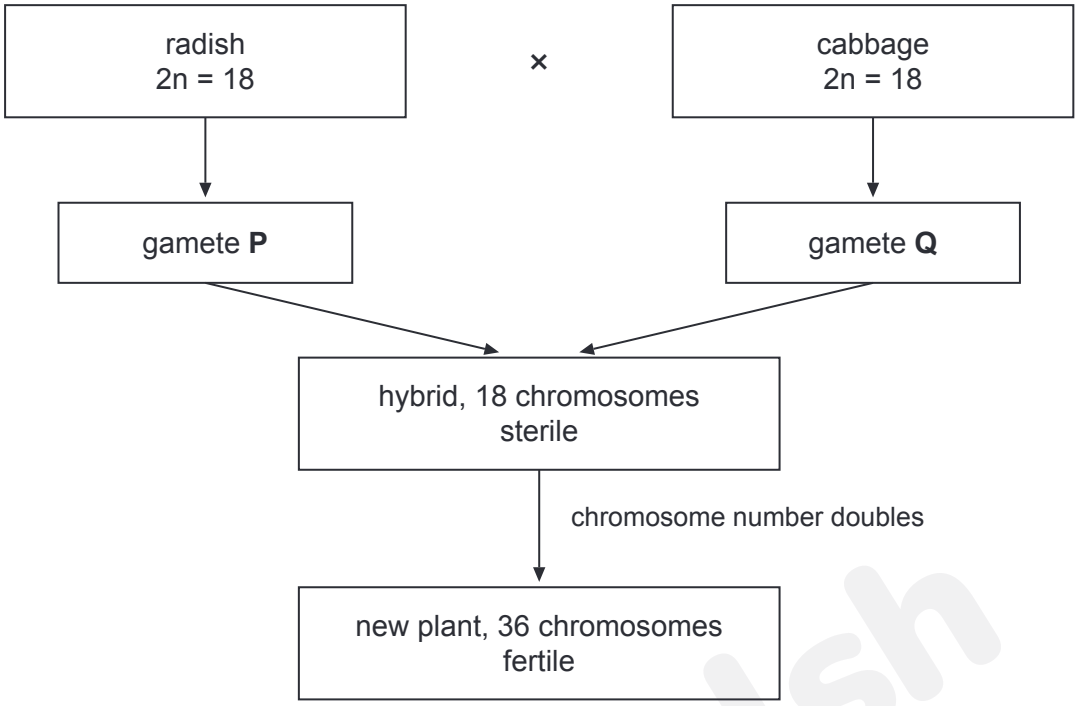

Image 12.1

(a) State the number of chromosomes in gametes **P** and **Q**. [1]

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(b) Explain why the hybrid is sterile. [3]

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(c) Explain how the plant with 36 chromosomes could have been formed, and why it is fertile. [3]

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Tutor only

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(d) When the new plant was crossed with radish, the offspring were sterile. Explain why the new plant is regarded as a new species. [2]

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Tutor only

13. Fossils show how whales evolved from land mammals. **Table 13.1** shows information about some of these fossils.

Table 13.1

Animal	Age / millions of years	Where it lived	Hind limbs
Pakicetus	50	on land and in shallow fresh water	long, used for walking
Ambulocetus	49	shallow coastal water	large, with big feet, used for swimming and walking
Rodhocetus	47	coastal sea	short, probably could not support the body on land
Dorudon	40	open sea	tiny, not attached to the backbone
modern whales	0	open sea	none visible; small bones inside the body

(a) Darwin's theory of evolution was based on observations of living organisms. State **two** of these observations. [2]

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(b) Explain how the evidence in **Table 13.1** supports the theory that existing species have arisen by modification of ancestral species. [3]

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(c) Use your knowledge of natural selection to explain the reduction in the size of the hind limbs. [3]

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Tutor only

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(d) Suggest **one** reason why there are gaps in the fossil record of whale evolution. [1]

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Tutor only

14. Ribwort plantain, *Plantago lanceolata*, is a plant with a rosette of long, narrow leaves. It grows both in grassland and on footpaths. A student investigated whether the length of plantain leaves on a footpath was different from the length in the undisturbed grassland beside it. **Image 14.1** shows how the length of each leaf was measured.

