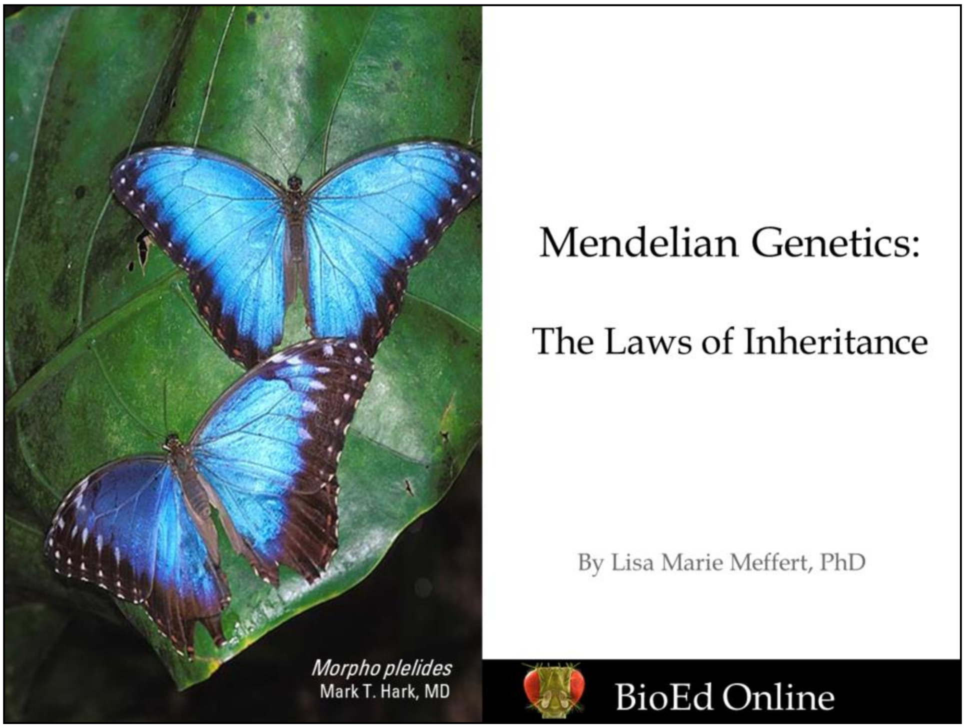
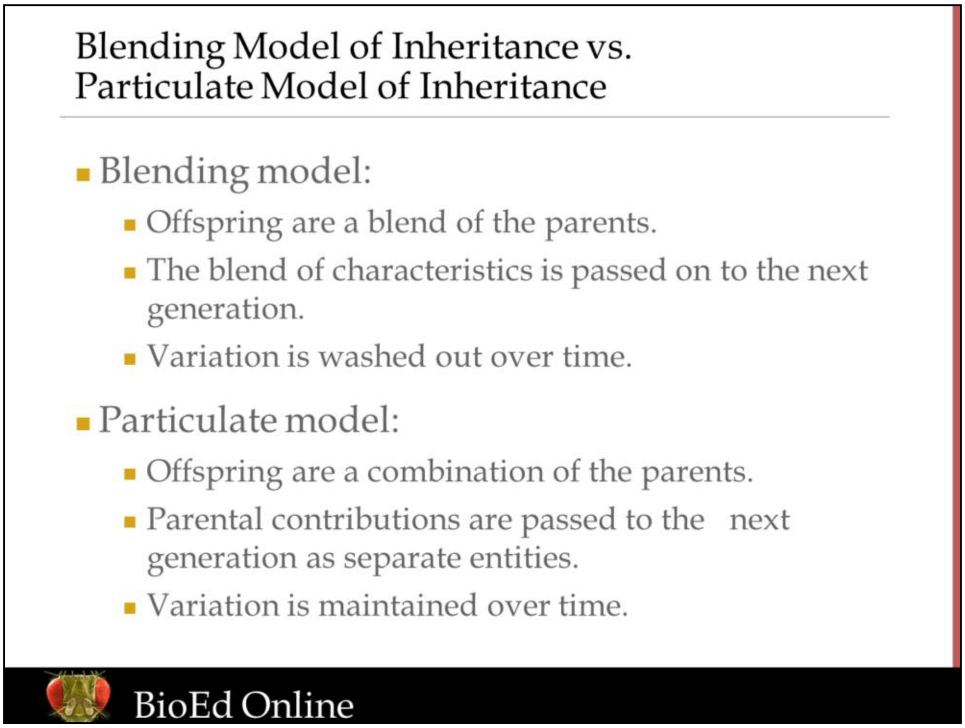


Image Reference:
Hark, M. T. *Morpho peleides* . Retrieved 04-28-2005 from
http://www.harkphoto.com/belize.html



Blending Model of Inheritance vs. Particulate Model of Inheritance

Mendel used experimental approaches to characterize a particulate model of inheritance. In doing so, he developed the three Laws of Inheritance: the Law of Segregation, the Law of Independent Assortment, and the Law of Dominance.

