62 GENE SYMBOLS

To explain the results of his experiments, Mendel proposed certain hypotheses. First, hereditary traits must be passed from one generation to the next as discrete units, rather than by some variable sort of blending. (Mendel called those units elements, but to avoid confusing them with chemical elements they are known today as genes.) Second, each individual plant must have a pair of these genes for each characteristic, one of them received from each parent. Third, when an individual has two conflicting genes, one dominates the other. (There are exceptions to this, but not among the traits Mendel studied.)

To illustrate how the experimental results could be produced, Mendel symbolized dominant genes with capital letters, such as "A," and recessive genes with small letters, such as "a." Modern biologists do the same, but they generally use the first letter of the recessive trait, such as the "w" for white flower in this plate.

Color titles A through B[1]. Use light purple for A and the color used for white on the previous plates for B. Color the headings P_1 Phenotypes and P_1 Genotypes and the associated illustrations.

The term "phenotype" is used to designate the observable or detectable traits of an organism being studied, as opposed to its "genotype," which is the set of genes that produced that phenotype. In this case, one plant had the phenotype of *purple flowers* while the other one had the phenotype of *white flowers.* (Be aware, however, that phenotype is really the result of both the genotype and the environment. Flower color is not easily influenced by the environment, but many traits are.)

Since Mendel made certain that the plants he started with were pure-breeding for their respective traits, each of the P_1 plants must have had two *genes* of the same kind. Today we would say they are "homozygous" (Greek: *homo,* "same"; *zygos,* "yoked" or "joined"). One is homozygous dominant (WW), while the other is homozygous recessive (ww).

Color the heading P_1 Gametes, titles C and D, and the associated illustration.

This section illustrates the fourth hypothesis Mendel made to explain his results: in the formation of pollen and ovules (today known collectively as *gametes*), the genes of each pair *"segregate"* into different gametes so that any gamete has only one gene of each pair. This fourth hypothesis is known as "Mendel's first law" or the "law of segregation." We see that because of segregation, each gamete of the homozygous purple-flowered plant has only one gene for flower color (purple), and each gamete of the homozygous white-flowered plant has only one gene for flower color (white).

Color the headings F_1 Phenotype and F_1 Genotype, title E, and the associated illustrations.

When two gametes fuse to form a new individual, the genes will be in pairs once again and will remain so as cell division occurs again and again to produce the mature plant. Here we see that *cross-pollination* of these particular plants results in F_1 individuals that all have the genotype "Ww"; that is, they all have one gene for purple flowers and one gene for white flowers. Such individuals are said to be "heterozygous" (Greek: *hetero,* "other"). Since purple is dominant over white, all of them will produce only purple flowers.

Color the remainder of the plate as you come to each part in the discussion.

When the heterozygous F_1 individuals produce gametes, the paired genes once again segregate so that each gamete contains only one gene of the pair. Half of the gametes will contain a gene for the dominant trait (W), and half will contain a gene for the recessive trait (w). When the F_1 plants are allowed to self-pollinate, four combinations are possible. The most error-free way of keeping track of these combinations is by means of a "Punnett square," named after its inventor, Reginald Punnett, an eminent British geneticist of the early 1900s. The gametes of one parent are listed along the top margin and the gametes of the other along the side margin. Then each possible combination of one gamete from each parent is written in the square where the appropriate column and row intersect. These combinations of genes are the genotypes of the F_2 generation. Since there are two different ways of getting one gene of each kind, half of the F_2 plants are heterozygous. One-fourth of them are homozygous dominant, and one-fourth are homozygous recessive. If you toss two coins 100 times and keep track of the resulting combinations of heads and tails, you will get approximately the same 1:2:1 ratio. With peas, however, purple is dominant over white, so the *phenotypic ratio* is three purple to one white.

GENE SYMBOLS.

PURPLE FLOWER A
PURPLE GENE (DOMINANT) A'
WHITE FLOWER B
WHITE GENE (RECESSIVE) B'

SEGREGATION C
GAMETE D
CROSS-POLLINATION E

P₁ PHENOTYPES ★

P₁ GENOTYPES ★

P₁ GAMETES ★

F₁ PHENOTYPE ★

F₁ GAMETES ★

PUNNETT SQUARE ★
(F₂ GENOTYPES) ★

F₂ PHENOTYPIC RATIO F

3:1