5.2 Variations in Heredity

complete dominance a situation where an allele will determine the phenotype, regardless of the presence of another allele

Mendel's experimental work involved the crossing of what he called "typical" plants (homozygous dominant) with "atypical" plants (homozygous recessive). Mendel had discovered **complete dominance**, in which only one of the alleles is expressed, despite the presence of the other allele.

Not all traits are passed on from parent to offspring in the simple patterns that Mendel proposed. Variations in the patterns of heredity exist, and dominance is not always complete.

LEARNING **TIP**

Notation of Alleles

Notation of alleles for a specific gene can be represented using superscripts. For example, consider the alleles for colour in snapdragons shown in Figure 1. The gene is *C* for colour. The alleles are red (*R*) and white (*W*). When you combine the notations for genes and alleles, the result is C^R for the red allele and C^w for the white allele.

incomplete dominance a situation where neither allele dominates the other and both have an influence on the individual; results in partial expression of both traits

Incomplete Dominance and Codominance

Mendel's work provided an explanation of why the traits of parents did not blend in the offspring. Yet blended inheritance is common in nature. In snapdragons one of the genes that controls flower colour (*C*) has one allele for red (C^R) and one allele for white (C^W). A homozygous C^RC^R plant will produce red flowers, while a homozygous C^WC^W plant will produce white flowers. However, the heterozygous plants will produce pink flowers (C^RC^W). In this case, the actual flower colour (phenotype) is a result of varying amounts of red and white pigments. The homozygous (C^RC^R) plant produces red pigment, the homozygous (C^WC^W) plant produces white pigment, and the heterozygous (C^RC^W) plant produces both red pigment and white pigment. Neither of the alleles is dominant, because the red pigment cannot mask the white pigment and the white pigment cannot mask the red pigment. This type of interaction, in which a heterozygous phenotype is a blend of the two homozygous phenotypes, is known as **incomplete dominance**. Interestingly, in this case, incomplete dominance still results in the same Mendelian genotype ratio of 1:2:1 (**Figure 1**).

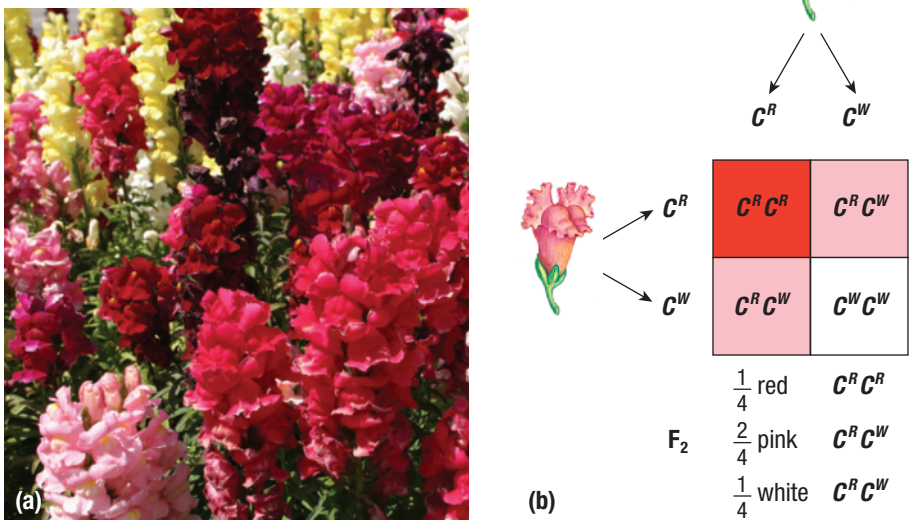

Figure 1 (a) Colour in snapdragons is an example of incomplete dominance. (b) When crossed, red-flowering and white-flowering snapdragons produce pink-flowering offspring. A cross between these pink F_1 individuals produces an F_2 generation with a ratio of 1 red to 2 pink to 1 white (1:2:1).

In the F_1 generation there is only a single phenotype with equal numbers of C^R and C^W alleles. Notice that in the F_2 generation there are now three different phenotypes but the total numbers of C^R and C^W alleles remain equal.

Another type of interaction between alleles occurs when both allele products appear in the offspring at the same time. In this case, a mixed phenotype is generated. This type of interaction is called **codominance**. A classic example of codominance appears in shorthorn cattle. A red bull crossed with a white cow will produce a roan calf (**Figure 2**). Roan calves have intermingled pure white and pure red hair.

codominance a situation where both alleles are expressed fully to produce offspring with a third phenotype

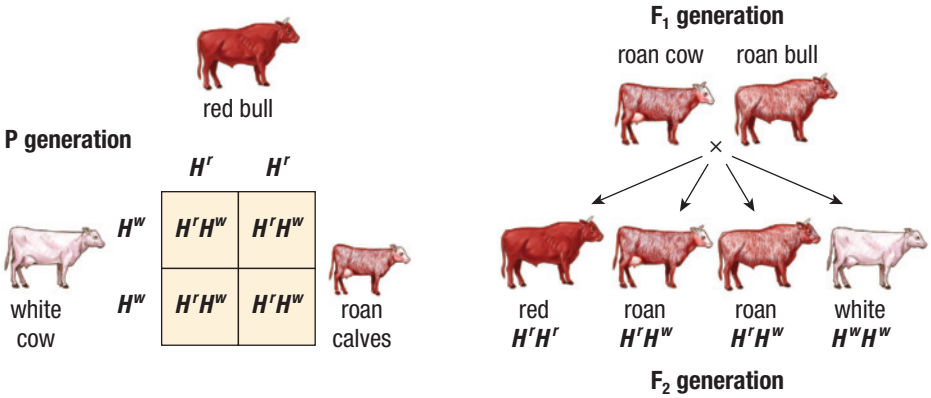

Figure 2 In codominance, one allele does not mask the other allele. Both alleles influence the final phenotype. In shorthorn cattle, roan calves have intermingled red and white hair.