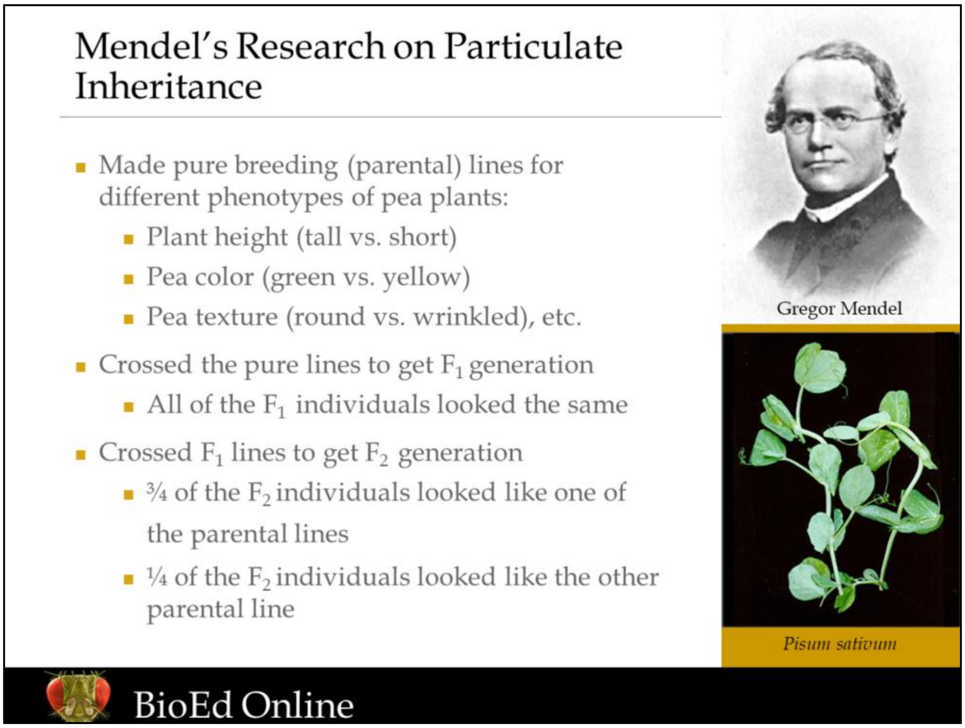
Before Mendel's experiments, prevailing thought about heritable characteristics revolved around the idea that contributions from each parent somehow blended together (the blending model) to generate inheritance patterns in offspring. For example, a tall father and a short mother would produce children of intermediate height. (Note that human height actually is determined by many genetic and environmental factors.) This blend then would be passed on to the next generation. The problem with this model was that it allowed for no variation over time. In our example, eventually everyone would be average or uniform in height. Clearly, this is not what really happens.

According to Mendel's particulate model, an individual receives some form of a particle from each parent. We now call this particle the "allele." Alleles represent the many forms that a gene can take. The two particles then dictate the inheritance pattern in the offspring. Returning to the example we used above, a tall father and a short mother still could produce offspring of average height. However, in the particulate model, the contributions from the parents (particles) are separated from one another when being passed on to the next generation. In this way, particles can continue to combine in various ways, thus maintaining variation through time.

In this module, we will examine how Mendel made this important discovery.

Reference

Campbell, N. E. & Reece, J. B. (2002). *Biology* (6th ed.). San Francisco: Benjamin Cummings.



Mendel's Research on Particulate Inheritance

Mendel found that pea plants were easy to breed and had distinctive visual traits (phenotypes), such as plant height, pea color, flower color, and texture. First, he established pure-breeding lines for each of these traits (the P, or "parental" lines). When two of the same line were mated, the offspring always were identical to the parents. Next, he selected a particular characteristic, such as plant height, and then mated two parents that were pure bred for contrasting traits (tall and short). He found that all offspring looked liked one of the parental lines (in this case, all tall). He then crossed these offspring (the F_1 or "first filial" generation). The resulting set of offspring (the F_2 generation, or second filial generation) had a combination of ¾ of the phenotypes (tall) found in the previous generation (the F_1). The remaining ¼ of the progeny looked like the other parental phenotype in the original cross (short).

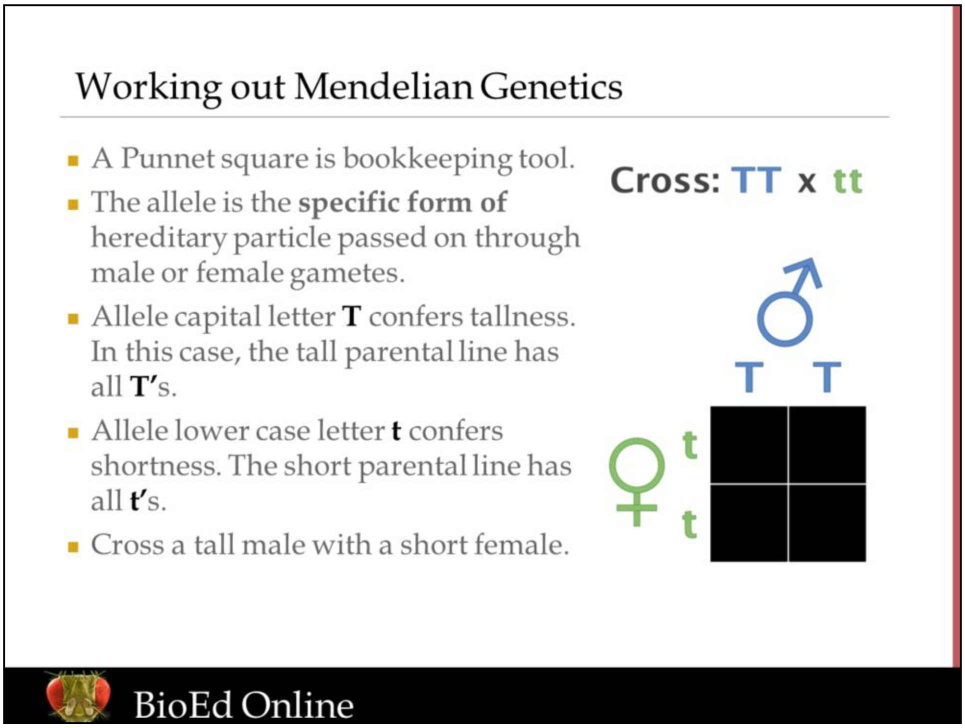
Reference

Campbell, N. E. & Reece, J. B. (2002). *Biology* (6th ed.). San Francisco: Benjamin Cummings.

Image References

Mendel. Retrieved 4-15-2005 from http://en.wikipedia.org/wiki/Mendel

Department of Primary Industries. (1997). *Image of Pea shoots (pisum sativum).* Institute for Horticultural Development (Permission granted 5-03-2005). Retrieved 4-20-2005 from http://www.dpi.vic.gov.au/trade/asiaveg/thes-48.htm



Working Out Mendelian Genetics

The Punnet square is a bookkeeping tool that allows us to work out all possible compositions of male or female gametes for a particular cross. For the sake of simplicity, we will refer to these male and female gametes as sperm and egg, respectively. The specific form of the "particle" that is passed on to the offspring is called the "allele." The boxes in the Punnet square help us to keep track of all possible offspring that can be produced by this particular cross.

