# Calculators

## Calculators

### Wang Laboratories, Inc. Calculator, Model 450-1, c. 1972

WANG Laboratories, Inc. Calculator, Model 450-1

Each of the four models of the Wang series 400 calculators incorporated functions particularly suited for a specific discipline. The Model 450-1 Calculator was designated as “Basic Scientific.” The 450-1 could be programmed by use of the numeric keypad and a set of special function keys whose location brings to mind the function keys found on today’s PCs. Programs could alternatively be loaded by use of an optional device that read punched or mark-sense cards. The specialized functions that especially suited the Wang 450-1 for general scientific applications, what Wang called “personality,” was provided by a plug-in discipline-specific circuit board containing read only memory (ROM) programs. Results from calculations were provided on a Panaflex display atop the keyboard comprised of a series of twelve neon bulbs with filaments, portions of which could form numerals from 1 to 9 as well as 0. The Model 450-1 Wang Calculator was actually quite expensive: when first introduced in 1972 it cost $1,300, or almost $7,400 in 2012 dollars.

This calculator was used by Dr. Earl Stadtman (1919–2008), recipient of the 1979 National Medal of Science for his work on anaerobic bacteria and enzymology, during his years of work as the chief of the Laboratory of Biochemistry at NHLBI.
[04.0009.003]

### Hewlett Packard HP-35 calculator, c. 1973

Hewlett Packard Calculator, Model 35

The HP-35 was the first pocket-sized scientific calculator, allowing scientists to abandon their slide rules for good. Named for its 35 keys, the HP-35 was the first scientific pocket calculator when it was introduced in 1972. The development of metal-oxide-semiconductor integrated circuits in the early 1970s made it possible to shrink the technology necessary for complicated calculations—at a price. Due to the high cost of the new circuits, the HP-35 debuted at a steep $395, but that didn't prevent 100,000 units from being sold during its first year in production. In addition to its cutting edge circuits, the HP-35 also used new Light Emitting Diodes (LEDs) in its screen.

Prior to the release of the HP-35, pocket calculators could perform only the four basic arithmetic functions, and slide rules were used for exponential and trigonometric functions. The HP-35 was able to reduce calculation times by almost 80%, effectively making the slide rule obsolete. In recognition of its revolutionary effect on the work of scientists and engineers everywhere, the HP-35 was awarded the IEEE Milestone in Electrical Engineering and Computing award in 2009. This particular calculator was used by Dr. Michael Channing, then a radiochemist, then later the group chief of the Radiopharmaceutical Production and Quality Control group in the Positron Emission Tomography department in the NIH Clinical Center. [06.0007.001]

## Texas Instruments SR-51A Calculator, c. 1975

Texas Instruments SR-51A Calculator

The Hewlett Packard HP 35, launched in 1972, is generally recognized as the first portable scientific calculator. But Texas Instruments, home of the invention of integrated circuits, launched its reply to the HP 35, the SR 50, in early 1975. As it was expensive to produce, it was soon replaced by the SR 51, which incorporated some cost-saving modifications. The liquid crystal display in the SR 50, for example, was replaced by a smaller CD bar behind a magnifier bubble. The SR 51A was promoted as a scientific-financial calculator in recognition of the higher mathematical capability. The SR 51A was capable of performing both trigonometric and statistical operations. The keyboard contained 20 keys for performing arithmetic, and an additional 15 keys are devoted to higher mathematical functions. The calculator was also equipped with a random number generator. The SR51A, like its counterpart the HP 35, has been credited with ending the long dominance of the slide rule for technical calculations. This model of calculator was introduced in June 1975 for $224.95. The “A” in the model number means that it was identical to the SR-51 model except it had no inner rigid keyboard frame, LED display, or bubble-lens magnifier, making it a cheaper high-end calculator. This calculator was used by Dr. Marshall Nirenberg, who won the Nobel Prize for breaking the genetic code. [10.0001.004]

## Hewlett Packard (HP) 41C Programmable Calculator, c. 1979

Hewlett Packard (HP) 41C Programmable Calculator front

By adding an alpha key to enable the keyboard to go between the alpha and normal keyboard modes, this calculator made inputting programs and functions easier. Functions could also be typed in with the “User” key and assigned to a specific key. The 41C also increased the amount of memory available in its predecessor, which could also be expanded with memory modules. The card reader had a translator for programs written for the HP 67. Hewlett Packard made the 41C from 1979 to 1985. This calculator pictured here belonged to Dr. Kenneth J. Rothman, founding editor of the journal *Epidem iology*. Rothman was working at the NIH National Cancer Institute in 1979 when he co-authored ”Epidemiologic Analysis with a Programmable Calculator” with Dr. John D. Boice, Jr. Later editions of the book [13.0013.002] referred specifically to this calculator model.
[13.0013.001]

