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Mana Tohu Mātauranga o Aotearoa
New Zealand Qualifications Authority

Level 2 Biology 2025

91157 Demonstrate understanding of genetic variation and change

Credits: Four

Achievement	Achievement with Merit	Achievement with Excellence
Demonstrate understanding of genetic variation and change.	Demonstrate in-depth understanding of genetic variation and change.	Demonstrate comprehensive understanding of genetic variation and change.

Check that the National Student Number (NSN) on your admission slip is the same as the number at the top of this page.

You should attempt ALL the questions in this booklet.

If you need more room for any answer, use the extra space provided at the back of this booklet.

Check that this booklet has pages 2–16 in the correct order and that none of these pages is blank.

Do not write in the margins (▨). This area will be cut off when the booklet is marked.

YOU MUST HAND THIS BOOKLET TO THE SUPERVISOR AT THE END OF THE EXAMINATION.

Merit

TOTAL **17**

QUESTION ONE: Snake genetics

Corn snakes (*Pantherophis guttatus*) are considered helpful to humans and are found in different parts of the eastern United States. This species lives in a wide variety of habitats including wooded areas, rocky hillsides, barns, and abandoned buildings.

They have a complete dominance inheritance pattern for body colour and scale pattern. The orange body-colour allele (G) is dominant to the white body-colour allele (g).The allele for striped scale pattern (B) is dominant to the allele for blotched scale pattern (b). The genes for body colour and scale pattern are not genetically linked.

Corn snake. Anerythristic Hurricane Motley corn snake.

(a) Conservationists crossed a corn snake homozygous for the orange body-colour allele and the striped pattern allele, with a corn snake homozygous for white body colour and blotched scale pattern.

State the genotype of the gametes produced by each parent:

Parent 1: GGBB Parent 2: ggbb

State the genotype of the F1 generation:

GgBb - Heterozygous

(b) Use the Punnett square below to show the gametes of the F1 generation, and all of the possible genotypes of the F2 generation.

F1 gametes

F1 gametes	GB	Gb	gB	gb
GB	GGBB	GGBb	GgBB	GgBb
Gb	GGBb	GGbb	GgBb	Ggbb
gB	GgBB	GgBb	ggBB	ggBb
gb	GgBb	Ggbb	ggBb	ggbb

(c) Describe the predicted phenotype (F2) ratio produced by the cross.

9 orange striped : 3 orange blotched : 3 white striped : 1 white blotched

(d) The garter snake (*Thamnophis sirtalis*) is another species of snake and has often been bred in captivity. When snakes are crossed that are heterozygous for a striped pattern and rough scale texture, striped (E) is dominant over unstriped (e), and smooth texture (R) is dominant over rough texture (r).

With this cross, the observed ratio is frequently found to be:

7 striped smooth : 1 striped rough :
1 unstriped smooth : 7 unstriped rough

Common garter snake.

Discuss how genes located on the same chromosome can show both linked and unlinked characteristics, using the information provided for BOTH species of snake.

In your answer, include discussion of:

- how the processes of crossing over and segregation can influence the inheritance patterns of both linked and unlinked genes
- the effect of gene location on the observed phenotype ratios
- why the dihybrid heterozygous crosses for these identified traits are so different in these two species of snake.

Linked genes are genes that are located on the same chromosome with their loci close together. This means they are often inherited together. Meiosis is a type of cell division that results in 4 genetically unique, daughter haploid gametes. This process creates new combinations of alleles. Crossing over occurs during metaphase 1, this is where homologous chromosomes touch + exchange genetic material. This creates recombinat chromosomes (chromosomes containing both maternal + parternal alleles) Segregation is where the homologous chromosome pairs are spilt into gametes, so that each gamete contains half the genetic info. Both of these increase variation as they allow for new allele combinations to occur. During fertilization it is likely that the alleles from the other gamete will be different resulting in new allele combinations, increasing variation in the population. But if linked genes are involved variation will decrease. During crossing over it is likely that the linked genes (Eg. unstripped + rough skin) will be inherited together so won't be seperated during segregation. This means less allele combinations are available. so the pop will find it harder to survive during times of enviro change, because it is less likely that both of these alleles are suited to the new enviro*. Unlinked genes can be seen in example one, where the phenotypic ratio is 9:3:3:1, This shows a complete dominance cross, where the dominant allele (orange or striped) fully masks the recessive allele (white or blotched). While these genes are located on the same chromosome, their loci are further apart so aren't necessarily inherited together. Unlinked genes increase variation as they allow for more allele combinations to be possible. The snake pop 1 (corn snakes) are more likely to survive during enviro change as it is likely that one of these phenotypes will be suited, so will survive, reproduce + increase in allele frequency

* If one allele wasn't suited but the other wasn't (Eg. rough skin is beneficial but un stripped harmful) then individuals with beneficial alleles would die out, due

do tu prescence of harmful linked genes.