As with Mendel's experiment on tall versus short pea plants, let's start with the characteristic of "plant height." Each individual has two "particles," called alleles, that correspond to height. One allele was inherited from each parent. "T" represents the allele that confers tallness and "t" represents the allele that is related to short plant height. Recall that Mendel started with pure breeding lines of tall and short plants. Thus, all individuals of our "tall" line have only "T" alleles, and all of the individuals of our "short" line have "t" alleles. The allelic combinations ("genotypes") of the tall and short individuals are "TT" and "tt," respectively. Individuals or genotypes that have two copies of the same allele are called "homozygotes."

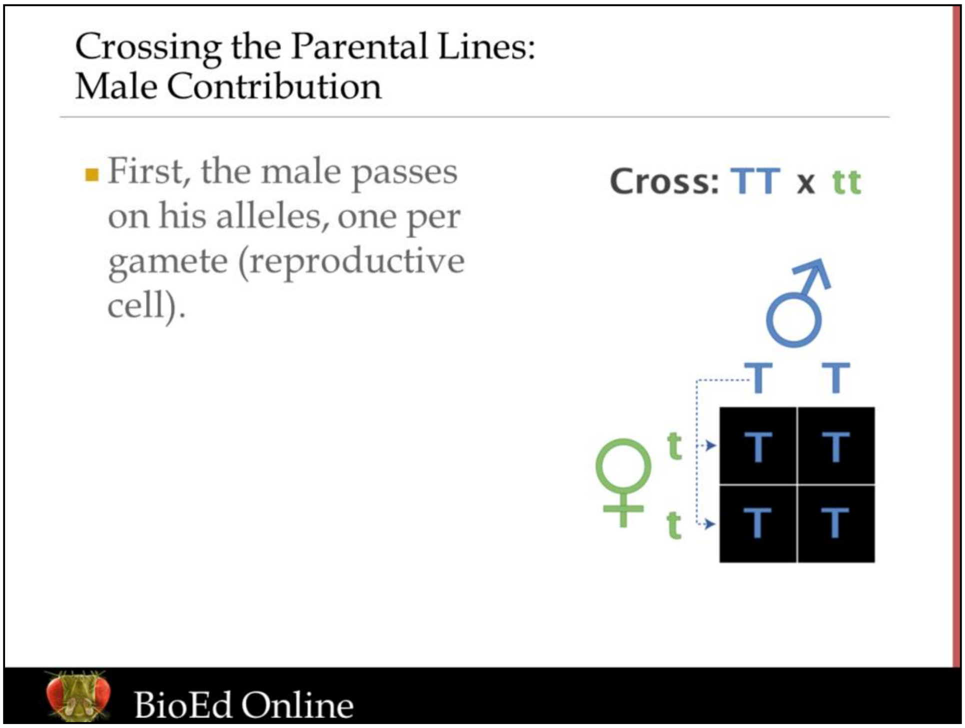
In this demonstration, we will cross a tall male with a short female. (We would get the same results if we crossed a tall female with a short male. However, in more complicated crosses, the direction of the cross, with regard to sex, can make a difference.) During fertilization, each parent contributes only one allele for plant height—even though each parent has two alleles, which can be the same or different. In our example, both alleles from the male parent are the same (T's, written as "TT"). Similarly, both alleles that could be contributed by the female are the same (t's, written as "tt"). Here, we are writing the potential male contributions on the top and potential female contributions on the left-hand side. By putting one "T" in each sperm, the alleles are following Mendel's first law of inheritance: The Law of Segregation. The two alleles that made the male tall are now segregating to produce reproductive cells (gametes) that can combine with contributions from the female to form the next generation. The same is true for the female.

Reference

Campbell, N. E. & Reece, J. B. (2002). *Biology* (6th ed.). San Francisco: Benjamin Cummings.

Image Reference

Young, M. (2005). *Punnet square.* Baylor College of Medicine, Center For Educational Outreach.



Crossing the Parental Lines

Each offspring will receive one allele for plant height from each parent (and thus will end up with two alleles for this characteristic). Write each type of allele that the male can contribute in each box, going down. In this case, the male parent only can contribute a "T" to the gametes that will go to each of the offspring.

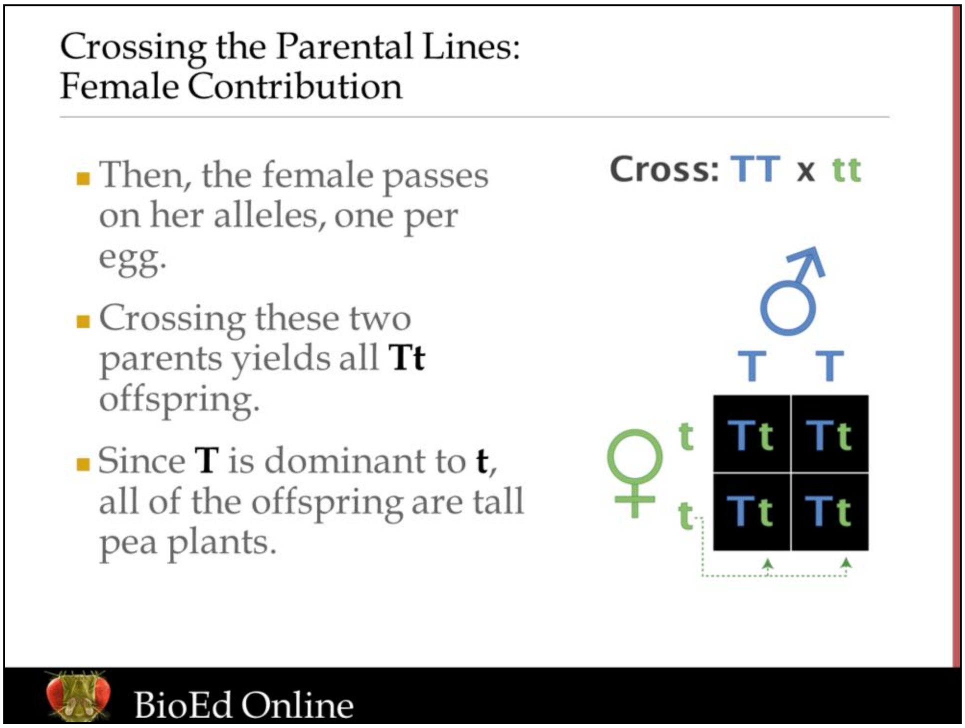
Since one "T" ends up in each male gamete, the alleles are following Mendel's first law of inheritance: The Law of Segregation. The two alleles that made the male tall are now segregating to produce the next generation.

