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## Mendel's Genetics

For thousands of years farmers and herders have been selectively breeding their plants and animals to produce more useful [hybrids](#). It was somewhat of a hit or miss process since the actual mechanisms governing inheritance were unknown. Knowledge of these genetic mechanisms finally came as a result of careful laboratory breeding experiments carried out over the last century and a half.



Gregor Mendel  
1822-1884

By the 1890's, the invention of better microscopes allowed biologists to discover the basic facts of cell division and sexual reproduction. The focus of [genetics](#) research then shifted to understanding what really happens in the transmission of hereditary traits from parents to children. A number of hypotheses were suggested to explain heredity, but Gregor Mendel, a little known Central European monk, was the only one who got it more or less right. His ideas had been published in 1866 but largely went unrecognized until 1900, which was long after his death. His early adult life was spent in relative obscurity doing basic genetics research and teaching high school mathematics, physics, and Greek in Brno (now in the Czech Republic). In his later years, he became the abbot of his



Hybridized domesticated horses

monastery and put aside his scientific work.

While Mendel's research was with plants, the basic underlying principles of heredity that he discovered also apply to people and other animals because the mechanisms of heredity are essentially the same for all complex life forms.



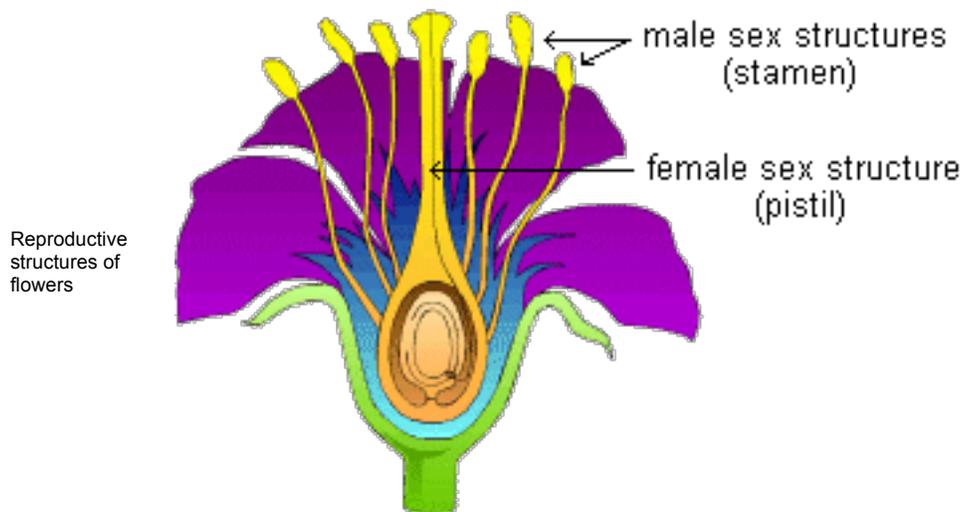
Common edible peas

Through the selective cross-breeding of common pea plants (*Pisum sativum*) over many generations, Mendel discovered that certain traits show up in offspring without any blending of parent characteristics. For instance, the pea flowers are either purple or white--intermediate colors do not appear in the offspring of [cross-pollinated](#) pea plants. Mendel observed seven traits that are easily recognized and apparently only occur in one of two forms:

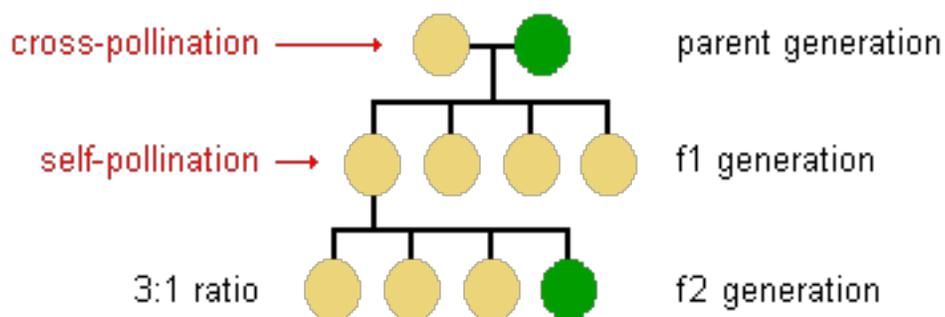
1. flower color is purple or white
2. flower position is axil or terminal
3. stem length is long or short
4. seed shape is round or wrinkled
5. seed color is yellow or green
6. pod shape is inflated or constricted
7. pod color is yellow or green

This observation that these traits do not show up in offspring plants with intermediate forms was critically important because the leading theory in biology at the time was that inherited traits blend from generation to generation. Most of the leading scientists in the 19th century accepted this "blending theory." Charles Darwin proposed another equally wrong theory known as "pangenesis". This held that hereditary "particles" in our bodies are affected by the things we do during our lifetime. These modified particles were thought to migrate via blood to the reproductive cells and subsequently could be inherited by the next generation. This was essentially a variation of Lamarck's incorrect idea of the "inheritance of acquired characteristics."

