Letters

Computers in Medicine

As a medical statistician, I read with much interest Robert S. Ledley's article on "Digital electronic computers in biomedical science" [*Science* **130**, 1225 (1959)]. I was happy to see how much attention is being given to some of the more mathematically complex problems in medicine today. I find some of Ledley's visions, however, not very realistic, in view of my own experiences. To cover these completely would require an article far more extensive than Ledley's, so I shall confine myself to a sketch of a few points.

Ledley states that there are a great many applications of computers in the straightforward statistical analysis of medical records. A large computer manufacturer investigated this problem, at the request of an organization I was with at the time, and found that the use of computers was too expensive. Standard punch-card machines are better.

With regard to statistical analysis of medical problems generally, I learned through eye-opening experience that large amounts of data and complex mathematical manipulations usually contribute nothing but disappointment and wasted effort. No more *valid* information can be gotten from a set of data than is inherent in the data. I think most people have to learn this the hard way.

Ledley states that measurements concerning an individual's normal state of health may serve as tools for instituting preventive measures before diseases occur. Vaccination and immunization programs come under this heading, but where do we go from here? It is almost a certainty that we will develop some circulatory-system "disease" before we die, if we live long enough, but how do we prevent it? We know very little about the prevention of many diseases, particularly those which afflict us later in life. Computers, to a certain extent, can help us study these problems, but that is all.

When a machine performs a discriminating function—the problem of diagnosis—it must have good data as well as a good discrimination program. What do we know about "normal values in medicine," fundamental data in this problem? I suggest that Ledley obtain a copy of a fairly recent book by F. W. Sunderman and F. Boerner, *Normal Values in Clinical Medicine* (W. B. Saunders, Philadelphia, 1950), and study some of these values. He should not be content with accepting the stated findings but should look up the original literature references, and should try to compare a set of "normal values" from one study with those of another study of the same thing. I have done some of this in connection with a book on medical statistics that I am now writing. I was so disturbed by what I found that I am attempting to interest the National Institutes of Health in giving the problem some serious study. In my opinion, adequate data as well as criteria for normality are lacking for many things in medicine.

Establishing normal "base lines" is only one step in dealing with medical problems. Current medical practices require continuous sources of accurate and precise measurements. How accurate and precise are current medical measurements? From the studies I have seen, they are subject to considerable improvement. Look, for example, at unit 3 of *A Syllabus of Laboratory Examinations in Clinical Diagnosis*, by T. H. Ham (Harvard Univ. Press, Cambridge, 1956). Results of a survey of the accuracy of some clinical laboratories are presented. The findings leave a great deal to be desired. Other more recent surveys show much the same thing. The main point here is that we have a long way to go before we can be satisfied with current practices in making some very basic medical measurements. Should we program a computer with data of unknown accuracy?

I would like somehow to convey to Ledley that medicine is *not* a mechanistic science. I know of no better way to learn this than by some first-hand experience. Ledley should visit a local hospital and listen while the physicians discuss their problems. If possible, he should talk to a few patients himself. This should be done in a small hospital in a small town.

I would like Ledley's opinion as to what to do in a case like this. An aged, senile member of a family is cared for in a nursing home. The financial drain on the family is very heavy, but he requires constant nursing care, too expensive to provide at home. His senility has advanced to the stage where he no longer even recognizes members of his own family. The patient develops pneumonia, which if not treated heroically will probably prove fatal. Should he be "cured" to return to his vegetable existence for a little while longer? Is "old age" a disease?

One prominent medical educator wrote not long ago, "In my opinion, what doctors say and do not say and what they do and do not do is one of today's most important factors in the cause and aggravation of illness" [W. Darley, "What is the next step in improving the teaching of preventive medicine," *Assoc. Teachers of Preventive Med. Newsletter* **6**, No. 2 (1959)]. A major factor in medicine is the inter-

personal relationship between the physician and the patient. What can computers do here?

Finally, I would like to repeat that I am much interested in learning about what is being done with computers in medicine. I think that Ledley's contribution will be greater, however, if he will learn more about the day-to-day problems and practices of medicine.

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Of the four general areas of applications of computers in biology and medicine discussed in my article—namely, (i) solutions to equations, (ii) simulations, (iii) data processing, and (iv) information retrieval—Hoffmann is evidently concerned only with aspects of the latter two. He seems to take issue, "in view of [his] own experiences," with my statement that "there are a great many applications of computers in the straightforward statistical analysis of medical records, experimental results, and other data." However, judging from Hoffmann's letter, apparently his own experiences with computers must be quite limited.