## Casio SL-300V Pocket Calculator, c 1980s

Casio SL-300VE Pocket Calculator

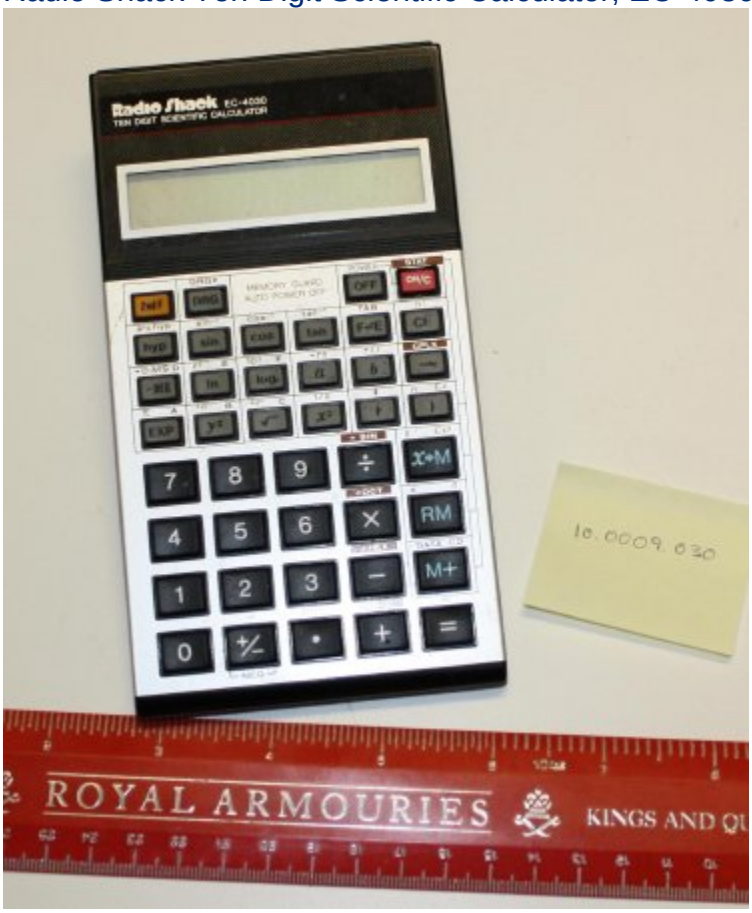
The Casio SL-300V was a typical example of the sizeable number of compact calculators that came on the market in the 1980s from different manufacturers. The 24-button keyboard on this calculator from Casio included numerals in addition to keys for functions. The keyboard also included a separate key for turning the calculator ON and another for turning it OFF. If left unattended while ON, the machine saved power by automatically shutting down in less than 10 minutes. The calculator had a limited memory, though: all entries and results were lost when the unit was shut down. The Casio SL-300V was a light-powered machine with a prominent photocell located in the top-right corner of face. A hearing aid-type 1.5 volt battery served as backup power for use when there is not enough light to provide operating power. Entries and results were shown on a large 8-digit liquid crystal display. First introduced in the early 1980s, the Casio SL300 and its later variants are still listed for sale in 2014. This calculator pictured her belonged to Ruth Kirschstein, who did important research on the polio vaccine and was the first female director of an NIH institute (NIGMS), NIH deputy director, and NIH acting director.
[10.0003.099]

## TI-66 Programmable Calculator, c. 1983

TI 66 calculator

With its 170 engineering and statistical functions, the TI-66 calculator was an indispensable piece of equipment for researchers such as Dr. Howard Nash, NIMH. State-of-the-art technology when it was introduced in 1983, the TI-66's landscape orientation of the customary 14 arithmetic keys as well as an additional 28 keys for mathematical operations and programming distinguished this machine from its competitors. The TI-66 could be programmed to perform up to 512 steps. Programs could be written on the keyboard or loaded from a magnetic card; user-written programs could also be copied onto those magnetic cards for later use. TI also provided an optional thermal printer that could be controlled by the calculator keyboard.
Although it was a Texas Instruments (TI) product, it was built by Toshiba from Toshiba components — a collaboration to challenge Hewlett Packard's successful HP-41 calculator. Hewlett Packard and TI each had introduced a programmable calculator in 1972, the HP-65 and TI-52, respectively. Each of these calculators incorporated a small motor for passing the card by a reading device; however, the dimensions of the HP and TI programming cards were quite different. In 1977, TI introduced the TI-59, a calculator with increased ROM (read-only memory), which could be further enhanced by a plug-in ROM module. The TI-66 further improved the design, offering more programmable steps and more memory in a smaller package. Howard Nash used this calculator pictured here in his research on the molecular neurobiological basis of general anesthetic action.
[12.0001.001]

