resulting knowledge was applied quickly in setting safety standards for the conduct of Operation Crossroads, the first postwar series of nuclear weapons tests at Bikini atoll. In Crossroads Test Baker, the second and last shot in the two-bomb series, the scientists for the first time detonated a nuclear device under water. This brought new surprises and concerns even as the completion of the test marked the end of the wartime endeavor. The newly created Atomic Energy Commission replaced the Manhattan Engineer District on 1 January 1947.

Hacker points out the strides made in the field of health physics (the term came from the Health Division of the Met Lab) as a result of the wartime race to build the bomb. Not only did new scientific knowledge emerge, technology was advanced in the development of such items as film badges, pocket dosimeters, and improved radiation counters. Nonetheless, new knowledge based on the experience could not settle the key issue: how much radiation exposure should be allowed a worker or member of the public? In detailing attempts to provide a practical solution Hacker recognizes that the question could not be answered empirically because it included questions of philosophy and public policy. The view that came to prevail was the threshold theory, with its premise that biological systems exposed to radiation below some "tolerance dose" would suffer no lasting effects. Of course, that issue remains debatable.

Unlike the polemical literature currently on the shelves, Hacker's study has successfully sought to reconstruct the World War II era according to its own pattern. That makes it good history. The book also sets the stage for the account of the even more controversial period that will follow in a further volume planned by Hacker.

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Trials and Tabulations

Statistics and the Law. MORRIS H. DEGROOT, STEPHEN E. FIENBERG, and JOSEPH B. KADANE, Eds. Wiley, New York, 1986. xx, 484 pp., illus. $39.95. Wiley Series in Probability and Mathematical Statistics.

Oliver Wendell Holmes wrote in 1897, "For the rational study of the law, the black-letter man may be the man of the present, but the man of the future is the man of statistics and the master of economics." Though his statement is one that the quantitative among us are fond of quoting, one legal scholar has observed wryly that Holmes's prediction might equally well be made today (C. H. Baron, *Am. J. Law Med.* **5** (no. 3), 247 [1979]). We still await a world where lawyers and judges are skilled in the analysis and interpretation of data.

This state of affairs is not due to any lack of relevance of statistics to the law in carrying out its dual tasks: to find facts in particular disputed cases and to set optimal policy, both under conditions of uncertainty. *Statistics and the Law* concentrates on the former, which the law terms adjudicative fact-finding. (Where statistical studies are used to inform policy-making, the law is engaged in the finding of "legislative facts.") Sometimes statistics is not merely relevant but essential for such fact-finding. Some illegal acts, such as employment discrimination or price fixing, normally cannot be perceived except through inferences drawn from statistical information. Individual acts of hiring cannot be in themselves observably discriminatory; only a pattern of hirings statistically analyzed is likely to be able to reveal what the law wants to know.

Statistics and the Law takes an unusual route to the Holmesian future. There are a number of books on law and statistics that are aimed at raising the statistical consciousness of legal people (for example, Baldus and Cole's *Statistical Proof of Discrimination* [Shepard's, 1980]; Barnes's *Statistics as Proof* [Little Brown, 1983]; and Finkelstein's *Quantitative Methods in Law* [Free Press, 1978]). *Statistics and the Law*, by contrast, is "by statisticians for statisticians." It presents a sampling of statistical applications to legal issues written, for the most part, by statisticians who served as expert witnesses in the cases about which they write. The book's purpose is to provide statisticians with examples of the kinds of legal questions that in recent years have invited statistical answers and, perhaps equally important, to introduce them to "the fundamental difference in outlook between lawyers and statisticians" and the challenge of presenting statistical information in a courtroom.