Reference

Campbell, N. E. & Reece, J. B. (2002). *Biology* (6th ed.). San Francisco: Benjamin Cummings.

Image Reference

Young, M. (2005). *Punnet square*. Baylor College of Medicine, Center For Educational Outreach.



Crossing the Parental Lines

Now write in each type of allele that the female can contribute in each box going across. In this case, every offspring gets a "t," again following Mendel's Law of Segregation. Each combination in the grid results in an offspring that is "Tt." A genotype with two different alleles (forms of a characteristic) is called a "heterozygote."

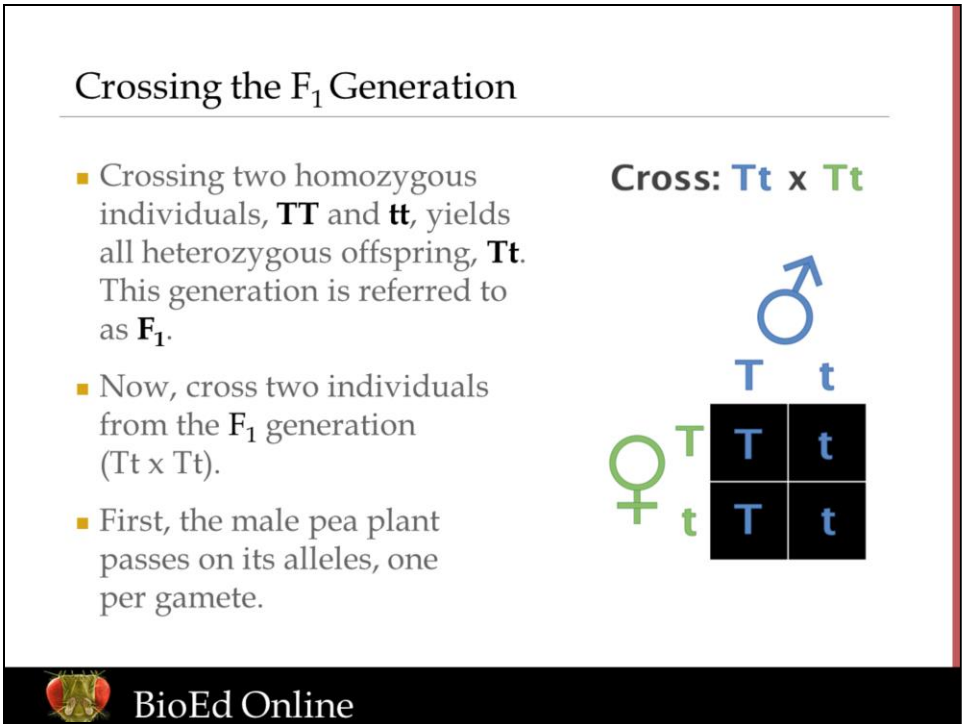
In pea plants, the "T" allele masks the effects of the "t" allele. The terms "dominant" and "recessive" are used for the masking and the covered allele, respectively. All offspring from this cross are heterozygotes in terms of their genotypes. They also are tall (because the allele for tall masks the allele for short) in terms of their "phenotype" (the observable feature produced by the genotype). These alleles thus follow Mendel's third law of inheritance: The Law of Dominance. Mendel had the advantage of the simple inheritance pattern of pea plant height. Unlike human height, which is determined by multiple factors, plant height is determined by one major heritable factor. In addition, dominant alleles do not always cover up the recessive allele entirely. Sometimes, the dominant allele only partially masks the recessive allele. This is called "incomplete dominance."

Reference

Campbell, N. E. & Reece, J. B. (2002). *Biology* (6^{th} ed.). San Francisco: Benjamin Cummings.

Image Reference:

Young, M. (2005). *Punnet square.* Baylor College of Medicine, Center For Educational Outreach.



Crossing the F_1

We'll now cross two heterozygotes (the F_1) that resulted from our original parent cross (P), TT x tt. First, write the two possible alleles that the male contributes to the Punnet square above. Then, write the the two possible alleles that the female can contribute on the left-hand side of the Punnet square. Write the alleles that the male contributes to the offspring in each box, going down.

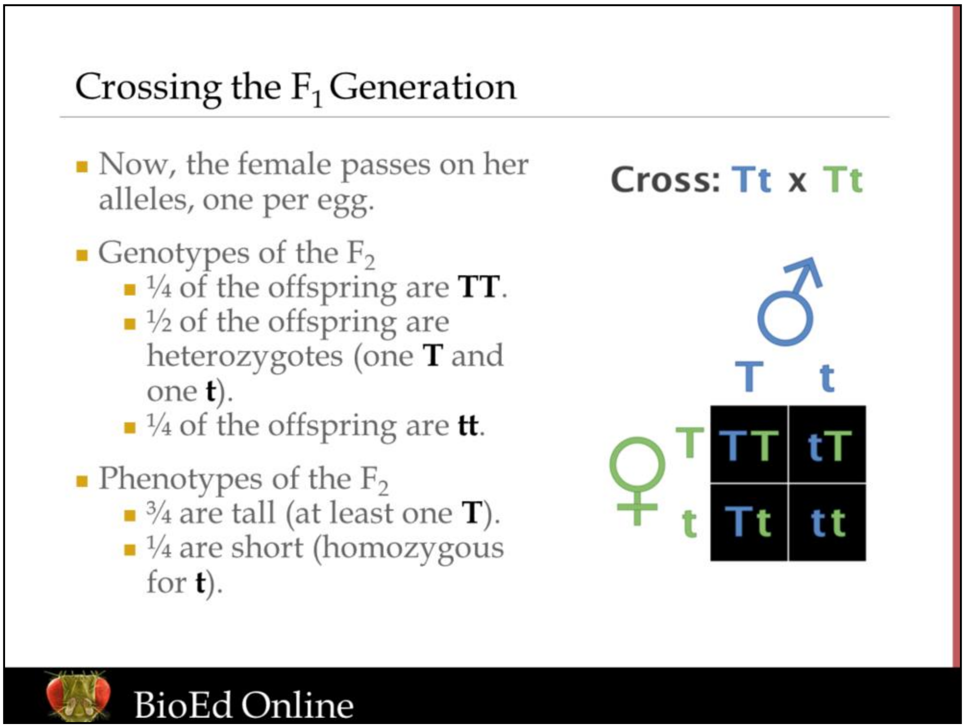
References

Campbell, N. E. & Reece, J. B. (2002). *Biology* (6th ed.). San Francisco: Benjamin Cummings.
Frisch, K. von. (1947). The dances of the honey bee. *Bulletin of Animal Behaviour*, 5, 1-32.

