MENDELIAN GENETICS

Mendel's experiments on the inheritance of single traits and pairs of traits, illustrated here, led him to postulate the concept of discrete, particulate units of heredity that pass unchanged from generation to generation. He studied seven traits (characteristics) of the garden pea, each of which exhibited two alternative forms. For example, pod color could be either green or yellow, and flower color could be either violet or white. As described in the main text, Mendel found that one form of each trait was dominant and the other recessive and that the progeny of controlled breedings exhibited one form or the other in definite ratios. The observed mathematical regularities led to the model of inheritance described here. Mendel knew that his plants reproduced sexually, but he did not know that chromosomes exist nor that the number of chromosomes was reduced by one-half during the formation of gametes. As a result his terminology was rather imprecise. He did not clearly distinguish the form of a trait from the units of heredity whose actions determine the trait. That distinction was made almost half a century later by Johannsen, who coined the term gene for the particulate units of heredity, the term genotype for the genes whose action determines a trait, and the term phenotype for the form of the trait determined by the genotype. The more precise terminology is used in the following description of Mendel's model and in the accompanying figures.

Mendel's model of inheritance includes four postulates.

1. Each plant contains a pair of genes for each trait; that is, the genotype for a trait is specified by a pair of genes.

2. During the formation of gametes, the gene pair for a trait segregates equally; that is, the genes in the pair are parceled out to the gametes in a fashion such that each gamete receives only one member of the pair and has an equal chance of receiving either member of the pair (the law of equal segregation).

3. A gene has two forms, or alleles, designated by, say, *A* and *a*. Only plants with the genotype *aa* (homozygous for *a*) exhibit the recessive phenotype. A plant with the genotype *AA* (homozygous for *A*) or the genotype *Aa* (heterozygous) exhibits the dominant phenotype.

4. During the formation of gametes, segregation of the gene pair for any one trait is independent of the segregation of the other gene pairs. Consequently a plant heterozygous for two traits (genotype *AaBb*) produces gametes containing *AB*, *Ab*, *aB*, and *ab* with equal probability (the law of independent assortment). Note that the law of independent assortment holds only if the genes for the different traits are on different pairs of homologous chromosomes.

Mendel's laws of equal segregation and independent assortment can be applied in two ways. If one knows the genotypes of both parents, one can predict the probability of the genotype of a future offspring. Or, working backward, if one observes in existing offspring the approximate ratios of phenotypes predicted by Mendel's laws, one can often infer the genotypes of the parents, just as Mendel did.

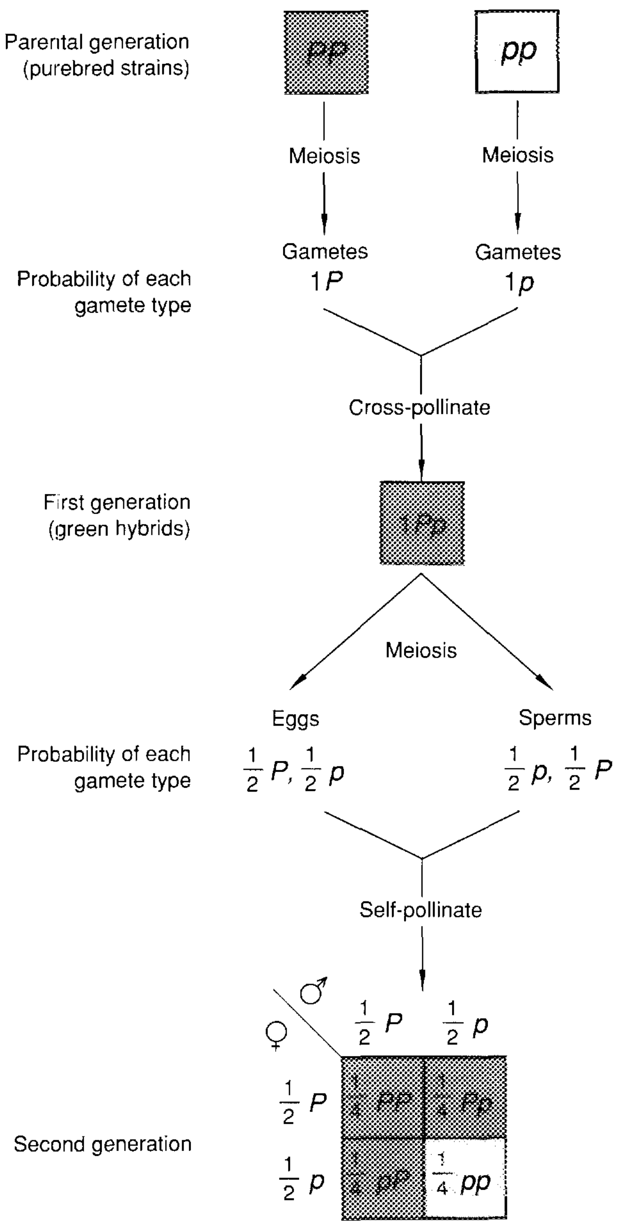
Mendel's Experiments on Inheritance of One Trait (Pod Color)

