8.5: Non-Mendelian Inheritance

Family Portrait

This photo of a South African family shows some of the variations that exist in human skin color. The color of human skin can range from very light to very dark with every possible gradation in between. As you might expect, the skin color trait has a more complex genetic basis than just one gene with two alleles, which is the type of simple trait that Mendel studied in pea plants. Like skin color, many other human traits have more complicated modes of inheritance than Mendelian traits. Such modes of inheritance are called non-Mendelian inheritance, and they include inheritance of multiple allele traits, traits with codominance or incomplete dominance, and polygenic traits, among others, all of which are described below.

Figure \(\PageIndex{1}\): (Public domain; Henry M. Trotter via Wikimedia Commons)

Multiple Allele Traits

The majority of human genes are thought to have more than two normal versions or alleles. Traits controlled by a single gene with more than two alleles are called multiple allele traits. An example is ABO blood type. Your blood type refers to which of certain proteins called antigens are found on your red blood cells. There are three common alleles for this trait, which are represented by the letters \(I^A\), \(I^B\), and \(i\).

<table>
<thead>
<tr>
<th>Genotype</th>
<th>Phenotype (blood type)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(I^A)(I^A)</td>
<td>A</td>
</tr>
<tr>
<td>(I^A)(i)</td>
<td>A</td>
</tr>
<tr>
<td>(I^B)(i)</td>
<td>B</td>
</tr>
</tbody>
</table>

Table \(\PageIndex{1}\): ABO Blood Group

https://bio.libretexts.org/Bookshelves/Human_Biology/Book%3A_Human_Biology_(Wakim_and_Grewal)/08%3A_Inheritance/…

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As shown in the table below, there are six possible ABO genotypes because the three alleles, taken two at a time, result in six possible combinations. The IA and IB alleles are dominant to the i allele. As a result, both IAIA and IAi genotypes have the same phenotype, with the A antigen in their blood (type A blood). Similarly, both IBIB and IBi genotypes have the same phenotype, with the B antigen in their blood (type B blood). No antigen is associated with the i allele, so people with the ii genotype have no antigens for ABO blood type in their blood (type O blood).

### Codominance

Look at the genotype IAIB in the ABO blood group table. Alleles IA and IB for ABO blood type are neither dominant nor recessive to one another. Instead, they are codominant to each other. **Codominance** occurs when two alleles for a gene are expressed equally in the phenotype of heterozygotes. In the case of ABO blood type, IAIB heterozygotes have a unique phenotype, with both A and B antigens in their blood (type AB blood).

### Incomplete Dominance

Another relationship that may occur between alleles for the same gene is **incomplete dominance**. This occurs when the dominant allele is not completely dominant, so an intermediate phenotype results in heterozygotes who inherit both alleles. Generally, this happens when the two alleles for a given gene both produce proteins but one protein is not functional. As a result, the heterozygote individual produces only half the amount of normal protein as is produced by an individual who is homozygous for the normal allele.

An example of incomplete dominance in humans is Tay Sachs disease. The normal allele for the gene, in this case, produces an enzyme that is responsible for breaking down lipids. A defective allele for the gene results in the production of a nonfunctional enzyme. Heterozygotes who have one normal and one defective allele produce half as much functional enzyme as the normal homozygote, and this is enough for normal development. However, homozygotes who have only defective alleles produce only the nonfunctional enzyme. This leads to the accumulation of lipids in the brain beginning in utero, which causes significant brain damage. Most individuals with Tay Sachs disease die at a young age, typically by the age of five years.

### Polygenic Traits

Many human traits are controlled by more than one gene. These traits are called **polygenic traits**. The alleles of each gene have a minor additive effect on the phenotype. There are many possible combinations of alleles, especially if each
gene has multiple alleles. Therefore, a whole continuum of phenotypes is possible.

![Graph showing distribution of adult heights for women and men.](https://bio.libretexts.org/Bookshelves/Human_Biology/Book%3A_Human_Biology_(Wakim_and_Grewal)/08%3A_Inheritance/...)