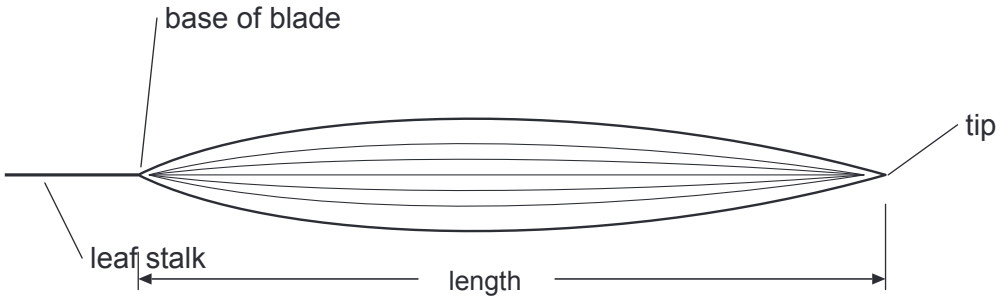

Image 14.1

(a) Describe how the student could choose 15 plants at random in each area. [2]

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(b) State **two** variables that should be controlled. [2]

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Table 14.2 shows the length of the leaves measured on the footpath.

Table 14.2

Leaf length, plants 1 to 5 / mm	Leaf length, plants 6 to 10 / mm	Leaf length, plants 11 to 15 / mm
48	60	66
52	61	67
55	62	69
57	63	71
58	64	74

Tutor only

(c) Complete **Table 14.3** by calculating the mean and s^2 for the footpath. [2]

Table 14.3

	Footpath	Grassland
number of leaves, n	15	15
mean length, $\bar{x}$ / mm	.....	95.0
$\Sigma(x - \bar{x})^2$	710.4	1302.0
$s^2 = \Sigma(x - \bar{x})^2 \div (n - 1)$	.....	93.0

The student used a t test with the formula:

$$t = (\bar{x}_1 - \bar{x}_2) \div \sqrt{(s_1^2/n_1 + s_2^2/n_2)}$$

(d) Calculate the value of t. Give your answer to **1 decimal place**. [2]

t = ...

(e) State the null hypothesis for this investigation. [1]

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Table 14.4 shows critical values of t.

Table 14.4

Degrees of freedom	26	28	30
p = 0.05	2.06	2.05	2.04
p = 0.01	2.78	2.76	2.75

(f) State the number of degrees of freedom and use **Table 14.4** to explain what the value of t shows. [3]

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Tutor only

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(g) Suggest whether the shorter leaves on the footpath are caused by genetic or environmental factors, and describe how the student could find out. [2]

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Tutor only

15. Salamanders of the species *Ensatina eschscholtzii* live in damp woodland on the mountains that surround the Central Valley of California. The valley floor is too hot and dry for them. **Image 15.1** is a simplified map of some of their populations (not to scale).

