Although computer science is in its infancy, it has already contributed significantly to society in the fields of business and commerce, communication, exploration, and scientific discovery. In contrast, the contributions of computers to medicine have thus far been minimal for reasons which I shall discuss in a moment. It is this lack of application of computers to medicine which makes medicine one of the most fruitful areas for the computer-oriented scientist. I can promise you the rewards will be great for those of you who choose to apply your talent for the benefit of human health and welfare. There are two reasons for this:

1. The systematic methods of scientific thinking which naturally lead to success in the application of computers to a scientific discipline have already been developed, and they have proven phenomenally successful in such fields as high-energy physics and molecular biology. Discovery in the field of medicine waits like a ripe apple to be plucked by the computer-skilled scientist.

2. Society will generously support your efforts. The value judgment that society places on health and longevity ultimately is the same as that which the individual places on them. I have yet to see a man who is dying of cancer of the lung, whether he be laborer or corporation president, who would not trade all of his money, business, commerce, communication, and transportation for 18 more months of healthy existence. Therefore, the computer scientist who devotes his effort to promoting human health and welfare will be both generously supported and greatly appreciated by his fellow man.

What do we expect computer science to do for medicine? The daily newspapers would lead us to believe that computers will diagnose disease, store medical records, interpret X rays, and perhaps remove a patient’s appendix untouched by human hand. Perhaps this will come to pass—but I do not find the possibility intellectually exciting.

Each of you has a much more important attribute to bring to medicine: the problem-solving technique of the physical scientist. You would be amused—and I embarrassed—to see a full exposition of the way most of us in medicine go about the business of scientific discovery.

The difference in problem-solving techniques of the physical scientist and the physician is best illustrated by my favorite analogy. Isaac Newton, after watching the red apples fall from the tree for some weeks, finally formulated a generalization which described the behavior of falling bodies. A little boy came up and said, “That’s all right, Dr. Newton, for falling red
have given the boy the formula $D = \frac{1}{2}gt^2$ and said, "Run along and figure it out for yourself, sonny." A physician, to answer the problem about falling red apples, would instead have gone to the store, bought a bushel of apples, a stopwatch, paper and pencil, and a slide rule. He would have dropped the apples one at a time from the top of the apple tree and carefully observed and recorded the time it took them to reach the ground. At the end of that time he would have been able to say that it was 2.3 seconds with a standard deviation of ±.25 second. If the same little boy had come along and said, "That's fine, Doctor, but how fast do acorns fall?" the 20th-century physician would then have run down to the store, bought a bushel of acorns, another stopwatch, paper and pencil, and repeated the same procedure. The modern physician is inclined to gather masses of random information without ever defining his question and its answer in exact physical terms.

As Vincent Dole of the Rockefeller Institute so colorfully puts it, "Physicians are obliged to swim in an ocean of detail, surrounded by great truths in high dilution."

The physician already has available more facts than the human mind is capable of bringing to bear on the solution of a single patient's problem or in the performance of a single medical experiment. "Like gold in seawater, facts lose value when mixed with irrelevancies and can be recovered only by special techniques of analysis."

It is the conceptual approach to problem-solving which I believe will be the computer scientist's greatest contribution to medicine. John Platt of the University of Chicago has attributed the stunning successes in the fields of high-energy physics and molecular biology to the regular, systematic application of Francis Bacon's system of inductive inference to the design of experiments. The physician has much to learn from the physical scientist in this regard.

There are many impediments to the introduction of computer technology into medicine:

1. There is a communication barrier. Unfortunately, the biologist is poorly equipped by virtue of his education and thought patterns to make use of the physical sciences.
2. Physicians are understandably fearful of machines and methods they don't understand.
3. There are limitations in both hardware and software. For example, we can train a medical student to recognize appendicitis, but we cannot train a machine to do so.

It is well recognized that appendicitis is frequently characterized by nausea, abdominal pain, fever, and a high white blood count. And yet a medical student will not fail to diagnose appendicitis even if only one of these four cardinal signs is present. On the other hand, he may make a correct diagnosis of intestinal flu even if all four of the signs of appendicitis are present. Twenty medical students may all arrive at a correct diagnosis of appendicitis, but each one may do so by a different logical pathway. In contrast, we seem to be able to approach the problem by computer only by (1) Bayesian statistics, which give us a probability of the diagnosis of appendicitis; or (2) sequential branching logic, which usually leads us to the wrong diagnosis.

Several problems with our hardware and software seem to be:

1. Computers do not have $10^{12}$ bits of storage like the human brain.
2. Computers do not have redundancy like the human mind.
3. We do not understand the pattern-recognition of the human mind sufficiently to be able to duplicate it in software.

Nevertheless, I am encouraged. The educational background of our medical students is improving tremendously. For example, in our current freshman medical student class, 90% of the students have completed undergraduate courses in calculus. Unfortunately, these freshman medical students just out of college have another four years of medical school, another five years of postgraduate training, and several more years after that before they become productive and begin to reap the benefits of their physical-science orientation.

In our Department of Surgery at UCLA, we are overcoming these impediments, bringing together both physicians and physical scientists to work in cooperation on common problems in a medical environment. A pilot program has been established with Drs. Edward C. DeLand, James DeHaven, and Norman Shapiro of The RAND Corporation. By supporting this program, The RAND Corporation has given us in medicine a unique insight into the potential contributions of the physical scientist to biology and medicine. We have taken engineers with advanced degrees, brought them into the University hospital, and started them on the road to a Ph.D. degree in biological science. We are introducing physicians who have had from two to five years postdoctoral training in medicine to mathematical modeling and other computer techniques. The physical scientists and physicians work side by side in the same laboratory. In this way we achieve some of the same
benefits as if each individual were educated in both sciences. Thanks to the progressive attitudes of the National Institutes of Health and its civilian consultants, it has been possible for us to fund several million dollars' worth of hardware and other facilities to bring medicine and computer science together in a hospital environment. Although the program is new and it is too early to judge it critically, we are tremendously excited by the strides that have been made by bringing computer science and medicine together.

During a recent 36-month period, 4 Nobel prizes in physiology and medicine and in chemistry, were given for computer-based discourses. From this evidence alone it is apparent to me that computer science is going to be at the forefront of medical discovery in the coming decade.