"Representation of medical knowledge" is a very big monster to grapple with. PROMIS divides medical knowledge into two large bodies:

1. Knowledge concerning the individual patient--knowledge that has traditionally resided in scattered, multiple, and largely unedited, "first draft" medical records; and

2. Knowledge concerning populations of people or kidneys or bacteria or diseases or drugs or surgical procedures--knowledge that resides in the medical libraries, textbooks, and journals.

The knowledge that exists in medical record rooms should form the basis for much of the medical knowledge that resides in the medical libraries. Unfortunately, the libraries are thought of as the foundation for medical science, whereas the record rooms are thought of as chaotic rooms in the basements of medical establishments. The precise connections between the two bodies of knowledge are not defined and controlled at the present time.

The business of the PROMIS Laboratory is to house and to couple the two bodies of knowledge to achieve:

1. Comprehensive care for individuals over a long period of time minimizing confusion, omissions, duplications, and mistakes as the process proceeds;

2. Documentation of the care provided in a manner whereby the outcomes of the applications of medical knowledge can be studied and the "knowledge" itself updated and corrected; and

3. A system which is capable of growth and being maintained.

For the purposes of achieving the comprehensive care, one must relate all medical knowledge to the needs of individuals in the broadest possible context and in the most coordinated manner possible. Concerning context, from the patient's point of view, medical knowledge can come from many sources. Those sources include: medical textbooks and journals; the patient's own medical records (scattered over offices, hospitals, schools); technical sources of many types that contain information on the toxins in the patient's home and work environment; entertainment opportunities and trends that determine life style; and all the beliefs, facts, and notions in the minds of medical providers and patients that are not recorded anywhere but are an enormous influence as verbal exchanges abound in the medical care system. The PROMIS Laboratory is making an effort to deal with as much of this information as possible in a coordinated way so that isolated, elegant pieces of medical decision making do not turn out to be trivial, irrelevant, or harmful in the life of a whole individual.

For the purpose of improving the medical knowledge of the PROMIS system by studying the output, we must precisely understand the input and uses of the knowledge in the first place, i.e., the terms must be defined, the logic unambiguously known, the context complete, and the options known at each step. This precludes the direct use of writing or dictating from human memory either to collect basic data or to implement decision pathways. The very tools people use to collect and analyze this data and to implement decision pathways in a meaningful way require that the parameters of guidance and currency of information be defined and controlled so that work can be done correctly. To the extent that we fulfill the above requirements for the meaningful study of outputs, we go a long way toward establishing the conditions that make automation of the input (i.e., medical actions and decisions) possible.

The first step was the establishment of the POMR system in which the problem-oriented record was the organizing principle. This enabled the precise coupling of action with thought among a group of people working on the problems of a single individual. The POMR was the set of rules that made possible coordination in a broad context over a long period of time.

The next step was taken several years ago when we set out to create a completely electronic POMR--accessible to the patient and all providers through a touch-sensitive CRT. In such a manner, medical knowledge properly represented in computer systems could be displayed almost instantly to any provider in the context of a patient's problems. Direct coupling of patient's problems to the body of library knowledge is possible because of an overall common use of terms and logical approaches to problem solving and decision making. The speed and precision of the coupling depend upon the structures that have been created, the codes that have been assigned, and the tools for manipulation of data that have been built.
The details of a patient's problems, the libraries full of medical knowledge, and the individual's values and goals are not rigorously coupled easily or in a single step. The coupling is enabled by structures within structures, proceeding from the largest possible structure required for comprehensive care to the smallest structure that accommodates the final level of detail.

The larger structures that form the foundation of the computerized problem-oriented system are outlined in some detail in previous publications. Inherent in these larger structures are the coordination and context that make comprehensive care to an individual possible. These larger structures are the "algorithm" for making medical decisions. The algorithm is currently "executed" by people as they take action using PROMIS. Varying amounts of guidance are provided depending upon which step is taken and which problem is being pursued. Over time, more of this processing will be done by the computer. In Appendix 4 of a book written for patients (see Reference number 3), the above is particularly well illustrated in the eight steps of a plan for a problem and the accompanying explanations that have been reproduced from the computer displays. It was not feasible to put all the branching logic from those eight steps on paper, but one can see the beginning steps for achieving coordination. All the branching logic that is available in the complete electronic system is precisely what makes it possible for the computer system, as opposed to paper systems, to accommodate the many variables and uniqueness of an individual.

The more we have command of the details that uniqueness implies and the broader our understanding of the context of any single problem in an individual, the more we can use those details and the context to guide and simplify a step-wise search for the solutions among the vast possibilities that exist in medical knowledge. The more one knows about a patient, the less chance one takes of falsely categorizing that individual's diagnoses and treatment. There is no question that everyone is unique—the only question is how many variables do you have to look at before that uniqueness is established, and how relevant is that uniqueness to the problem at hand? One x-ray of a femur will tell whether there is a fracture in anybody, regardless of all other characteristics. One x-ray of a heart for size, on the other hand, will not tell us if digitalis is necessary regardless of all other variables. We can, in the latter case, ignore the other variables and make a probability statement and take a therapeutic chance, but we may not need to do that if we look at more variables until we can say with far more certainty who responds to digitalis and who does not. In this regard, some of the most productive areas to explore when caring for an individual are the previous patterns of that individual in manifesting disease and responding to treatments. Although patients are unique, they repeat their patterns of uniqueness. When these patterns are not available to help and we are forced to take chances or use probabilities, we should always remember not to convert what was once a mere probability to an absolute conviction once we have made a decision. We should use probability statements not to deny uniqueness and falsely categorize, but rather to get started in the right direction and be prepared to alter approaches when the patient's uniqueness is revealed by their course. We can get to the bottom of most problems, no matter how unusual (or improbable), if we take small, secure steps in a broad context and keep going until we have reached a secure conclusion (a probability of one as in the fracture) or until we have developed a willingness to tolerate ambiguity and let time and further developments guide us. We can take this latter course if we are prepared to see the new evidence when it appears and if the patient is in no danger.

The specialist has an enormous tendency to try to be certain about what he can diagnose and treat (is there a torn meniscus that can be operated upon in that knee or is there not?) and deny responsibility for all the possibilities outside of his specialty, even though the patient has cast his lot with that specialist at the outset. Computer programmers that use sophisticated calculations of probabilities on some of the causes—not all—for a given problem can act as a specialist in this regard. No patient wants to be tagged with a diagnosis for treatment that is wrong just because it is closer to the specialist's actual diagnosis than all the other wrong choices. The patient should have the answer unique to him no matter how unusual his problem, or he should have the honest advice to tolerate ambiguity as the problem unfolds.

Until better structures for approaching medical records were available, until we recognized the patients' crucial role in guiding their own health care (see book for patients listed as Reference 3), and until computers for dealing with large numbers of variables came along, we were unable to deal with and to couple the two bodies of medical knowledge as we now can. Indeed, when uncoupled and on paper, both bodies of knowledge are full of holes and misinformation. Coupling of the two bodies forces the quality of each to rise.

Using a portion of the PROMIS system, we can now show how structured and branching logic displays are used, how medical knowledge is represented in those structures and displays, how the structures and displays are used to generate medical records, how the displays are built, and how their maintenance and updating are enabled.

For an illustration, we shall begin with the third phase of medical action, "Initial Plans," which is a choice on a display containing the other three phases of medical action—"Data Base," "Problem List," and "Progress Notes." When one touches "Initial Plans" on the CRT, a display containing eight choices appears. Each of the eight steps then branches to many more choices or options—not just one or two in a chain. And then each of those choices offers many options. No two individuals progress through the series of options in identical ways if the patient's values, unique characteristics, and goals are carefully considered at each step.
As one progresses from the basic structural displays to a finer level of detail, one comes upon choices which are specific medical knowledge such as the causes of a problem or the specific drug used to treat a given disease in a certain age group with a particular set of manifestations. Since one of the main goals of PROMIS deals with coordination and context, ideally I should now progress through each of the eight steps of a plan and show how they work together to achieve meaningful comprehensiveness for an individual—making the specific medical facts servants to, and not masters of, the approach to an individual. But since that has been done in previous publications, since space is limited, and since many are expecting from this conference "representations of medical knowledge" in the usual sense, I shall take only one of the eight steps of the Plan (Step 6) and progress through it to illustrate a portion of our representation of medical knowledge (see Figure 1 below).

Figure 1

---Initial Plan for Dx Entity or Pathophys. Abn.---

-1. State Aims for problem management

-2. Check how problem may be contributing to patient's "sickness"

-3. Check for effects/disabilities produced by problem

-4. Check function/status of systems that may be involved with problem

-5. Assess and follow course

-6. Investigate problem and its etiology

-7. Watch for/prevent complications of problem

-8. If indicated, institute and monitor treatment

-Emergency management * Choose another problem *

If one touches Step 6 of the above eight steps of a Plan, he immediately progresses to the next display with its seven steps to be considered in the investigation of the cause of a problem. But before touching the choice itself, new users of the system can touch "-Exp-" next to the choice and immediately branch to the explanation seen in Figure 2.

*Each of these choices is not necessary to our present discussion and will not be explained here.