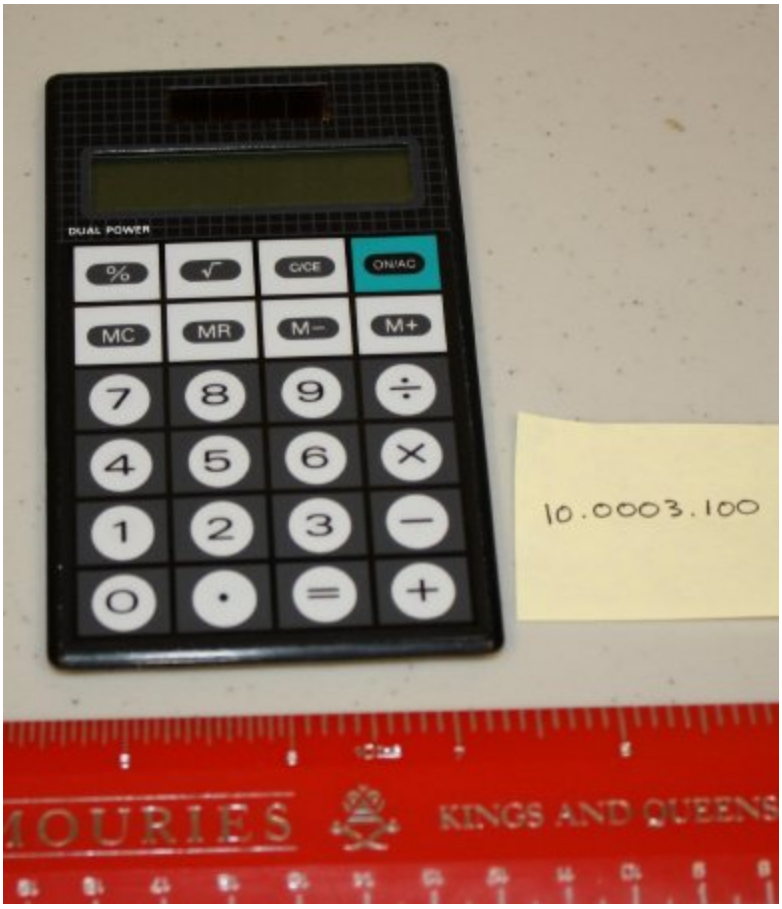
## Radio Shack Ten Digit Scientific Calculator, EC-4030, c. 1988



Radio Shack Ten Digit Scientific Calculator, EC-4030

The Radio Shack EC-4030 electronic calculator, introduced in 1988, was somewhat of a latecomer to this field. This portable calculator, as noted by the term "Scientific" on the nameplate, was designed for handling more complex mathematics in addition to simple arithmetic. The capacity of this device resembled that of the HP 35 from Hewlett Packard and the Texas Instruments SR 50, both of which became available in the early 1970s. Advances in the design and manufacture of chips since the 1970s arguably resulted in decreasing the cost of components used for the EC-4030. Like its predecessors, the EC-4030 featured a keyboard with 42 keys. Twelve of those keys are numerals and the arithmetic operations. The remaining keys are dedicated mathematical functions such as the trigonometric functions and logarithms. Results of calculations are shown on a ten-digit liquid crystal display above the keyboard. This calculator pictured here was used by Dr. Ichiji Tasaki, NIMH, who introduced the giant squid axon as a system for studying nerve conduction and pioneered the use of dyes that fluoresce upon exposure to electrical stimulation. His research career spanned nearly 70 years.
[10.0009.03]