Before considering his specific points, I would like to note that he need not worry about a lack on my part of direct personal experience with patients for, although presently not in practice, I have spent several years working in clinics and with private patients. Hoffmann should heed the statement made in the article that presently most applications of computers in biomedical science are being made by people with extensive cross-discipline backgrounds.

I believe that Hoffmann has missed the most important point in his comparison of punched-card machines and computers. As was pointed out in my article, "the advantage in the use of computers . . . is not derived merely from the fact that the computer can perform complex mathematical and logical operations rapidly, but rather from the observation that the electronic computer makes feasible the solutions to problems that could not otherwise be approached." Sometimes the use of computers can save money, sometimes not; no categorical statement can be made—it depends entirely on the particular circumstances. But the fact that an electronic computer presents vastly increased capabilities is beyond question. Consider, for example, just the basically simple case of handling ease: The information on a stock of punched cards that reaches as high as the Washington Monument and weighs about two tons would be difficult to manipulate with punched-card machines; under some circumstances a project involving so many cards might be considered unfeasible. But the same information can be recorded on a 1-foot-high stack of magnetic-tape reels weighing only 30 to 40 pounds, and conveniently processed by electronic computers. Also, it is usually not practical to perform on conventional punched-card equipment any mathematical calculations other than counting or sorting; in many such cases digital computers become a necessity. I certainly agree with Hoffmann that "no more valid information can be gotten from a set of data than is inherent in the data," but obviously no information at all can be obtained from a set of data without processing it. The kind and extent of processing evidently depends on each particular situation.

Hoffmann disagrees with my opinion that the biochemical and physiological indices of an individual's normal state of health can be used as a tool for instituting preventive measures before diseases occur—because, he says, "we know very little about the prevention of many diseases. . . ." The meaning of the words *very little* is of course relative, but it is certain that present knowledge of preventive measures for various diseases is far from zero. When an individual survives a heart attack, his physician frequently suggests many changes in his daily habits to prevent another attack. If these changes in his daily habits had been instituted *before* the first attack, the attack might have been avoided, leading to greater longevity for that individual. [See, for example, M. M. Gertler, M. A. Woodbury, L. G. Gottsch, P. D. White, H. A. Rusk, "The candidate for coronary heart diseases," *J. Am. Med. Assoc.* **170**, 194 (1959)].

Hoffmann appears distraught over the facts that "normal values in medicine" do not seem to be accurately known, and that "current medical measurements" are not always accurate or precise. Because of these inaccuracies he concludes that computers cannot be used. Certainly there are areas in medicine requiring vast improvements, but, quite contrary to Hoffmann's opinion, this indicates to me areas where computers can be significantly utilized—as aids to the more systematic collection of data, the more detailed analysis and evaluation of the results, the planning of improved studies, and so on. For example, perhaps the "normal values in medicine" appear not to be accurately known because without the aid of a computer individual variability has not been adequately considered or because it may have been too difficult to consider a sufficient number of factors or data.

In asking my opinion of euthanasia, which is quite irrelevant to the article, Hoffmann probably means to pose a question about computer aids to medi-

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cal diagnosis that is covered in the article "Reasoning foundations of medical diagnosis," by R. S. Ledley and L. B. Lusted [*Science* **130**, 9 (1959)]. In that article mathematical methods are used to separate basically quantitative values from the so-called "intangibles" or value decisions frequently required of the physician that involve moral, ethical, social, and economic considerations of great complexity. As pointed out in that article, the use of the computer might "enable the physician to define more clearly the intangibles involved and therefore enable him to concentrate full attention on the more difficult judgments."

However I am afraid the computer cannot be of aid in the "interpersonal relationship between the physician and the patient," as Hoffmann puts it, unless of course we stretch a point and say that any assistance a computer may give the physician in making a more precise diagnosis and a more scientific determination of the plan of treatment will tend to improve physician-patient relationships in general.

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Cardiotachometer

In a report by Rowley, Głagov, and Stoner published in *Science* [**130**, 976 (1959)], entitled "Measurement of human heart rate during usual activity," the authors stated, "Quantitative data on heart rate in beats per many minutes to many hours during various kinds of activity and work are not available."

It is apparent that the authors are unfamiliar with past developments in this field. In 1929, the late Ernst P. Boas developed the "cardiotachometer," which was designed to take continuous records of the heart rate for periods of hours or days. The many papers relating to this development were summarized in a text, *The Heart Rate* (Thomas, Springfield, Ill., and Baltimore, 1932). Since that time the device has been used extensively in many countries of the world and has been incorporated in many diagnostic and research tools.

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We should like to express our gratitude to Norman F. Boas for calling our attention to the outstanding work of the late Ernst P. Boas, who published a detailed description of his cardiotachometer in 1928 ["The cardiotachom-