Course: B.Sc. (Hons.) , Part –III

Paper – VII (Cytogenetics and Molecular Biology)

Topic –Law of Inheritance Proposed By Mendel

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Law of Inheritance

Mendel postulated that genes (characteristics) are inherited as pairs of alleles (traits) that behave in a dominant and recessive pattern. Alleles segregate into gametes such that each gamete is equally likely to receive either one of the two alleles present in a diploid individual.

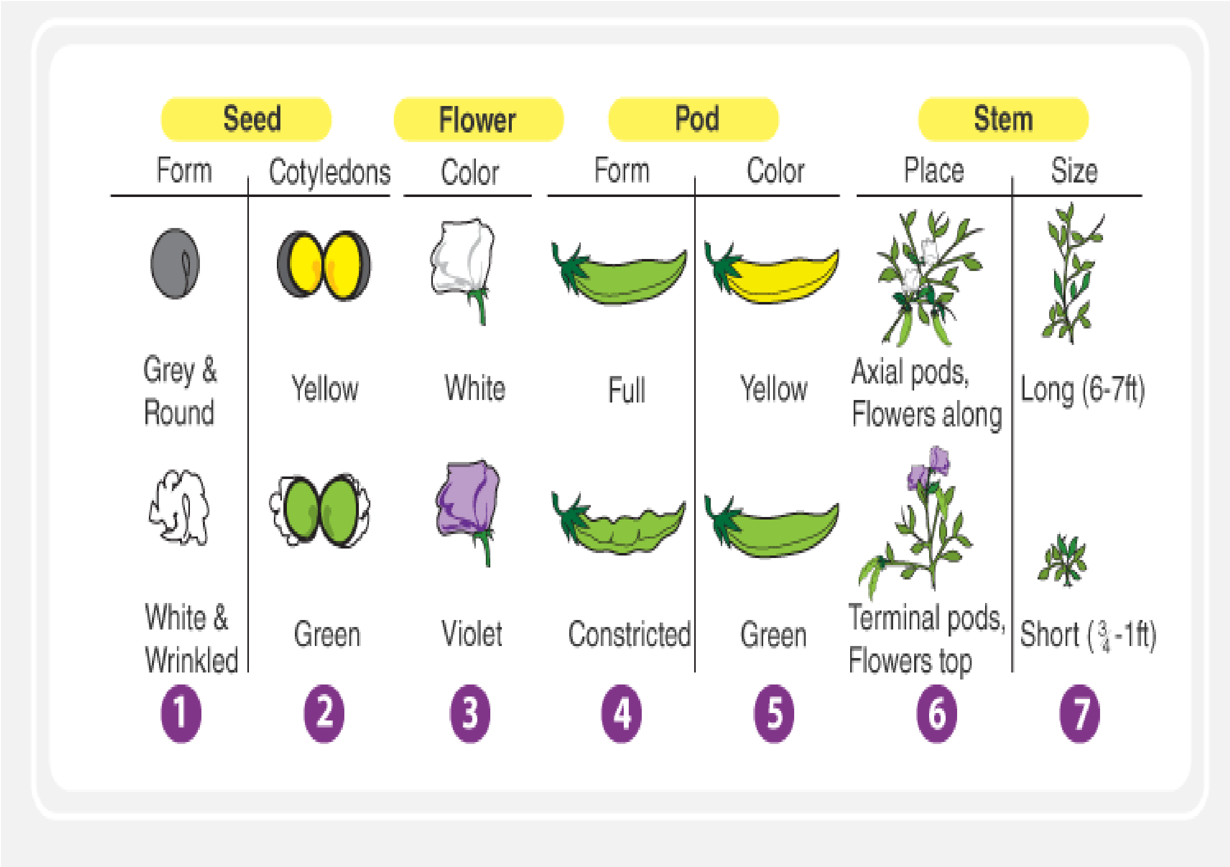
Inheritance can be defined as the process of how a child receives genetic information from the parent. The whole process of heredity is dependent upon inheritance and it is the reason that the off springs are similar to the parents. This simply means that due to inheritance, the members of the same family possess similar characteristics.

It was only during the mid19th century that people started to understand inheritance in a proper way. This understanding of inheritance was made possible by a scientist named Gregor Mendel, who formulated certain laws to understand inheritance known as Mendel's laws of inheritance.