Codominance and Dominance: ABO Blood Types

Human blood type is both a codominant and dominant genetic trait. There are four major blood types: A, B, AB, and O. The blood type gene has three possible alleles. They are I^A, I^B, and i. Each allele codes for a different enzyme that places different types of sugars on the surface of a red blood cell. If you are I^AI^A (type A), an enzyme places one type of sugar on the surface of the cell. If you are I^BI^B (type B), another enzyme places a different sugar on the cell surface. If you are $I^A I^B$ (type AB), both sugars are placed on the cell surface. Type AB blood is an example of codominance. The allele i codes for an enzyme that makes a simpler surface molecule that lacks the extra sugars of the A, B, or AB blood types. If an individual is ii, he has type O blood. If i is paired with I^A or I^B, then the individual expresses the dominant allele (I^A or I^B) and is either type A or type B. Type I^Ai blood and type I^Bi blood are examples of dominant inheritance. **Table 1** shows the distribution and expression of the blood type alleles. One of the gametes is provided by the father and the other is provided by the mother.

Because different blood types exist, it is important that individuals who receive blood transfusions receive blood that is compatible with their own. For example, an individual with type A blood produces an immune response against type B and type AB blood. An individual with type B blood produces an immune response against type A blood and type AB blood. If an incompatible blood type is transfused, the patient's life may be put at risk. In an emergency situation when there is no time to test the patient's blood type, or if a certain blood type is in short supply, type O blood may be used (**Figure 3**). Type O blood is known as the "universal donor." Type AB blood is the "universal recipient."

Table 1 The Distribution and Expression of the Blood Type Alleles

Genotype	Blood type	Able to receive blood from
I^AI^A	A	A, O
I^Ai	A	A, O
I^BI^B	B	B, O
I^Bi	B	B, O
I^AI^B	AB	A, B, AB, O
ii	O	O

Figure 3 Blood banks are always in need of blood donations. Type O blood is valuable because it is compatible with all blood types.

CAREER **LINK**

Phlebotomist

Phlebotomists are technicians who are specially trained and are certified to draw blood. To learn more about a career in phlebotomy,

GO TO NELSON SCIENCE

The frequency of the blood type alleles varies throughout the world. Genetically isolated populations sometimes have very high frequencies for particular alleles. For example, about 80 % of the Native Americans of the Blackfeet Nation Pikuni Indians in Montana have type A blood because the frequency of the I^A allele is very high in this population.

Codominance can provide an even greater variation in the population: there are genes that have many more alleles than just three or four. For example, the gene that helps determine the acceptance or rejection of a transplant has more than 200 different types of alleles.

WEB LINK

To learn more about blood types,

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Investigation 5.2.1

Gummy Bear Genetics (page 215)

You can now complete Investigation 5.2.1.

In this observational study you will use the type and number of "offspring" you have to predict the possible genotypes of the parents. Before starting, review the different Mendelian monohybrid crosses.

5.2 Summary

- Alleles that determine the phenotype regardless of the presence of other alleles follow a pattern of inheritance called complete dominance.
- A heterozygous individual with an intermediate phenotype between the phenotypes of the two homozygous individuals follows a pattern of inheritance called incomplete dominance.
- Codominance occurs when both alleles are fully expressed. Type AB blood is an example of codominance.
- Blood type is an example of a gene with multiple alleles. The three blood type alleles are I^A, I^B, and i. Different combinations of the three alleles produce type A, type B, type AB, and type O blood.

5.2 Questions

1. Explain in your own words the meaning of dominance, codominance, and incomplete dominance. K/U
2. In some chickens, the gene for feather colour is controlled by codominance. The allele for black is F^B and the allele for white is F^W. The heterozygous phenotype is known as erminette. T/I A
   (a) What is the genotype for black chickens?
   (b) What is the genotype for white chickens?
   (c) What is the genotype for erminette chickens?
   (d) If two erminette chickens are crossed, what is the probability that they would have a black chick? A white chick?
3. A geneticist notes that crossing a round radish with a long radish produces oval radishes. When oval radishes were crossed with oval radishes, the F_2 generation had these phenotypes: 100 long, 200 oval, and 100 round radishes. Use symbols to explain the results obtained for the F_1 and F_2 generations. T/I C
4. How would Mendel's conclusions have differed if he had worked with plants whose alleles were incomplete dominant? K/U T/I
5. Thalassemia is an inherited anemic disorder in humans. Individuals can exhibit major anemia, minor anemia, or neither. Assume only one gene is involved with two alleles in the inheritance of this condition. What type of inheritance is thalassemia governed by? What are the corresponding genotypes to the three scenarios? K/U T/I
6. List the possible genotypes for an individual with type A blood. K/U T/I A
7. Suppose a father of blood type A and a mother of blood type B have a child of type O. What are the possible blood types of the mother and father? K/U T/I A
8. Suppose a father of blood type B and a mother of blood type O have a child of type O. What are the chances that their next child will be blood type O? Type B? Type A? Type AB? K/U T/I A
9. Why is blood type inheritance an example of both codominance and complete dominance? K/U
10. Another characteristic of human blood is the presence or absence of a blood protein called the Rh factor. People with the protein are Rh+ and those without it are Rh−. Use the Internet and other resources to answer the following questions: K/U T/I A
    (a) What are the genotypes of individuals who are Rh− and Rh+? Is this an example of complete dominance, incomplete dominance, or codominance?
    (b) How can the Rh blood type of two parents be of concern during a pregnancy? How can possible harmful complications be avoided?

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