9.3 Extensions of the Laws of Inheritance

Learning objectives

By the end of this section, you will be able to:

- *Identify non-Mendelian inheritance patterns such as incomplete dominance, codominance, pleiotropy, polygenic inheritance, and environmental factors*
- *Follow traits passed down through incomplete dominance and codominance using a monohybrid cross and be able to predict the genotypes and phenotype of the offspring*
- *Be able to define and explain all bolded terms*

Mendel's experiments with pea plants suggested that: (1) two alleles exist for every gene (2) alleles maintain their integrity in each generation, and (3) in the presence of the dominant allele, the recessive allele is hidden and makes no contribution to the phenotype. Recessive alleles can be "carried" and not expressed by individuals. Mendel's work suggested that the presence of the dominant allele, independent of whether an individual had one copy or two, always resulted in the same phenotype, a concept referred to as **complete dominance**. The work put forth by Mendel forms the basis of classical, or Mendelian, genetics.

Not all traits are passed from parents to offspring according to Mendelian genetics. Further genetic studies in other plants and animals have shown that much more complexity exists. With that being said, the fundamental principles of Mendelian genetics still hold true. In this section, we consider modes of inheritance that differ from classical Mendelian genetics. If Mendel had chosen an experimental system that exhibited these genetic complexities, it's possible that he would not have understood what his results meant.

Incomplete Dominance

Mendel's results that traits are inherited as dominant and recessive pairs contradicted the view that offspring exhibited a blend of their parents' traits. However, the heterozygote phenotype occasionally does appear to be an intermediate phenotype between the two parents. For example, in the snapdragon, *Antirrhinum majus* (Figure 9.11), if a homozygous parent with white flowers (*rr*) is crossed with a homozygous parent with red flowers (*RR*) all offspring will have pink flowers (*Rr*). The heterozygous offspring has half as much red pigment as their red homozygous dominant parent. This pattern of inheritance is described as **incomplete dominance**.

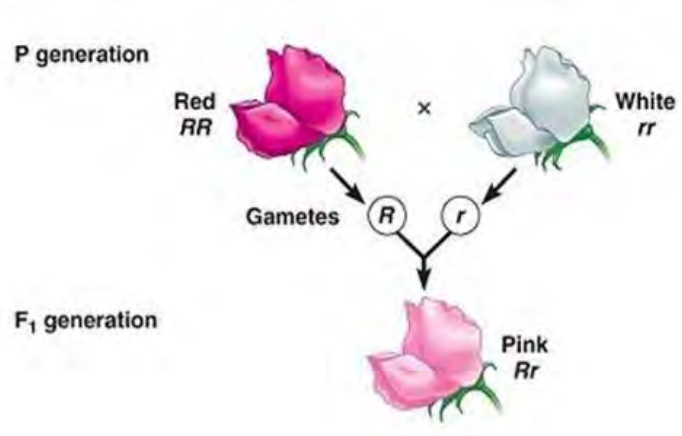


Figure 9.11 These pink flowers of a heterozygote snapdragon result from incomplete dominance. (credit: RudLus02 / Wikimedia commons)

With incomplete dominance, heterozygous individuals have intermediate phenotypes. The allele for red flowers is incompletely dominant over the allele for white flowers. Although the pink intermediate phenotype would appear to support the blending hypothesis, this is not the case. Recall that if genes blended, the paternal phenotypes would not appear in future generations, which is not the case in snapdragons. The results of a heterozygote self-cross provide data that rejects the blending hypothesis with the reappearance of both the red and white phenotypes (Figure 9.12). In this case, the genotypic ratio would be 1 *RR*: 2 *Rr:* 1 *rr*, and the phenotypic ratio would be 1:2:1 for red: pink: white (Figure 9.12).

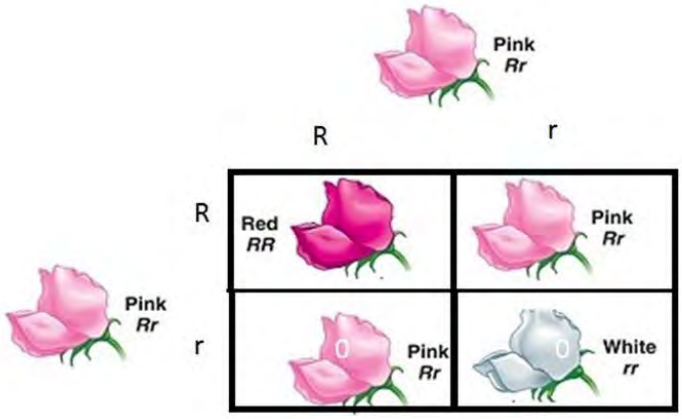


Figure 9.12 These pink flowers of a heterozygote snapdragon result from incomplete dominance. (credit: RudLus02 / Wikimedia commons)

