LETTERS

Synfuel Development

I wholeheartedly support Philip H. Abelson's suggestion (Editorial, 17 Aug., p. 649) that we look closely at the South African experience for producing fuels and chemicals from coal. It should be pointed out, however, that this technology was developed by an American company: the research and development, pilot plant studies, commercial design, construction, and initial operation and debugging of the process for Sasol I were performed for the Sasol Corporation by the M. W. Kellogg Company—now Pullman Kellogg of Houston, Texas.

As Abelson points out, there were difficulties in putting the plant on stream and getting it up to design capacity, but this often happens when new technology is brought to commercial scale.

The people of the United States need to know that we have vast technical resources in this country that can be tapped. We can develop our own synthetic fuels industry—if we can make up our minds that this is what we must do to ensure our future.

ALEX G. OBLAD
Department of Mining and Fuels Engineering, University of Utah, Salt Lake City 84112

Dorfman's Data Analysis

We return to the subject of our earlier exchange of letters (20 Apr., p. 242; p. 245) with D. D. Dorfman (20 Apr., p. 246) pertaining to his article "The Cyril Burt question: new findings" (29 Sept. 1978, p. 1177). We are neither condoning Burt's deficient reporting nor defending Burt's integrity. Burt's description of his work is very vague in many respects, and precisely because of this sloppiness it is impossible to determine, with the type of statistical investigation attempted by Dorfman, whether or not Burt fabricated data. We here focus on one particularly important example of an inappropriate use of statistics to detect fraudulent data (*1*).

When trying to determine whether data fit an assumed model "too well," one cannot reach valid inferences by Dorfman's technique of collapsing tables and rounding data in a manner exaggerating any regularity that may be present in the original tables and data. Such a technique followed by χ^2 statistics testing the collapsed and rounded tables for the constructed regularity can lead to the conclusion that most data are fabricated. Dorfman's treatment of Burt's tables follows this illogical paradigm. In his original article he relied on χ^2 tests; in his reply he relied primarily on informal visual impressions.

To illustrate the dramatic visual effects that can be achieved by Dorfman's technique of collapsing and rounding, let us look at a different data set that is of unquestioned integrity; like Dorfman (29 Sept. 1978, p. 1181), we have chosen one that caught the eye of the Belgian statistician Adolphe Quetelet. Table 1 presents a cross-classification of 5732 Scottish militiamen by height and chest circumference. These data are taken from an 1817 Edinburgh medical journal, and they enjoy some fame in the history of statistics due to Quetelet's use of them for investigating distributions in 1846 and subsequent years (*2*). Presumably these data have not been rescaled along the margins in any manner, and since we now know that the distributions of physical measurements are not exactly normal (see Dorfman's article, pp. 1180–1181 and notes 54 and 57 for evidence of this), we might a priori expect a worse fit here than was found by Dorfman in Burt's tables, assuming the data were not fabricated.

Following Dorfman's techniques for detecting fabricated data, Table 2 shows the data of Table 1 collapsed to six columns and expressed as rounded percentages; in parentheses are the corresponding rounded percentages from a bivariate normal distribution with correlation $\rho = .45$ (*3*). The appearance of agreement is striking. For example, 63 percent of the entries agree perfectly; the analogous rates of agreement for Dorfman's rendering of Burt's tables are 61, 72, 56, and 69 percent. (If we only look at nonzero cells, the rates of agreement are 45 percent for the Scottish data and 30, 57, 0 (!), and 44 percent for Dorman's tables.) Of course, inappropriate χ^2 tests, such as used by Dorfman, will suggest too good a fit to normality, and even better apparent fits can be obtained by coarser grouping and more rounding. Yet despite this constructed remarkable fit of the Scottish data to the theoretical normal distribution, even the most skeptical analyst would find it difficult to argue that the Scottish tailor who published these data in 1817 had concocted them from a table of the bivariate normal distribution more than a century before one was printed. Dorfman's dramatic tables and graphs do not provide any more evidence that Burt fabricated his data than our Table 2 provides evidence that this 19th-century tailor was an

Table 1. Heights and chest circumferences (inches) of 5732 Scottish militiamen, data compiled by an army contractor and printed in 1817 (*2*).