Mendel's Laws of Inheritance

The laws of inheritance were derived by Gregor Mendel, a 19th century monk conducting hybridization experiments in garden peas (Pisum sativum). Between 1856 and 1863, he cultivated and tested some 28,000 pea plants. From these experiments, he deduced two generalizations that later became known as Mendel's Laws of Heredity or Mendelian inheritance. He described these laws in a two part paper, "Experiments on Plant Hybridization", which was published in 1866.

Between1856-1863, Mendel conducted the hybridization experiments on the garden peas. During that period, he chose some distinct characteristics of the peas and conducted some cross-pollination/ artificial pollination on the pea lines that showed stable trait inheritance and underwent continuous self-pollination. Such pea lines are called true-breeding pea lines.

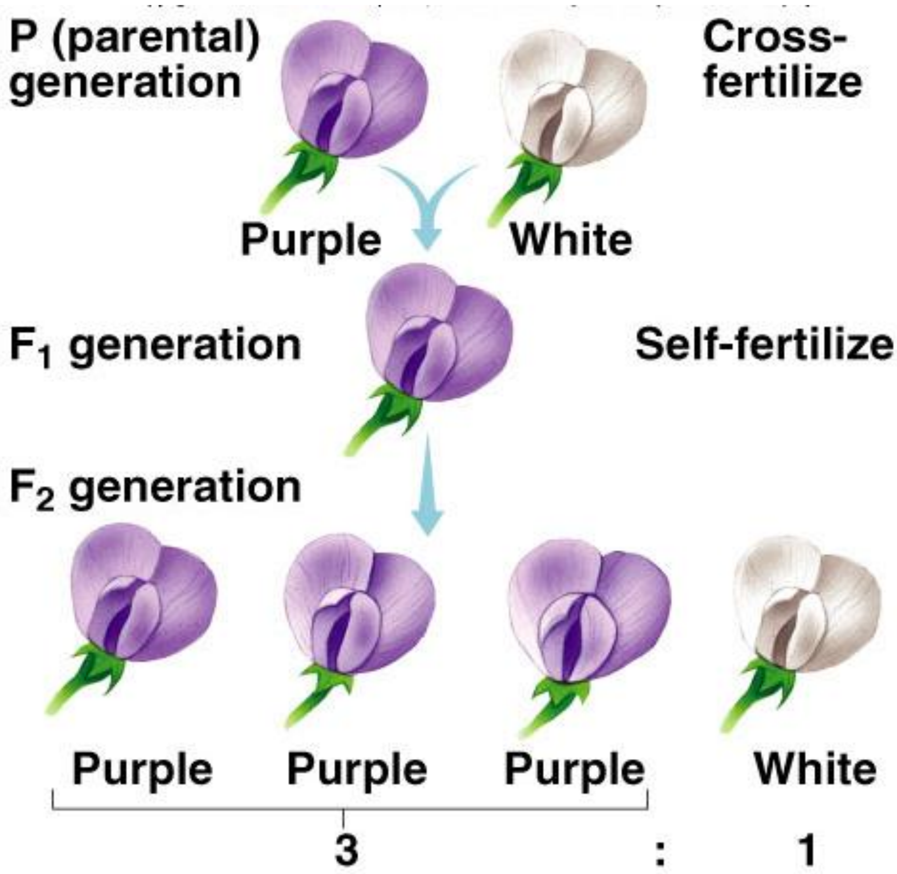


There are the three laws of inheritance

The Mendel's laws of inheritance include law of dominance, law of segregation and law of independent assortment.

Law of dominance:

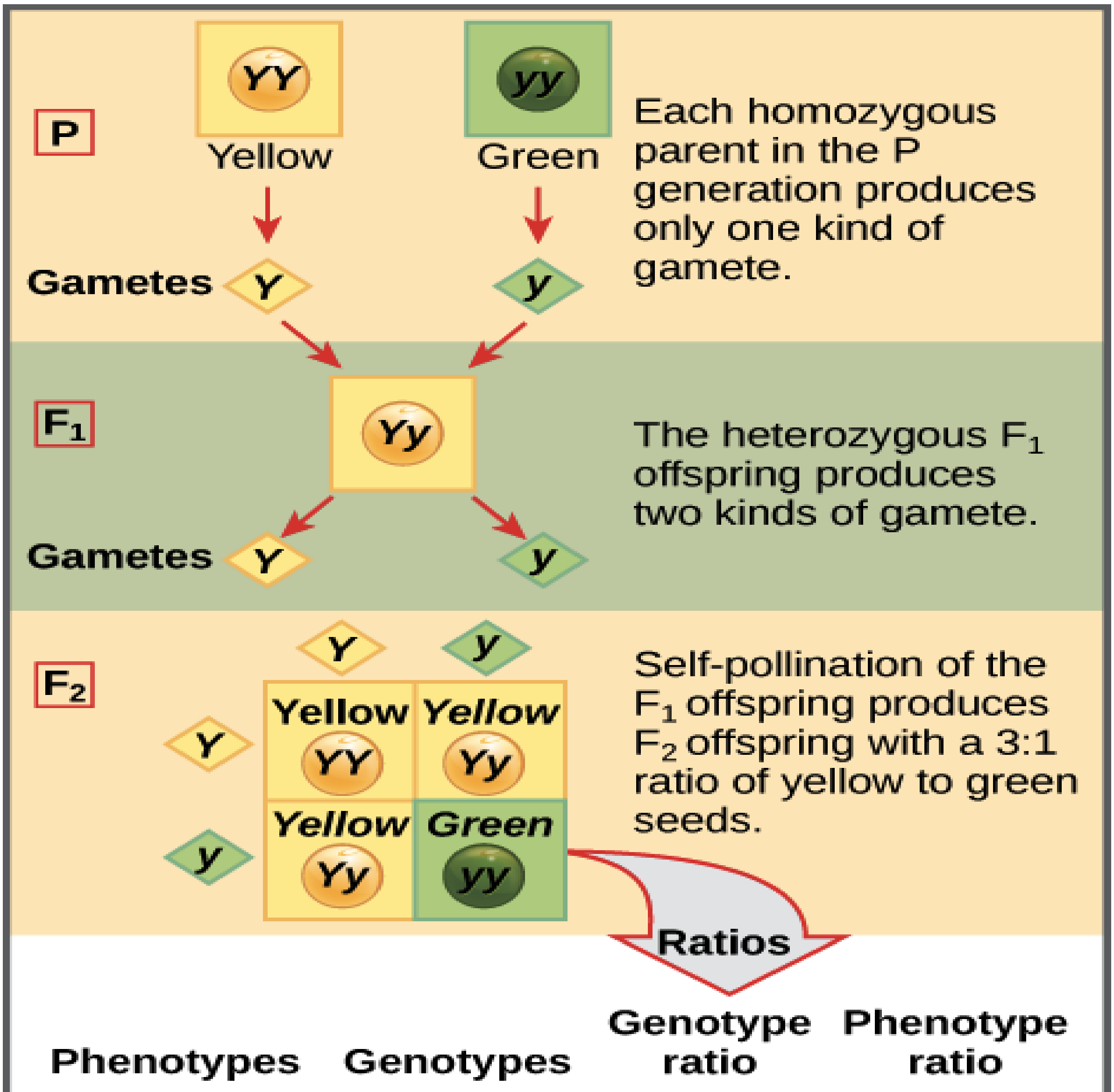
Mendel discovered that by crossing true-breeding white flower and true-breeding purple flower plants, the result was a hybrid offspring. Rather than being a mix of the two colours, the offspring was purple flowered. He then conceived the idea of heredity units, which he called “factors”, one of which is a recessive characteristic and the other dominant. Mendel said that factors, later called genes, normally occur in pairs in ordinary body cells, yet segregate during the formation of sex cells. Each member of the pair becomes part of the separate sex cell. The dominant gene, such as the purple flower in Mendel’s plants, will hide the recessive gene, the white flower. After Mendel self-fertilized the F1 generation and obtained an F2 generation with a 3:1 ratio, he correctly theorized that genes can be paired in three different ways for each trait: AA, aa, and Aa. The capital A represents the dominant factor while the lowercase a represents the recessive.



Law of segregation:

Mendel's Law of Segregation states that a diploid organism passes a randomly selected allele for a trait to its offspring, such that the offspring receives one allele from each parent.

