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MENDEL'S 2ND LAW AND GENETIC PROBLEMS

Learner Note: *Mendel's Second Law can be difficult to grasp. Ensure that you are comfortable with monohybrid crosses before you begin to do dihybrid crosses. A dihybrid cross works with TWO characteristic at a time (di = two). The process is the same as for a monohybrid crosses, it is just that the two characteristics are passed to the offspring in* ***different possible combinations****. If one characteristic has 4 possible outcomes, then two characteristics will be 4 x 4 = 16 possible outcomes/combinations. Learn each of the steps carefully as they are in the Section C Additional Content notes. Once you are comfortable with this, then try the homework questions. You MUST know Mendel's pea plant crosses. Follow each step and look at* ***WHY*** *each step is done. If you get stuck, refer to the Additional Content notes.*

SECTION A: TYPICAL EXAM QUESTIONS

Question 1: - 25 minutes *(Taken and adapted from Bios Grade 11 – 2002)*

In guinea-pigs, black fur (B) is dominant over albino (b) and course hair (R) is dominant over smooth hair (r).

1.1. Supply the genotypes and phenotypes of a cross between homozygous black animal with course hair and an albino animal with smooth hair in the F1 generation. (10)

1.2. Supply the genotypes and phenotypes of the F2 generation if two of the offspring from the F1 generation are crossed. (15)

1.3. Explain Mendel's Law of Independent Assortment (4)

Question 2: - *13 minutes*

A woman with brown eyes and dark hair marries a man with blue eyes and blonde hair. All the children have dark hair, but half have blue eyes and the other half have brown eyes. Provide the genotypes of the parents and the children. Let (E) represent dominant brown eye colour and (e) recessive blue eye colour. Let (B) represent dominant brown hair colour and (b) recessive blonde hair colour. (Show all your workings in punnet squares). (13)

SECTION B: SOLUTIONS AND HINTS

1.1. **Dihybrid cross of homozygous parents:**

B = black fur (dominant) b = albino (recessive)

R = course hair (dominant) r = smooth hair (recessive)

Note: Each √ = ½ mark

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The parent are as follows:
'Parent 1': BBRR – homozygous black AND homozygous course hair and
'Parent 2': bbrr – homozygous albino AND homozygous smooth hair

Step 1: ***(find the separate gene combinations)***

BBRR x bbrr √√

'Parent 1': BB x RR - Meiosis √

Gametes √	**B**	**B**	√
R	BR	BR	
R	BR	BR	
√			

'Parent 2': bb x rr - Meiosis √

Gametes √	**b**	**b**	√
r	br	br	
r	br	br	
√			

Step 2: ***(Cross all 16 gene combinations. Remember to choose one letter that you will always write first and write capital letter for the same characteristic in front of the lower case letter)***

P_1 √

Gametes √	**BR**	**BR**	**BR**	**BR**	√
Br	BbRr	BbRr	BbRr	BbRr	
Br	BbRr	BbRr	BbRr	BbRr	
Br	BbRr	BbRr	BbRr	BbRr	
Br	BbRr	BbRr	BbRr	BbRr	
√					

Fertilization √

F_1 √ **Genotype:** 16:16 √ Heterozygous BbRr √ **Phenotype:** 100% √ black with course hair √ **(10)**

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1.2. F_2 generation: **BbRr x BbRr** √ √

Bb x Rr - Meiosis √ **Bb x Rr - Meiosis** √

Gametes √	**B**	**b**		√	**Gametes** √	**B**	**b**	√
R	BR	bR			**R**	BR	bR	
r	Br	br			**r**	Br	br	
√					√			

P_2 √

Gametes√	**BR**	**Br**	**bR**	**br**	√ √
BR	BBRR	BBRr	BbRR	BbRr	
Br	BBRr	BBrr	BbRr	Bbrr	
bR	BbRR	BbRr	bbRR	bbRr	
br	BbRr	Bbrr	bbRr	bbrr	
√ √					

Fertilization √

F_2 √

Genotype: 1:16 BBRR √; 2:16 BBRr √; 1:16 BBrr √; 2:16 BbRR √; 4:16 BbRr √; 2:16 Bbrr √; 1:16 bbRR √; 2:16 bbRr √ and 1:16 bbrr √

