Teacher Tune-up

Quick Content Refresher for Busy Professionals

Beyond Mendel's Laws: What else do we know about genetics, beyond Mendel?

Mendel discovered two important patterns in his data on pea plants, which scientists later named "Mendel's Laws." The first of these, now known as the **Law of Segregation,** suggests that each parent has two genes for a particular trait. For reproduction to occur, regular cells divide to form sex cells, such as eggs and sperm for animals. This division has a special twist: during the process, pairs of genes separate, or segregate, and only one of a parent's two genes for any given trait end up in an individual sex cell. As a result, each parent passes on only one of their two genes for a given trait. Mendel developed the **Law of Independent Assortment** to explain how the inheritance of one trait appeared to be unrelated to the inheritance of another, which suggested that genes are passed along independently of each other.

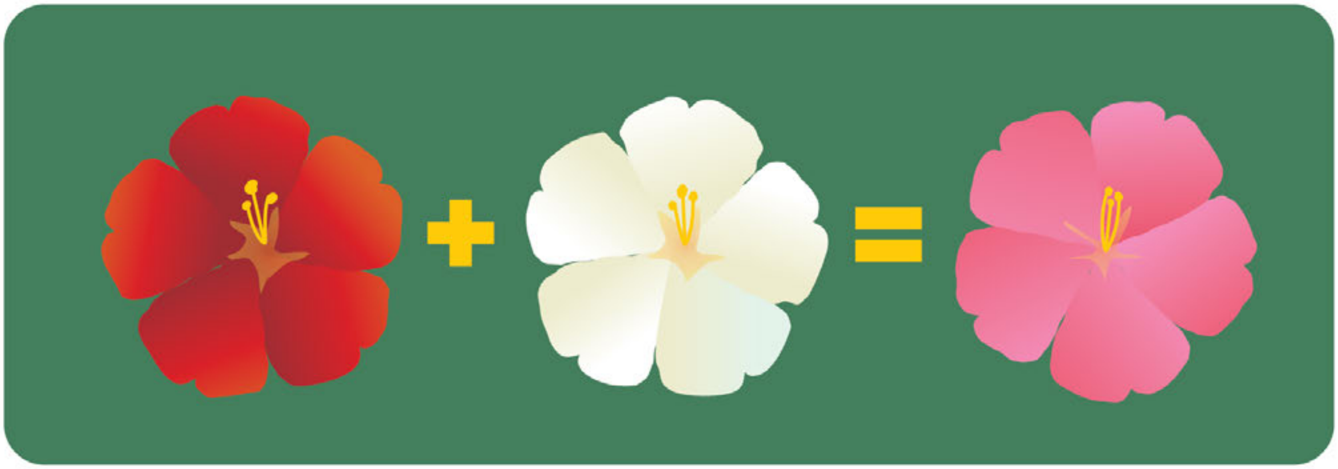
Mendel's Laws worked well for understanding heredity in the seven traits he selected for pea plants, but they don't describe every pattern of inheritance that scientists observe. Some traits seem much harder to predict, and Mendel turned out to be quite lucky that he chose pea plants as his first species to study. His later studies of hawkweed and bees turned out to be failures, and his mathematical models didn't work for all the traits of a pea plant. Over the past century, however, scientists have made great discoveries that add on to Mendel's basic ideas and explain how different traits have somewhat more complicated patterns of inheritance. Here are a few examples of how genetics gets complex.

Environmental factors

In Mendel's research, he grew all of his plants together under similar environmental conditions, and he did not study the role of environmental factors on his plants' traits. For centuries, however, scientists have argued about the role of the environment in developing traits. Long-ranging debates occurred, particularly in psychology, over whether behaviors were genetically determined or environmentally determined, leading to the use of the expression "nature vs. nurture" as early as the Middle Ages. Some traits have clear genetic origins, such as Mendel's traits of peas. Others have clear environmental origins, such as what language a person speaks. Other traits, such as height, seem to depend on both genes and environmental factors, such as a person's diet. More recently, many scientists have come to believe that the nature vs. nurture debate is outdated, as they have learned the many ways that the environment influences the expression of genes (that is, how a gene gets turned into a trait), and that genetics and environment are too closely linked to be considered two opposite concepts.