Figure 2

DETERMINE THE CAUSE OF THE PROBLEM:

Statistics on causes of a given problem in a large population may not be the best guide to effectively finding the cause in a given individual. A patient's own data base and problem list are full of clues that help provide order to the investigation. Some clues can force statistically unlikely problems to early investigation (for example, absent femoral pulses suggesting coarctation of the aorta in the hypertensive) and other clues make unnecessary investigation of a cause otherwise statistically quite common or scientifically quite attractive from other points of view. The broader the knowledge of a patient as a whole, the more efficient and more meaningful the investigation of the specialist can be. Physicians are forced to over-emphasize statistical textbook knowledge and under-utilize knowledge of the patient himself. The latter knowledge is not in textbooks and journals—it is in good records on a particular patient and in the mind of an old time physician in an isolated community who has had sole medical control of a patient over a long period of time.

-Next Frame-

From the point of view of our present discussion of "representation of medical knowledge," we can see from the above that some of the most important medical knowledge to represent and control is the knowledge about individual patients. But this requires a system for generating those records that is far more disciplined than present written and dictated inputs now are. To that end we can now progress to Figure 3 which is the display appearing when Step 6 on Figure 1 is touched.
Investigate problem and its etiology

1. Check for previous patterns of similar problems
2. Characterize problem further (if appropriate) -Exp-
3. Check problem list for possible etiologic relationships
4. Check current treatment for possible etiologic relationships
5. Investigate causes of initial concern (if appropriate) -Def-
6. Investigate other causes (if appropriate)
7. Screen for predisposing problems (if appropriate)

It will be noted that the first four steps above require us to return to the specific knowledge of that patient which in turn can guide us in our interactions with "library" medical knowledge. By touching Step 1 you are led to previous present illnesses and discussions of this problem. In the same touch you are also led to powerful flowsheet programs that reveal trends, patterns, and where and whether data are available within the known structures. In this way, efforts of various providers can be cumulative, the patient's uniqueness can be recognized, and duplications of unproductive and expensive approaches can be avoided.

For implementation of Step 3 above, one merely needs to touch the choice and the problem list appears. One then reviews what list to see which problems are on it which are also present in the textbook lists of causes that are seen when you touch Steps 5 and 6. At the present time this matching is done by the user, but it is apparent that, when all the problems are properly coded and the necessary programs written, the computer can do this matching and immediately confront the user with the causes with which to start his investigation instead of giving the user all the possible causes and a lot of probability data. In this way, the patient's unique problem list can give priority to investigations and thereby make them uniquely efficient for him as an individual. But that problem list will not be complete and precise if defined data bases are not present, if choices are not made in defined language by all information originators, and if system rules are not followed.

Frequently one immediately sees information on the problem list or treatments that make further investigation of the new problem unnecessary. But if that is not the case, one touches Step 5 and Figure 4 appears. (Since time and space are limited, I shall omit a discussion of Step 2 although it is a powerful step in ordering the investigation of causes on a given individual.)

Figure 3

----------Investigate problem and its etiology----------

---1. Check for previous patterns of similar problems
---2. Characterize problem further (if appropriate) -Exp-
---3. Check problem list for possible etiologic relationships
---4. Check current treatment for possible etiologic relationships
---5. Investigate causes of initial concern (if appropriate) -Def-
---6. Investigate other causes (if appropriate)
---7. Screen for predisposing problems (if appropriate)

---toxemia
---hypokalemic syndrome
---renal tumor
---renal artery disease
---renin secreting tumor
---ovarian tumor
---primary aldosteronism
---essential hypertension
---pseudoaldosteronism
---coarctation of the aorta
---steroid therapy
---sympathomimetic therapy
---monoamine oxidase inhibitor
---Cushing's syndrome

If an investigation of hypertension is necessary and the patient data have not provided clues as to what causes to look for, we have the question: "What causes, of all the possibilities, should be looked for first?" i.e., what are the "causes of initial concern?" For this and many such questions there must be a decision methodology. When deciding on the "causes of initial concern," the builders of the above frame looked at all the possible causes of hypertension and chose those which: 371
Figure 4 (continued)

1. have effective treatments;
2. progress rapidly; and
3. may not be easily and eventually revealed in the pursuit of another problem.

The above example is an illustration of "the representation of medical knowledge" for the purpose of solving the problem of diastolic hypertension. The medical provider is no longer expected to retain this list in his memory. The user may touch one of them--e.g., "Renal Artery Disease" and progress to the next problem-solving step as seen in Figure 5.

Figure 5

---------------Investigate for cause-------------------

-1. Screen for cause
-2. R/O cause

or

-report negative screen for cause -Exp-
-discontinue investigation for cause -Exp-
-report cause as ruled out -Exp-
-report cause as present -Exp-

At this point the user is given guidance and is told to first see if the cause is likely from readily available information before plunging into risky and/or expensive "rule-out" procedures. This he does by touching "Screen for Cause" and Figure 6 appears.

Figure 6

-------------------Diastolic hypertension: cluster to screen for cause-------------------

Cause: Renal artery disease
--- Findings that suggest this cause ---
H/O onset of hypertension < age 30 --- Sensitiv. --- --- Conf. Rate ---
Sudden increase in severity or onset after abdominal trauma --- --- ---
Epigastric upper quadrant pain --- --- ---
Lateralized bruit, especially in the costovertebral angles --- --- ---

-Order screening procedures -Flowsheet of screening procedures already in record
-Contingency Plan -Recommendations

It will be seen from the above that any reasonably complete data base on a patient will contain the information called for and will guide the user as to whether to proceed. Over and over again a data base can serve many specialists in this way. One can see where a data base reliably coded and available at all times can pay for itself because of its great power in organizing, stopping, and starting more sophisticated investigations by all sorts of providers.

It will be noted that there are columns for sensitivity and confirmation rates. Frequently we do not have good data in the medical literature for these nor for incidence and prevalence of a problem in a given population. The phrase "given population" is of great importance. It means to say: when you were getting your figures, how many variables did you use to categorize the population that you used in the first place? For example, a given culture medium and level of oxygen may be almost 100% sensitive for septicemia when
used in diabetics with urinary tract infections with E. coli organisms, whereas it may be very poor in finding the problem septicemia in non-diabetic young women who have infections with the organism "bacteroi"de" after childbirth. Any system, whether it be digital computers that have been programmed in a known way or human computers that have been programmed and which operate in unknown and strange ways, can misuse all sorts of statistical and probability data. How we use data can sometimes be as important as what the actual data are. Up until now in our "representation of medical knowledge" much of these data have not been available because we have not organized and studied most of the "knowledge" on patients. To do that, we need to examine personal records on a day-to-day basis in a serious and disciplined way, in a broad context, and in a manner consistent among many providers so that population studies are possible. We are particularly deficient in our knowledge of the course of various problems, in various contexts, with or without treatment. Both patients and providers should have this knowledge in order to arrive at decisions. We must begin to use structured inputs--gather data, study it, and then slowly the empty columns on the display will be filled out; the numbers will change as populations and diseases change, and the number of variables will increase as new tests appear.

We have probably already arrived at the point where it is not possible for human minds to extemporaneously use these isolated figures at the bedside. Well-thought-out guidance is essential just as good, up-to-date maps are useful even to the most sophisticated traveler except over the most traveled and familiar paths.

In the meantime, the present frame extends the human memory and can be used very effectively even before more quantitative data are available and before the inevitable coding and automatic checking are completed.

At this point we might pause and relate the system thus far described to medical decision making as described in a general way by many authors. By using defined input and guidance structures, we begin to deal with some of the criticisms of Herrick Wulff in his book on Rational Diagnosis and Treatment in which he states that medical students learn to imitate the decisions of the master but do not learn to evaluate those decisions. He also points out that participants in postgraduate courses rarely can agree upon the meanings of terms and that textbook authors have a special responsibility for the standardization of terms. PROMIS believes that the latter can only be achieved when we all use electronic systems which have a common language, interchangeable codes, operate within similar contexts and overall goals, and are capable of corrective feedback loops. Differences in hardware and software will probably not be important when at least this degree of commonality can be achieved. If it can be achieved, we can all grow wiser from our actions, as arbitrary as those original actions may now have been as first approximations.

We can also pause to re-look at Figure 4, "Diastolic Hypertension: Causes of Initial Concern," and ask the questions: how should a user, and eventually a machine, deal with all the possibilities on that list, and by what calculations and assumptions was the list created in the first place?

Dealing with the last question first, one could say the creators of the list in Figure 4 have merely reviewed standard library medical literature and asked experts for those causes of hypertension that fulfill the PROMIS criteria for "causes of initial concern." Many writers have been critical of that medical literature in that the proper studies and mathematical analyses were not done to support the conclusions in some of those articles; therefore, PROMIS personnel have had to develop rules for selecting data from the literature. After reviewing the best available data, the list was made as a first approximation to be improved with usage and feedback loops.

Dealing with the issue of how one should approach such a list, once it has been created, there are several possibilities:

1. One could touch each choice, look for the "screen for" data, and match it to the data in the patient's record to see if the fit is sufficient to proceed to the "rule-out" (see Figure 5). Of course, the phrase "is the fit sufficient" is not a trivial one. To answer such a question requires an understanding of probabilities, utilities, sensitivities, and incidences, etc. that the average practitioner does not possess; even if he did, he would have the time on every problem to apply that understanding and make the necessary calculations. But the user might say he is not dependent upon absolutes--he could see which ones have clusters that fit better than others and pursue them. Indeed, he might say with some validity that he can easily take the time to check each one since much of the time he may never get to this step because the steps of checking patterns and problem lists and drugs, etc. described above will have already given him an answer. Knowing his patient in a broad way does a lot to overcome his mathematical inability to work out the causes based on probabilities starting with a single factor; especially if the computer tells him what to check for on the problem list or actually checks it for him.