Methodology

Step 1: Cross-pollinate two strains of peas, one purebred for green pod color, the other purebred for yellow pod color. Result: All first-generation hybrids bear green pods.

Step 2: Self-pollinate the green hybrids. Result: Second-generation plants bear either green or yellow pods in the approximate ratio of 3 green to 1 yellow. Further selfing shows that half the second generation (or two-thirds of the green-podded members) are hybrids.

Theoretical Model



Mendel assumed that each plant contains a pair of genes for pod color. Therefore, each purebred parent is homozygous; that is, each contains two identical genes for pod color.

P = green-pod-color allele

p = yellow-pod-color allele

Since a fertilized egg results from the union of two gametes, each gamete contains one allele for pod color.

Because all first-generation offspring bore green pods, Mendel called green the dominant pod color and yellow the recessive pod color. Mendel inferred that whenever *P*, the allele for the dominant pod color, is present, the plant bears green pods (the law of dominance).

Mendel inferred that the pair *Pp* segregates equally into the gametes; that is, each gamete (whether egg or sperm) receives *P* or *p* with equal probability of one-half (law of equal segregation).

Random union of eggs and sperms produces four possible combinations of alleles in the offspring. As shown by the table, the probabilities of each gamete type are multiplied to yield the probabilities of the four possible genotypes in the second-generation offspring. Since *Pp* and *pP* are equivalent genotypes, the probabilities of each are added to yield a probability of one-half for the genotype *Pp*. Mendel's model predicts, for members of the second generation, phenotypes in the ratio 3 green : 1 yellow (in agreement with Mendel's observations) and genotypes in the ratio 1 *PP* : 2 *Pp* : 1 *pp*.