Tinbergen, N. (1951). *The study of instinct*. London: Clarendon Press.

Image Reference

Young, M. (2005). *Punnet square.* Baylor College of Medicine, Center For Educational Outreach.



Crossing the F_1

Next, write in the female's allelic contributions to the potential offspring. In this case, there are three possible genotypes, in the ratio 1:2:1, for the TT, Tt, and tt combinations, respectively (note that Tt is the same as tT). Since the T allele is dominant to the t allele, every individual with at least one T has the tall phenotype. Only individuals homozygous for "t" will be short. Thus, we find that the phenotypes of the offspring are in the ratio of 3:1 for tall and short, respectively.

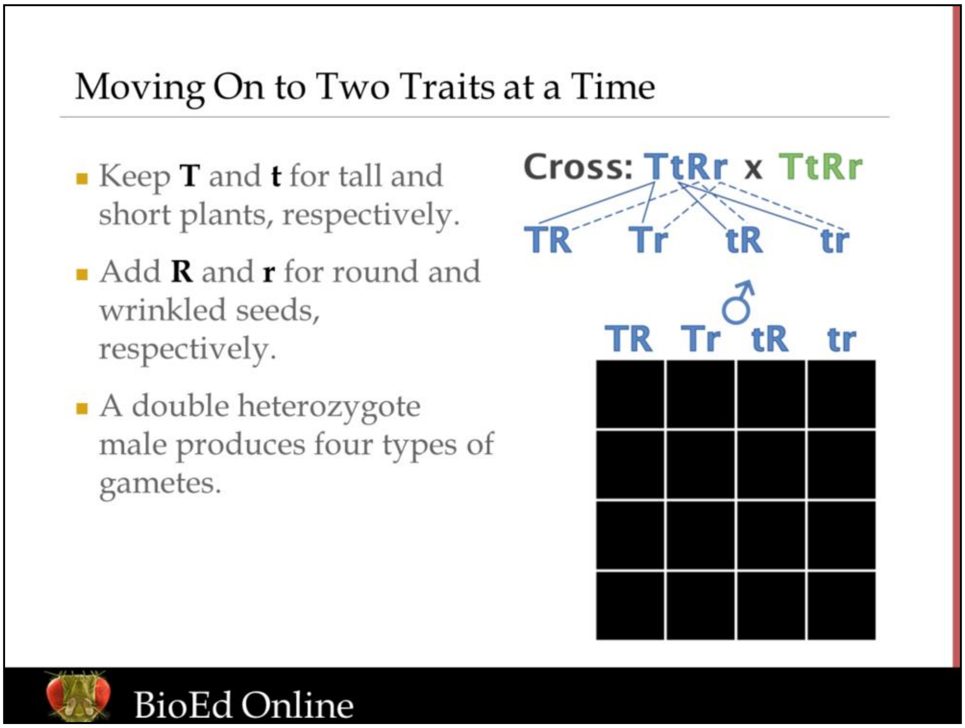
Note how this particulate model of inheritance maintains variation. Under the blending model of inheritance, one would expect a mating of two tall individuals to produce only tall offspring. Instead, the crossing of the F_1 recovered the variation in the parental lines.

Reference

Campbell, N. E. & Reece, J. B. (2002). *Biology* (6th ed.). San Francisco: Benjamin Cummings.

Image Reference

Young, M. (2005). *Punnet square.* Baylor College of Medicine, Center For Educational Outreach.



Moving on to Two Traits at a Time

Increasing now to two traits, we will keep the designations of "T" and "t" for tall and short pea plants, respectively, and then add "R" and "r" for round and wrinkled seeds, respectively. In this example, we will cross a male that is heterozygous for tallness and rounded seeds with a female that has the same genotype (TtRr). A Punnet square will, again, help us to work out all possible genotypes (and phenotypes) of the resultant offspring.

The male can produce four types of sperm, each with one allele for each trait. The four types of sperm for a double-heterozygote male are TR, Tr, tR, and tr.

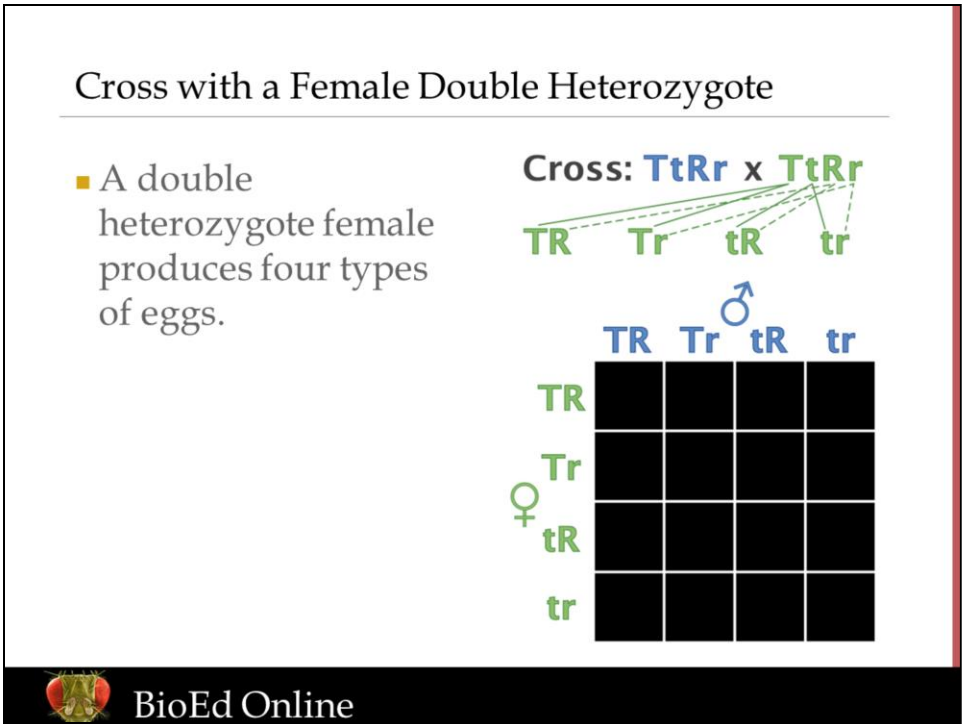
Because the allele for one gene (or characteristic) is independent of (does not dictate) the allele of the other gene, the alleles are said to assort independently. The is Mendel's second law of inheritance: The Law of Independent Assortment. This law would be violated, for example, if the "T" allele was always associated with the "R" allele (and thus eliminating the possibility of Tr and tR sperm).