Figure \(\PageIndex{2}\)). Human Adult Height. Like many other polygenic traits, adult height has a bell-shaped distribution. (CC BY-NC 3.0; Mariana Ruiz Villarreal (LadyofHats) via CK-12 Foundation)

An example of a human polygenic trait is adult height. Several genes, each with more than one allele, contribute to this trait, so there are many possible adult heights. For example, one adult’s height might be 1.655 m (5.430 feet), and another adult’s height might be 1.656 m (5.433 feet). Adult height ranges from less than 5 feet to more than 6 feet, with males being somewhat taller than females on average. The majority of people fall near the middle of the range of heights for their sex, as shown in the graph in Figure \(\PageIndex{2}\)).

### Environmental Effects on Phenotype

Many traits are affected by the environment as well as by genes. This may be especially true for polygenic traits. For example, adult height might be negatively impacted by poor diet or illness during childhood. Skin color is another polygenic trait. There is a wide range of skin colors in people worldwide. In addition to differences in skin color genes, differences in exposure to ultraviolet (UV) light cause some of the variations. As shown in Figure \(\PageIndex{3}\)), exposure to UV light darkens the skin.

![Arm with darker skin on the lower part compared to protected skin near the top.](https://bio.libretexts.org/Bookshelves/Human_Biology/Book%3A_Human_Biology_(Wakim_and_Grewal)/08%3A_Inheritance/...)

Figure \(\PageIndex{3}\)): Skin on the lower part of the arm is much darker in color than protected skin near the top due to the effects of UV radiation. (CC BY 3.0; Onetwo1 via Wikipedia)
Pleiotropy

Some genes affect more than one phenotypic trait. This is called **pleiotropy**. There are numerous examples of pleiotropy in humans. They generally involve important proteins that are needed for the normal development or functioning of more than one organ system. An example of pleiotropy in humans occurs with the gene that codes for the main protein in collagen, a substance that helps form bones. This protein is also important in the ears and eyes. Mutations in the gene result in problems not only in bones but also in these sensory organs, which is how the gene's pleiotropic effects were discovered.

Another example of pleiotropy occurs with sickle cell anemia. This recessive genetic disorder occurs when there is a mutation in the gene that normally encodes the red blood cell protein called hemoglobin. People with the disorder have two alleles for sickle-cell hemoglobin, so named for the sickle shape (Figure 4) that their red blood cells take on under certain conditions such as physical exertion. The sickle-shaped red blood cells clog small blood vessels, causing multiple phenotypic effects, including stunting of physical growth, certain bone deformities, kidney failure, and strokes.

![Image of sickle-shaped red blood cells](https://bio.libretexts.org/Bookshelves/Human_Biology/Book%3A_Human_Biology_(Wakim_and_Grewal)/08%3A_Inheritance/…)

Figure 4: The sickle-shaped red blood cell on the left is shown next to several normal red blood cells for comparison. (CC BY 3.0; OpenStax College via [Wikimedia.org](https://commons.wikimedia.org/wiki/File:Sickle_cells.png))

Epistasis

Some genes affect the expression of other genes. This is called **epistasis**. Epistasis is similar to dominance, except that it occurs between different genes rather than between different alleles for the same gene.

Albinism is an example of epistasis. A person with albinism has virtually no pigment in the skin. The condition occurs due to an entirely different gene than the genes that encode skin color. Albinism occurs because a protein called tyrosinase, which is needed for the production of normal skin pigment, is not produced due to a gene mutation. If an individual has albinism mutation, he or she will not have any skin pigment, regardless of the skin color genes that were inherited.
Feature: My Human Body

Do you know your ABO blood type? In an emergency, knowing this valuable piece of information could possibly save your life. If you ever need a blood transfusion, it is vital that you receive blood that matches your own blood type. Why? If the blood transfused into your body contains an antigen that your own blood does not contain, antibodies in your blood plasma (the liquid part of your blood) will recognize the antigen as foreign to your body and cause a reaction called agglutination. In this reaction, the transfused red blood cells will clump together, as shown in the image below. The agglutination reaction is serious and potentially fatal.