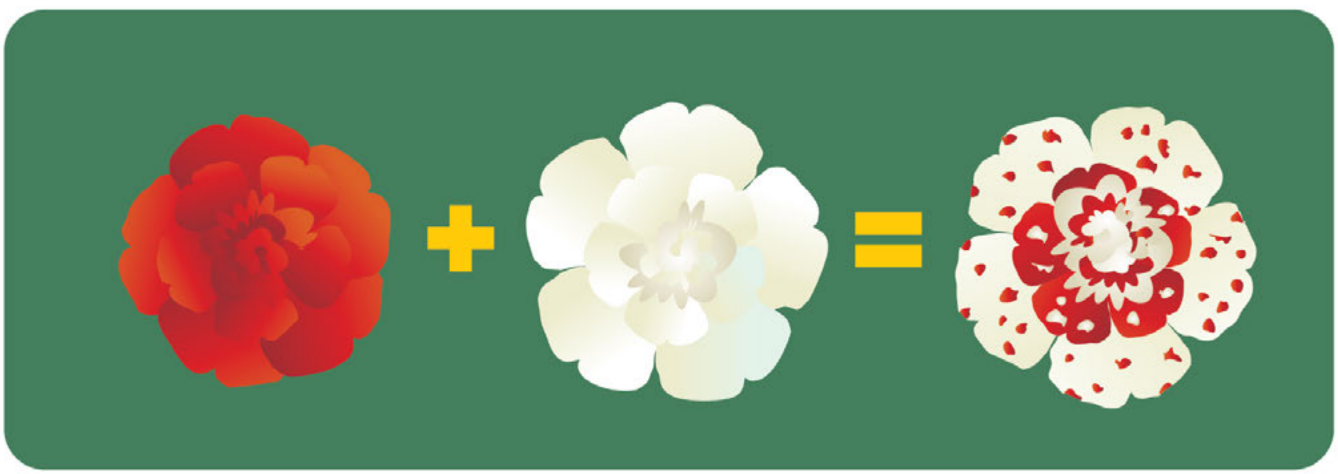
Polygenic traits

A majority of traits are influenced by more than one gene, and are called polygenic (meaning "many genes"). For example, there are at least three genes that contribute to height in humans, and scientists estimate that around 16 genes influence eye color. When Mendel performed his experiments, he intentionally selected traits that had no more than two possible options, and these all turned out to be single gene traits with two alleles, which dramatically simplified his mathematical models. You can still use Mendel's ideas to predict polygenic traits, but the more genes you add, the more complex the Punnett Square becomes. More genes lead to more options and combinations. This complexity is one of the reasons you can see such a range in traits such as height or the colors of hair, eye, and skin – they are all determined by multiple genes.



Incomplete dominance

In pea plants, flowers can be either purple (the dominant trait) or white (the recessive trait), but nothing in between. If Mendel had started work with another plant, such as snapdragons, he might have had a harder time developing his model. Snapdragon flowers can be not only red or white, but also an intermediate pink. In snapdragons, having one dominant allele for red and one recessive allele for white will result in this pinkish trait. This pattern of inheritance is known as incomplete dominance. Many plants show this pattern of color inheritance, which made some early scientists think that genes blended together. We now see that Mendel's patterns of inheritance still hold and that blending doesn't happen – the dominant allele and recessive allele are both still present in the plant. In some circumstances, however, having one dominant allele and one recessive allele can create a different trait than having two dominant alleles.



Co-dominance: Sometimes a dominant allele and a recessive allele can both be expressed at the same time, leading to a pattern of inheritance known as co-dominance. Sickle cell disease is a clear example of this. Sickle cell disease is caused by a mutation in a gene for hemoglobin, which causes red blood cells to lose their round shape. If a person has two alleles for sickle cell, they only make red blood cells with the abnormal shape. If they have one allele for sickle cell and one normal allele, they make two kinds of red blood cells, some with a regular round shape and some with the abnormal shape. This occurrence is different from incomplete dominance, in which having one of each kind of gene gives you a blended trait somewhere in between the dominant and recessive trait. In co-dominance, both the dominant and recessive traits get expressed at the same time, meaning that the organism gets both traits. In the flower world, a flower with both red and white parts on its petals would be an example of co-dominance; a pink flower would be an example of incomplete dominance.

Genetic linkage

Mendel was lucky in many ways in his selection of traits to study. One of their most important features, only discovered much later, was that these traits are mostly found on different chromosomes. This fact helped Mendel to develop his Law of Independent Assortment, which stated that traits were inherited independently of one another. This law is true when genes are on different chromosomes, but scientists have found that when genes are located close to one another on the same chromosome, they are more likely to stick together when passed on to a sex cell. In 1905, Reginald Punnett (inventor of the Punnett Square), along with Edith Rebecca Saunders (considered the "Mother of British Plant Genetics") and William Bateson, discovered that flower color and pollen shape in pea plants were traits that appeared linked together. Mendel never studied pollen shape; had he explored this path, his results would have been much more complicated, and he might not have seen the clear mathematical patterns that allowed him to draw important conclusions about inheritance.