Phenotype: 9 black with course hair √; 3 black with smooth hair √; 3 albino with course hair √; 1 albino with smooth hair √ (15)

1.3. Mendel's Law of independent assortment states that different √ pairs of genes **segregate independently** √ of the members of other pairs √, when two or more characteristics √ (traits) are involved in a dihybrid cross. ***(You must know this definition well)*** (4)

2. B = brown hair colour (dominant) b = blonde hair colour (recessive)
E = brown eye colour (dominant) e = blue eye colour (recessive)

Note: Each √ = ½ mark

Female parent: BBEe – homozygous brown hair AND heterozygous

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brown eyes **Male parent: bbee** – homozygous blonde hair AND homozygous blue eyes

Step 1: ***(find the separate gene combinations)***

BBEe x bbee √√

Mother: BB x Ee - Meiosis √

Gametes √	**B**	**B**	√
E	BE	BE	
e	Be	Be	
√			

Father: bb x ee - Meiosis √

Gametes √	**b**	**b**	√
e	be	be	
e	be	be	
√			

Step 2: ***(Cross all 16 gene combinations. Remember to choose one letter that you will always write first and write capital letter for the same characteristic in frnt of the lower case letter)***

P_1 √

Gametes √	**BE**	**BE**	**Be**	**Be**	√ √
Be	BbEe	BbEe	Bbee	Bbee	
Be	BbEe	BbEe	Bbee	Bbee	
Be	BbEe	BbEe	Bbee	Bbee	
Be	BbEe	BbEe	Bbee	Bbee	
√ √					

Fertilization √

F_1 √ **Genotype:** 8:16 √ BbEe √ ; 8:16 √ Bbee √

Phenotype: 50% √ brown hair and brown eyes √
50% √ brown hair and blue eyes √ (13)

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SECTION C: ADDITIONAL CONTENT NOTES

Mendel's Law of Independent Assortment

You have learned that each trait is controlled by **allele genes**, located on a separate pair of chromosomes. Mendel stated that different pairs of genes **segregate independently** of the members of other pairs, when two or more characteristics (traits) are involved in a dihybrid cross. This means that each characteristic separates on its own during meiosis.

For example: hair colour and eye colour are two characteristics. The following are possible expamples of the combinations if B = brown hair, b = blonde hair, N = brown eye colour and n = blue eye colour:

BB, NN – Homozygous brown hair, Homozygous brown eyes
BB, Nn – Homozygous brown hair, Heterozygous brown eyes
BB, nn – Homozygous brown hair, Homozygous blue eyes
Bb, NN – Heterozygous brown hair, Homozygous brown eyes
Bb, Nn – Heterozygous brown hair, Heterozygous brown eyes
Bb, nn – Heterozygous brown hair, Homozygous blue eyes
bb, NN – Homozygous blonde hair, Homozygous brown eyes
bb, Nn – Homozygous blonde hair, Heterozygous brown eyes
bb, nn – Homozygous blonde hair, Homozygous blue eyes

This means that each characteristic can combine with any number of other combinations. Remember that ONE characteristic presents FOUR possible combinations when fertilization takes place between TWO parents.
Male parent = 2 allele genes and Female = 2 allele genes. During meiosis, **each gene** from the allele pair will **separate independantly** in the male and the same will take place in the female. Mother (2) x Father (2) = 4

In a **dihybrid cross** (di = two) - **two parents** will each have **two characteristic** that are passed to their offspring. Each parent will therefore present **4 sets** of possibilities in the genotype. Mother (4) x Father (4) = 16 possible combinations of the genotype.

Mendel used peas to explain a dihybrid cross where two traits/characteristics were crossed. A genetic trait for a round seed versus a wrinkled seed will be **independent** of the combinations for a yellow versus green colour of the seeds. This means that seeds can be round and yellow, round and green, wrinkled and yellow or wrinkled and green – so, there will be 16 combinations.