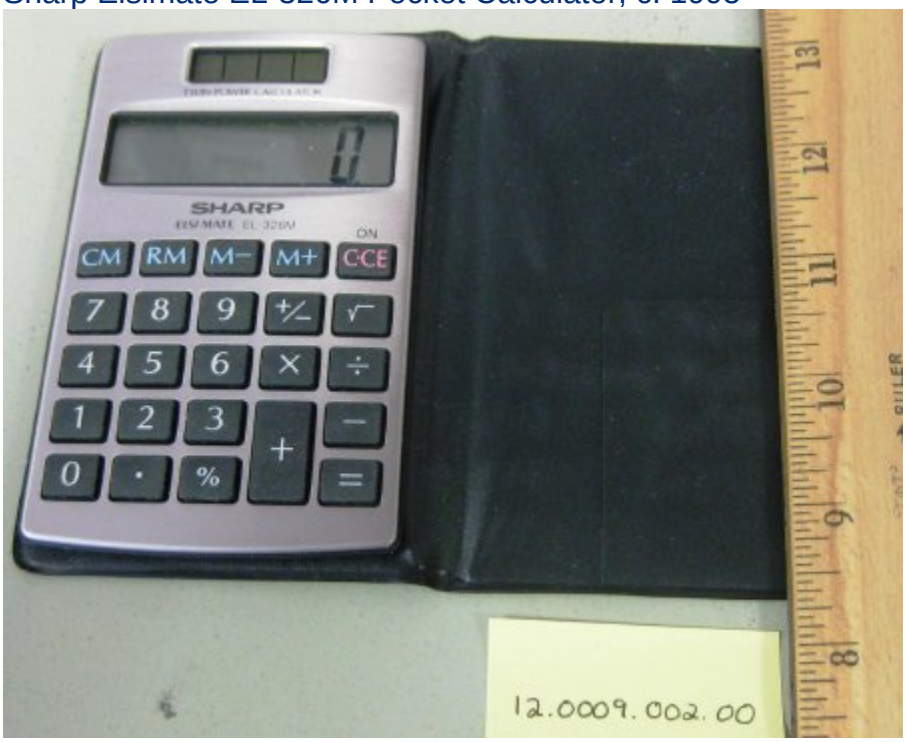
## "Dual Power" Pocket Calculator, c 1990s



Electronic Calculator

The “Dual Power” label on the face of this calculator from an unknown manufacturer in Taiwan, as well as the presence of a solar cell, indicates that this machine incorporated a battery that takes over when there is insufficient light. While the 24-button keyboard was typical for this class of calculators, the use of round key labels for numerals and arithmetic operations was unusual and set these apart from other functions represented by rectangular buttons. Like other small calculators, data entry and results of calculations are shown on a liquid crystal display. This calculator belonged to Dr. Ruth Kirschstein and was likely acquired as part of a promotional giveaway, due to its lack of branding.
[10.0003.100]

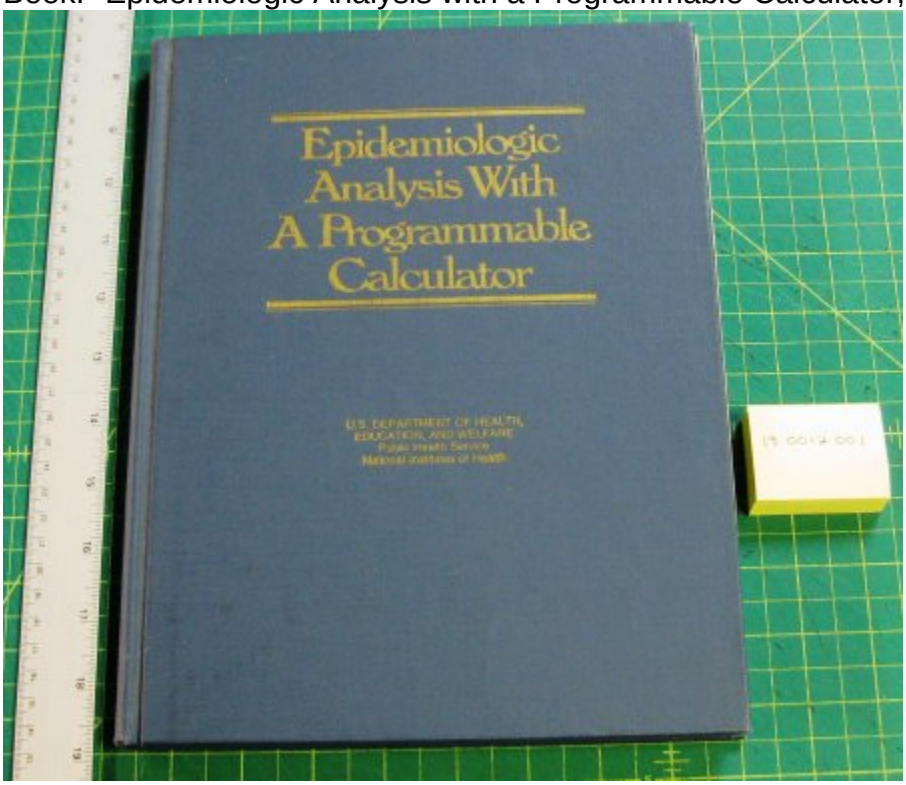
## Sharp Elsimate EL-326M Pocket Calculator, c. 1995