373
2. Instead of going down the list and doing the above in order, one could start with those diagnoses that, at first glance, would lead one to say such things as "he is not female, so toxemia and ovarian tumor do not need to have their screening clusters even examined" or "he has had the problem a long time and renal tumor is not likely, so I shall skip reading the screening cluster on that," etc.

3. One could say machines will eventually do that searching and correlating, so in the meantime, let us skip this system altogether and let each provider use his own plans, hoping for reasonable efficiency and correction of poor performance by audit.

4. One might say medicine is an art, and we should not try to make lists and put numbers and probabilities on everything anyway.

5. One could say that he is grateful for the list in Figure 4 with all its imperfections because he knows he would not have thought of some of those crucial possibilities; he will go straight to those on the list with an unequivocal "rule-out" (such as a pathognomonic blood level) and just not worry about all these probability problems. For those diagnoses that do not have definite causes and are just patterns of findings to which we have attached a name, he might say he will not worry about mathematically close fits if the treatment may work; just start the treatment and see if the patient can be helped. For those causes where patterns do not work and single causes are not demonstrable and probabilistic reasoning is necessary, he might say he still will not worry about the probabilities too much; he will just keep doing tests on all the possibilities until he comes up with the answer. The individual who reasons in this way might say to himself: "In medical school conferences I may be asked after a presentation what I think the diagnosis is and be judged on an analysis or a guess, but in everyday life I can keep going until I get to the bottom of the matter (even if in retrospect a knowledge of probabilities and methods of analysis would have made the pursuit of the problem more efficient, less dangerous to the patient, and cheaper for society)."

Obviously what is going on now in medicine is a little of all the above. The belief of PROMIS is that no unaided human mind or collections of minds, thinking at the time of action can do what needs to be done. We also recognize that we do not yet have the tools to do what could be done with present knowledge and could be done to improve present knowledge from everyday use in medical care. We are concentrating now on creating overall structures of guidance that assure a broad context for manipulation of data within those structures in the most rigorous way possible. We can create, and have created, many displays such as Figures 3 and 4 and many programs for the manipulation of data on them. Such displays can raise the overall standard of input of self-corrective systems, even with present limitations. At the same time from that base, we are moving further and further into territory previously under the control of obscure human thought processes. With the proper coding, retrieval mechanisms and tools for mathematical analysis, screening clusters can be matched and the rule-outs ordered in the most efficient way possible. But we shall control this process so that whenever the patient's own value judgments should be introduced to determine alternatives, we shall make every effort to see that it is done. For example, we are promoting the policy that the patient should have a printout of his own record and be free to interact with his electronic record. At each appropriate decision point the patient should be encouraged to look at information in tables on risk factors, complications, manifestations (which include expected course with treatment and expected course without treatment), etc. The more we involve patients, the more they themselves will find ways to be involved and to become more responsible in their own health care. To this end, we have written the book for patients referred to earlier (see Reference 3).

The patient should be able to have the best of medical science without getting automatically the set values of the person who created the tools for adequate scientific analysis. Unfortunately at the present time, patients are getting the set values of providers far more than they realize as personal problem-solving techniques are obscurely applied in the name of the "art" of medicine.

We should remind ourselves that all of the last few paragraphs of discussion have grown out of considering one display from Step 5 of seven steps in pursuing causes. The first two steps in turn came from one step, Step 6, of eight more basic steps in the planning for any problem.

In summary, we have been dealing with the issue of the "confidence" with which we make decisions to diagnose or treat. Since total confidence is not possible 100% of the time, we are forced into the position of helping the patients to take chances. We could do this if we could tell the patients the probabilities at each step of doing a new test or starting a new treatment so that they could factor them along with their goals and values into each decision. But frequently even their goals and values are determined by stories they have been told and the opportunities offered which in turn have unaanalyzed probabilities. The human need for certainty is so great, the calculation of probabilities sufficiently complex as each new variable is added, and the basic data on probabilities to insert into our calculations so rare, that we all degenerate into quite unrigorous thoughts and actions most of the time. The words "expert," "experience," "art" are frequently used to put the best face possible on this difficult situation. Some investigators have done rigorous calculations using Bayes' rule and other techniques on a few variables in one or two medical situations that lend themselves to reasonable results and have otherwise separated themselves from the millions of everyday decisions in medicine. Statisticians want to help medical people in this difficult situation,
but at the very outset they are horrified by the state of the data in everyday medical affairs. Statisticians are absolutely dependent upon consistent use of terms, reliable collections of data, structures and indices for efficiently organizing and accessing that data, and collections on large numbers of individuals so that they can make the most elementary calculations to help medical people bootstrap themselves toward wiser and wiser actions. It will not help to give courses on decision making to medical students in which we tell them what they could or should do if they had the right data and the time to make the calculations at every decision point. They will not have the time to make the calculations and get their work done anymore than they have the time to build their own car to get to work everyday. Nor will they stumble over the right data to feed into someone else's calculations if we just leave them memorizing facts inadequately, verbally communicating sloppily, and dictating and recording as they please with the terms they personally choose and with the decisions that they generate off the tops of their heads. Never was the following quote of Whitehead's more appropriate to a situation than it is to the situation in which medicine now finds itself.

"It is a profoundly erroneous truism, repeated by all copy-books and by eminent people when they are making speeches, that we should cultivate the habit of thinking about what we are doing. The precise opposite is the case. Civilization advances by extending the number of important operations which we can perform without thinking about them. Operations of thought are like cavalry charges in a battle—they are strictly limited in number, they require fresh horses, and must only be made at decisive moments."

The whole thrust of PROMIS has been first to create the structures and the successive steps such as the eight steps of the Plan described above (and all the other detailed structures described in other publications about the four phases of medical action) that will begin to dictate to us what basic data we need to have to begin to make first approximations, calculate our probabilities as experience accumulates, modify our approximations, and slowly create a wiser and wiser system.

The workers at PROMIS are more than willing to recognize that computers are superb for calculating probabilities, providing structures and guidance, and enabling feedback loops and growth of medical science, but they also recognize their responsibility to base the calculations and growth either on sound data in a broad context or on data from a system that is used consistently and can be updated as insights grow. We do not want to do trivial calculations prematurely in a narrow context just for the sake of "automatic checking," and above all we do not want to deny the patients a great deal of benefit from well-established ideas with a known high probability for success just because the patient was left to the memory and haphazard problem-solving structures of an uncoordinated host of medical providers.

It is perfectly legitimate to take the first approximations for actions at every step from the minds of "experts" and "experienced" people, providing we recognize they are not necessarily valid but just the basis for an initial hypothesis. We cannot let everyone become his own expert using terms in any old way, throw consistency to the winds, and have specialists publish articles on the few little experimental situations they were able to control. If the symphony is going to sound right, then all the players must use the same score and have a common understanding of standard musical notation—to say nothing of many years of practice in using it all correctly. Medical providers are like unicellular organisms that can no longer make it on their own, but who resist accepting constraints and limitations that make this multicellular organism possible, with all its homeostatic mechanisms and ruthless demands for conformity (move the body's pH 4 tenths of a unit and the whole, massive, multicellular structure can die).

PROMIS is a multicellular organism whose business is to practice medicine, and the bigger it gets, the stricter the rules for survival of any given cell within it. The whole is more appropriate to the situation than it is to the situation in which medicine now finds itself. It is perfectly legitimate to take the first approximations for actions at every step from the minds of "experts" and "experienced" people, providing we recognize they are not necessarily valid but just the basis for an initial hypothesis. We cannot let everyone become his own expert using terms in any old way, throw consistency to the winds, and have specialists publish articles on the few little experimental situations they were able to control. If the symphony is going to sound right, then all the players must use the same score and have a common understanding of standard musical notation—to say nothing of many years of practice in using it all correctly. Medical providers are like unicellular organisms that can no longer make it on their own, but who resist accepting constraints and limitations that make this multicellular organism possible, with all its homeostatic mechanisms and ruthless demands for conformity (move the body's pH 4 tenths of a unit and the whole, massive, multicellular structure can die).

PROMIS is a multicellular organism whose business is to practice medicine, and the bigger it gets, the stricter the rules for survival of any given cell within it. The whole is more appropriate to the situation than it is to the situation in which medicine now finds itself. It is perfectly legitimate to take the first approximations for actions at every step from the minds of "experts" and "experienced" people, providing we recognize they are not necessarily valid but just the basis for an initial hypothesis. We cannot let everyone become his own expert using terms in any old way, throw consistency to the winds, and have specialists publish articles on the few little experimental situations they were able to control. If the symphony is going to sound right, then all the players must use the same score and have a common understanding of standard musical notation—to say nothing of many years of practice in using it all correctly. Medical providers are like unicellular organisms that can no longer make it on their own, but who resist accepting constraints and limitations that make this multicellular organism possible, with all its homeostatic mechanisms and ruthless demands for conformity (move the body's pH 4 tenths of a unit and the whole, massive, multicellular structure can die).

Having made this digression, we can now continue our step-by-step progression through a very small part of our PROMIS structures. Returning to actual displays from the system, let us consider that the "Screen for" cluster for renal artery disease did match our patient, and we wanted to go further and begin to rule it out with more specific diagnostic measures. We merely have to touch "Renal Artery Disease" as seen on Figure 4, then touch "Rule out cause" as seen on Figure 5, and Figure 7 would appear (see Figure 7 on next page).