Codominance

Mendel implied that only two alleles, one dominant and one recessive, could exist for a given gene. For example, violet or white flowers and yellow or green seeds. We know now that this is an oversimplification in most cases. Many genes have more than just two different alleles. Human blood type is an example of a character that is determined by three different alleles (Figure 9.13). The alleles are notated as I^O, I^A, and I^B. Each person should have only two alleles for blood type, one from each parent. The two alleles a person inherits leads to one of four possible phenotypes: blood type A, B, AB, or O. The letters represent two different carbohydrates that can be found on the cell membrane of red blood cells. For example, someone who is type A has the A carbohydrate, whereas someone who is O has neither the A nor the B carbohydrates. Someone who is AB has both the A and the B carbohydrates on their red blood cells. To explain the AB blood type, we need to discuss codominance, which is another variation of Mendelian inheritance.

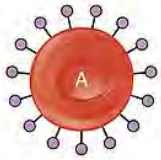
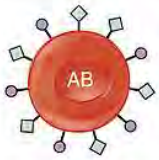
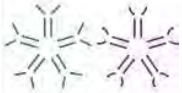
Blood Type	A	B	AB	O
Red Blood Cell Type				
Antibodies in Plasma	 Anti-B	 Anti-A	None	 Anti-A and Anti-B
Antigens in Red blood Cell	A antigen	B antigen	 A and B antigens	None
Blood Types Compatible in an Emergency	A, O	B, O	A, B, AB, O (AB^+ is the universal recipient)	O (O is the universal donor)

Figure 9.13 The four different ABO blood types. (credit: Betts et. al / Anatomy and Physiology OpenStax)

With **codominance**, both alleles for the same characteristic are simultaneously expressed in the heterozygote genotype. For example, a person that inherits the I^A allele from one parent and the I^B allele from the other parent will have the genotype $I^A I^B$ and the phenotype of AB blood type. Homozygotes (I^A I^A and I^B I^B) express either the A or B blood type, respectively. Someone who is I^A I^O or I^B I^O will also express either the A or B blood type. Only individuals that receive an I^O allele from both parents will have the O blood type. If the genotypes of the parents are known, the Punnett square can still be used to predict the possible outcomes of the offspring's phenotype. For example, if a male has the genotype I^A I^O and the female has the genotype I^B I^O then they can produce offspring that have all four phenotypes, A, B, AB, or O (Figure 9.14).

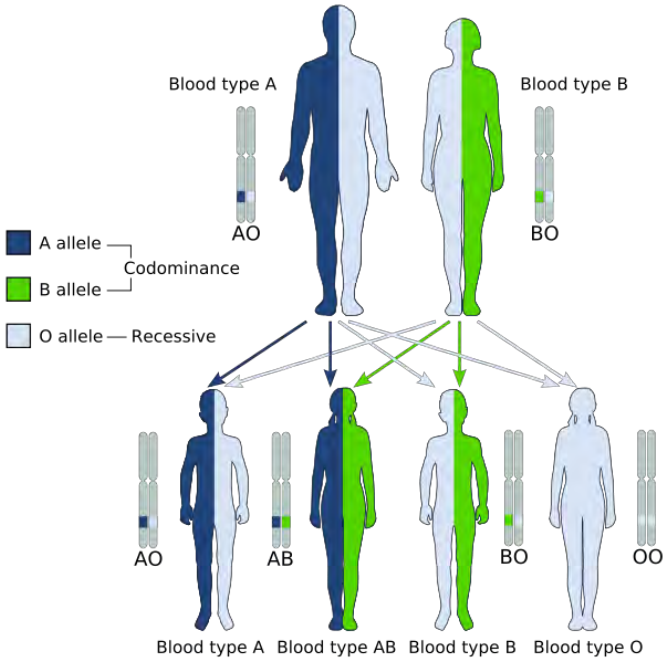


Figure 9.14 A blood typing genetic cross between a male with the genotype I^A I^O and the female with the genotype I^B I^O and the possible offspring they can produce. (credit: YassineMrabet / Wikimedia commons)