Reference

Campbell, N. E. & Reece, J. B. (2002). *Biology* (6th ed.). San Francisco: Benjamin Cummings.

Image Reference

Young, M. (2005). *Punnet square*. Baylor College of Medicine, Center For Educational Outreach.



Cross with a Female Double Heterozygote

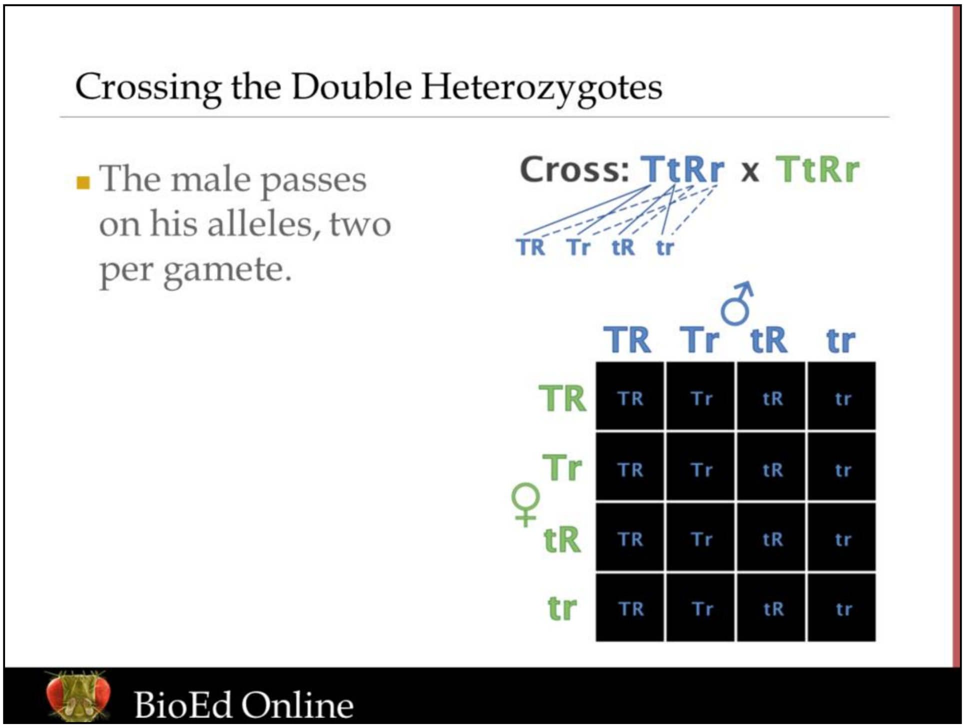
A double heterozygote female produces four kinds of eggs, again in accordance with Mendel's Law of Independent Assortment.

Reference

Campbell, N. E. & Reece, J. B. (2002). *Biology* (6th ed.). San Francisco: Benjamin Cummings.

Image Reference

Young, M. (2005). *Punnet square.* Baylor College of Medicine, Center For Educational Outreach.



Crossing the Double Heterozygotes

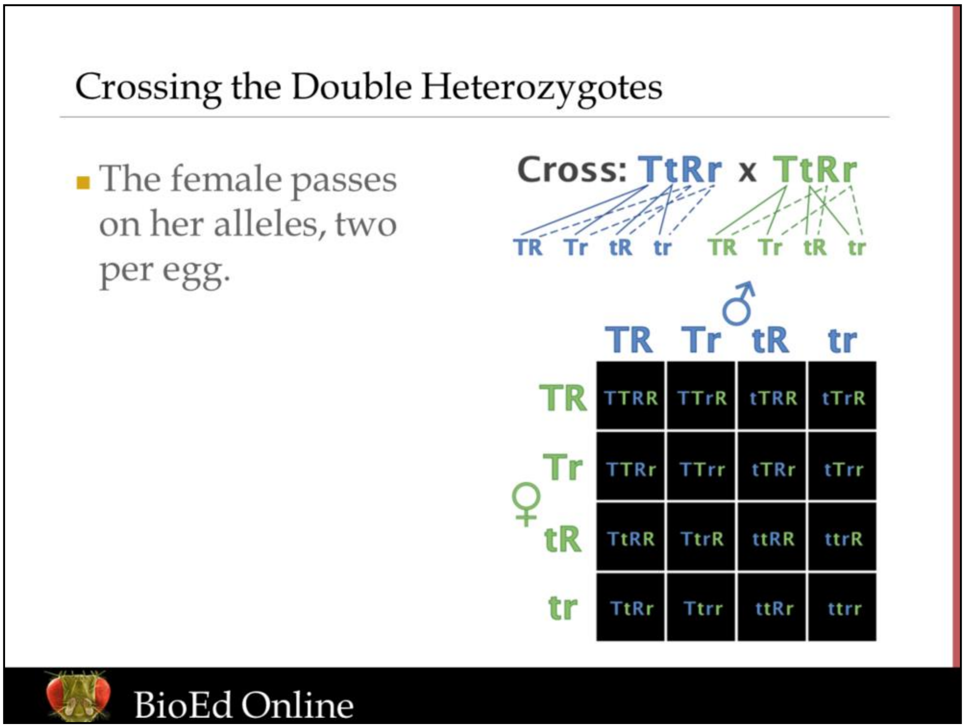
Again, write in the types of gamete that the male can contribute in each box, going down.

