Although a fundamental characteristic of medical practice is clinical problem solving, there is little formal attention given to teaching the student the necessary skills of problem solving: how to integrate and interpret the available clinical data, how to decide what additional information should be collected, how to decide what action to take next, what are the relative cost-benefit implications of further data collection versus choosing among the different possible therapeutic actions or the management alternatives.

I believe there is a pressing need for the students to have more opportunity to practice clinical problem-solving, particularly for experimentation in the application of medical knowledge to actual patient care situations. Textbooks and lectures must by their very nature focus on the description of individual disease states, but the physician in most of his/her medical practice deals not with a theoretical model of known disease, but with the patient who presents with a particular set of signs and symptoms. Knowledge of disease states is a necessary but not sufficient basis for medical practice.

In addition, current teaching of clinical medicine is dominated by simple categorical reasoning, which is the main format of textbook descriptions of disease. A more realistic view of clinical practice should emphasize the probabilistic component, and the necessity for decision-making to be based on optimal manipulation of an incomplete and often imprecise set of findings, taken in the context of a complex set of utility judgements. There is the same need for problem solving experimentation in pathophysiology and clinical medicine as there is for laboratory experimentation in physiology and bacteriology.

I submit that the critical problem in medical school education should not be stated simply as "information overload." The problem is not merely the student's inability to comprehend or to recall the appropriate bit of factual data, but a lack of appreciation and experience in how to manage information, how to integrate the clinical data obtained from the patient with the medical knowledge taught in the curriculum.

It is futile to expand the content of the curriculum, to try to teach more and more detail; the scope of medical knowledge is expanding far too rapidly to have any hope of keeping up. In addition, the attempt to focus on teaching more facts is made even less justifiable by the phenomenon that new information makes old knowledge less relevant (if not incorrect.) What our students learn today will almost certainly be different from what they will need to know ten to twenty years in the future. I propose that a more rational teaching strategy is to focus on the management and interpretation of information, and on the underlying problem-solving skills associated with clinical decision making.

These recommendations are not unique or novel; most of the courses, particularly in the clinical departments, have this concept as their central theme. My argument is that this concept can be enhanced considerably if computer-based patient simulations are used to supplement traditional education technique. This technique will never replace the individual student-instructor relationship nor will it replace bedside experience. However it can be a very valuable complement to both.
Computer-based patient simulations combine individualized, self-paced instruction with precisely defined educational objectives; they combine the challenge and involvement inherent in personal decisions about patient care with the structure and safety of a simulation; they combine the variety of an enormous patient population and even larger set of therapeutic options with the ability to provide a reproducible experience with detailed monitoring and reporting capability.

In 1966, the MGH Laboratory of Computer Science began the development of computer-assisted educational programs, and since 1972 has made these programs available to over 150 medical schools, hospitals, and physician offices across the United States and Europe. These programs are accessed through a national communications network with local nodes in over 200 cities. At present on the network, there are over 20 different modules which teach clinical problem solving using computer simulated patient encounters. These programs range in content from the differential diagnosis of abdominal pain to the use of cardio-pulmonary resuscitation to the management of diabetic ketoacidosis. Over 100,000 medical students and physicians have used these programs during the decade during which the educational network has been operational. The programs have been greatly improved by a large number of comments and criticisms made by the users through an integrated mailbox program. This educational network is completely self-supporting through user charges. We are in the process of increasing the availability of the programs through two different channels: (1) making the programs available through a new medical network; and (2) transforming the programs to operate on a floppy disk for microcomputer use.

We are now planning a major expansion of these programs, integrating the computer-based patient simulations to teach clinical problem solving in a new medical curriculum. Students often do not appreciate the relevance of the pre-clinical science courses; well-constructed programs illustrating the applicability of the material to the diagnosis and management of a simulated patient case could provide a valuable teaching supplement with a high student appeal. Program development of these computer simulations would require significant faculty planning and involvement, but the potential benefits are great, particularly when balanced against the following advantages of the computer-based system:

1. The programs would be available at all times for student use, with the number of students who can simultaneously use the system only limited by the number of terminals which are provided.
2. The programs could be used repeatedly by a single student or by groups of students without requiring additional time on the part of the instructor.
3. Individualized feedback and criticism would be immediately available to each student.

A second potential application is the development of computer-based teaching/testing programs to identify areas of individual student weaknesses, and automatically provide appropriate remedial work. The fragmentation of the curriculum, the emphasis on elective course selection, and the geographical dispersion of the faculty are both strengths and weaknesses of many medical schools. At Harvard Medical School, this breadth of educational opportunities makes possible an enormous variety of student experiences, but it also creates a significant problem in auditing the many different learning experiences. Because of the diversity of the education environment, we have considerable difficulty in evaluating an individual student's performance in a standardized and reproducible protocol. A well-designed and comprehensive computer-based program would not only provide an attractive self-assessment opportunity for the student, but it would also provide the faculty with a resource for monitoring the student's achievement of defined educational objectives.

A further advantage of computer-based education and assessment is its self-paced nature, with the student using the material and the examination whenever he/she deems appropriate. In addition, feedback, interpretation, criticisms and suggestions for further study can be highly individualized.

Interchange between the student and the instructor can also be promoted by using the computer-based education program as an automated mailbox. At any point in the interaction, the student may enter a comment or a question into the computer system. These messages are given the next day to the appropriate instructor, who may in turn reply through the computer system with comments, responses, and interpretations for the specific issue raised by each student. The instructor's responses are transmitted automatically.
and privately to the student the next time he/she uses the computer. This two-way interaction has been one of the most interesting and valuable elements of the national educational network which we operate.

The flexibility and individual responsiveness should be welcomed by most medical students, who are generally serious, self-motivated students, capable of independent study. Self-paced, individualized education seems particularly appropriate in the professional education of a student preparing for a career which requires independent judgment and life-long commitment to continuing education. In supporting the proposed problem-solving experimentation, the computer is simply a convenient tool. There is no obvious alternative that is competitive in terms of power, flexibility, availability, responsiveness, and cost. In addition, the revolution in computer technology is not yet complete—without question the next decade will see more sophisticated terminals, memories with more capacity for less expense, and software that is easier to use.

It is no longer science fiction to predict a computer in every home, since many homes already have specialized micro-computers in stoves, thermostats, washing machines, etc., and a favorite Christmas present is the latest computer TV game. Indeed, an argument could be made that an introduction to computer applications is warranted by the pervasive role that computer technology will have in our students' future medical careers. The increasing complexity both of medical knowledge and of medical practice, and the decreasing cost and increasing availability of the microcomputer systems (and of network access to large systems) makes this an almost certain prediction.

This trend will continue at an even faster rate with the scope and complexity of future applications difficult to predict. The expanded use of computers in medical education would not be a panacea to provide an understanding of the new technology, but would facilitate a familiarity and awareness of the potentials and problems of computer applications that would be useful in understanding and perhaps in shaping future computer applications.

Even now the practicing physician may use a national computer network to perform library searches, may have computer-generated laboratory reports on his hospital patients, may have a computer-supported billing and accounts receivable system for his office practice, and may have his practice patterns analyzed in a PSRO computer-based databank.