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REVIEW

Gregor Mendel and the Seven Genes (2)

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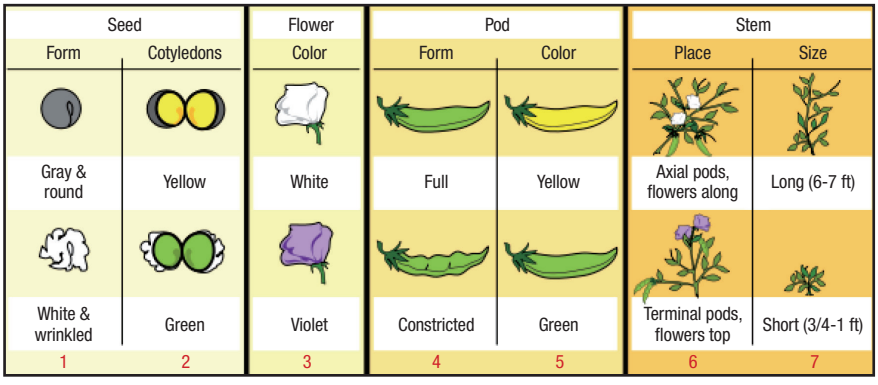
SYNOPSIS

Unlike the traditional view, it is not mysterious about how G. Mendel chose the seven characters of the pea, *Pisum sativum*, that he studied. He first chose the pea that met three conditions he set up and repeated experiments for two years. Apparently, he knew that those characters were controlled by countable elements. Then, he derived the prediction on the basis of his idea about the elements, and selected the seven characters that satisfied the prediction. He knew "no prediction no science".

In population genetics the Hardy-Weinberg principle is well known and cited in many papers and books. However, Mendel already derived the same principle in his paper, because he was acquainted also with physics and mathematics. Actually, the principle was trivial when they derived, but not at all when Mendel did. It is also well known that Mendel's laws were forgotten and rediscovered at the term of the 19th century. That may not be true either. His laws were internationally well known before the rediscovery. In fact, the 1881-year version of the Encyclopedia Britannica contains his laws.



Key Words: *Pisum sativum*; seven characters; law of segregation; law of independent assortment; Hardy-Weinberg principle

Around in 1857 G. Mendel began the experiment by using *Pisum sativum* (pea), which led him to publish his one and only paper "Experiment in Plant Hybridisation" in 1865[1]. He was very careful for choosing the pea as his experimental material. He previously spent two years to choose it among 34 or so varieties of peas under the conditions he set up, as follows;

1. To have constant differentiating characters over generations.
2. The hybrids of such a plant must be protected from the foreign pollens and thus easily capable of the protection against them.
3. The generation time of the plant should be short enough to make it possible to perform the experiment for generations.

For the second condition, he had a greenhouse on the premise of the Monastery which was offered by a prominent scholar who regarded Mendel's scientific work as high. In the greenhouse he cultivated 29,000 plants of *Pisum sativum* in total. He knew from statistics that the more samples, the more accurate estimates he could obtain.

For the (genetic) characters he mentioned that if two plants differ in characters, common characters were transmitted unchanged, while each pair of differentiating characters united in the hybrid to form a new character, which in the progeny was variable1. Therefore, he determined his experimental object to observe theses variations in each pair of differentiating characters, and *to deduce the law* by which they appear in the successive generations. He then chose 15 characters of the pea that seemed to meet the object. However, some of them did not show *a clear-cut separation* in the hybrid offspring. Excluding those characters he finally chose the well - known seven characters, 1) the form of the ripe seed, 2) color of the seed albumen, 3) color of the seed coat, 4) form of the ripe pods, 5) color of unripe coat, 6) positions of the flowers, and 7) length of the stem[1].

It may be mysterious about how Mendel chose the seven characters. In those days there was absolutely no concept of gene, not mention to chromosome. Now, we know that the pea has seven chromosomes (2n = 14), and that each of the seven characters is located in each of the seven chromosomes. In retrospect, those were the reasons why Mendel observed the clear-cut separations of the seven characters in the hybrid offspring. – I speculate that he had a prediction before choosing the seven characters, because he was also a theoretician. The prediction, I think, was that a character was controlled by a countable element. – He then chose the seven characters that satisfied the prediction. It is true that a scientific research starts with a prediction. No prediction, no science. Mendel was a scientist, as W. Whewell (1794-1866) coined it in 1840. In biology he is perhaps only one scientist with "originality". In physics Michael Faraday (1791-1867) may be the one.