Figure \(\PageIndex{5}\): Two samples of the same blood are shown here. The sample on the left is mixed with anti-B antibodies; the sample on the right is mixed with anti-A antibodies. Agglutination by the anti-A antibodies on the right shows that the sample is type A blood. (Public domain; Alextrevelian 006 via Wikimedia.org)

Knowing the antigens and antibodies present in each of the ABO blood types will help you understand which type(s) of blood you can safely receive if you ever need a transfusion. This information is shown in the table below for all of the ABO blood types. For example, if you have blood type A, this means that your red blood cells have the A antigen and that your blood plasma contains anti-B antibodies. If you were to receive a transfusion of type B or type AB blood, both of which have the B antigen, your anti-B antibodies would attack the transfused red blood cells, causing agglutination.

![Table: ABO blood types](https://bio.libretexts.org/Bookshelves/Human_Biology/Book%3A_Human_Biology_(Wakim_and_Grewal)/08%3A_Inheritance/…)

Figure \(\PageIndex{6}\): Antigens and antibodies in ABO blood types (Public Domain; InvictaHOG via Wikimedia.org)

You may have heard that people with blood type O are called universal donors and that people with blood type AB are called universal recipients. People with type O blood have neither A nor B antigens in their blood, so if their blood is transfused into someone with a different ABO blood type, it causes no immune reaction. In other words, they can donate blood to anyone. On the other hand, people with type AB blood have no anti-A or anti-B antibodies in their blood, so they can receive a transfusion of blood from anyone. Which blood type(s) can safely receive a transfusion of type AB blood, and which blood type(s) can be safely received by those with type O blood?
Summary

- Non-Mendelian inheritance refers to the inheritance of traits that have a more complex genetic basis than one gene with two alleles and complete dominance.

- Multiple allele traits are controlled by a single gene with more than two alleles. An example of a human multiple allele trait is ABO blood type, for which there are three common alleles: I^A, I^B, and i.

- Codominance occurs when two alleles for a gene are expressed equally in the phenotype of heterozygotes. A human example of codominance also occurs in the ABO blood type, in which the I^A and I^B alleles are codominant.

- Incomplete dominance is the case in which the dominant allele for a gene is not completely dominant to a recessive allele for the gene, so an intermediate phenotype occurs in heterozygotes who inherit both alleles. A human example of incomplete dominance is Tay Sachs disease, in which heterozygotes produce half as much functional enzyme as normal homozygotes.

- Polygenic traits are controlled by more than one gene, each of which has a minor additive effect on the phenotype. This results in a whole continuum of phenotypes. Examples of human polygenic traits include skin color and adult height.

- Many traits are affected by the environment as well as by genes. This may be especially true for polygenic traits. For example, skin color.

- Pleiotropy refers to the situation in which a gene affects more than one phenotypic trait. A human example of pleiotropy occurs with sickle cell anemia. People who inherit two recessive alleles for this disorder have abnormal red blood cells and may exhibit multiple other phenotypic effects, such as stunting of physical growth, kidney failure, and strokes.

- Epistasis is the situation in which one gene affects the expression of other genes. An example of epistasis is albinism.

Review

1. What is non-Mendelian inheritance?

2. Explain why the human ABO blood group is an example of a multiple allele trait with codominance.

3. What is incomplete dominance? Give an example of this type of non-Mendelian inheritance in humans.

4. Explain the genetic basis of human skin color.

5. How may the human trait of adult height be influenced by the environment?

6. Define pleiotropy, and give a human example.

7. What is the difference between pleiotropy and epistasis?

8. Which of the following terms best matches each trait description? Choose only the one term that best fits each trait.

   codominance; multiple allele trait; Mendelian trait; polygenic trait

   a. A trait controlled by four genes.

   b. A trait where each allele of a heterozygote makes an equal contribution to the phenotype.

   c. A trait controlled by a single gene that has three different versions.

   d. A trait controlled by a single gene where one allele is fully dominant to the only other allele.
9. People with type AB blood have:
   A. anti-O antibodies
   B. anti-A and anti-B antibodies
   C. A and B antigens

10. True or False. People with type O blood cannot receive a blood transfusion from anyone besides others with type O blood.

11. True or False. People with type O blood can be heterozygous for this trait.

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https://bio.libretexts.org/link?16764#Explore_More

To learn more about non-Mendelian Inheritance, check out these videos:

Media, iframe, embed and object tags are not supported inside of a PDF.