According to the law of segregation, only one of the two gene copies present in an organism is distributed to each gamete (egg or sperm cell) that it makes, and the allocation of the gene copies is random. When an egg and a sperm join in fertilization, they form a new organism, whose genotype consists of the alleles contained in the gametes. The diagram below illustrates this idea:



Phenotypes	Genotypes	Genotype ratio	Phenotype ratio
Yellow	*YY* *Yy*	1 2	3
Green	*yy*	1	1

The four-squared box shown for the F2 generation is known as a Punnett square. To prepare a Punnett square, all possible gametes made by the parents are written along the top (for the father) and side (for the mother) of a grid. Here, since it is self-fertilization, the same plant is both mother and father.

The combinations of egg and sperm are then made in the boxes in the table, representing fertilization to make new individuals. Because each square represents an equally likely event, we can determine genotype and phenotype ratios by counting the squares.

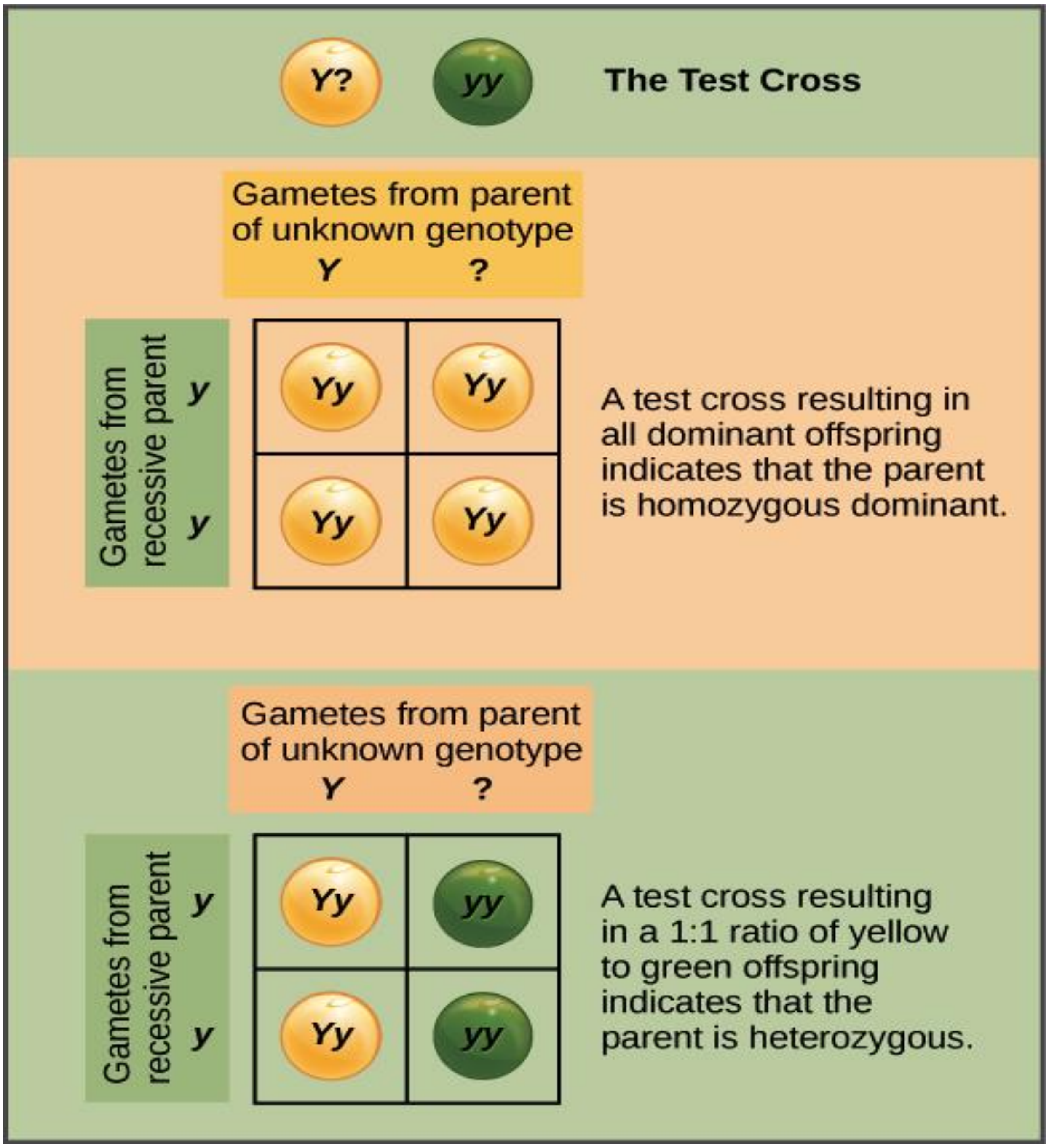
The test cross

Mendel also came up with a way to figure out whether an organism with a dominant phenotype (such as a yellow-seeded pea plant) was a heterozygote (Yy) or a homozygote (YY). This technique is called a test cross and is still used by plant and animal breeders today.