Sharp Elsimate EL-326M Pocket Calculator

Introduced in 1995, this Sharp pocket calculator has seven functions, 24 keys, and an LCD display for people with low vision. It is powered by a solar cell. This variant of the popular EL-326 product line came with an attached cardboard and plastic case. A very similar model, the EL-326S, is still available. This calculator pictured here was used by Dr. Ira Levin, former scientific director of NIDDK.
[12.0009.002]

## Book: "Epidemiologic Analysis with a Programmable Calculator," 1979



# PREFACE

Our purpose in writing this book is to present a collection of pocket calculator programs developed to handle the range of analyses that most epidemiologists face routinely. The programs are accompanied by step-by-step descriptions of their use and examples taken from epidemiologic studies. We have assumed a basic familiarity with epidemiologic principles, this book being intended as a handbook or reference work for epidemiologists rather than as a textbook. Most of the examples are drawn from the area of chronic disease epidemiology and are meant to exemplify the application of calculator programs and not epidemiologic findings.

Before the advent of moderately priced programmable pocket calculators, complicated numerical calculations could be accomplished only by relying upon a sizeable computer or upon a willingness to plow through tedious computations, recording intermediate results along the way. The disadvantages of the large computer are inaccessibility and expense. The pencil and paper approach is often frustrating and unreliable. Fortunately, recent advances in electronic technology have introduced literally into the hands of the general public the capability to solve complex computational problems quickly, accurately and inexpensively.

In the past, the most appropriate analytic procedures for epidemiologic data have often not been applied either because they were too complicated for routine use or not widely known among epidemiologists. Today programmable pocket calculators are available which are essentially low-priced computers that can be programmed to handle nearly all calculations routinely encountered in epidemiologic analysis. Programs can be permanently stored on thin magnetic cards which are kept with the calculator, eliminating the need to renew familiarity with analytical formulas each time a particular set of equations is to be solved. These small, self-contained, battery-operated calculators are transported conveniently from office to home, to conferences, or to classrooms.

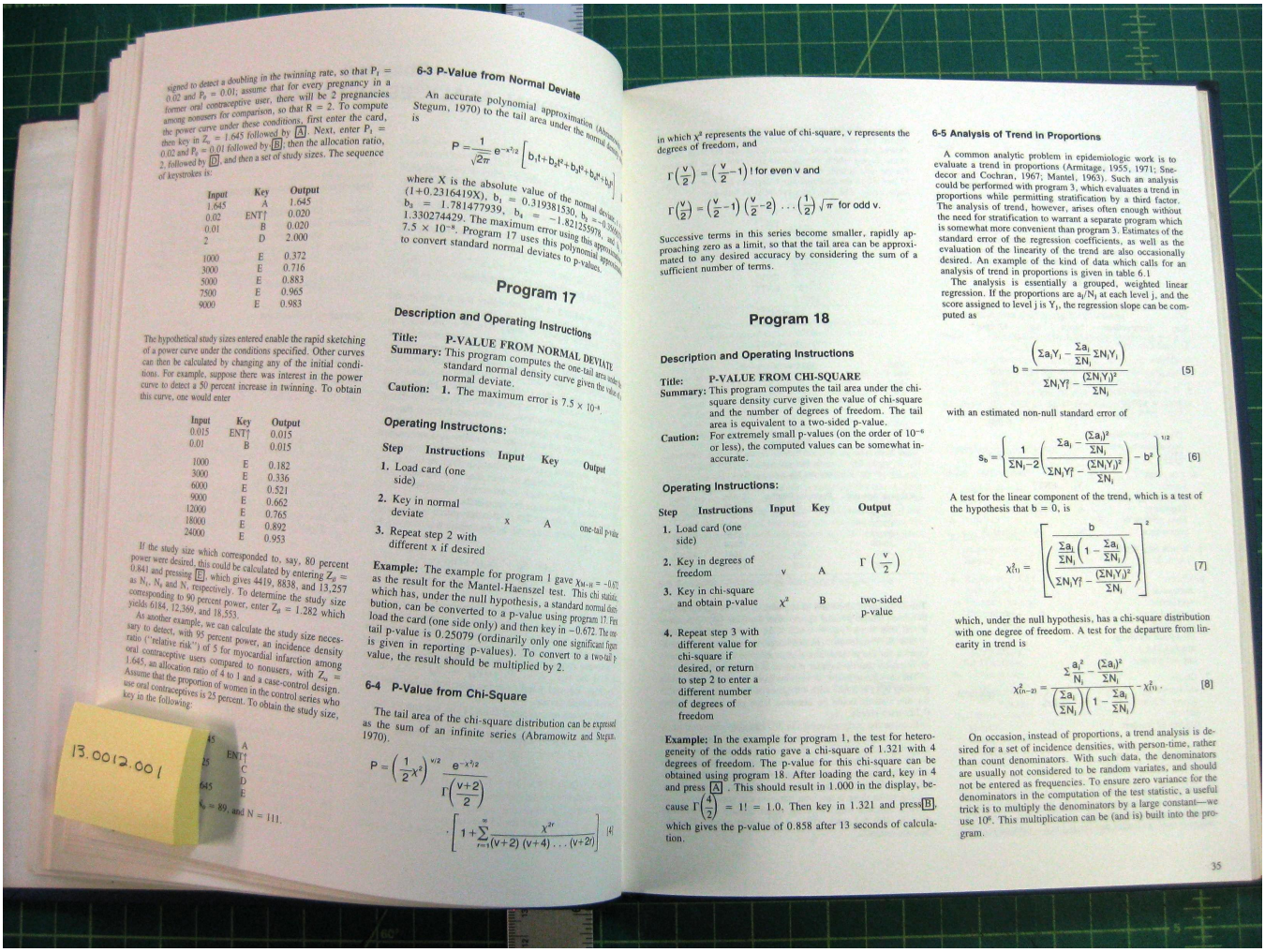
The epidemiologic programs developed and presented here are for a particular calculator, the Hewlett-Packard 67 (HP-67). The individual programs, however, could be rewritten for other comparable machines. With improvements in pocket computer technology, one or two programs might profitably be revised, but today's computer technology has already placed sufficient power into a pocket calculator to cope effectively with nearly the full range of epidemiologic analyses. We therefore believe that present-day calculators, purchased to perform the computations described in this book, are not likely to be obsolete in the near future.

