Medal by V. A. Kovanic for the Czechoslovakian Academy of Sciences.

Mendel's Peas: A Matter of Genius or of Guile?

By JULIE ANN MILLER

Whether the plan upon which the separate experiments were conducted and carried out was the best suited to attain the desired end is left to the friendly decision of the reader.

Gregor Mendel, "Experiments in Plant Hybridization," 1865.

A U.S. geneticist recently touring China was approached by a local student. The student asked whether the geneticist had heard of a British statistician named Fisher and of a paper demonstrating that Mendel's experimental results were too good to be true. The geneticist replied, yes, the paper was well-known. The student inquired, then why hadn't Mendel's name been expunged from the textbooks and historical references to his work erased?

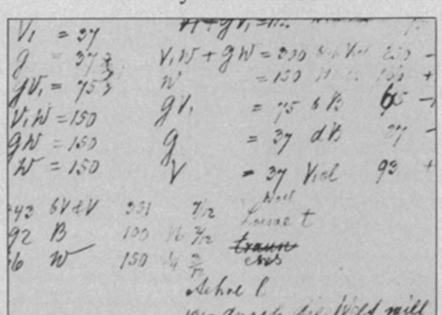
While Gregor Mendel remains indelibly inscribed in the history of modern genetics, Fisher's accusation tarnishes the sterling image of the monk who, raising peas in his monastery garden, arrived at what are now considered to be the basic laws of inheritance. Nobody challenges the validity and importance of the theory he proposed. But for half a century statisticians, geneticists and historians have been arguing about the veracity of the data he published to support it.

Chances are only about one in 30,000 that a patch of peas would yield results as favorable to Mendel's theory as those Mendel reported, Sir Ronald Fisher wrote in 1936. He concluded that Mendel's observations were "biased strongly," and wrote elsewhere, "The data have been falsified."

In the years since Fisher's statistical challenge, Mendel's work has been accused and defended on various levels: Mendel might have been fraudulent. His gardener may have doctored the data to please the monk. Mendel might have stopped short of counting all his peas. He might have been just plain lucky. Fisher's statistical analysis might be wrong.

There has been plenty of room for argument because almost all of Mendel's laboratory notebooks were burned around the time of his death in 1884. His theory had been published in an obscure journal in 1865 and was little noticed until 1900 when three botanists each independently rediscovered those same laws of inheritance. So nobody can precisely reconstruct Mendel's methods of counting peas and working with that data.

Mendel had set out to find a generally applicable law governing the formation and development of plant hybrids. His novel ideas may have arisen from his study of statistics. He succeeded in showing that parent peas contribute to their offspring discrete factors (which are now called genes) that retain their individuality from generation to generation. For a given characteristic, each parent contains a pair of these factors but passes on to the offspring only one factor, selected randomly from the pair. Mendel believed these rules to be applicable only to a small number of characteristics in peas.



Notes by Mendel show that he tried several groupings of pea coat colors in order to reach the ratios he expected from the experiment. (Mendel-Notizblatt, reproduced by courtesy of the Great Mendel Department of Genetics, Moravian Museum, Brno)

A recent paper, which its author says exonerates Mendel from charges of fraudulence, proposes a simple explanation for the theory-fitting experimental results. The classification of peas, for example, by shape and color fits a concept now popular in mathematics — fuzzy sets. Biological characteristics do not fall into the discrete categories that statisticians employ. Some seeds are smooth, and some clearly wrinkled, but what about those with only a few dimples? They are the key to the problem of Mendel's data, says Robert S. Root-Bernstein, a biochemist, also trained in the history of science, who is exploring how people invent scientific theories. He is working at the Salk Institute in San Diego under a MacArthur Foundation fellowship.

Root-Bernstein asked 50 undergraduate biology students to count purple or yellow, wrinkled or smooth, kernels of maize from genetic experiments. He found that 6 percent of the kernels were classified as "indeterminant." He cites a 1911 study in which fifteen trained geneticists were asked to analyze 532 yellow or white, starchy or sweet, maize kernels. That study reported, "No two of the fifteen highly trained and competent observers agreed as to the distribution of these 532 kernels."