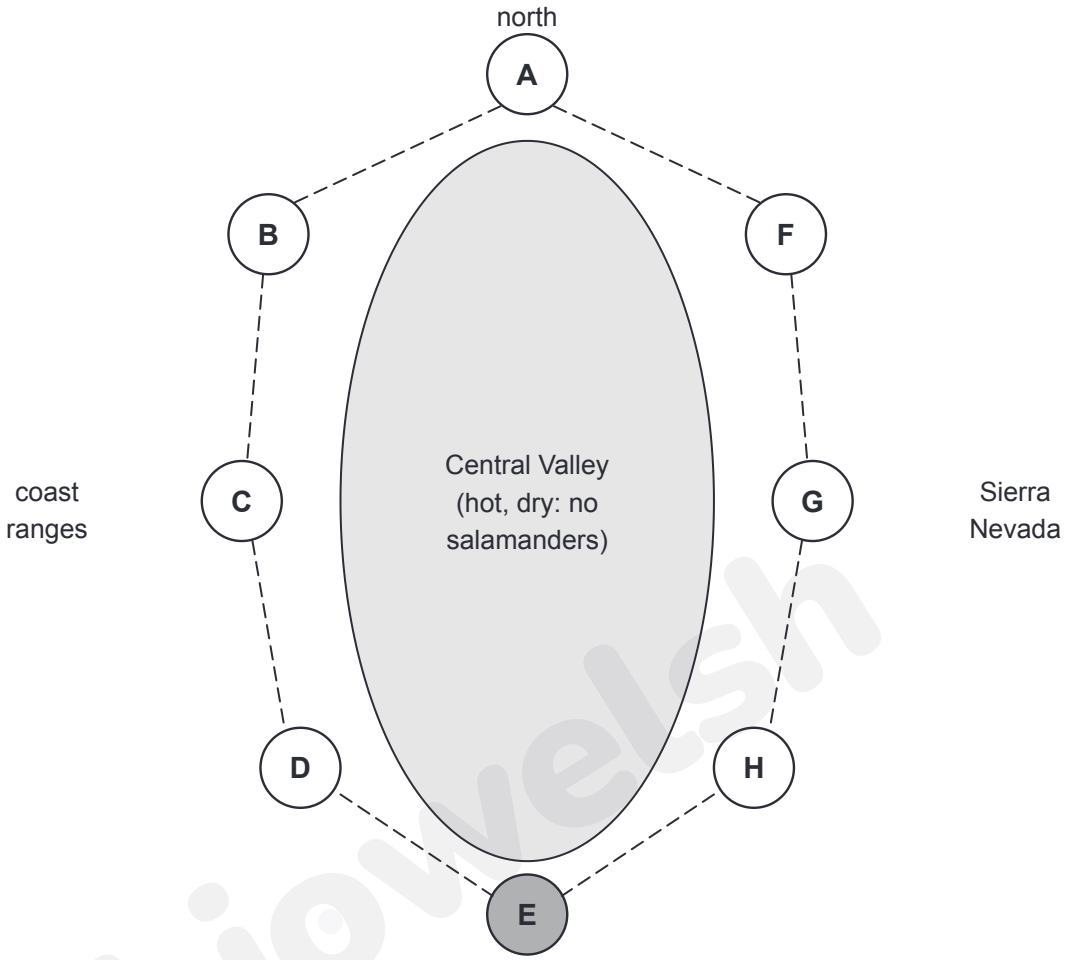

Image 15.1

The salamanders are thought to have spread south from the north (population **A**) along both sides of the valley. Neighbouring populations interbreed. Populations on the coastal side (**B** to **D**) are plain orange-brown, similar to a poisonous newt that predators avoid. Populations on the inland side (**F** to **H**) are blotched, which camouflages them on the forest floor. At **E**, coastal and inland salamanders live in the same area but rarely interbreed, and the few hybrids produced survive less well.

Explain how natural selection could have produced the different colour patterns on the two sides of the valley. Describe how isolation and changes to the gene pools could have led to the coastal and inland salamanders at **E** being unable to interbreed successfully. Discuss whether the salamanders at **E** should be classified as two separate species. [9 QER]

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END OF WORKSHEET

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A Tutor Meets Tutee project

BioWelsh worksheets are written and checked by Tutor Meets Tutee tutors for WJEC A level Biology students.

Mark this worksheet with the BioWelsh mark scheme **BW-A2-4.4-W1** (MS).

Acknowledgements

Image 4.1: Photos: U.S. Fish and Wildlife Service, public domain (Wikimedia Commons, 'Snowshoe Hare (50567233951)'), and NPS/Jim Peaco, public domain (Wikimedia Commons, 'Snowshoe hare in winter'). Cropped and placed side by side.

Image 6.1: Engraving: John Gould, public domain (Wikimedia Commons, 'Darwin's finches by Gould'). Cropped to one head.

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