Height	Chest circumference																To-tal
	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	
64–65	1	7	31	69	108	154	142	118	66	17	6	3	0	0	0	0	722
66–67	1	9	30	78	170	343	442	337	231	124	34	12	3	1	0	0	1815
68–69	1	2	16	34	91	187	341	436	367	292	126	70	13	3	2	0	1981
70–71	0	1	4	7	31	62	117	153	209	148	102	40	16	7	0	0	897
72–73	0	0	0	1	9	7	20	38	62	65	45	43	18	7	1	1	317
Total	3	19	81	189	409	753	1062	1082	935	646	313	168	50	18	3	1	5732

Table 2. Data from Table 1 reclassified and expressed in rounded percents, together with rounded percents (in parentheses) from a bivariate normal distribution with correlation .45. The means and standard deviations of the bivariate normal distribution were fixed to be $39\frac{7}{8}$ inches and $2\frac{1}{16}$ inches (chests) and $67\frac{1}{2}$ and $2\frac{1}{8}$ inches (heights) (*3*).

Height	Chest circumference						To-tal
	33–35	36–38	39–40	41–42	43–45	46–48	
64–65	1 (1)	6 (6)	5 (6)	1 (2)	0 (0)	0 (0)	13 (15)
66–67	1 (1)	10 (9)	14 (14)	6 (8)	1 (2)	0 (0)	32 (34)
68–69	0 (0)	5 (5)	14 (13)	11 (11)	4 (3)	0 (0)	34 (32)
70–71	0 (0)	2 (1)	5 (5)	6 (7)	3 (3)	0 (0)	16 (16)
72–73	0 (0)	0 (0)	1 (1)	2 (1)	2 (1)	0 (0)	5 (3)
Total	2 (2)	23 (21)	39 (39)	26 (29)	10 (9)	0 (0)	100 (100)

unheralded Gauss who constructed his data using techniques now considered not to have been invented until at least half a century later.

As statisticians we decry both inadequate statistical reporting and inappropriate statistical analyses. But both shortcomings are too common in the literature of the past and present to permit them alone to serve as evidence of fraud or intentional deceit. Dorfman's article has served the worthy purpose of stimulating discussion highlighting the inadequacies of Burt's descriptions. But using Dorfman's inappropriate statistical techniques to detect fraudulent data would be to condemn a major portion, if not all, of empirical science as fabrication.

DONALD B. RUBIN
Educational Testing Service, Princeton, New Jersey 08541

STEPHEN M. STIGLER
Center for Advanced Study in the Behavioral Sciences, Stanford, California 94305

References and Notes

1. Among the other problems with Dorfman's statistical analyses are that (i) Dorfman's assumption in his reply (p. 251) that "column totals are not changed by the weighting along rows" does not follow from our proposed method of constructing the tables. It is in fact a tacit assumption of the conclusion he wishes to prove; the algebra here is irrelevant, and the conclusion that "the column totals are determined by the row totals" (p. 254) is incorrect. (ii) It is not unusual to obtain high correlations among class means of approximately multivariate normal data. For example, the correlation of the row means and the height midpoints of the Scottish data (our Table 1) is .99604, not far short of the value .99867 Dorfman (p. 252) found for Burt's means. Analogously, regression of one group of class means on another may, with data like these, produce a remarkably close fit to a straight line, like that exhibited in Dorfman's figure 1 (p. 254), where his "fabrication equation" and the means are displayed.
2. *Edinburgh Med. Surg. J.* **13**, 260 (1817). Table 1 was constructed by aggregating separate tables for 11 different regiments. The compiler of the tables is only identified as "an army contractor, a gentleman of great observation and singular accuracy." Quetelet used the chest measurements in his *Lettres . . . sur la theorie des probabilités* (1846) and other books.
3. The figures in parentheses were found from a bivariate normal distribution with chest mean $39\frac{7}{8}$, chest standard deviation $2\frac{1}{16}$, height mean 68, height standard deviation $2\frac{1}{8}$, and correlation coefficient .45. The columns were considered as corresponding to classes (0, 35.5), (35.5, 38.5), (38.5, 40.5), (40.5, 42.5), (42.5, 45.5), (45.5, ∞). The row classes were taken to be (64, 66), (66, 68), (68, 70), (70, 72), (72, 74). Apparently no Scotsmen below 64 inches or above 74 inches were admitted to the militia, so the distribution was truncated at these values and renormalized so that the sum of the probabilities for the given cells was 1.0. The bivariate normal probabilities were found from the *Tables of the Bivariate Normal Distribution Function and Related Functions* (Applied Mathematics Series No. 50, National Bureau of Standards, Washington, D.C., 1959). All standardized cell boundaries were rounded off before entering in the table, to eliminate the need to interpolate. Means, standard deviations, and the correlation coefficient were chosen as being standard fractions near sample estimates, and they may not produce the best possible fit. Incidentally, published tables are ill-suited to this purpose, and the required computations seemed laborious to us.

Chemical Carcinogens: Estimating the Risk

We would like to respond to the letter by Hooper, Harris, and Ames (16 Feb., p. 602), in which the authors comment on what they feel are ". . . several errors of fact and interpretation" in an earlier series of articles on chemical carcin-