In preparing this book we have tried to delineate the conditions for which all programs and program formulas are applicable. Generally the computations performed conform to what is accepted as theoretically most desirable by methodologists, although our personal biases have undoubtedly influenced our choice of certain epidemiologic methods. We have attempted to avoid controversial or esoteric methods, but it is inevitable that objections will be raised over our choice in the selection of some computational techniques. Many methods have been described, for example, for large-sample interval estimation, and there is little unanimity among statisticians as to which is preferable. Disagreement about the desirability of adjusting statistical tests of discrete data for noncontinuity has persuaded us to follow the dictates of parsimony and omit such an adjustment. In choosing among these and other techniques, we were guided mainly by theoretical considerations but partly by technical issues such a programming space, storage requirements and computational time.

Kenneth J. Rothman

John D. Boice, Jr.

June 1978



signed to detect a doubling in the twinning rate, so that $P_1 = 0.02$ and $P_0 = 0.01$; assume that for every pregnancy in a former oral contraceptive user, there will be 2 pregnancies among nonusers for comparison, so that R = 2. To compute the power curve under these conditions, first enter the card, then key in $Z_\alpha = 1.645$ followed by [A]. Next, enter $P_1 = 0.02$ and $P_0 = 0.01$ followed by [B], then the allocation ratio, 2, followed by [D], and then a set of study sizes. The sequence of keystrokes is:

| Input | Key | Output |
|---|---|---|
| 1.645 | A | 1.645 |
| 0.02 | ENT↑ | 0.020 |
| 0.01 | B | 0.020 |
| 2 | D | 2.000 |
| 1000 | E | 0.372 |
| 3000 | E | 0.716 |
| 5000 | E | 0.883 |
| 7500 | E | 0.965 |
| 9000 | E | 0.983 |

The hypothetical study sizes entered enable the rapid sketching of a power curve under the conditions specified. Other curves can then be calculated by changing any of the initial conditions. For example, suppose there was interest in the power curve to detect a 50 percent increase in twinning. To obtain this curve, one would enter

| Input | Key | Output |
|---|---|---|
| 0.015 | ENT↑ | 0.015 |
| 0.01 | B | 0.015 |
| 1000 | E | 0.182 |
| 3000 | E | 0.336 |
| 6000 | E | 0.521 |
| 9000 | E | 0.662 |
| 12000 | E | 0.765 |
| 18000 | E | 0.892 |
| 24000 | E | 0.953 |

If the study size which corresponded to, say, 80 percent power were desired, this could be calculated by entering $Z_\beta = 0.841$ and pressing [E], which gives 4419, 8838, and 13,257 as $N_1$, $N_0$ and N, respectively. To determine the study size corresponding to 90 percent power, enter $Z_\beta = 1.282$ which yields 6184, 12,369, and 18,553.