* * * * * * * * * * * *

Please Note. The displays that have appeared thus far (Figures 1-6) have been single frame displays. Some of the figures from this point on will be multiple frame displays. A broken line with the title of that display repeated in the center means that only the information between each broken line is seen at any one time on the CRT in the PROMIS system.
---\textbf{R/O renal artery disease}---

1. Do \textit{-hypertensive IVP -Int-}

2. If hypertensive IVP findings are diagnostic, then renal artery disease is present.
   
   If IVP findings are within normal limits but clinical suspicion is high, then do \textit{-selective renal arteriogram -Int-}

3. If selective renal arteriogram is abnormal, then do \textit{-renal vein renins -Int-}

---\textbf{R/O renal artery disease}--- (cont.)

4. If renal vein renins are diagnostic, then renal artery disease is present.

---\textbf{Contingency Plan}---

\textbf{-Recommendations}

At this point the user is given specific guidance. By touching the "-Int-," one can immediately be informed as to how to interpret results as seen in Figure 8.

---\textbf{Procedure interpretation: renal arteriogram in renal artery disease}---

1. Stenosis (occlusion) main renal artery, arteriosclerotic. /\#0BF/

2. Branch stenosis, renal artery /\#00G,00H/

3. Fibrosing lesion(s) renal artery /\#00D,00F/

4. Aneurysm, renal artery /\#08H/

It will be noted that there are numbers and letters after statements. These designate references to the original articles from which the information was derived. This leads us to a discussion of how the various lists of causes and procedures, etc. are generated and stored in the system.

When one makes a selection such as "Causes of Initial Concern," the system goes into a table for the particular problem such as hypertension or otitis media, etc. and goes to the appropriate slot in that table. New information about problems or procedures is entered into these tables using pointers to frames. (The frames, therefore, can be used for storage and display.) The use of tables allows one to be sure that a single "up-date" or addition can immediately affect all the points in the branching logic that access the particular slot in the table. One must be able to know these points of access so that information can be used in the right context.

Figure 9 is a list of slots in a typical problem table. A builder arrives at such a table easily by progression through a series of displays beginning with Figure 10.
-Definition                   -"Corr" ther                   -Incid/prev                   -Unclass rule
-Goal course                  -Goal respons                 -Predis fact                  -Test 1
-Char further                 -Manifest stats               -Diagnoses                   -Test 2
-Cause-init                   -Predis prob                  -Operat defs                  -Updates
-Cause-other                  -Rx protocols                 -Inst gen1                    -Family members
-R/O entity                   -temp-15                       -Prev rules                   -member of
-Complications                -temp-16                       -Probs PredTo                 -Rad report
-Screen proc                  -temp-17                       -Symptoms                     
-Prev measur                  -Rx rules                      -Prob Table Specs             -Pres Illness

---Problem Table Information Access---(cont.)---

To review table content in context of superstructure, touch here and then pick appropriate superstructure (no messages generated will store).

-cause cluster

-radiology procedures for this problem

---Table access using alpha list---

Look up table via Alpha list:
-Problem table (> 127/299) Citation table: -by title
-Procedure table (< 121/5700) -by author
-Drug dosage group table
-Clinical lab proc table
-Ward proc table
-Radiology proc table
(includes isotope & ultrasound)

One merely touches "Problem table" then types in the first two letters of the problem (e.g., "ot" for otitis media) and Figure 11 is presented.
The first slot in this table, "Definition," provides the opportunity to develop a common terminology among providers so that communication will be precise and feedback loops and population studies more reliable. It deals with the conclusions of Wulff mentioned earlier. A problem definition is a set of criteria which are fulfilled by all patients who have the problem and by no patients who do not have the problem. The criteria may be terms of clinical findings, clinical chemistry, or tissue pathology. Its purpose is to serve as a basis of deciding on the correct usage of the information in the table.

One notes that selection #4 in this list is the "Causes of Initial Concern" referred to earlier. Another choice is "Rx rules" at the bottom of the second column. If one touches that, he gets Figure 13.
Figure 13

---Acute otitis media: treatment rules---

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Rules</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>-ampicillin</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>-amoxicillin</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>-erythromycin</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>-sulfisoxazole</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>-penicillin V</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>-penicillin G benzathine</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>-penicillin G procaine</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

---Acute otitis media: treatment rules---(cont.)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Rules</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>-kanamycin</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>-aspirin</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>-acetaminophen</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>-codeine</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>-actifed</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>-phenobarbital</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>-chlorpheniramine</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

---Acute otitis media: treatment rules---(cont.)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Rules</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>-ENT consult</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>-myringotomy</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>-co-trimoxazole</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 13 shows a list of treatments for acute otitis media for which there are detailed statements or rules in the literature. To get the rule and the references that support it, one merely has to touch the "X" under the rule column. The rule may be good or bad. The statistics that underlie the conclusions may be faulty, non-existent, or in too limited a context for transfer to the average clinical situation. At any rate, this is the slot to "represent" that piece of "medical knowledge" with all its virtues and failings.

Decision methodologies will integrate these facts or rules into a series of steps for treatment. Frequently this universe of choices is not known to a reader of a regular article wherein the author may just reference the particular treatments or causes that he uses but fails to show the universe from which his choice was made. An article on coronary type personalities, e.g., may appear scientific and complete, but the reader has no way of knowing about all the articles that come to opposite conclusions. Again, it is the matter of breadth of context that can be so powerful in broadening our perspective and in questioning many of our notions in medicine. Contradictory rules abound in the medical literature on most subjects, and students should be aware of them. Figure 13A, on the other hand, is a step-by-step approach to treatment.
Figure 13A

Otitis media: treatment

If patient greater than 6 weeks or less than or equal to 5 years old,

- Ampicillin, P.O., 50-100 mg/kg per day in 4 doses for 10-14 days
- Amoxicillin, P.O., 20-40 mg/kg per day in 3 doses for 10-14 days

If allergic to penicillins or if local signs or symptoms persist or worsen despite ampicillin therapy for 10 days,

- Erythromycin, P.O., 30-50 mg/kg per day in 4 doses
- Sulfisoxazole, P.O., 100-150 mg/kg per day in 4 doses

If patient greater than 5 years old,

- Penicillin V, 125-250 mg per day or 30-40 mg/kg per day in 4 doses for 10 days
- Erythromycin, P.O., 38-50 mg/kg per day in 4 doses for 18 days
- Sulfisoxazole, P.O., 188-150 mg/kg per day in 4 doses for 18 days

If patient severely ill (temperature greater than 104 degrees F or 48 C, vomiting, or diarrhea), give indicated medication I.M. then begin oral in 1-2 days.

- Ampicillin, I.M. or - Penicillin G procaine, I.M.
- Erythromycin, I.M. (if allergic to penicillin)

If patient less than or equal to 6 weeks old, use parenteral treatment according to sensitivities of aspirate growth and

- Ampicillin, P.O., 200 mg/kg in 4 doses (unless vomiting, then I.M.)

Until culture results have returned, in addition to the ampicillin, use
- Kanamycin, I.M., 15 mg/kg per day in 2 doses

For all patients, the following may be helpful:

- Analgesics
- Actifed

If relief of severe pain is needed, or specimen for culture is needed, or imminent spontaneous perforation is suspected, then Do
- myringotomy

If H/O or H/O febrile seizures in siblings,

- Phenobarbital

If seasonal allergic rhinitis,

- Chlorpheniramine

If infections recurrent (greater than or equal to 18 days between and greater than or equal to 3/year), then update problem to recurrent otitis media.
- ENT consult (to investigate etiology, particularly to R/O structural abnormalities)
In displays such as the above, the references are directly related to rules in the system which in turn can be referenced to the standard paper medical literature.

Let us now review another Rx sequence and note at each step where automatic checking might come in (see Figure 14).

Figure 14

--- Initial Plan for Dx Entity or Pathophys. Abn. ---

-1. State Aims for problem management
-2. Check how problem may be contributing to patient's "sickness"
-3. Check for effects/disabilities produced by problem
-4. Check function/status of systems that may be involved with problem
-5. Assess and follow course
-6. Investigate problem and its etiology
-7. Watch for/prevent complications of problem
-8. If indicated, institute and monitor treatment

--- Emergency management ---

Choose another problem

In the sequence that follows, we shall begin by choosing Step 8 for the problem of moderate, diastolic hypertension. As we touch it, Figure 15 immediately appears.

Figure 15

--- Institute and monitor treatment ---

-1. Assess response to treatment (if any currently being done)
-2. Order procedures for treatment baseline data
-3. Order treatment: supportive/nursing care
   - symptomatic treatment
   - "corrective" therapy
-4. Order procedures to follow response to treatment

--- Enter planned treatment protocol ---

The first step above reminds us to take advantage of what is already known about a unique individual. The second step reminds us that any treatment we begin has no absolute assurance of doing as predicted since all the variables in a given patient can never be known. We must be prepared to stop or alter treatments far more than we have been inclined to before serious difficulties arise. It is the immediate "representation of medical knowledge" on unique individuals that is seldom acquired or is ignored in favor of "knowledge" from books and laboratories.

The third step reminds us that there are many aspects to treating a problem and one, without the others, is frequently a futile gesture. But isolated actions are frequently taken in busy wards and in busy clinics and offices.