Statistical analysis can inform a broad range of legal matters, from the relatively esoteric where it is most often found today to the mundane tort and contract cases where it may be found tomorrow. The legal topics examined in this book include several aspects of employment discrimination, antitrust litigation, educational equity, and environmental regulation—areas where statisticians already are familiar figures. In addition, there are accounts of the application of statistical methods to more novel problems such as estimating the value of equipment damaged in a strike against an aluminum manufacturer, determining the amount of coins stolen by parking meter collectors in New York City, determining in a gambling prosecution whether an electronic poker game is essentially one of chance or of skill, establishing disputed paternity, and measuring the probability of reversal in contested elections.

The chapters are fairly technical in content and sometimes contentious in argument. This may reflect the infectious nature of the adversary process, and that may serve as an additional lesson for the book's statistical readers. Indeed, the editors have borrowed a characteristic invention from the adversary system and use it to good advantage. Half of the chapters are followed by comments from statisticians who do not share the chapter authors' views on technical statistical issues. And half of the comments are followed by rejoinders from the authors. A particularly good example is the exchange between D. A. Conway and H. V. Roberts (who defend the use of reverse multiple regression analysis—a technique that generally produces results favorable to defendants—in a federal employment discrimination suit in which Roberts was an expert for the defendant bank) and Stephan Michelson (the government's chief statistical expert in the same case). Their debate succeeds in creating some of the feeling of a battle of experts.

By using such exchanges the editors illustrate for readers some of the virtues of the adversary process. At its best, the adversary process is unequaled in its ability to identify and make salient areas of disagreement, expose assumptions, and compel expert witnesses to make themselves understood. The readers of most statistics (or other scientific) books or journals would conclude that a high degree of agreement and certainty reigns. By contrast, in the short scope of this one book an impressive sampling of disagreement about fundamental statistical theory is displayed. The lesson for statisticians who will enter the legal arena is to expect comfortable assumptions to be questioned vigorously.

From these presentations a number of themes emerge. The most important of these center on substantive applied statistical issues, ethics, and the challenge of communicating statistical ideas to non-statisticians in legal forums.

One issue after another pertaining to the correctness of statistical application is held up and debated in chapter after chapter.

Techniques that are familiar and appropriate in one context may be doubtful in answering a similar question in a different context. Where altogether different statistical approaches may be directed to solving a given problem—and yield different conclusions—how do we justify one over another? The debate embraces, among other issues, (i) the use and meaning of significance tests (how well do these answer the questions posed by the law? what is the relation to any test of practical significance? should the risk of Type I error, and the ratio of Type I to Type II error, be reset for different legal questions?); (ii) multiple regression analysis (direct versus reverse regression; how do we defend the choice of a model, the choice of explanatory variables, the choice of proxy variables? how do we deal with explanatory variables that are correlated with the independent variables of interest, the risk of underadjusted beta weights, or overfitted models?); (iii) time series analysis (all the preceding problems, plus the choice of whether and how much to lag variables and the choice of time periods to compare); and (iv) the proper application of Bayes's theorem.

The message that permeates all these discussions is that the proper application and correct meaning of many if not most statistical analyses is subject to debate. Truth is elusive. The day will be won by the statistician who can reason better, or at least present more persuasive evidence and argument. At the end of the day, is there really anything more than that for us humans to hold onto, in statistics or anywhere else?

As if it were not enough that the legal method compels statisticians to confront the epistemological and the existential, the law also rubs their noses in problems that usually are categorized as ethical. Nearly every chapter hints at or addresses directly the ethical dilemmas that technical people face when they come to court. Here the issues include the partisan climate of litigation, the tensions between the experts' commitment to completeness and balance and the lawyers' commitment to advocacy, confusion of roles (when experts forget that they are witnesses and begin to think of themselves as advocates), limited control over the data and the analyses, and how much to disclose to the other side or to the court. What is disappointing is that these troublesome issues tend to be discussed with a simplicity and unwarranted certainty that contrasts ironically with the complex and subtle discussion of technical matters.