As another example, we can calculate the study size necessary to detect, with 95 percent power, an incidence density ratio ("relative risk") of 5 for myocardial infarction among oral contraceptive users compared to nonusers, with $Z_\alpha = 1.645$, an allocation ratio of 4 to 1 and a case-control design. Assume that the proportion of women in the control series who use oral contraceptives is 25 percent. To obtain the study size, key in the following:

| | |
|---|---|
| 45 | A |
| 25 | ENT↑ |
| 645 | C |
| | D |
| | E |

$N_0 = 89$, and N = 111.

13.0012.001

### 6-3 P-Value from Normal Deviate

An accurate polynomial approximation (Abramowitz and Stegun, 1970) to the tail area under the normal density is

$$P = \frac{1}{\sqrt{2\pi}} e^{-x^2/2} \left[ b_1 t + b_2 t^2 + b_3 t^3 + b_4 t^4 + b_5 t^5 \right]$$

where X is the absolute value of the normal deviate, $t = 1/(1+0.2316419X)$, $b_0 = 0.319381530$, $b_2 = -0.356563782$, $b_3 = 1.781477939$, $b_4 = -1.821255978$, and $b_5 = 1.330274429$. The maximum error using this approximation is $7.5 \times 10^{-8}$. Program 17 uses this polynomial approximation to convert standard normal deviates to p-values.

## Program 17

### Description and Operating Instructions

**Title:** P-VALUE FROM NORMAL DEVIATE

**Summary:** This program computes the one-tail area under the standard normal density curve given the value of a normal deviate.

**Caution:** 1. The maximum error is $7.5 \times 10^{-8}$.

### Operating Instructons:

| Step | Instructions | Input | Key | Output |
|---|---|---|---|---|
| 1. | Load card (one side) | | | |
| 2. | Key in normal deviate | x | A | one-tail p-value |
| 3. | Repeat step 2 with different x if desired | | | |

**Example:** The example for program 1 gave $\chi_{(M-H)} = -0.672$ as the result for the Mantel-Haenszel test. This chi statistic, which has, under the null hypothesis, a standard normal distribution, can be converted to a p-value using program 17. First load the card (one side only) and then key in −0.672. The one-tail p-value is 0.25079 (ordinarily only one significant figure is given in reporting p-values). To convert to a two-tail p-value, the result should be multiplied by 2.

### 6-4 P-Value from Chi-Square

The tail area of the chi-square distribution can be expressed as the sum of an infinite series (Abramowitz and Stegun, 1970).

$$P = \left(\frac{1}{2}\chi^2\right)^{v/2} \frac{e^{-\chi^2/2}}{\Gamma\left(\frac{v+2}{2}\right)} \cdot \left[ 1 + \sum_{r=1}^{\infty} \frac{\chi^{2r}}{(v+2)(v+4)\ldots(v+2r)} \right] \quad [4]$$

in which $\chi^2$ represents the value of chi-square, v represents the degrees of freedom, and

$$\Gamma\left(\frac{v}{2}\right) = \left(\frac{v}{2}-1\right)! \text{ for even v and}$$

$$\Gamma\left(\frac{v}{2}\right) = \left(\frac{v}{2}-1\right)\left(\frac{v}{2}-2\right)\ldots\left(\frac{1}{2}\right)\sqrt{\pi} \text{ for odd v.}$$

Successive terms in this series become smaller, rapidly approaching zero as a limit, so that the tail area can be approximated to any desired accuracy by considering the sum of a sufficient number of terms.

## Program 18

### Description and Operating Instructions

**Title:** P-VALUE FROM CHI-SQUARE

**Summary:** This program computes the tail area under the chi-square density curve given the value of chi-square and the number of degrees of freedom. The tail area is equivalent to a two-sided p-value.

**Caution:** For extremely small p-values (on the order of $10^{-6}$ or less), the computed values can be somewhat inaccurate.

### Operating Instructions:

| Step | Instructions | Input | Key | Output |
|---|---|---|---|---|
| 1. | Load card (one side) | | | |
| 2. | Key in degrees of freedom | v | A | $\Gamma\left(\frac{v}{2}\right)$ |
| 3. | Key in chi-square and obtain p-value | $\chi^2$ | B | two-sided p-value |
| 4. | Repeat step 3 with different value for chi-square if desired, or return to step 2 to enter a different number of degrees of freedom | | | |

**Example:** In the example for program 1, the test for heterogeneity of the odds ratio gave a chi-square of 1.321 with 4 degrees of freedom. The p-value for this chi-square can be obtained using program 18. After loading the card, key in 4 and press [A]. This should result in 1.000 in the display, because $\Gamma\left(\frac{4}{2}\right) = 1! = 1.0$. Then key in 1.321 and press [B], which gives the p-value of 0.858 after 13 seconds of calculation.