"What in fact Mendel published was not a 'real' description of his peas, but his *perception* of how those peas could be categorized into 'ideal', discrete groups," Root-Bernstein says in HISTORY OF SCIENCE (Vol. 21, p. 275, 1983). "... no one else would have reported exactly the same data even had they counted exactly the same peas as Mendel."

Root-Bernstein proposes that Mendel counted his peas and then reassigned the "indeterminant" peas to the "ideal" categories in a way that maximized agreement with the ratios expected from the theory. "In short, I am proposing that Mendel used a subjective, theory-directed counting procedure to accommodate a statistically significant group of 'difficult to classify' peas and plants," Root-Bernstein says.

Mendel apparently recognized the arbitrary nature of his imposition of discrete categories on nature and was willing to revise them to fit theory, Root-Bernstein says. In a fragmentary document known as the "Mendel-Notizblatt," Mendel considered the inheritance of seed coat color in a pea breeding experiment. Initially Mendel hypothesized six categories: white, violet, light violet, dark brown, light brown and violet-brown. The results of the experiment agreed poorly with his theory. He then tried combining light-violet and violet. Again there were poor results. Finally he consolidated his categories into only white, violet and brown, and thus established the most advantageous boundary lines between the colors.

"It must therefore be admitted that he was fully conscious of the 'bias' he employed in manipulating and interpreting his results in terms of his theoretical expectations," Root-Bernstein says. "My point is that there is subjectivity in the process of inventing categories for comprehending nature and there is subjectivity in the process of assigning objects to these categories."

"Does that make him guilty of the charge of fraudulence?" Root-Bernstein asks."I believe not."

Geneticist James F. Crow of the University of Wisconsin in Madison comments, "I think [Root-Bernstein's explanation] is very reasonable. That explanation comes pretty close to what I think most biologists think."

Although that manner of classifying data would not be acceptable in a laboratory today, Mendel didn't have available a modern understanding of statistics. In addition, Crow says, he believes Mendel considered his publication a "demonstration" of his theory as much as a report of individual experiments.

The matter of Mendel's pea data is only part of a larger problem of distinguishing inspired scientific insight from fraud. Recent analyses, such as *Betrayers of the Truth* by William Broad and Nicholas Wade (Simon and Schuster, 1983), put the questionable data of such scientists of the past on a continuum with the deceit of some more recent scientists who faked experiments, invented data or plagiarized papers to further their own careers (SN: 5/23/81, p. 331; 9/12/81, p. 165; 4/30/83, p. 279).