As with ethical issues, many of the chapters offer observations and advice on the difficulties associated with communicating statistical information to legal fact-finders who are not conversant with statistical concepts and need to become so within a few hours or days. Homespun suggestions for how to be understood are offered. The problem is exacerbated by trial forums that favor oral over written or visual presentations of evidence and that elicit that oral testimony by a question-and-answer process. The problem is made still more difficult by statistical techniques that hide their rationales under layers of foundational concepts that are opaque, given only the technique (regression analysis and significance tests being good examples), and that in any event are often inconsistent with human intuition. For example, whereas inferential statistics flies on the wings of the law of large numbers, humans implicitly believe in a law of small numbers (see A. Tversky and D. Kahnemann, *Psychol. Bull.* **76**, 105 [1971]). After all, if human statistical intuitions could deliver reasonably accurate estimates, formal statistical analysis would have less to contribute than it does. The chasm between intuitive legal decision-makers and statistical experts may require that both the law and statisticians learn more about human processing of quantitative information than either now knows.

If the law is not yet what Holmes thought it would by now have become, the explanation is not that statistics has nothing to offer. Such advances face hurdles not dreamed of a century ago.

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The Rise of Enumeration

Medicine and American Growth, 1800–1860. JAMES H. CASSEDY. University of Wisconsin Press, Madison, 1986. xviii, 299 pp., illus. $39.50; paper, $19.95. Wisconsin Publications in the History of Science and Medicine, no. 5.

The title of James H. Cassedy's new book has a double meaning. Cassedy is writing, within a medical context, about the period of Manifest Destiny, when national growth obsessed many Americans; he is also writing about the growth of the statistical method and the accumulation of demographic data needed to record and interpret a rapidly changing society. In both respects he has produced a useful and graceful essay.

The first half of the 19th century saw physicians, under the inspiration of the Paris school and especially of Pierre-Charles-Alexandre Louis, beginning to apply statistical method in a systematic way to the phenomena of health and disease. This development accompanied a more general spread of interest in the virtues of enumeration as a guide to truth (and, more frequently, as a weapon in controversy). Both influences worked on American doctors and placed them among the leaders in a national endeavor whose roots led back to the founding of the Republic and the creation of the federal census as a tool of popular government.

As Cassedy shows, the results were varied and sometimes surprising. The theory that climate caused disease helped to turn Army doctors into the nation's first systematic collectors of weather data, by order of the Surgeon General. Preoccupation with national growth meant a pervasive interest in national fecundity, and hence widespread interest in collecting data on the health of women and, in some cases, fabricating data on the evils of birth control as well. Military adventures in Mexico meant an influx of statistics on casualties. A variety of pressures in government, business, and science produced efforts to create reliable mechanisms at both the national and state level to record accurate vital statistics.

The author is quick to demonstrate that all of this activity led to very spotty results. The bumptious and sectarian age was rarely a friend to objectivity in any form. The supposed dry light of statistics took on a rainbow of hues, political, religious, and personal. Mormons collected statistical information to advance their faith; southern physicians to prove the natural inferiority of blacks; members of the Oneida community to celebrate the virtues of male continence, or sperm retention, and to refute the charge of licentiousness made by the conventional against their practice of complex marriage. Know-Nothings labored to demonstrate the many faults of poor and sickly immigrants; slave owners to prove the good health of their chattels; and Abolitionists to demonstrate the wickedness of slavery. To be sure, such combative uses of statistics are not unknown today, but the lack of reliable data made the early 19th century a sort of golden age for controversialists.

In the end, a laissez-faire era found its soundest (if still imperfect) employment of demographic information and statistical method appropriately enough in a business venture—the life insurance industry, whose rapid growth began in the 1840s. Even here, southerners suspected the existence of sectional prejudice in the higher rates that the mostly northern companies, relying on the South's reputation as a sickly land, charged their insurees in Dixie. (A perfectly genuine point of southern distinctiveness, according to Cassedy, was the region's indifference to collecting accurate statistics, which enabled the companies to ignore the complaints.) Overall, however, the pressures of competitive business demanded objectivi-