Going back to his paper, what he observed for the seven characters in ten plants was as follows (see the Figure 1):

1. Form of seed; among 437 seeds, 336 were round and 101 were angular, resulting in the proportion of 3.3 : 1,
2. Color of albumen; among 478 albumens, 355 were yellow, and 123 were green, resulting in the proportion of 2.9 : 1,
3. Color of seed coat; among 929 coats, 705 were grey-brown, and 224 were white, resulting in the proportion of 3.1 : 1,
4. Form of pod; among 1,181 pods, 882 were inflated, and 299 were constricted, resulting in the proportion of 2.9 : 1,
5. Color of unripe pod; among 580 pods, 428 were green, and 152 were yellow, resulting in the proportion of 2.8 : 1,
6. Position of flowers; among 858 flowers, 651 were axial, and

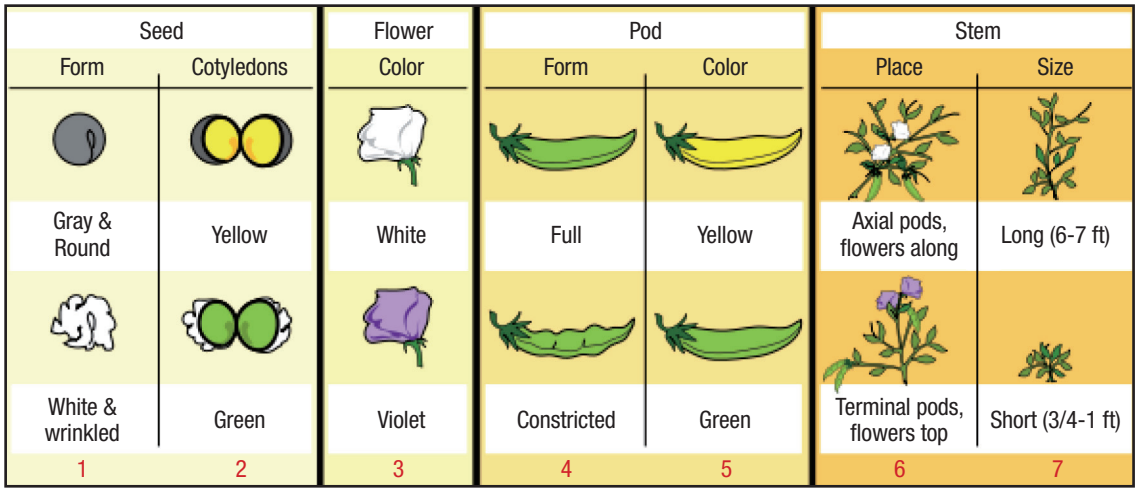


Figure 1. The characters Mendel finally chose for his experiment.

201 were terminal, resulting in the proportion of 3.2 : 1,

7. Length of stem; among 1064 stems, 789 were long, and 277 were short, resulting in the proportion of 2.8 : 1. In 1997, the gene (*Le*) responsible for the stem length was discovered by D. R. Lester and the colleagues. They found that *Le* encoded gibberellin 3B-hydroxylase which *grew* the pea stem regularly. When *Le* was mutated to *le -3, le, le*^{d} by nucleotide deletions or changes, the three mutant alleles no longer functioned normally, and made the stem length shorter than the normal, as a result[2].

From the results above, Mendel deduced on the statistical view point that the *average* proportion for each character was 3 : 1. He called the proportion the *dominant* and *recessive* ratio. The results clearly showed that each character was separated and united and inherited independently of the others. He thus proposed *the law of segregation* and *law of independent assortment*. We now know that the inheritance in unit of a chromosome follows the two laws except for recombination.

To explain his results, Mendel then used the following algebra. Suppose a hybrid male parent had a dominant character (A) and recessive one (a), and so did a hybrid female parent, the characters of their progeny were expressed as,

$$(A+a)(A+a) = A^2+2Aa+a^2,$$

in which the left hand term showed the characters of the both parents, and the right term showed the characters of progeny individuals[1]. The first group of the progeny individuals had $A+A$ characters, the second one had $A+a$ characters, and the third group had $a+a$ character. In the formula, if A was dominant over a, A^2 (AA) and Aa showed the phenotype of A, while a^2 (aa) showed that of a. The ratio of dominance to recessive was thus 3 : 1. That was his theoretical background for interpreting the results.

Incidentally, in 1908 G. H. Hardy (English) and W. Weinberg (German) independently proposed laws that were copies of Mendel's formula mentioned above. In population genetics, their laws are collectively called the Hardy - Weinberg law, and cited even now. In my opinion, however, the law is trivial and not worthy being cited in a paper or else. They apparently did not read Mendel's paper, or ignored it. The formula should instead be called Mendel's formula of hybridization or the like. In Mendel's days the formula was not trivial at all.

In 1884 G. Mendel passed away at the age of 64 or so in Brno. If Mendel lived longer, he could be the winner of the Nobel Prize. Well, that is just a grumbling remark. Many people do not know the first winner of the Nobel Prize of Physiology or Medicine, but they do know Gregor Mendel.

It is well known that Mendel's work was forgotten and rediscovered in 1900 by the three scholars. That may not be true. His work was already known in Europe, Russia and USA, before the rediscovery. For example, in 1892 H. Bailey in USA published the book, "Cross Breeding and Hybridizing", in which he cited Mendel's work. In addition, the Encyclopedia Britannica contained Mendel's law in the 1881 version. We should not believe anything until we read and understand it in the original paper or book. Once, A. Einstein said " Unthinking respect for authority is the greatest enemy of truth."[3]

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