QUESTION TWO: The New Zealand giraffe weevil / pepeke nguturoa

The New Zealand giraffe weevil / pepeke nguturoa (*Lasiorhynchus barbicornis*) is an insect endemic to New Zealand. The most notable phenotypic variation in this species is observed in males, particularly in the length of their snout, known as a rostrum, and overall larger body size. These phenotypes are influenced by genetic and environmental factors and are subject to strong sexual selection (mate selection) where females are choosing the males based on their phenotypes.

New Zealand giraffe weevil.

The table below shows the common distribution of these phenotypes:

	North Island	**South Island**	**Smaller offshore islands** (limited food and habitat resources, smaller populations)
Long-rostrum males	Dense native forests (e.g. Waipoua Forest, Tongariro National Park).	Dense native forests (e.g. Fiordland National Park, Westland Tai Poutini National Park).	Phenotype distribution is far more random and shows less relationship to the dominant type of vegetation.
Short-rostrum males	More open or smaller patches of native forests.	Drier or more open habitats (e.g. Canterbury Plains).	

Discuss what factors may cause allele frequencies in a gene pool to change, using the information provided above.

In your answer, include discussion of:

- how the gene pool of the New Zealand giraffe weevil could be affected by their migration between habitats AND by genetic drift
- how sexual selection (mate selection) and natural selection may have influenced these two distinct phenotypes of long-rostrum and short-rostrum males.

Allele frequency is how common/uncommon an allele is in a gene pool. Allele frequency can be influenced by multiple factors. migration or geneflow is the movement of individuals in (immigration) + out (emigration) of populations (gene pools). Giraffe weevils moving into dense native forests from open habitats, that have long-rostrums will find it easier to survive as they will be able to forrage for food through deep underground easier due to their longer snouts. These individals will survive + reproduce, passing their long-rostums on to their offspring. while those with shorter-rostrums won't be able to find food as easily so will decrease in allele frequency over time. This is known as natural selection. where the enviro selects for the individuals with alleles best suited to the selection pressures of the habitat. Females are more likely to mate with males that can survive better, - eg. longer-rostum so their offspring will have similar, beneficial traits. The allele frequency in a gene pool can also change due to genetic drift. this is when chance events cause the allele frequency of a pop to decrease. In the smaller offshore islands, the founder effect is likely to have occured. this is where a small group of individuals randomly leaves the original pop + begins a new pop. Giraffe weevils that have moved to these smaller islands is only a small sample of the original pop. this new pop is smaller, containing less individuals + ~~[illegible]~~ less alleles so is not representative of the original pop. some alleles may be lost - only found in original pop. or alleles could be fixed. - where only one allele for a trait is left. All weevils on smaller island could have a long-rostrum. Even though this may not be the allele best suited to the enviro this is the only allele available. This means long-rostrums would increase in allele frequency despite not being beneficial. Genetic drift is random so the alleles that remain are not selected for (by the enviro or females). So harmful alleles may be present + beneficial alleles may be lost. This new smaller pop is more likely to suffer from enviro change or genetic drift. The bottleneck effect is where a random, catastrophic event kills a large number of the pop. This causes the gene pool to decrease + the allele frequency to change. This is more likely to effect smaller pop's as they have less individuals + therefore less alleles. The alleles + individuals that remain is random so aren't necessarily beneficial or suited to the enviro. Weevils on offshore islands are more likely to suffer from this as there are less individuals. Genetic variation in these pops could be increased through mutations or gene flow. In these new founder / bottleneck pops, natural selection will occur + females will mate with the males with the best alleles. Males that meet these requirements will increase in allele frequency over multiple generations

QUESTION THREE: Blood types

If a patient needs a blood transfusion during surgery, it is essential to match their blood type correctly. Receiving the wrong blood type can cause serious, potentially life-threatening reactions.

Blood type in humans is controlled by multiple alleles. The alleles I^A and I^B are dominant over i^O. I^A and I^B are examples of alleles that show co-dominance.

The pedigree chart below shows the blood types/phenotypes of two children and their parents.

