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unit 18. basic principles of heredity

ACTIVITY 18-1. MENDELIAN GENETICS

Many of the basic concepts of heredity were worked out in the mid-1800s by the Austrian monk Gregor Mendel (1822-1884). Mendel cultivated garden peas, which he used to study plant inheritance. From these experiments, Mendel concluded that each hereditary trait is controlled by two separate factors, one from each parent, and that these factors are passed on unchanged from generation to generation. Mendel knew nothing of chromosomes or genes. However, what he called "factors" are now known to be genes, which are found on the chromosomes.

Mendel was very careful in his studies to use plants that "bred true"—that is, plants that showed the same traits generation after generation. Also, he studied only seven different traits, and there were two contrasting forms for each trait.

LAW OF DOMINANCE

When Mendel crossed two true-breeding pea plants that showed one pair of contrasting traits, only one of these traits was evident in the resulting offspring. For example, if he crossed a tall plant and a short plant, all offspring were tall. The trait that was expressed was described as *dominant*, while the trait that did not show in the offspring was *recessive*. Of the pairs of contrasting traits that Mendel studied, he found that in each case one trait proved dominant. Tall stems were dominant, short stems recessive; round seeds were dominant, wrinkled seeds, recessive, etc. Mendel concluded that of every pair of contrasting traits, one is dominant and the other recessive.

The pure-breeding parent generation is called the P generation. The offspring of the crosses between members of the P generation are called the first filial, or F_1, generation. Crosses between members of the F_1 generation produce the second filial, or F_2, generation, and so on. In Mendel's experiments members of the F_1 generation were *hybrids*—they were the offspring of unlike parents.

Questions

1. In Mendel's experiments, he crossed pea plants with green pods with plants with yellow pods. He found that all the offspring had green pods.
   a. The plants used in the original cross are members of the _____ generation.
   b. The offspring of the cross make up the _____ filial, or _____, generation.
   c. The pod color that is dominant is _____, while the pod color that is recessive is _____.
2. What is a hybrid?

LAW OF SEGREGATION

In another experiment, Mendel allowed the hybrid members of the F_1 generation to undergo self-fertilization. The offspring of this cross were the F_2 generation. Of the F_2 generation, three-fourths showed the dominant trait and one-fourth showed the recessive trait. This showed that although members of the F_1 generation all showed the dominant trait, these plants also carried the recessive factor (gene), and that this factor was passed on to the F_2 generation. These results led Mendel to the conclusion that each trait is controlled by a pair of factors, one from each parent. (The F_1 hybrids obviously carried the dominant factor of one parent and the recessive factor of the other parent.) This is Mendel's law of segregation.

Since the gametes fuse in fertilization, each gamete must carry only one of the factors, and the zygote formed by the fusion of the two gametes then carries two, one from each parent. In the formation of gametes, the two factors must separate, or *segregate*. Each gamete receives one factor for each trait. The dominant trait is expressed whenever the dominant factor (gene) for that trait is present. For example, in the experiments on stem length, all members of the F_1 hybrid generation were tall. Only an organism posessing two recessive factors for a given trait will show the recessive trait.

An individual with two dominant or two recessive genes is said to be *homozygous*, while the hybrid, with one dominant and one recessive gene, is *heterozygous*. The dominant trait is shown by two capital letters (TT for tallness, for example), and the recessive by two lower case letters (tt for shortness). The homozygous dominant is TT, the homozygous recessive is tt, and the hybrid is Tt.

Questions

1. What is Mendel's law of segregation?

2. In the pea plants studied by Mendel, how many factors controlled a given trait?

   _____

3. Use G for green pods (dominant) and g for yellow pods (recessive).
   a. A pea plant that is homozygous dominant for green pods would be shown as _____.
   b. A pea plant that is heterozygous for green pods would be shown as _____.
   c. A pea plant that is homozygous recessive for yellow pods would be shown as _____.

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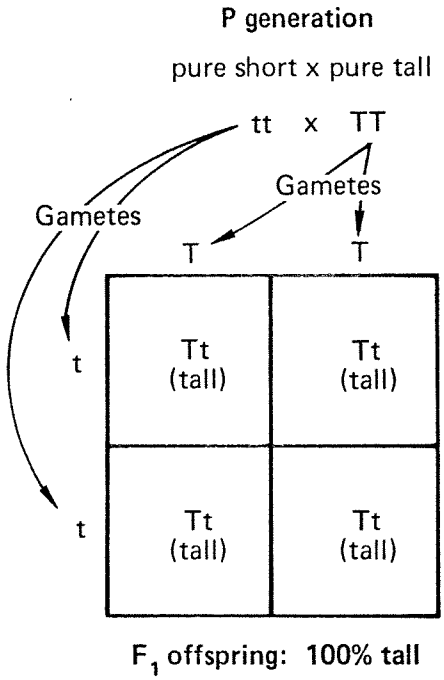
PUNNETT SQUARES

The Punnett square is a convenient method for visualizing genetic crosses. The boxes that make up the square show all possible zygotes resulting from a cross of gametes bearing a specific trait. The letters representing each possible type of sperm are placed along the top of the square, and those for each possible type of egg along the side. For example, in a pea plant that was heterozygous for stem length (Tt), half the gametes would receive the dominant factor for stem length (T) and half would receive the recessive (t). Thus, the plant would produce two types of gametes. A plant that was pure dominant (TT) or pure recessive (tt) would produce only one type of gamete—T or t respectively.