Reference

Campbell, N. E. & Reece, J. B. (2002). *Biology* (6th ed.). San Francisco: Benjamin Cummings.

Image Reference

Young, M. (2005). *Punnet square.* Baylor College of Medicine, Center For Educational Outreach.



Crossing the Double Heterozygotes

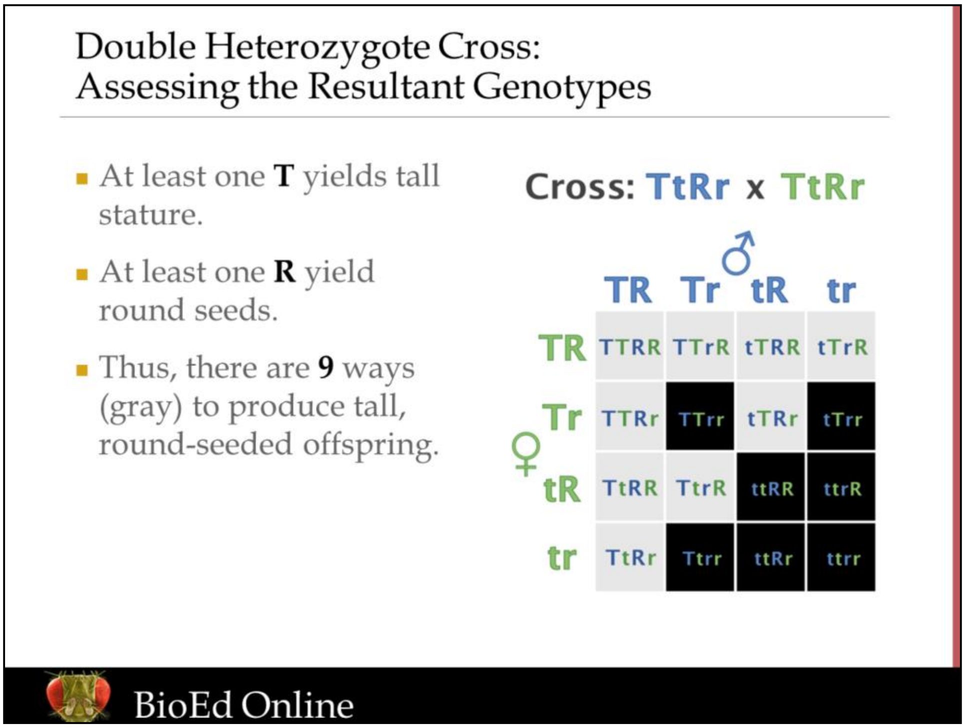
Again, we write in the types of eggs that the female can contribute in each box, going across.

Reference

Campbell, N. E. & Reece, J. B. (2002). *Biology* (6th ed.). San Francisco: Benjamin Cummings.

Image Reference

Young, M. (2005). *Punnet square.* Baylor College of Medicine, Center For Educational Outreach.



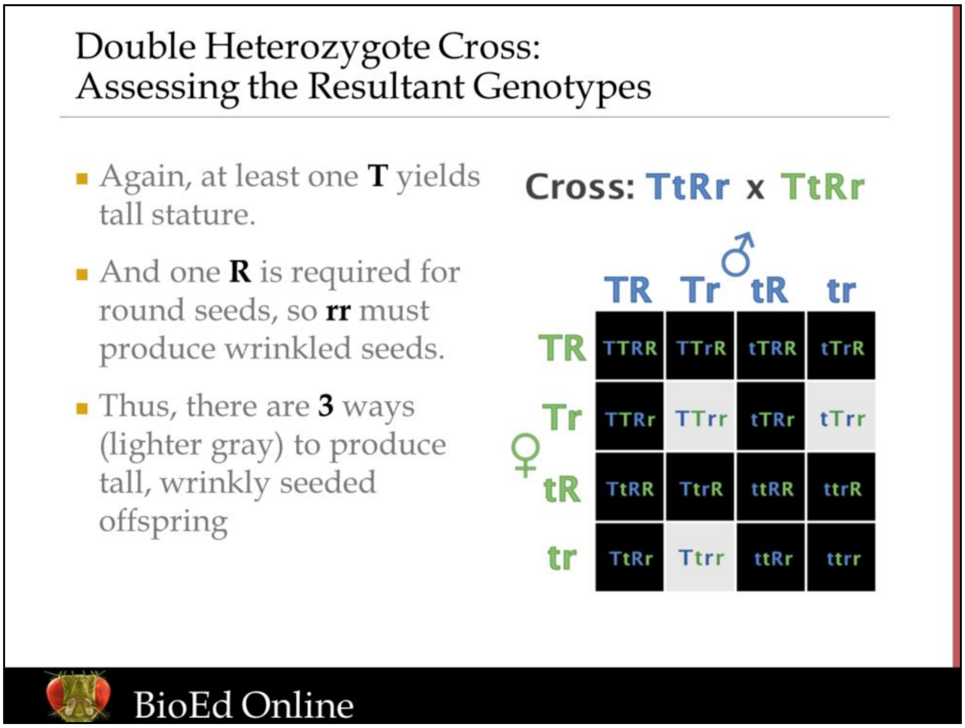
Assessing the Resultant Genotypes

Recall that “T” is dominant to “t” and “R” is dominant to “r.” Thus, any offspring with at least one “T” and one “R” will be tall with round seeds. There are nine combinations that yield this phenotype**. Keep in mind that genotype refers to the genetic makeup of each individual. Genotype is the genetic composition of an individual.**

Reference
Campbell, N. E. & Reece, J. B. (2002). *Biology* (6th ed.). San Francisco: Benjamin Cummings.

Image Reference

Young, M. (2005). *Punnet square*. Baylor College of Medicine, Center For Educational Outreach.