Step 4 follows naturally from Step 2.
Figure 15 (continued)

Let us touch "Corrective therapy" under Step 3 and progress to either Figure 16 or Figure 17 depending on how the system is set up in a given environment. Figure 17 is much more specific guidance whereas Figure 16 is a large universe of choices depending on the mechanism of action of a drug. In either case, after choosing a drug, you progress to Figure 18.

Figure 16

Antihypertensive agents - by mechanism of action

alpha-adrenergic blockers
- phentolamine (Regitine)

beta-adrenergic blockers
- propranolol (Inderal)

- centrally acting
  clonidine
  methyldopa

-direct arteriole dilators
  diazoxide (Hyperstat)
  hydralazine (Apresoline)
  nitroprusside (Nipride)

- diuretics, loop acting
  ethacrynic acid (Edecrin)
  furosemide (Lasix)

- diuretics, potassium sparing
  spironolactone (Aldactone)
  triamterene (Dyrenium)

- diuretics, thiazide/thiazide-like

Antihypertensives - by mechanism of action, cont:

ganglionic blockers
- mecamylamine (Inversine)
- trimethaphan (Arfonad)

vasodilator (via effect on cyclic AMP)
- prazosin (Minipress)

-post-ganglionic agents
  guanethidine (Ismelin)
  reserpine (sandril)

combination products
- Dyazide

Figure 17

Hypertension: treatment

Goal: to maintain BP < 140/90 without development of unacceptable side effects.

First start with
- Thiazide diuretic
  or
- Furosemide

If BP not controlled after trial of 2-3 weeks, add
- Methyldopa
- Propranolol
- Reserpine
Figure 17 (continued)

Hypertension: treatment (cont.)

If BP not controlled with acceptable doses of above, add
-Hydralazine

If BP not controlled by combination of above, may add
-Guanethidine or -Propranolol

Figure 18

General Ordering Methodology for Drugs

Explanation of this frame

-1. Check "Aims for Problem Management" for consistency -Exp-
-2. Check for duplicate order
-3. Check for findings which may affect use of drug in patient
-4. Discuss use of drug with patient
-5. Check dosage and frequency

-6. Continue to order -Exp-

The above five steps are further opportunities for coordination, understanding context and control in a complex situation. If we touch choice 3, we progress to Figure 19.

Figure 19

Types of circumstances which may effect the use of a treatment

-1. Drug-Problem Interactions -Exp-
-2. Drug-Drug Interactions -Exp-
-3. Drug-Test Interactions
-4. Review mechanism of action
-5. Review absorption, distribution, metabolism and excretion

Serial Check

When each of the above is touched, displays containing the indicated information appear. When a system such as this is complete and all items are coded and quantitative aspects understood, then touching #1 above would yield those interactions appropriate to the drug and problem at hand whereas at present one may get a complete list of interactions with all types of problems for a given drug. The same is true for choices 2 and 3. A careful examination of the displays in PROMIS reveals how much information there is that must be integrated with large numbers of facts about individuals. It is easy to write programs for automatic checking that deal with some of these but very difficult to deal with all. The user of the system who knows his patient and the patient who knows his own values and choices about risk should both be given the chance to see all the information; no data or logic should be denied them by over-simplified computer programs that decide risks and values for them. The block at the present time in automatic checking with computers is not any lack of understanding of what it means or how to do it. The block is rather in knowing precisely what to check, how to code it in a consistent fashion as part of a total system for care, how to factor in the patient's values and unique characteristics that so profoundly affect risks and outcomes, how to develop structures and indices and groupings of data so crucial bits of information can be accessed in reasonable amounts of time, and how to assure reliable maintenance and growth of the system itself.
In the present medical care system, which is memory based in large part and in which inputs are poorly controlled, we allow provincial and inadequate decisions to be made and then use computer checking programs in pharmacies and laboratories to point them out. Medical providers make mistakes and often get discouraged about all they have to know and remember. They should resent being put in an impossible system in the first place. Just trying harder with present approaches will not necessarily solve their problems.

Having completed this small sequence on treatment, we shall now deal with the issue of building and maintaining displays, using one of the displays we used earlier as an example (see Figure 20).

---_--_--------

Diastolic hypertension: causes of initial concern---

- toxemia
- hypokalemic syndrome
- renal tumor
- renal artery disease
- renin secreting tumor
- ovarian tumor
- primary aldosteronism
- Begin/continue/resume other investigation

This display will be used to demonstrate some of the building and maintenance mechanisms of PROMIS. Since so much is done with the computer to facilitate these processes, it is difficult to describe them on paper effectively. However, to provide a rough idea, a series of displays follow that illustrate how a "frame editor" allows maintenance in the PROMIS system. A system that cannot be effectively maintained and kept up-to-date may be worse than no system at all. We can begin with the above display which is the same as Figure 4 which we came upon in the pursuit of the problem, hypertension.

At the bottom of such a display you will note function pads (choices). These include "-Fred-" which stands for Frame Editor. If we touch "-Fred-", the display above changes, and additional characters appear as shown in Figure 21.
The characters on the display above (that are in addition to the medical words themselves) allow a whole series of actions to take place. For example, a selection on a frame may or may not:

1. be included in the patient's record
2. indicate which of hundreds of parts of the record it is to be stored in
3. order a procedure
4. report a procedure
5. branch to a certain frame
6. return to itself after branching some place else
7. allow entry of keyboard information
8. act as a prefix to other selections on the frame
9. act as a suffix to another selection on the frame
10. request the retrieval of certain information from the patient's record
11. request the retrieval of certain medical information about a problem or a procedure
12. add interpretation codes to a selection, e.g., indicate that the report of a procedure is abnormal
13. require a special location on the frame
14. act as a column heading
15. be translated to a message other than the phrase which was selected
16. indicate formatting information for entry into the patient's record
17. perform different functions in different situations
18. be set up as a potential cause being investigated for the problem

The first line of function pads or choices at the bottom of the display can apply to any or all of the choices. The second line of choices brings up displays that deal with the frame as a whole. In order to deal with the controls of any single choice we touch the pad "TOUCH" and then touch any choice and a display appears which allows us to deal with the details controlling that choice. Reviewing some of these steps, let us first touch "CHOICE CONTROL" and Figure 22 will appear.

CONTROL #: 02 X code first call DLIST call RETRIEVE call FLOWSHEET call GRAPH

#1 RETURN; BRANCH #1, : 064/00229
#2 RETURN; BRANCH #2, : 
#3 RETURN; BRANCH #3, : 
CHC CTROL SRC: CALL (RCODE);

It will be noted at the top of the above display that a series of program calls may be associated with the particular choice control. This assures that certain lists used in other contexts and flowsheets can contain this choice. At the same time we can control to what extent the choice will branch so logical thought and action can be combined. If instead of touching "CHOICE CONTROL" we had turned on the "TOUCH" pad by touching it and then touched the choice, "Renal Artery Disease," Figure 23 would have appeared.
It can be seen from the above that we now have the opportunity to set a prefix and designate references, etc. as mentioned in the partial list of functions above. One either puts the appropriate number in or merely turns the pad on by touching it, such as setting an "Explanation Branch" opposite a choice. In the actual display in the terminal the choice appears in inverse video and stays set until touching it again unsets it. By touching "DISPLAY ALL" at the bottom of the display, Figure 24 appears.

The above display is similar to Figure 23 but has considerably more elements to be considered in the case of the choice "Renal Artery Disease." The items on Figure 23 are things that can be altered by the builder whereas the additional elements on Figure 24 are (for the most part) flags and other data set up by the frame editor itself in order to efficiently display the frame.

If we now return to the original frame in "FRED" and touch "FR VAR SEN" (Frame Variable Sentence), we see Figure 25.
The above display allows us to deal with the original frame as a whole. For example, if we touch "ENABLE NEXT FRAME" the phrase "NEXT FRAME" will appear in the corner of the display as an actual choice for progression to the next display. Review references and citations can also be designated. If we touch "MAINT SEN" (maintenance sentence) on the original or the above display, Figure 26 would appear.

The above illustrations of just some of the opportunities and rules for building and maintaining frames show how crucial every detail of syntax can be. An absent phrase or a wrong branch can be harmful. Computer programs have been written at PROMIS that review the thousands of frames at the time of building and maintaining for adherence to the rules. The "Syntax Checker" can do in an evening that which individuals would take months to do. Furthermore, the results of the check can be given to builders and checks repeated until no errors appear.
The teaching of medical students gains a whole new perspective with the experience of building, maintaining, and using displays in patient care. How carefully and rigorously do teachers build, in terms of both semantics and syntax, when dealing with the minds of students? How good is the mental and physical equipment of the student for rigorously coupling medical knowledge to clinical action on the behalf of patients? What is the "Syntax Checker" for medical providers? What do the results show? What do we do about them?

Having touched upon some elements of building and maintaining frames, we can now return to a sequence of retrievals that reflect some of the uses of the system. We shall begin with a discussion and demonstration of flowsheets. Flowsheets are valuable for seeing the whole situation at a glance, determining where the action is and where interventions are most indicated. But we must remind ourselves that at the present time it is the computer, properly programmed, that takes masses of data, organizes it, and presents it in flowsheet form. It is the human mind that comprehends context, perceives trends, and recognizes patterns within these flowsheets. We do not know how the mind does this (like recognizing a face in an instant), but it does it at incredible speed, without being paralyzed or prohibitively slowed by sequentially processing and analyzing details over long periods of time. We take advantage of this human capacity, especially when we are fulfilling our goals of comprehensiveness and broad contexts in the care of a whole patient.

