

# This Week's Citation Classic

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Henderson C R. Estimation of variance and covariance components.  
*Biometrics* 9:226-52, 1953. [Cornell University, Ithaca, NY]

**Three methods for estimating variances from data with unequal subclass numbers are described and illustrated. Methods 1, 2, and 3 are suited to random models, mixed models with no interactions nor nesting of fixed within random factors, and any mixed model respectively. [The SC<sup>i</sup>® indicates that this paper has been cited over 185 times since 1961.]**

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"This paper resulted from methods which I developed as a graduate student at Iowa State University to estimate variances for general, maternal, and specific combining abilities in crosses among inbred lines. These data were from a mixed model with missing subclasses. Most previous work on estimation of variances with unequal numbers dealt only with nested designs and random factors. The design of my experiment resulted in a mixed model with cross-classified factors. The method I used was called Method 3 in my paper in *Biometrics*. I also described Method 1 in my thesis.

"I joined the staff of the department of animal science at Cornell in 1948 where many records of production of cows produced by artificial insemination had accumulated. These posed a more difficult problem of unequal numbers than the analysis of my thesis. I used Method 1 to estimate the magnitude of several sources of variation. I am puzzled now as to why I did not publish my methods immediately, but

perhaps the pressures of developing a research and graduate training program in the rapidly expanding field of animal breeding took precedence. Meanwhile research workers in animal breeding learned of my methods and started to use them extensively. In 1952 I was invited by Gertrude Cox to discuss estimation of variances at the North Carolina Summer Statistics Conference. Method 2, developed at Cornell, was described in addition to those in my thesis. I was pleased to find that Fisher and Yates, who were in attendance, listened with interest and made several pertinent comments. When I expressed doubts about the computational feasibility of Method 3, Fisher stated that this should be no problem in the US with our powerful computers. At that time I had available only an IBM 602A calculating punch, hardly a powerful computer!

"Following the meeting at North Carolina, Miss Cox asked me to publish my results in *Biometrics* of which she was then editor. I was astonished at the number of requests for reprints and our supply was soon exhausted. For many years thereafter we substituted copies of the manuscript that had been distributed at the meeting.

"I think that this paper has been so widely cited because it filled a real need in fields of research involving survey data and also because good numerical examples were presented. A resurgence of interest occurred following a review of my work presented by Shayle Searle at the 1968 joint meetings of the Biometrics Society and the American Statistical Association.<sup>1</sup> His book on methods for linear models, published in 1971, also described these methods in detail and further popularized them."<sup>2</sup>

1. Searle S R. Another look at Henderson's methods of estimating variance components.  
*Biometrics* 24:749-88, 1968.

2..... *Linear models*. New York: Wiley, 1971. 532 p.