In a test cross, the organism with the dominant phenotype is crossed with an organism that is homozygous recessive (e.g., green-seeded):

If the organism with the dominant phenotype is homozygous, then all of the F1 offspring will get a dominant allele from that parent, be heterozygous, and show the dominant phenotype. If the organism with the dominant phenotype organism is instead a heterozygote, the F1offspring will be half heterozygotes (dominant phenotype) and half recessive homozygotes (recessive phenotype).

The fact that we get a 1:1 ratio in this second case is another confirmation of Mendel’s law of segregation.



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Monohybrid Cross

In this experiment, Mendel took two pea plants of opposite traits (one purple and one white) and crossed them. He found the first generation offsprings were tall and called it F1 progeny. Then he crossed F1 progeny and obtained both tall and short plants in the ratio 3:1. To know more about this experiment, visit Monohybrid Cross – Inheritance of One Gene.

Mendel even conducted this experiment with other contrasting traits like green peas vs yellow peas, round vs wrinkled, etc. In all the cases, he found that results were similar. From this, he formulated the laws of Segregation and Dominance.

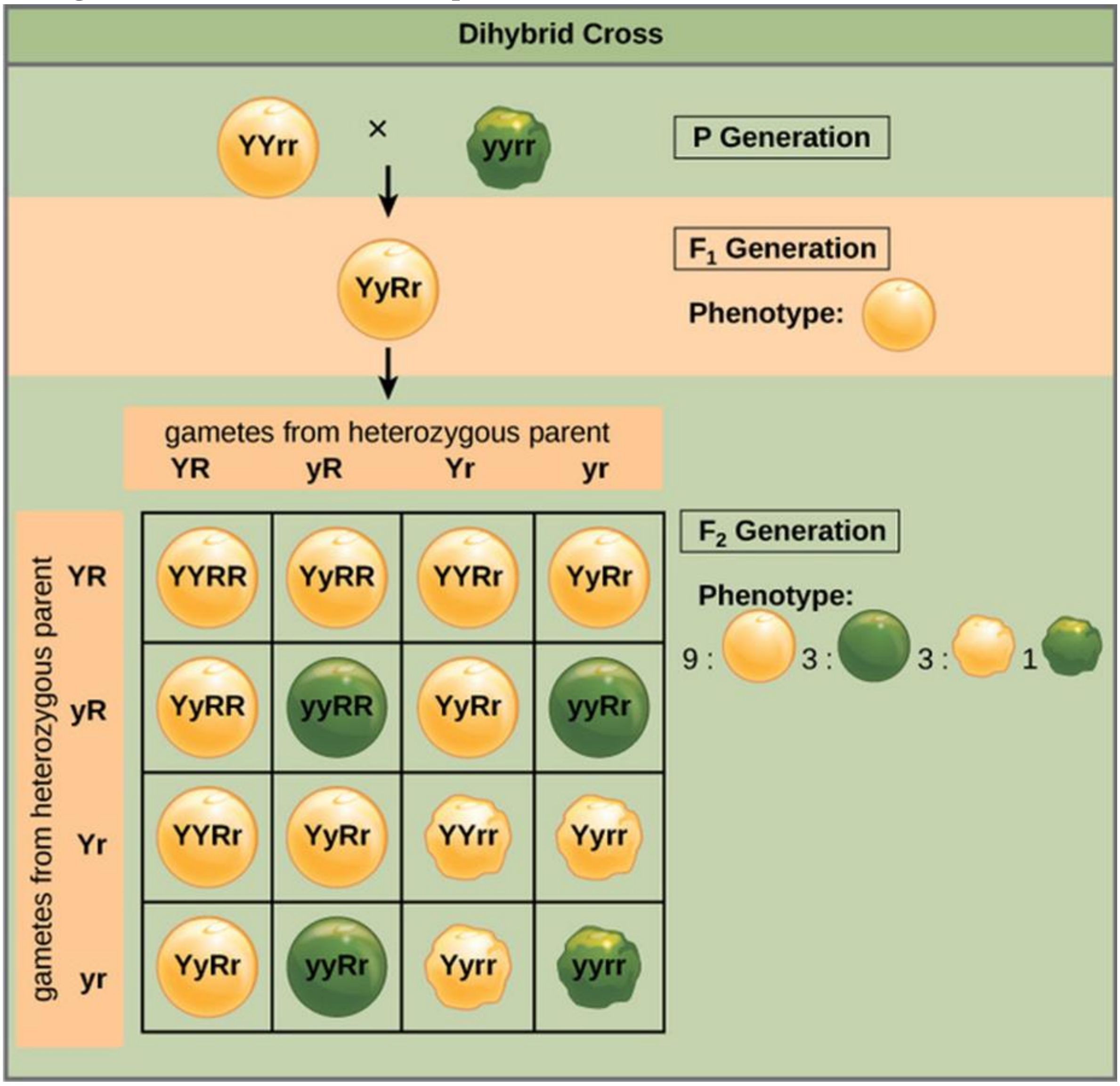
Law of independent assortment:

Separate genes for separate traits are passed independently of one another from parents to offspring

Independent assortment allows the calculation of genotypic and phenotypic ratios based on the probability of individual gene combinations.

Mendel's law of independent assortment states that genes do not influence each other with regard to the sorting of alleles into gametes: every possible combination of alleles for every gene is equally likely to occur. The independent assortment of genes can be illustrated by the dihybrid cross: a cross between two true-breeding parents that express different traits for two characteristics. Consider the characteristics of seed colour and seed texture for two pea plants: one that has green, wrinkled seeds (yyrr) and another that has yellow, round seeds (YYRR). Because each parent is homozygous, the law of segregation indicates that the gametes for the green/wrinkled plant all are yr, while the gametes for the yellow/round plant are all YR. Therefore, the F1 generation of offspring all are YyRr.

For the F2 generation, the law of segregation requires that each gamete receive either an R allele or an r allele along with either a Y allele or a y allele. The law of independent assortment states that a gamete into which an r allele sorted would be equally likely to contain either a Y allele or a y allele. Thus, there are four equally likely gametes that can be formed when the YyRr heterozygote is self-crossed as follows: YR, Yr, yR, and yr. Arranging these gametes along the top and left of a 4×4 Punnett square gives us 16 equally likely genotypic combinations. From these genotypes, we infer a phenotypic ratio of 9 round/yellow: 3 round/green:3 wrinkled/yellow:1 wrinkled/green. These are the offspring ratios we would expect, assuming we performed the crosses with a large enough sample size .



Genotype:

YYRR: YyRR: YYRr: YyRr: yyRR: yyRr: Yyrr: yyRr: yyrr

1: 2: 2: 4: 1: 2: 1: 2: 1 =16

Dihybrid Cross

Because of independent assortment and dominance, the 9:3:3:1 dihybrid phenotypic ratio can be collapsed into two 3:1 ratios, characteristic of any monohybrid cross that follows a dominant and recessive pattern. Ignoring seed colour and considering only seed texture in the above dihybrid cross, we would expect that three-quarters of the F2 generation offspring would be round and one-quarter would be wrinkled. Similarly, isolating only seed colour, we would assume that three-quarters of the F2 offspring would be yellow and one-quarter would be green. The sorting of alleles for texture and colour are independent events, so we can apply the product rule. Therefore, the proportion of round and yellow F2 offspring is expected to be $(3/4) \times (3/4) = 9/16$, and the proportion of wrinkled and green offspring is expected to be $(1/4) \times (1/4) = 1/16$. These proportions are identical to those obtained using a Punnett square. Round/green and wrinkled/yellow offspring can also be calculated using the product rule as each of these genotypes includes one dominant and one recessive phenotype. Therefore, the proportion of each is calculated as $(3/4) \times (1/4) = 3/16$.