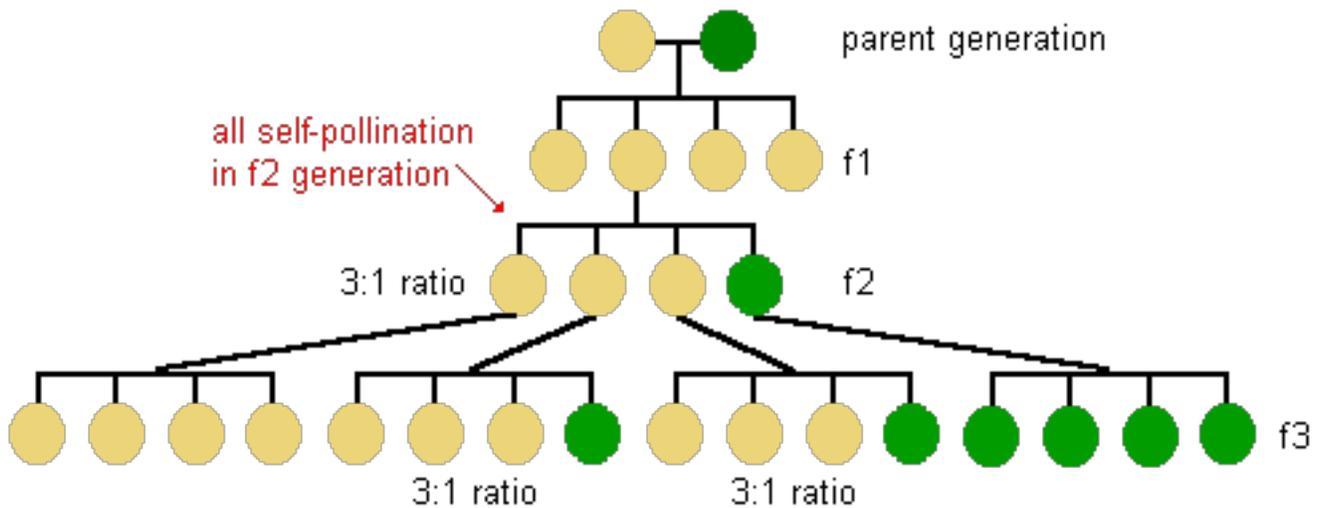
Mendel picked common garden pea plants for the focus of his research because they can be grown easily in large numbers and their reproduction can be manipulated. Pea plants have both male and female reproductive organs. As a result, they can either self-pollinate themselves or cross-pollinate with another plant. In his experiments, Mendel was able to selectively cross-pollinate purebred plants with particular traits and observe the outcome over many generations. This was the basis for his conclusions about the nature of genetic inheritance.



In cross-pollinating plants that either produce yellow or green pea seeds exclusively, Mendel found that the first offspring generation (f1) always has yellow seeds. However, the following generation (f2) consistently has a 3:1 ratio of yellow to green.



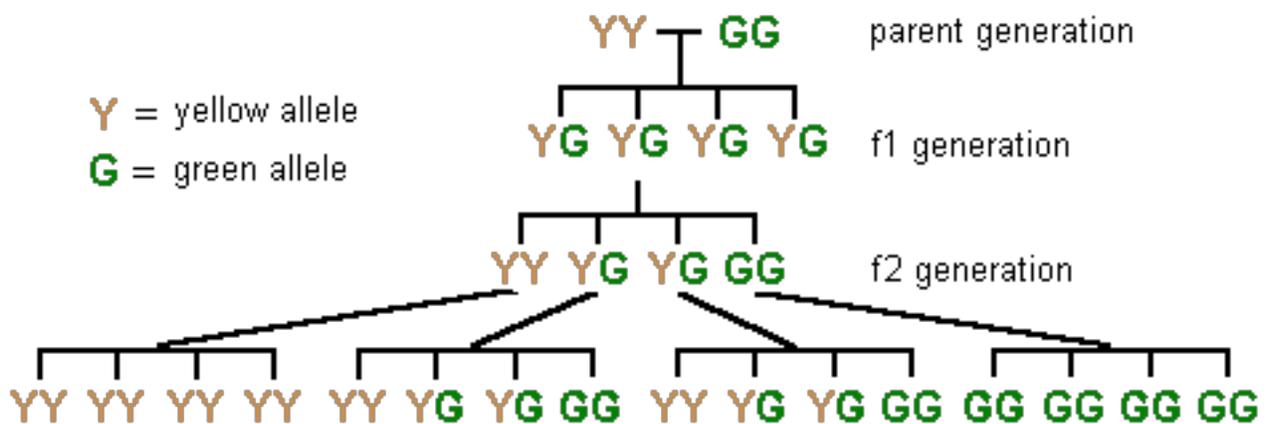
This 3:1 ratio occurs in later generations as well. Mendel realized that this underlying regularity was the key to understanding the basic mechanisms of inheritance.