Blood types

Phenotype	Genotype
A	I^AI^A, I^Ai^O
B	I^BI^B, I^Bi^O
AB	I^AI^B
O	i^Oi^O

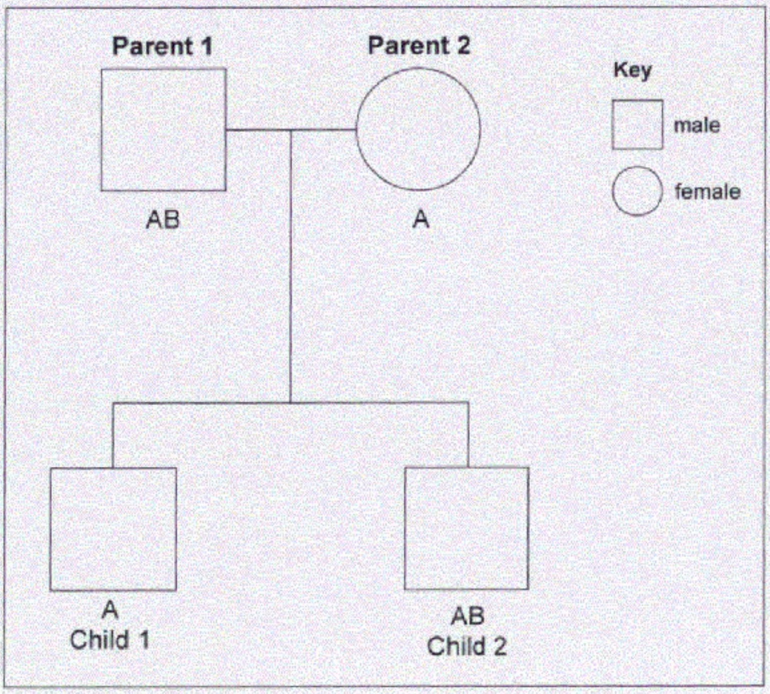
①

	A	B
A	AA	AB
A	AA	AB

②

	A	B
A	AA	AB
O	AO	BO

Pedigree chart



③

	O	O
A	AO	AO
A	AO	AO

④

	O	O
A	AO	AO
O	OO	OO

Discuss the inheritance of these blood types, using the information provided above. You may include a Punnett square to support your answer (optional).

In your answer, include discussion of:

- what is meant by the term multiple alleles
- the possible genotypes of Child 1
- the difference between dominant alleles and co-dominant alleles
- how to determine the genotype of Child 1 using the blood types of **his** children, if his partner is a blood type O female
- why the determination of Child 1's genotype may **not** be guaranteed as correct if determined using his children's blood types.

multiple alleles is where there are more than 2 alleles for a trait so more than 3 phenotypes available. these alleles can have varying degrees of dominance over each other. complete dominance is where one allele is fully dominant over the recessive, so in a heterozygous individual, the recessive allele is masked, so the dominant allele is expressed. I^A + I^B are dominant over i^o. This means the i^o allele is masked so that I^A or I^B is expressed. - Blood type A or B. Co-dominance is where neither allele is fully dominant over the other so in a heterozygous, both alleles are equally expressed. this is seen in blood type AB where both the I^A + I^B alleles are expressed together. Child 1 has blood type A so could either have the genotype $I^A I^A$ or $I^A I^o$ (as seen in punnet squares 1 + 2). This is because his mother could have either the genotype $I^A I^A$ or $I^A I^o$. For both child 1 + his mother the dominant I^A allele would fully mask the recessive I^o allele. Child 1's genotype could be determined from his children's blood types. If one of his children had blood type O, then they must have inherited 2 recessive I^o alleles in order to be expressed. This would mean that child 1's genotype is $I^A I^o$, where he is a carrier of the recessive I^o allele. Although this allele isn't expressed in his blood type, it could be expressed in his child that inherits the recessive I^o allele along with an I^o allele from the mother. But if all of child 1's children had blood type A we could assume that he has the genotype $I^A I^A$

so that all the recessive I^O alleles from the mother are masked by his dominant I^A allele. This would result in a phenotypic ratio of all offspring with blood type A. (as seen in punnet square 3) But this is not guaranteed as all of child 1's offspring could have blood type A even though he has the genotype $I^A I^O$. This results in a 50:50 ratio (as seen in punnet square 4) A punnet square only shows the possible outcomes of a cross. All of his children could have the same blood type, despite the possibility of them having either blood type A or O. So we can't confirm that child 1's genotype is $I^A I^A$ but we could confirm his genotype is $I^A I^O$

Merit

Subject: Biology

Standard: 91157

Total score: 17

Q	Grade score	Marker commentary
One	A4	The response identified the genotype of the F1 generation and completed the Punnett square for the F2 generation with correct ratios for the phenotype. The response defined the process of crossing over, segregation, and linked and unlinked genes. Further explanation of the idea of unique gametes created due to segregation or the effect of crossing over and segregation on linked and unlinked genes would have allowed this response to reach Merit level.
Two	M6	The response explained the process of natural selection and genetic drift and its effect on a small population. Thorough discussion of the process of natural selection linked to the selection pressure driving the phenotypes observed in the different environments would have allowed this response to reach Excellence level. Further explanation of the idea of migration and linking the effects to the random phenotype distribution observed within the small population would have allowed this response to reach Excellence level.
Three	E7	The response explained: • the gametes passed on by both child 1 and their partner to the offspring, linked to the pedigree chart and correct ratios to discuss the idea of non-guarantee of child 1’s genotype using the information provided in the question. • the patterns of complete and co-dominant inheritance. The explanation could be improved by including a discussion of these patterns using the genotype of the parents of child 1.