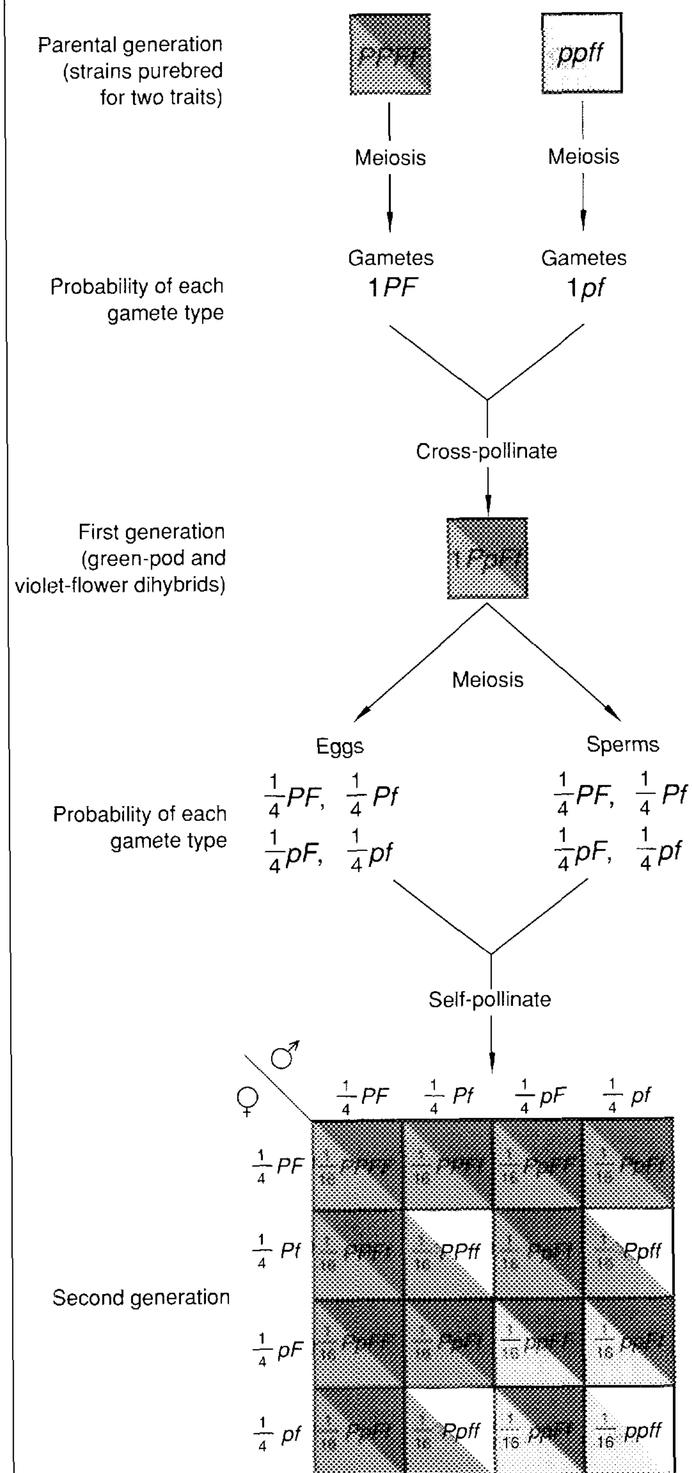
Mendel's Experiments on Inheritance of Two Traits (Pod Color and Flower Color)

Methodology

Step 1: Cross-pollinate two strains of peas, one purebred for the two dominant phenotypes (green pods and violet flowers), the other purebred for the two recessive phenotypes (yellow pods and white flowers). Result: All first-generation dihybrids bear green pods and violet flowers.

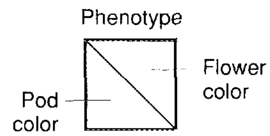
Step 2: Self-pollinate the first-generation dihybrids. Result: Second-generation plants exhibit four composite phenotypes (pod color, flower color) in the ratio of 9 (green, violet) : 3 (yellow, violet) : 3 (green, white) : 1 (yellow, white).

Theoretical Model



Each purebred parent is homozygous for both pod color and flower color.

P = green-pod-color allele
p = yellow-pod-color allele
F = violet-flower-color allele
f = white-flower-color allele



Each gamete carries only one gene for each trait.

All first-generation (dihybrid) offspring bear violet flowers and green pods, the dominant phenotypes, in agreement with the law of dominance.

Independent equal segregation of each allele pair (*Pp* and *Ff*) produces gametes containing one of four equally probable combinations of alleles (law of independent assortment).

Random union of eggs and sperms produces offspring containing one of sixteen equally probable combinations of alleles. All are equally probable because all gamete types are equally probable. The sixteen combinations reduce to nine different genotypes and four different composite phenotypes, which are predicted from the probability table to occur in the ratio 9:3:3:1 in agreement with Mendel's observations.