He came to three important conclusions from these experimental results:

1. that the inheritance of each trait is determined by "units" or "factors" that are passed on to descendants unchanged (these units are now called **genes**)
2. that an individual inherits one such unit from each parent for each trait
3. that a trait may not show up in an individual but can still be passed on to the next generation.

It is important to realize that, in this experiment, the starting parent plants were **homozygous** for pea seed color. That is to say, they each had two identical forms (or **alleles**) of the gene for this trait--2 yellows or 2 greens. The plants in the f1 generation were all **heterozygous**. In other words, they each had inherited two different alleles--one from each parent plant. It becomes clearer when we look at the actual genetic makeup, or **genotype**, of the pea plants instead of only the **phenotype**, or observable physical characteristics.



Note that each of the f1 generation plants (shown above) inherited a Y allele from one parent and a G allele from the other. When the f1 plants breed, each has an equal chance of passing on either Y or G alleles to each offspring.

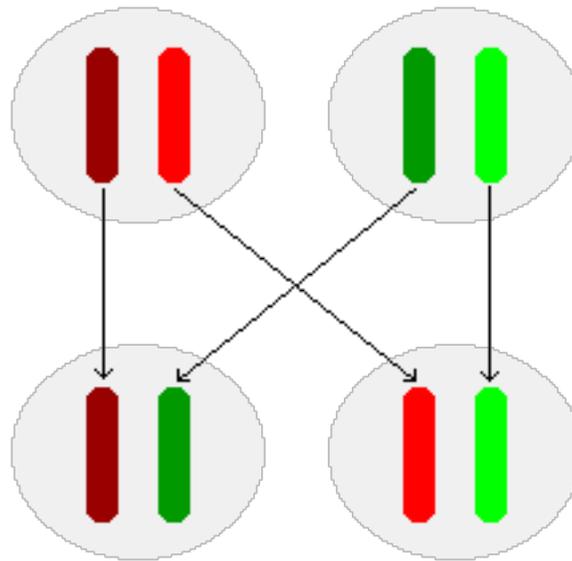
With all of the seven pea plant traits that Mendel examined, one form appeared **dominant** over the other, which is to say it masked the presence of the other allele. For example, when the genotype for pea seed color is YG (heterozygous), the phenotype is yellow. However, the dominant yellow allele

does not alter the **recessive** green one in any way. Both alleles can be passed on to the next generation unchanged.

Mendel's observations from these experiments can be summarized in two principles:

1. the principle of segregation
2. the principle of independent assortment

According to the **principle of segregation**, for any particular trait, the pair of alleles of each parent separate and only one allele passes from each parent on to an offspring. Which allele in a parent's pair of alleles is inherited is a matter of chance. We now know that this segregation of alleles occurs during the process of sex cell formation (i.e., meiosis).



Segregation of alleles in the production of sex cells

According to the **principle of independent assortment**, different pairs of alleles are passed to offspring independently of each other. The result is that new combinations of genes present in neither parent are possible. For example, a pea plant's inheritance of the ability to produce purple flowers instead of white ones does not make it more likely that it will also inherit the ability to produce yellow pea seeds in contrast to green ones. Likewise, the principle of independent assortment explains why the human inheritance of a particular eye color does not increase or decrease the likelihood of having 6 fingers on each hand. Today, we know this is due to the fact that the genes for independently assorted traits are located on different [chromosomes](#) .

These two principles of inheritance, along with the understanding of unit inheritance and dominance, were the beginnings of our modern science of genetics. However, Mendel did not realize that there are exceptions to these rules. Some of these exceptions will be explored in the third section of this tutorial and in the [Synthetic Theory of Evolution](#) tutorial.

By focusing on Mendel as the father of genetics, modern biology often forgets that his experimental results also disproved Lamarck's theory of the inheritance of acquired characteristics described in the [Early Theories of Evolution](#) tutorial. Mendel rarely gets credit for this because his work remained essentially unknown until long after Lamarck's ideas were widely rejected as being improbable.

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**NOTE:** Some biologists refer to Mendel's "principles" as "laws".

**NOTE:** One of the reasons that Mendel carried out his breeding experiments with pea plants was that he could observe inheritance patterns in up to two generations a year. Geneticists today usually carry out their breeding experiments with species that reproduce much more rapidly so that the amount of time and money required is significantly reduced. Fruit flies and bacteria are commonly used for this purpose now. Fruit flies reproduce in about 2 weeks from birth, while bacteria, such as *E. coli* found in our digestive systems, reproduce in only 3-5 hours.

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