Mendel’s Principles

Activity A: The Chromosomal Basis of Segregation

Diploid cells contain two sets of homologous chromosomes. One set, or one member of each pair, comes from each parent. Each pair of homologous chromosomes carries genes that govern the same traits. For example, in pea plants, flower color is determined by a single gene $F$, which can have two different forms, $F$ or $f$, called alleles. Every cell in the diploid plant has two copies of the gene, one on each member of a homologous pair of chromosomes. These two versions of the same gene may be alike (homozygous) or different (heterozygous). The genetic makeup of the cell is known as its genotype. In this example, a cell with two $F$ alleles would have the genotype $FF$. A cell with two $f$ alleles would have the genotype $ff$. If the cell has one $F$ and one $f$, its genotype is $Ff$. The genotypes $FF$ and $ff$ are homozygous, and the genotype $Ff$ is heterozygous. All of the cells of the plant should have the same genetic composition.

In pea plants, the $F$ allele is dominant over $f$. When one $F$ is present it masks the $f$ allele. The $f$ allele is called recessive. A capital letter is used to denote the dominant allele. A pea plant having either the $FF$ or $Ff$ genotype has the phenotype, or outward appearance, of purple flowers. The phenotype that results from the $ff$ genotype is white flowers.

Genetic traits are passed from one generation to the next by reproduction. When animal cells undergo meiosis they produce gametes, which are haploid. When plant cells undergo meiosis they produce spores, which then become the plants that produce gametes. This difference between plant and animal reproduction is explained in detail in Lab Topic 11 (Plant Diversity).

In the next example we will follow a gene $R$ that codes for the tongue-rolling ability in humans. The allele $R$, which gives a person this ability, is dominant over $r$.

Fig 9.1: Tongue-roller phenotype. This person can roll her tongue into a “U” shape

1. What is the phenotype of an individual whose genotype is $RR$?

2. What is the phenotype of an individual whose genotype is $Rr$?

3. What is the phenotype of an individual whose genotype is $rr$?

4. What are your phenotype and genotype?

The distribution of alleles during the formation of gametes was one of the principles described by Gregor Mendel. It is called the principle of segregation: The two alleles of a gene segregate, or separate, from each other so that each one ends up in a different gamete. Mendel, however, did not know about the existence of chromosomes or meiosis. Not until decades after his death was the chromosomal basis of Mendel’s law discovered.

5. If a person’s genotype is $RR$, what are the genotypes of the resulting gametes?

6. If the person’s genotype is $rr$, what are the genotypes of the resulting gametes?

7. If the person’s genotype is $Rr$, what are the genotypes of the resulting gametes?

Activity B: Predicting the Outcome of a Monohybrid Cross

When the genotypes of the parents are known, we may determine what gametes the parents can make and in what proportion the gametes will occur. This information allows us to predict the genotypes and phenotypes of the offspring. The prediction is simply a matter of listing all of the possible combinations of gametes. In this section you will be doing monohybrid crosses: Only one trait is followed.

By convention, the parental generation is called $P$. The first generation of offspring is called $F_1$. $F$ stands for filial, which refers to a son or daughter, so $F_1$ is the first filial generation. If members of the $F_1$ generation are crossed, their offspring are called the $F_2$ generation, and so on. Predict the results of the following cross (using $R$ to denote tongue rolling ability):

$P$ generation: $RR \times RR$

1. What genotype(s) will be found in the $F_1$ generation?

2. What phenotype(s) will be found in the $F_1$ generation?

3. Explain why you made these predictions.
Predict the results of the following cross:

**P generation:** RR X rr

4. What genotype(s) will be found in the F₁ generation?

5. What phenotype(s) will be found in the F₁ generation?

6. Explain why you made these predictions.

In the examples given so far, each parent has only been able to produce one type of gamete, so the outcomes of the crosses are fairly simple. The Punnett square was devised to keep track of all possible combinations of genotypes when more than one type of gamete can be produced. Fill out the Punnett square in Figure 9.2 for the F₂ generation by crossing offspring of the previous cross (Rr X Rr).

![Punnett Square](image)

**Figure 9.2** Punnet square for monohybrid cross

7. What are the possible genotypes in the F₂ generation?

8. What is the phenotype of each genotype in the F₂ generation?

9. What is the phenotypic ratio for this cross?

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Activity C:
The Chromosomal Basis of Independent Assortment

Genes that are located on the same chromosome are linked with each other. If genes are located on separate, nonhomologous chromosomes they are not linked, or unlinked. Unlinked genes separate independently during meiosis. For example, consider the allelic pair R and r and a second allelic pair A and a. If the R gene and the A gene are not linked, their alleles can be found in any combination in the gametes. That is, the R allele can be in the same gamete as either A or a. This is Mendel's principle of independent assortment. The word assortment in this case refers to the distribution, or sorting, of alleles into gametes.

In Figure 9.3 draw a cell that represents the following conditions: diploid; two homologous pairs of chromosomes; two unlinked genes called R and A; cell is heterozygous for both genes.

![Simplified picture of a diploid cell carrying two unlinked genes](image)

**Figure 9.3** Simplified picture of a diploid cell carrying two unlinked genes

1. What is the genotype of this cell?

R is the gene for tongue-rolling, as used in the previous examples. A determines arch characteristics. A person who has the dominant allele has normal arches. An individual who is homozygous recessive has flat feet.

2. What is the phenotype of the individual represented by the cell in Figure 9.3?

3. Recall that when this cell undergoes meiosis, each gamete receives one member of each homologous pair. List the possible combinations of alleles that will be found in the gametes.

4. In what proportion would you expect these gametes to occur?