DW1: Basic Mendelian genetics and allele interactions

Exercise 1

In a sheep population, coat color is controlled by an autosomal locus with two alleles:

- B = black (dominant)
- b = brown (recessive)

A black ewe that breeds true for black color is mated to a brown ram.

Questions:

1. Assign genotypes to both parents.
2. Determine the genotype and phenotype of all F1 lambs.
3. Which Mendelian law is illustrated by this F1 generation?
4. When two F1 animals are mated together, what are the expected genotypic and phenotypic ratios in F2?
5. Which Mendelian law is illustrated in F2?

***Solution*:**

1. Genotypes of the parents

A black ewe that breeds true for black color must be homozygous dominant:
Black ewe = BB
A brown ram must be homozygous recessive:
Brown ram = bb

2. Genotype and phenotype of all F1 lambs

Cross: BB x bb
Gametes:

- the ewe produces only B gametes
- the ram produces only b gametes

Therefore, all F1 lambs are:
F1 genotype = 100% Bb
F1 phenotype = 100% black

3. Mendelian law illustrated by the F1 generation

The F1 generation illustrates the law of uniformity of the first filial generation.

4. Expected genotypic and phenotypic ratios in F2

Cross: Bb x Bb
Punnett combinations:

- BB
- Bb
- Bb
- bb

Expected genotypic ratio in F2: 1 BB : 2 Bb : 1 bb
Expected phenotypic ratio in F2: 3 black : 1 brown

5. Mendelian law illustrated in F2

The F2 generation illustrates the law of segregation, because the two alleles separate during gamete formation and recombine at fertilization.

Exercise 2

In a cattle herd, two traits are considered:

- Trait 1: coat color
  - A = solid black
  - a = red
- Trait 2: presence of a white head
  - H = white head
  - h = colored head

A bull that is heterozygous for both genes (black with white head) is mated to a cow that is also heterozygous for both genes (black with white head).

***Questions*:**

1. Write the genotypes of the parents.
2. Using a Punnett square or reasoning, list all possible genotypes in the offspring.
3. Give the phenotypic ratio for the four combinations (black-white head, black-colored head, red-white head, red-colored head), assuming the two loci segregate independently.
4. Which Mendelian principle is illustrated by the independence of these two traits?

***Solution*:**

1. Genotypes of the parents

Both parents are heterozygous for both genes:
Bull = AaHh
Cow = AaHh

2. Possible genotypes in the offspring

Each parent produces four types of gametes: AH, Ah, aH, ah
Cross: AaHh x AaHh
Possible genotypes in the offspring and their expected proportions are:

- AAHH = 1/16
- AAHh = 2/16
- AAhh = 1/16
- AaHH = 2/16
- AaHh = 4/16
- Aahh = 2/16
- aaHH = 1/16
- aaHh = 2/16
- aahh = 1/16

3. Phenotypic ratio

Phenotypes:

- A_ H_ = black with white head
- A_ hh = black with colored head
- aa H_ = red with white head
- aa hh = red with colored head

Expected phenotypic ratio:

9 black-white head : 3 black-colored head : 3 red-white head : 1 red-colored head

4. Mendelian principle illustrated

This exercise illustrates the law of independent assortment, because the two loci are assumed to segregate independently.

Exercise 3

In goats, the polled condition is controlled by the dominant allele H, while the horned condition is controlled by the recessive allele h.
A breeder has two polled bucks of unknown genotype. He wants to determine whether each buck is pure-breeding polled or heterozygous, so he performs a test cross with horned does (hh). The following results are obtained:

- Buck 1: 18 offspring, all polled
- Buck 2: 20 offspring, including 11 polled and 9 horned

Question:
Interpret these results and determine the most likely genotype of each buck.
Solution:
Since polled is dominant, a polled buck may have one of two possible genotypes:

- HH = homozygous dominant, pure-breeding polled
- Hh = heterozygous polled

The horned does have the genotype: hh

Case 1: If the buck is HH
Cross: HH x hh
Gametes:

- the buck produces only H gametes
- the doe produces only h gametes

Offspring: 100% Hh
Phenotype: 100% polled

Case 2: If the buck is Hh
Cross: Hh x hh
Gametes:

- the buck produces H and h gametes
- the doe produces only h gametes

Offspring:

- 1/2 Hh = polled
- 1/2 hh = horned

Phenotypic ratio: 1 polled : 1 horned

Conclusion:

- Buck 1 is HH
- Buck 2 is Hh

This test cross helps determine whether an individual showing the dominant phenotype is homozygous dominant or heterozygous.

Exercise 4

In a cattle breed:

- Gene 1 controls hair type:
  - T = straight hair (dominant)
  - t = curly hair
- Gene 2 controls coat color:
  - C = red
  - c = white
  - heterozygotes Cc are roan (red mixed with white hairs), showing no dominance

A red curly-haired cow is mated to a white bull with straight hair that is homozygous for both traits.

Later, this F1 calf is mated with a roan cow with curly hair (heterozygous for color, homozygous tt). The sheet explicitly states that heterozygotes Cc are roan, which is a no-dominance or incomplete-dominance situation where the heterozygote is phenotypically distinct.

Questions:

1. Give the genotypes of the parents.
2. Determine the genotype and phenotype of the single F1 calf.
3. Later, this F1 calf is mated with a roan cow with curly hair (heterozygous for color, homozygous tt).
   - List the possible phenotypes in the offspring for both traits.
   - Indicate the proportion of each phenotype.

Solution:

1. Genotypes of the parents

Red curly-haired cow:

- red means CC
- curly hair means tt

So: Cow = CCtt

White bull with straight hair, homozygous for both traits:

- white means cc
- straight hair, homozygous dominant means TT

So:

Bull = ccTT

2. Genotype and phenotype of the F1 calf

Cross: CCtt x ccTT

Gametes:

- the cow produces only Ct
- the bull produces only cT

Therefore all F1 offspring are: F1 genotype = CcTt

Phenotype:

- Cc = roan
- Tt = straight hair

So: F1 phenotype = roan with straight hair

3. Cross between the F1 calf and a roan curly-haired cow

Second parent:

- roan means Cc
- curly hair means tt

So: Second parent = Cctt
Cross: CcTt x Cctt

Color cross: Cc x Cc
Expected color proportions:

- 1/4 CC = red
- 1/2 Cc = roan
- 1/4 cc = white

Hair-type cross: Tt x tt
Expected hair-type proportions:

- 1/2 Tt = straight hair
- 1/2 tt = curly hair

Combine the two traits:

- red, straight hair = 1/4 x 1/2 = 1/8
- red, curly hair = 1/4 x 1/2 = 1/8
- roan, straight hair = 1/2 x 1/2 = 1/4
- roan, curly hair = 1/2 x 1/2 = 1/4
- white, straight hair = 1/4 x 1/2 = 1/8
- white, curly hair = 1/4 x 1/2 = 1/8

Second cross: CcTt x Cctt
Offspring phenotypes and proportions:

- red, straight hair = 1/8
- red, curly hair = 1/8
- roan, straight hair = 1/4
- roan, curly hair = 1/4
- white, straight hair = 1/8
- white, curly hair = 1/8