### 6-5 Analysis of Trend in Proportions

A common analytic problem in epidemiologic work is to evaluate a trend in proportions (Armitage, 1955, 1971; Snedecor and Cochran, 1967; Mantel, 1963). Such an analysis could be performed with program 3, which evaluates a trend in proportions while permitting stratification by a third factor. The analysis of trend, however, arises often enough without the need for stratification to warrant a separate program which is somewhat more convenient than program 3. Estimates of the standard error of the regression coefficients, as well as the evaluation of the linearity of the trend are also occasionally desired. An example of the kind of data which calls for an analysis of trend in proportions is given in table 6.1

The analysis is essentially a grouped, weighted linear regression. If the proportions are $a_j/N_j$ at each level j, and the score assigned to level j is $Y_j$, the regression slope can be computed as

$$b = \frac{\left(\Sigma a_j Y_j - \frac{\Sigma a_j}{\Sigma N_j}\Sigma N_j Y_j\right)}{\Sigma N_j Y_j^2 - \frac{(\Sigma N_j Y_j)^2}{\Sigma N_j}} \quad [5]$$

with an estimated non-null standard error of

$$s_b = \left\{ \frac{1}{\Sigma N_j - 2}\left( \frac{\Sigma a_j - \frac{(\Sigma a_j)^2}{\Sigma N_j}}{\Sigma N_j Y_j^2 - \frac{(\Sigma N_j Y_j)^2}{\Sigma N_j}} \right) - b^2 \right\}^{1/2} \quad [6]$$

A test for the linear component of the trend, which is a test of the hypothesis that b = 0, is

$$\chi^2_{(1)} = \left[ \frac{b}{\sqrt{\left(\frac{\frac{\Sigma a_j}{\Sigma N_j}\left(1-\frac{\Sigma a_j}{\Sigma N_j}\right)}{\Sigma N_j Y_j^2 - \frac{(\Sigma N_j Y_j)^2}{\Sigma N_j}}\right)}} \right]^2 \quad [7]$$

which, under the null hypothesis, has a chi-square distribution with one degree of freedom. A test for the departure from linearity in trend is

$$\chi^2_{(n-2)} = \frac{\Sigma \frac{a_j^2}{N_j} - \frac{(\Sigma a_j)^2}{\Sigma N_j}}{\left(\frac{\Sigma a_j}{\Sigma N_j}\right)\left(1-\frac{\Sigma a_j}{\Sigma N_j}\right)} - \chi^2_{(1)}. \quad [8]$$

On occasion, instead of proportions, a trend analysis is desired for a set of incidence densities, with person-time, rather than count denominators. With such data, the denominators are usually not considered to be random variates, and should not be entered as frequencies. To ensure zero variance for the denominators in the computation of the test statistic, a useful trick is to multiply the denominators by a large constant—we use $10^6$. This multiplication can be (and is) built into the program.

35

Book: "Epidemiologic Analysis With A Programmable Calculator"

Starting in the mid-1970s, the development of programmable pocket calculators meant that an epidemiologist could work anywhere and at any time, which is especially important in fieldwork. But would the epidemiologist know how to use the calculator? Even after the basic operations of the calculator were mastered, would the person remember all the calculations required for different analytical equations?

Drs. Kenneth J. Rothman and John D. Boice, Jr. sought to help the technologically and mathematically challenged epidemiologist, introducing their 1979 book *Epidemiologic Analysis with a Programmable Calculator* by stating:

> *"Our purpose in writing this book is to present a collection of pocket calculator programs developed to handle the range of analyses that most epidemiologists face routinely....Before the advent of moderately priced programmable pocket calculators, complicated numerical calculations could be accomplished only by relying upon a sizable computer or upon a willingness to plow through tedious computations, recording intermediate results along the way. The disadvantages of the large computer are inaccessibility and expense. The pencil and paper approach is often frustrating and unreliable....In the past, the most appropriate analytic procedures for epidemiologic data have often not been applied either because they were too complicated for routine use or not widely known among epidemiologists."*

Some of the equations in the book, which includes those for case control studies and cohort (follow-up) studies, are used today and some are not published anywhere else. While geared specifically for the Hewlett Packard HP67 calculator, later editions of the book encompassed the HP41, 41C, and 41CV. You can see an HP 41C in our collection elsewhere on this page.

Rothman and Boice worked at the Environmental Epidemiology Branch of the National Cancer Institute.

13.0012.001

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