Since we do not know how minds do this and each mind is different, human minds are not ideal for consistency of analysis and inputs and are therefore not ideal for corrective feedback loops. Also, just as the mind does not create the face whose pattern it recognizes, neither does it rapidly and consistently acquire masses of medical data and organize them into patterns for the mind to work on. So the human mind, when alone with patient and pencil and paper tools, often fails and is often helpless to sharply define and correct those failures. At present we must employ a combination of man and machine, and the following displays about flowsheets show how powerful the machines are in doing their part. The human mind writes the computer programs but can never equal the machine in manipulating the data at speeds necessary for everyday use on large numbers of patients.

The respective roles of man and machine are not fixed, and we should always be prepared to reassess our position and employ the one that consistently assures the best result at any step in the process of caring for large numbers of people. The machine's capability to perceive trends and generate patterns from masses of data, as in a CAT scanner in radiology, is underutilized in many areas. We can expect machines to go far beyond what they now do. In this whole process of allotting tasks to man or machine, we should be careful to compare the machine to what the average patient receives from the average human mind in the average encounter and not to what a rare human mind can do with lots of time and money. The facts that machines can be more consistently understood, corrected, and maintained in what they accomplish often makes up for their limitations in speed and subtleties of ideal pattern recognition.

To arrive at a basic set of options for flowsheet retrieval, we start at the basic "RETRIEVE-ADD TO" display in the system and touch the choice "Flowsheets," as seen in Figure 27.
When "Flowsheet Retrievals" above is touched, Figure 28 appears. Although the graphic displays will not be demonstrated here, one can see that they can be retrieved by touching "Graph Retrieval" above.

Figure 28

--- Flowsheet Retrievals ---

--- Record retrievals ---
- Data Base
- Problem List
- Initial Plans
- Progress Notes
- For specific problem

--- Non problem specific ---
- Source oriented flowsheets:
- Other flowsheet retrievals:

--- Standard flowsheets ---
- Routine Vital Signs
- Neuro Vital Signs
- Venous Pressure
- Fluid & Electrolyte
- Bone Marrow Exam
- Check related systems

--- Flowsheet information:

This display (and its continuation displays, Figures 29 and 30, which are made available by touching "Source Oriented Flowsheets" and "Other Flowsheets" respectively) provides us with many options for organizing and reviewing the data on an individual in flowsheet form. The same data can be seen in many different contexts, and one can highlight relationships from many points of view. For example, when we touch "Routine Vital Signs," we get Figure 31, and we see the respiratory rate along with the other vital signs. If we touch "Check Related Systems," we can flowsheet parameters appropriate to a given system. In so doing (with the respiratory system, for example) we get Figure 32. Figure 32 shows the same respiratory rate but associated with respiratory system parameters.

Figure 29

--- Other flowsheet retrievals ---

- Single Lab procedure
- Drugs for pharmacy review
- Gentamicin drug-drug interactions
- EKG/Vitalor

- Administrative Flowsheet
  (each occurrence, entire record)

--- Flowsheet information:

This display (and its continuation displays, Figures 29 and 30, which are made available by touching "Source Oriented Flowsheets" and "Other Flowsheets" respectively) provides us with many options for organizing and reviewing the data on an individual in flowsheet form. The same data can be seen in many different contexts, and one can highlight relationships from many points of view. For example, when we touch "Routine Vital Signs," we get Figure 31, and we see the respiratory rate along with the other vital signs. If we touch "Check Related Systems," we can flowsheet parameters appropriate to a given system. In so doing (with the respiratory system, for example) we get Figure 32. Figure 32 shows the same respiratory rate but associated with respiratory system parameters.
Figure 30

<table>
<thead>
<tr>
<th>Symptoms</th>
<th>Consult notes</th>
<th>Exp-</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical Exam</td>
<td>Attending notes</td>
<td></td>
</tr>
<tr>
<td>Hematol, Serology, Blood Bank</td>
<td>Contingency plans</td>
<td>Exp-</td>
</tr>
<tr>
<td>Chemistry</td>
<td>Recommendations</td>
<td></td>
</tr>
<tr>
<td>Microbiology</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Histology, Cytology</td>
<td>All laboratory</td>
<td></td>
</tr>
<tr>
<td>Urinalysis</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Radiology, Ultrasound</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drugs</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

Flowsheets

---

Consult notes

---

Exp-

---

Attending notes

---

Contingency plans

---

Recommendations

---

All laboratory

---

Flowsheet information:

---

Other time intervals:

---

Next Frame

---

Review Erase 1

---

Optical

---

Fred:

Orient

---

64.567

---

Figure 31

- - - - - - - - - - - - - - Routine Vital Signs including weight- - - - - - - - - - - - -

| Time span: | 9/15/78 00:00 to 9/21/78 00:00 |
| Resolution: | 1 day |

| Mode = Retrieval | 9/15/78 00:00 | 9/16/78 00:00 | 9/17/78 00:00 | 9/18/78 00:00 | 9/19/78 00:00 | 9/20/78 00:00 |
| BP | 112/80 | 110/80 | 110/80 | 110/80 | 110/80 | 110/80 |
| Temperature | 39.5 | 39.5 | 39.5 | 39.5 | 39.5 | 39.5 |
| Pulse | 88 | 88 | 88 | 88 | 88 | 88 |
| Respiration | 20 | 20 | 20 | 20 | 20 | 20 |
| Weight | 78 | 78 | 78 | 78 | 78 | 78 |

If one touches the date at the head of a column, one gets all the values of that day, e.g., touching 9/20/78 immediately leads to Figure 31A.

Figure 31A

- - - - - - - - - - - - - - Routine Vital Signs including weight- - - - - - - - - - - - -

| Time span: | 9/20/78 00:00 to 9/20/78 23:59 |
| Resolution: | 4 hours |

| Mode = Retrieval | 9/20/78 00:00 | 04:00 | 08:00 | 12:00 | 16:00 | 20:00 |
| BP | 110/80 | 110/80 | 95/50 | 100/60 | 100/60 | 100/60 |
| Temperature | 37.2 | 36.5 | 36.5 | 37.2 | 36.2 | 37.5 |
| Pulse | 88 | 64 | 88 | 88 | 88 | 88 |
| Respiration | ... | ... | 18 | ... | 18 | 18 |
| Weight | ... | ... | ... | ... | ... | ... |

---

390
Figure 32

- - - - - Check function/status of system: Respiratory/thorax - - - - -

Time span: 9/15/78 00:00 to 9/21/78 00:00
Resolution: 1 day

<table>
<thead>
<tr>
<th>Mode = Retrieval</th>
<th>9/15/78</th>
<th>9/16/78</th>
<th>9/17/78</th>
<th>9/18/78</th>
<th>9/19/78</th>
<th>9/20/78</th>
</tr>
</thead>
<tbody>
<tr>
<td>decreased exerc</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>_rise capacity</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>dyspnea</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>cough</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>respirations</td>
<td>20 &gt;&gt;</td>
<td>20 &gt;&gt;</td>
<td>18 &gt;&gt;</td>
<td>20 &gt;&gt;</td>
<td>20 &gt;&gt;</td>
<td>20 &gt;&gt;</td>
</tr>
<tr>
<td>pulse</td>
<td>100 &gt;&gt;</td>
<td>88 &gt;&gt;</td>
<td>88 &gt;&gt;</td>
<td>96 &gt;&gt;</td>
<td>84 &gt;&gt;</td>
<td>88 &gt;&gt;</td>
</tr>
<tr>
<td>temperature</td>
<td>38.2 &gt;&gt;</td>
<td>38.5 &gt;&gt;</td>
<td>37.5 &gt;&gt;</td>
<td>38.0 &gt;&gt;</td>
<td>37.8 &gt;&gt;</td>
<td>36.5 &gt;&gt;</td>
</tr>
<tr>
<td>chest/lung</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>_exam</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>chest</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>_inspection</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>chest</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>_palpation</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>chest percuss.</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>chest ascult.</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>position extre</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>vitalor</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>Hct</td>
<td>29.5 =</td>
<td>29.1 =</td>
<td>28.3 &gt;&gt;</td>
<td>28.9 =</td>
<td>27.4 =</td>
<td>...</td>
</tr>
<tr>
<td>WBC count</td>
<td>10.3 =</td>
<td>9.7 =</td>
<td>10.5 &gt;&gt;</td>
<td>15.8 =</td>
<td>12.7 =</td>
<td>...</td>
</tr>
<tr>
<td>Hgb</td>
<td>10.0 =</td>
<td>9.8 =</td>
<td>9.8 &gt;&gt;</td>
<td>9.8 =</td>
<td>9.1 =</td>
<td>...</td>
</tr>
</tbody>
</table>

Figure 33

- - - - - - - Data Base Flowsheet - - - - - -

Time span: 9/15/78 00:00 to 9/21/78 00:00
Resolution: 1 day

<table>
<thead>
<tr>
<th>Mode = Flowsht</th>
<th>9/15/78</th>
<th>9/16/78</th>
<th>9/17/78</th>
<th>9/18/78</th>
<th>9/19/78</th>
<th>9/20/78</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sickness</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>Administrative</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>Admission</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>_Screening</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>Health Care/</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>_Social Prof.</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>History Data</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>Physical Exam</td>
<td>...</td>
<td>ni data</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>Lab Data Base</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>Pres Illness</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>Reports w/o</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>_Orders</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>

391
Figure 33 (continued)

One may see a patient for a "check-up" and want to see a flowsheet of all additions to various components of the data base. The above display shows us that there was physical exam data on a given date. The same display was arrived at by touching "Data Base" on Figure 28.