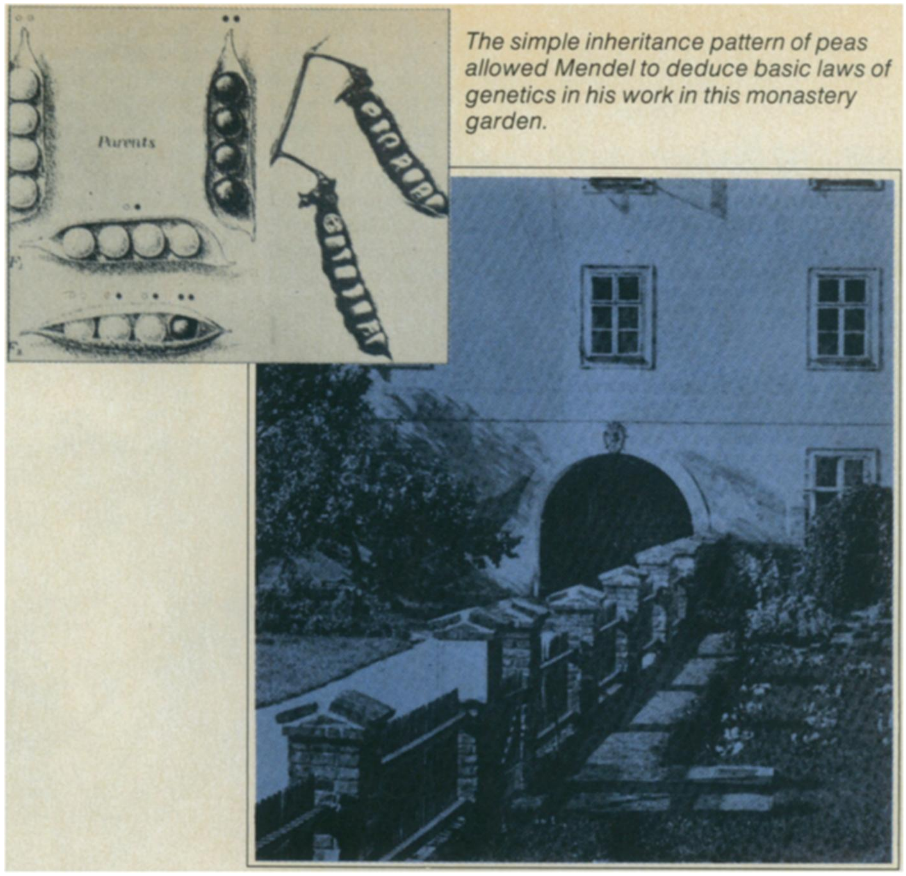
But Root-Bernstein charges that some of those who criticize past scientists for the creative selection of the data they published have little understanding of how competent scientists operate. "Scientists always do a bunch of preliminary experiments they don't report, then publish the experiment that gives the best possible result," he says.

A Canadian chemist who is focusing his attention on replicating historical experiments agrees. "Selection of data is not fraud unless it is done with the deliberate attempt to deceive someone," says Mel Usselman of the University of Western Ontario in London, Canada. "Mendel was a committed amateur. He did not have the motivation for fraud that modern scientists have with their careers at stake."

In fact Usselman sees selection of data as an aspect of scientific brilliance, rather than a form of deceit. "The difference between the great scientists and the average researcher is the flashes of insight, seeing in scattered data something with theoretical appeal," he says. "Scientists can't just open the book of nature and expect a single experiment to give a clear answer. The real problem in science is separating what is useful from what is not. Selection and interpretation are what makes a scientist great."

Some of the questionable practices of scientists of the past also may be found, for better or for worse, among those who would evaluate them. Are the historians of science who set out to find fraud biased in how they examine the records and fuzzy in their interpretations?

"Indeed, careful *interpretation* of [Fisher's statistical] test itself reveals that the test is not objective, for the *interpretation* involves use of a 'fuzzy' set of linguistic concepts such as 'too good' and 'suspicious' that cannot be objectively or unambiguously defined," Root-Bernstein says. "Attempts to make a normative judgment of the validity of Mendel's results therefore seem to me misguided." □



The simple inheritance pattern of peas allowed Mendel to deduce basic laws of genetics in his work in this monastery garden.

Austrian Press and Information Service, New York

Mendel's Results of Crossing Hybrid Peas

	Dominant Trait	Recessive Trait	Ratio
Form of seed	5474 round	1850 wrinkled	2.96 to 1
Color of albumen	6022 yellow	2001 green	3.01 to 1
Color of seed coats	705 gray-brown	224 white	3.15 to 1
Form of pods	882 inflated	299 constricted	2.95 to 1
Color of unripe pods	428 green	152 yellow	2.82 to 1
Position of flowers	651 axial	207 terminal	3.14 to 1
Length of stem	787 long	277 short	2.84 to 1
Average			2.98 to 1
Conclusion			3 to 1

Both dominant and recessive characteristics show up among offspring of hybrid peas and this "occurs in the definitely expressed average proportion of three to one," Mendel reported in 1865. The data he presented have since generated intense controversy.