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Dihybrid cross of homozygous parents:

R = round seeds (dominant) r = wrinkled seeds (recessive)
Y = yellow seeds (dominant) y = green seeds (recessive)

The parent are as follows:
'Parent 1': RRYY – homozygous round AND homozygous yellow and
'Parent 2': rryy – homozygous wrinkled AND homozygous green
Step 1: RRYY x rryy - we need to find the combination of gametes for each of the parents

'Parent 1': RR x YY - Meiosis

Gametes	R	R
Y	RY	RY
Y	RY	RY

'Parent 2': rr x yy - Meiosis

Gametes	r	r
y	ry	ry
y	ry	ry

Step 2: The Dihybrid cross
Now take the 4 combinations for 'parent 1' and the 4 combinations for 'parent 2'

P_1

Gametes	RY	RY	RY	RY
ry	RrYy	RrYy	RrYy	RrYy
ry	RrYy	RrYy	RrYy	RrYy
ry	RrYy	RrYy	RrYy	RrYy
ry	RrYy	RrYy	RrYy	RrYy

Fertilization

F_1
Genotype: 16:16 Heterozygous RrYy

Phenotype: 100% round and yellow

Hint: Choose one letter as the letter to be written **first** in each case. Here we chose R. Always write the **capital letters** before the small letters so write RR or Rr or rr first and then the Y, either YY or Yy or yy.

Now if we cross these F_1 seeds (offspring of the P_1) we must follow **Step 1** again:
So, to find the **P_2** we need to find the combinations of :
'Parent 1': RrYy and
'Parent 2': RrYy (both parents are heterozygous round and heterozygous yellow)
RrYy x RrYy (to find the combination of gametes for each parent)

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Rr x Yy - Meiosis

Gametes	R	r
Y	RY	rY
y	Ry	ry

Rr x Yy - Meiosis

Gametes	R	r
Y	RY	rY
y	Ry	ry

P_2

Gametes	RY	Ry	rY	ry
RY	RRYY	RRYy	RrYY	RrYy
Ry	RRYy	RRyy	RrYy	Rryy
rY	RrYY	RrYy	rrYY	rrYy
ry	RrYy	Rryy	rrYy	rryy

Fertilization

F_2

Genotype: 1:16 RRYY, 2:16 RRYy, 1:16 RRyy, 2:16RrYY, 4:16 RrYy, 2:16 Rryy, 1:16 rrYY, 2:16 rrYy and 1:16 rryy

Phenotype: 9 round and yellow, 3 round and green, 3 wrinkled and yellow, 1 wrinkled and green. (There will always be a total of 16 combinations in a dihybrid cross)

SECTION D: HOMEWORK

(Refer to the Additional Content notes from session 12 and this if you get stuck. If you still can't answer the homework questions, then refer it to your class teacher)

Question 1 – *30 minutes*

(Taken and adpated from Bios Grade 11 – 2002)

In a particular pigeon type, it was found that red eye colour (R) is dominant over black eye colour (r), while grey tail feathers (G) is dominant over white tail feathers (g).

Use punnit squares to show the genotype and phenotype of the offspring that would result from the following crosses:

1.1. GgRr x GgRr (15)
1.2. GgRr x GgRR (14)

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SECTION E: SOLUTIONS TO SESSION 15 HOMEWORK

1.1. Black = B White = b

P^1 √ Bb x Bb - Meiosis √

Gametes	**B**	**b**	√
B	BB	Bb	√
b	Bb	bb	√
√			

Fertilization √

F^1 √

Genotype: 1:4 Homozygous black – BB √ , 2:4 Heterozygous black – Bb √ , 1:4 Homozygous white – bb √

Phenotype: 75% black {1 homozygous black √ + 2 heterozygous black} √
25% white {1 homozygous white} √ **(Each tick = ½ mark)** (7)

1.2. Black = B White = b

P^1 √ Bb x bb - Meiosis √

Gametes	**B**	**b**	√
b	Bb	bb	√
b	Bb	bb	√
√			

Fertilization √

F^1 √

Genotype: 2:4 Heterozygous black – Bb √ , 2:4 Homozygous white – bb √

Phenotype: 75% black {1 homozygous black + 2 heterozygous black} √
25% white {1 homozygous white} √ **(Each tick = ½ mark)** (6)

2.1. Mare is bb √ x stallion Bb √ (if the stallion was BB the they would not be able to produce a white foal). (1)

2.2.

Gametes	**b**	**b**
B	Bb	Bb
b	bb	bb

***(Teacher note:** Learners will have to do their own punnit square / cross to answer 2.2. – no marks are allocated but 2 marks are allocated for each of the answers to the question)*

First foal = bb √ √
Second foal = Bb √ √ (4)

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