A cross between a homozygous tall plant (TT) and a homozygous short plant (tt) is shown below.



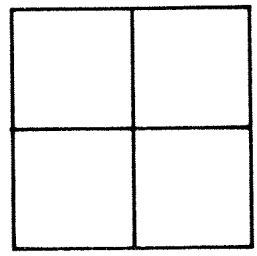
F_1 offspring: 100% tall

The F_1 generation is all heterozygous tall. The physical appearance of an individual is called the *phenotype*. Thus, the phenotype of all members of the F_1 generation is tall. The *genotype*, on the other hand, is the genetic makeup of the individual. In this case all members of the F_1 generation have a heterozygous, or hybrid, genotype. The genotypes of the P generation were homozygous dominant and homozygous recessive.

Questions

1. The physical appearance of an individual is its _____, while the genetic makeup of an individual is its _____.

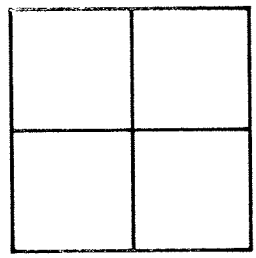
2. Use a Punnett square to show the offspring of a cross between two pea plants that are heterozygous for stem length (Tt × Tt). Give the phenotypes and genotypes of the offspring.



Phenotypes: _____

Genotypes: _____

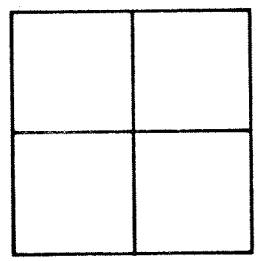
3. Use a Punnett square to show the offspring of a cross between a pea plant that is homozygous tall (TT) and one that is heterozygous (Tt). Give the phenotypes and genotypes of the offspring.



Phenotypes: _____

Genotypes: _____

4. Use a Punnett square to show the offspring of a cross between a pea plant that is heterozygous tall and one that is homozygous recessive for stem length. Give the phenotypes and genotypes of the offspring.



Phenotypes: _____

Genotypes: _____

LAW OF INDEPENDENT ASSORTMENT

Following his crosses of plants with one pair of contrasting traits, Mendel did crosses of plants that showed two pairs of contrasting traits. Such a cross might involve a plant with long stems and round seeds (both dominant) and one with short stems and wrinkled seeds (both recessive). The first plant could be represented as TTRR, the second as ttrr. Each plant would produce only one type of gamete—one would be TR and the other tr. All offspring of the cross would be hybrids with long stems and round seeds (TtRr).

To find out whether there was any relationship between the two traits—for example, whether the dominant traits segregated together—Mendel allowed the hybrid plants to undergo self-fertilization. This is a *dihybrid*

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cross, a cross involving organisms that are hybrid for two traits. The results of such a cross showed that the factors (genes) for each trait were segregated independently of any others in the course of gamete formation. This is Mendel's law of independent assortment. It has since been found that there are exceptions to this law.

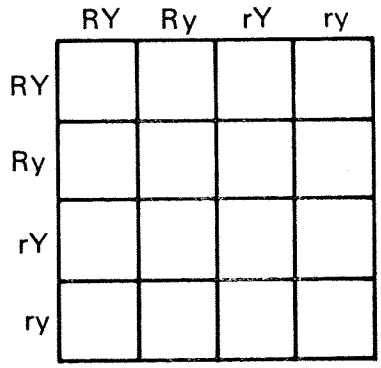
Questions

1. What is Mendel's law of independent assortment?

2. Work out the following dihybrid cross. Round seeds are dominant over wrinkled seeds, and yellow seeds are dominant over green seeds. A plant that is hybrid for both traits (RrYy) is allowed to undergo self-fertilization (RrYy × RrYy).

   a. The four types of gametes formed are _____,
   _____, _____, and _____.

   b. Fill in the Punnett square below. Give the phenotypes of the offspring of this cross and the percentage of each phenotype produced.



3. In the dihybrids that Mendel worked with, the genes for the individual traits were located on separate chromosomes. If the genes for two or more of these traits had been located on the same chromosome, would Mendel have developed his law of independent assortment?

4. Using the Punnett squares below, work out the following crosses.
   a. TTYY × TtYy b. rrYy × RRyy