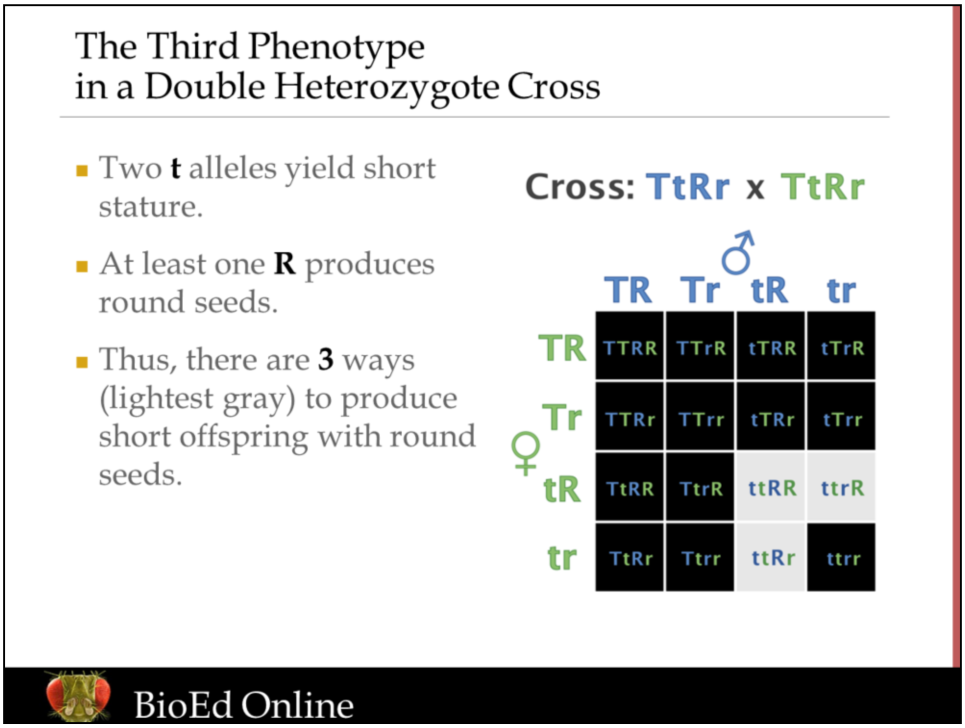
Assessing the Resultant Genotypes

Again, any offspring with at least one “T” will be tall, and at least one “R” is required to produce round seeds. Therefore, a genotype with at least one “T” allele and two “r” alleles will be tall with wrinkled seeds. There are three combinations that yield this phenotype**.**

Reference
Campbell, N. E. & Reece, J. B. (2002). *Biology* (6th ed.). San Francisco: Benjamin Cummings.

Image Reference

Young, M. (2005). *Punnet square.* Baylor College of Medicine, Center For Educational Outreach.



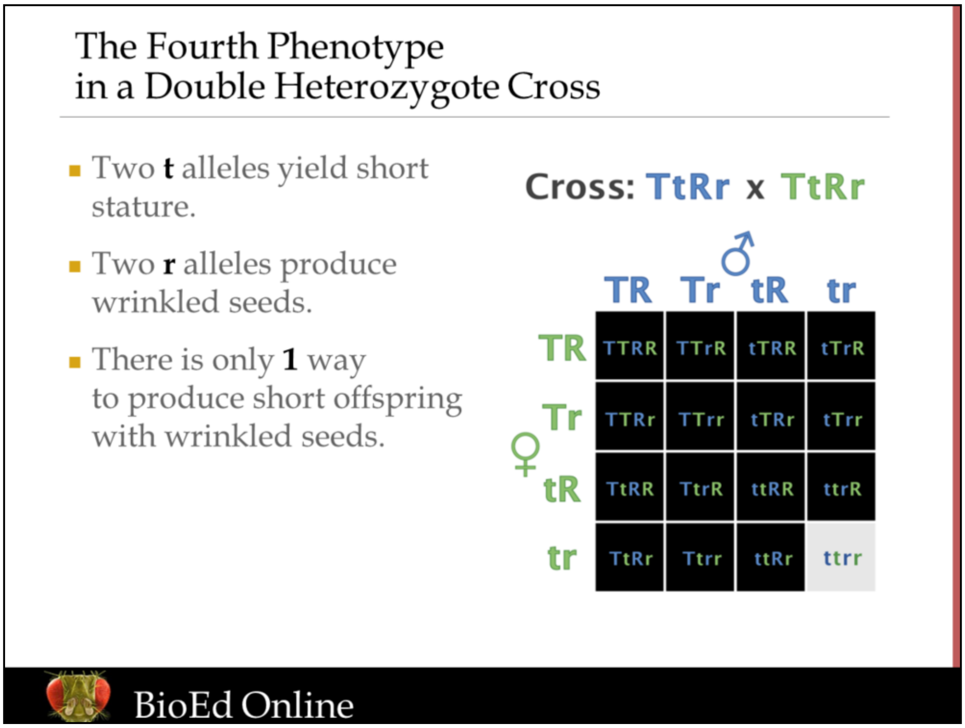
The Third Phenotype in This Cross

The third phenotype in this cross is a short plant with round seeds. There are three ways to produce this phenotype. The offspring must be homozygous for short but can be either homozygous or heterozygous for round.

Reference
Campbell, N. E. & Reece, J. B. (2002). *Biology* (6th ed.). San Francisco: Benjamin Cummings.

Image Reference

Young, M. (2005). *Punnet square.* Baylor College of Medicine, Center For Educational Outreach.



The Fourth Phenotype

The fourth (and final) offspring in this cross is short stature with wrinkled seeds. There is only one way to produce this phenotype: the offspring must be homozygous recessive for both genes (having the ttrr genotype). Thus, a cross between double heterozygotes for tall stature and round seeds yields a ratio of 9:3:3:1 in the offspring for the proportion of tall with round seeds:tall with wrinkled seeds:short with round seeds:short with wrinkled seeds.

These are the kinds of ratios that Mendel found in his experiments. Again, note how the particulate model of inheritance maintains variation. Under the blending model of inheritance, one would expect a mating of between two tall individuals with round seeds to produce only offspring that were also tall with round seeds. Instead, the mating between such phenotypically similar individuals produced four kinds of phenotypes. Imagine constructing such a Punnet square for even more traits. There would be great diversity in the offspring phenotypes.

Test yourself by working out the phenotypic ratios that would arise from a different kind of mating. For example, cross a Ttrr genotype with a ttRr genotype.

Reference
Campbell, N. E. & Reece, J. B. (2002). *Biology* (6th ed.). San Francisco: Benjamin Cummings.

Image Reference

Young, M. (2005). *Punnet square.* Baylor College of Medicine, Center For Educational Outreach.