Figure 34

| Time span: 9/15/78 00:00 to 9/21/78 00:00 |
| Resolution: 1 day |
| Mode = Flowsht |
| 9/15/78 9/16/78 9/17/78 9/18/78 9/19/78 9/20/78 |
| 00:00 00:00 00:00 00:00 00:00 00:00 |
| Vitalor with | ... | ... | ... | ... | ... | ... |
| isuprel 1/1 | ... | ... | ... | ... | ... | ... |
| Hospitaliz- | ... | ... | ... | ... | ... | ... |
| ation | ... | ... | ... | ... | ... | ... |
| 1. Anemia, chronic, normochromic, normocytic | ... | ... | ... | X > (1) | ... | ... |
| 2. Edema, loc- | ... | ... | ... | ... | X [4] | ... |
| ation both al | ... | ... | ... | ... | ... | ... |
| 3. Cigarette - smoking, 1 pl | ... | ... | ... | ... | ... | ... |
| 4. S/P Cparti- | ... | ... | ... | ... | ... | ... |
| _al cystectomy | ... | ... | ... | ... | ... | ... |

If one touches progress notes on Figure 28, the above display appears showing where notes are available and in what problem. If one touches the problem heading "Anemia," one gets Figure 35.

Figure 35

| Time span: 9/15/78 00:00 to 9/21/78 00:00 |
| Resolution: 1 day |
| Mode = Flowsht |
| 9/15/78 9/16/78 9/17/78 9/18/78 9/19/78 9/20/78 |
| 00:00 00:00 00:00 00:00 00:00 00:00 |
| Aims | ... | ... | ... | ... | ... | X > [1] |
| Symptomatic | ... | ... | ... | ... | ... | ... |
| Objective | ... | ... | ... | ... | ... | ... |
| Assessment | ... | ... | ... | ... | X > [4] | ... |
| Plans | ... | ... | ... | ... | ... | ... |

Figure 35 shows which sections of progress notes contain data. If one touches any section where data are said to be present, the actual data appears on the screen. If it is a retrieval to the printer, the above flowsheet is accompanied by annotated notes numbered as in the brackets above. These notes contain the actual data.
Figure 36

--- Plans Flowsheet ---

Time span: 9/15/78 00:00 to 9/21/78 00:00
Resolution: 1 day

Mode = Flowsht

<table>
<thead>
<tr>
<th>Date</th>
<th>00:00</th>
<th>00:00</th>
<th>00:00</th>
<th>00:00</th>
<th>00:00</th>
<th>00:00</th>
</tr>
</thead>
<tbody>
<tr>
<td>9/15/78</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>9/16/78</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>9/17/78</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>9/18/78</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>9/19/78</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>9/20/78</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>

Emergency Mgmt

Chk Relation -<@

Check Related-<@

Follow Course-<@

Investigate -<@

Problem-<@

Watch/Prevent-<@

Complication-<@

Treatment-<@

The above is displayed by touching "Plans" in Figure 35. Actual data is retrieved by touching any point where data are indicated to be present.

Figure 37

RADIOLOGY REPORT

T11. Fever, etiology unknown, onset on 09/14/78

Obj

Chest x-ray: portable stat (already done)
Study done as ordered.
Assessment of study:
No problem related findings.

Overall Impression: normal study.

The above type of report from radiology is immediately retrieved if one touches any square on a flow-sheet that says a chest x-ray is available. PROMIS contains a complete radiology reporting system with thousands of displays as an integral part of a total, coordinated system for patient care. The details of this part of the system and the laboratory reporting will not be discussed in this communication.

Figure 38

---------Fluid and electrolyte management flowsheets---------

Volume:
- current status parameters -Int-
- Exp of order of parameters
- I & O, totals/report (indicator of potential state) -Int-
- I & O, detailed breakdown

- Osmolarity parameters -Int-
- Acid/base parameters -Int-
- Potassium parameters -Int-

Note: due to retrieval limitations some parameters are more general than would be ideal, e.g. general motor activity is used to retrieve seizures.
The above display appears when one touches "Fluid and Electrolyte" in Figure 28. On this display, the user is given guidance as to how to think about any fluid and electrolyte problem. If we touch "-Int-", we get a discussion of how to use and interpret volume parameters or osmolarity parameters, etc. If we touch "Current Status Parameters" under volume, we see Figure 39.

One immediately sees from the above display not only the appropriate parameters for assessing current status of volume but the values available on the particular patient. Such an approach prevents us from just flowsheeting what we have and ignoring parameters that we should have but do not. Also it reminds us when we fall into the trap of favoring laboratory parameters over clinical observations. It is the broadest possible context that does most to avoid trouble in unique individuals. Returning to the basic "RETRIEVE-ADD TO" frame, (Figure 40) we can now appreciate some of the other retrievals possible.

On the above display we touch "Other Retrievals" and Figure 41 appears.
Concerning the "representation of medical knowledge" in individuals, one can see from the above displays that when information is in electronic form, properly stored and coded, it can be represented in many ways according to our needs. For example, if we wanted to see where the investigation of a given problem stood, we could touch "Abstract of a Problem" and progress through a series of displays until Figure 42 appeared. Then by touching the choices on that, we are immediately up-to-date on the investigation of the problem.

Figure 43 is a basic display for writing progress notes simply by touching choices on successive displays.

Concerning the "representation of medical knowledge" in individuals, one can see from the above displays that when information is in electronic form, properly stored and coded, it can be represented in many ways according to our needs. For example, if we wanted to see where the investigation of a given problem stood, we could touch "Abstract of a Problem" and progress through a series of displays until Figure 42 appeared. Then by touching the choices on that, we are immediately up-to-date on the investigation of the problem.

Figure 43 is a basic display for writing progress notes simply by touching choices on successive displays.
Figure 43 (continued)

Progress Note for Symptom, Physical Finding, Lab Finding

**Aims:**
- restate Aims for problem management

**Sx:**
- report symptoms from order list
- report other symptomatic data

**Obj:**
- report physical exam orders
- report other objective data

**Asmt:**
- assess progress

**Plan:**
- plan management
- Emergency management
- Choose another problem

Figure 44

Assessment

- Fluid management:

- Basis for problem statement:

- Present illnesses associated with problem

Assessments usually entered in course of planning:

- Condition of problem
- Response to treatment

- Causes with negative screen:

- Causes with discontinued investigation:

- Causes ruled out:

On the above display the user is given guidance for keeping up with his work on multiple problems in patients. It is at this point that he gets the rewards of all his initial planning efforts, because what appears on touching some of the above choices depends upon what treatments and investigations were set in motion in the first place.

There is not space in this communication to show a series of displays which reveal how population studies are performed. But all the order and coding that made the above retrievals possible in an individual patient also makes possible the study of many variables and their interrelationships in a population of patients. Questions such as how many patients are on gentamycin with a BUN above 30 can be answered with great speed simply by progressing through several displays which use exactly the same facilities that are used to care for those patients.

Conclusion

PROMIS is attempting to "represent medical knowledge" in a way that is useful in the care of a whole individual. Since each individual is unique, there is almost an infinite number of combinations of variables and personal values. One cannot create beforehand a fixed series of steps to deal with some textbook definition of a single problem. One must first create a structure that defines the universe of data for the care of a whole individual and which organizes problems for solution. The CPOMR is such a structure, and each basic structural unit such as the "Initial Plans" has content which can become the organizing structure for the next level of content. This cycle is repeated over and over to finer and finer levels of resolution. These structures allow us to start with global questions that are meaningful to the patient (such as "What is the diagnosis or treatment") and then to systematically break them into smaller questions until we reach a level where we can answer with reasonable confidence. In this way we build the larger answer from the smaller answers that the whole framework generates step by step.

The CPOMR structure is used in precise problem formulation. If the user of the system is careful
to start the problem at the level for which he has evidence and does not indulge in impressions and guesses, the computer system can guide him to higher levels of abstraction. For example, a single problem, chest pain, can systematically be shown to be a part of a problem stated at a higher level, such as myocardial infarction or pneumonia. One must not only know all the possibilities but the strategies for efficiently ruling them in or out. This really is the process of hypothesis formulation and then pursuit of those hypotheses. The detailed displays of the computer can rapidly provide the user with a broad range of hypotheses suggested by each problem and based on the broad statistics of a population. In contrast, the unaided human mind will tend toward very early hypothesis formation before a full data base is established (i.e., before the full range of important cues is available to him) because he uses hypothesis formation to organize data for problem solution and as "organizing rubrics in working memory." He will then limit the number of hypotheses and the "problem space" so that it is small enough to contain only the number of variables he can work with effectively. This varies enormously from mind to mind depending on basic ability and experience. Such human "lists of hypotheses and problem spaces" are usually large enough to solve some of the everyday problems (along with nature's help). But they are not large enough to consistently bring the best of medical science to every problem, simple or complex.

Having generated in the computer a full range of hypotheses for well-defined problems (by use of the literature which in turn uses proper mathematical tools for manipulating prevalence, sensitivities, etc. for specific diagnoses and treatments or by analyzing the data in the computer itself as experience grows), the guidance can then be given for systematically relating that medical knowledge to the unique constellation of data and problems on a given patient. Broad knowledge of a patient is extremely powerful in rerouting the pursuit of and safely limiting the number of hypotheses for organized testing. A diminished femoral pulse in the data base, for example, can push coarctation of the aorta from low to high on a list of causes when dealing with the problem of hypertension. A useful analogy is that an automobile map, created beforehand by a skilled cartographer, has on it an almost unlimited number of possible trips, and the user's goals and needs organize the use of it. Although we could not have created the whole map at the time of usage (and we certainly do not memorize maps and/or pass "board exams" before we can travel), we can frequently, at the time of travel, use data on the map to our advantage. Some of our needs become precise and definite as we travel and could only have been presented as a mass of probabilities at the outset of the trip. The principle is that large decisions should be made into as many smaller decisions as possible so that options become manageable and each successive decision can take advantage of and be controlled by the one that preceded it. The more that existing options are clearly delineated on a detailed map, the smoother and more secure the traveler's trip can be between two distant points, choosing the best option at each intersection, and creating a course unique to his needs and resources. The course of a person's health care is calculated decision by decision where each new decision operates on the results of past decisions and influences future alternatives; the options presented at each decision point result from a process which is defined and based on organized data from previous experience. The object of the guidance is to answer a global question, e.g., "What is the diagnosis?" or "What is the best treatment plan?" by a series of small steps and decisions. Given the goal of diagnosis and management and the "conditions at the time," the guidance keeps determining the next logical step and does not try to leap to the final answer. The problem-oriented system requires that the knowledge of those "conditions at the time" be as defined and as broad as possible so that the system's guidance can be relevant to the whole individual. The final diagnosis or the final treatment plan is the fallout of this calculus of successive decisions in a broad context; it may be determined early or late in the process depending upon the type of problem and the factors in each patient's situation.

A broken leg can be diagnosed starting with leg pain after one step (x-ray) with 100% confidence; cancer of the pancreas starting with jaundice or vague weight loss or abdominal pain may not be diagnosed until many steps later; one does not go directly to the step of surgery which gives the answer with 100% confidence because the risks and costs are too great and the yield is too small for every case of abdominal pain or jaundice. The patients must understand that how definite we can be and how many steps it will take is determined by the nature of the problem. Furthermore, patients are going to have to begin to appreciate the power of our diagnostic tools and our capacity to grow wiser from experience as we begin to keep track of what we have done and as we continually analyze that experience to learn the safest route and fewest steps leading to answers. Medical providers will always be in trouble if they stick to their present methods for acquiring, recording, and analyzing data and for making decisions. Our present folly grows out of our stubbornness in failing to recognize or admit the limitations of the human mind.

Recognition of limitations of the human mind has led to much of the development of PROMIS. To the extent PROMIS is an extension of the mind for problem solving, just as the automobile is an extension of the muscles for traveling, it may be worth concluding with a discussion of some of the basic characteristics of PROMIS.

The overall integrity of the logical structures of PROMIS is forced by a single characteristic of the system: you can proceed only one step at a time by choosing one decision by decision. A vast amount of medical knowledge that has been fed into the computer is available in no other way. [N.B. One step can represent the synthesis and application of a great deal of medical knowledge,
just as one mathematical formula can represent an extensive understanding of mathematics. For this reason the users' pathways can be efficient, rather than annoying and cumbersome. At the same time, the precise and full documentation for each action can be ascertained. [And no display from which you must proceed can be independent of the structure of the POMR.]

The user need not carry in his memory all the options appropriate to his problem or task, but the price he must pay to have at his fingertips such depth of information (literally thousands of displays and hundreds of thousands of choices) is to reveal where he is in his thinking, to relate directly and precisely to the logic pathways built into the computer, and to have the computerized POMR be the complete and sole record of the individual's health. Each of the displays is tightly coupled to the logic of the previous selection.

Contrast this procedure with a library, a lecture, a pharmacy, or a conference, in which there are almost an infinite number of opportunities to absorb information without any obligation to couple it to previous logic or future action. The librarian or journal editor is unable to determine or affect the information that has been extracted, how or whether it is stored or used, and whether it is remembered, forgotten, misinterpreted, or distorted over time. And when a patient is subjected to medical action of any type, it is not unambiguously known what the sources of the information were or what logic led to the actions upon him. The non-computerized systems of the library and present patient care activities are uncoupled.

Returning to the computerized POMR, not only is a single user tightly coupled to all parts of the system and to sharply defined logic pathways, but multiple users at multiple terminals are coupled to the same system and, therefore, to one another. Lewis Mumford has stated that one of the great powers of the clock in the early days of technology was that it could synchronize the actions of man; a great power of the computer is the ability to retain the logic pathways from which the selections are made or the memory of the pathways chosen for the individuals. Fortunately, because a machine can remember without fail and without distor- 

Our desire for maximum information has increasingly revealed the uniqueness among individuals, allowing us to meet their needs in more and more precise ways. But if we let the process of continuous elaboration of facts occur, uncoupled to logical structures and separated from the largest possible universe of a given individual's concerns, we get lost in details, unable to return successfully to the larger purpose for which the pursuit was originally undertaken.

Common Criticisms of Computerized Medical Decision Systems

1. "It forces complex human problems with many dimensions into a one-dimensional straightjacket with the companion danger of distorting the choices one ultimately makes."

Improper use of a computer will lead to the above criticism. Improper use occurs whenever:

a. value judgments are made other than by a user of the computerized decision process and those value judgments are not made known to the user so he can either accept them or reject the decision process;

b. the process operates on a limited base of knowledge;

c. the methodologies deal with only a fraction of the care for a patient, e.g., treatment of a problem in isolation from other problems.

The design of the PROMIS system does not take value judgments from the realm of the patient and the provider. Its knowledge base is presently limited, but it has been designed to house all medical knowledge. Its decision methodologies are capable of dealing with all aspects of care.

2. "Decisions are made with the aid of, and sometimes entirely by, computers whose programs no one any longer knows explicitly or understands. Hence, no one can know the criteria or rules on which such decisions are based. The systems of rules and criteria that are embodied in such computer systems become immune to change because, in the absence of a detailed understanding of the inner workings of a computer system, any substantial modification is very likely to render the whole system inoperable and possibly unrestorable. They provide no basis on which what the machine says can be challenged."

This is a just criticism of programs which have been built to make decisions without regard for how the system is to be maintained. The problem of "how to perform decision making" leads to the prob-
lem "how to build and maintain an information system to support decision making." Authors which have not recognized the second problem will eventually generate programs which "no one any longer knows explicitly or understands." Each action recommended by PROMIS guidance will be documented with the medical rules and decision methodology which serve as the basis for the recommendation.

It should also be pointed out that if one substitutes the words "human minds" for the word "computers" in the first sentence of criticism #2 as seen below, then it would appear as follows:

"Decisions are made with the aid of, and sometimes entirely by, human minds whose programs no one any longer knows explicitly or understands. Hence, no one can know the criteria or rules on which such decisions are based. The systems of rules and criteria that are embodied in such human minds become immune to change, because the absence of a detailed understanding of the inner workings of a human mind, any substantial modification is very likely to render the whole system inoperable and possibly irrevocable. They provide no basis on which "what the machine says" can be challenged."

The above paraphrased quotation gives one a clear statement of our most pressing problem in the audit and education of physicians and other medical providers. PROMIS was designed to deal with these limitations of human computers.

3. "It leads to concentrating on quantifiable factors instead of non-quantifiable factors which cannot be conveniently analyzed by the computer and which therefore do not get taken into account."

Frequent, non-quantifiable factors are the symptomatic complaints of the patient (the Patient's Sickness). One of the eight steps of the PROMIS planning methodology addresses itself solely to the analysis and treatment of the sickness. A principle of design for the PROMIS decision methodologies is: "If a factor can be shown to influence a decision, it must be represented in the associated decision methodology." If the decision methodologies do not accommodate the factor, then the decision methodology must be updated to accommodate it.

4. "Rather than responding to the ever-increasing complexity of modern medicine by simply using computers to speed things up, efforts should be directed toward simplifying medical procedures with a cold eye towards perpetuating only those diagnostic procedures that provide the most valuable information and those therapies that are demonstrably effective."

The complexity of modern medicine cannot be denied. Dealing with the complexity should take the form of building tools to simplify the practice of medicine as opposed to limiting the practice of medicine to procedures which can be simplified. The automatic transmission is a very complicated but yet reliable tool which greatly simplifies the task of driving. The practice of medicine needs like tools to make the everyday practice of medicine a simple task which can be reliably performed.

A goal of the PROMIS system is to determine what procedures are efficacious and in what contexts they are found to be efficacious so that only the use of such procedures in the proper contexts can be perpetuated. The efficacy of a procedure depends upon many factors other than the problem which is being treated or checked for. Paper-based information systems have difficulty keeping track of these many factors, combination of factors, and variations of factors over time. A procedure is generally not found to be uniformly efficacious or useless; it is efficacious if used in the proper context, and if used improperly, yields little benefit or does harm. Using procedures as best we currently understand and then studying their use through outcome analysis to improve our understanding of their proper use is a more realistic approach. Paper based information systems are not adequate for either the amount or the rigor of analysis required for this task.

References


2. Schultz, Jan R. "Promis: The Problem-Oriented Medical Information System (A medical and technical solution to four problems in medicine)." This paper will be a chapter in a forthcoming book published by the National Science Foundation, Office of Computing Research on Computer Science and Engineering Research. Written June 1977.


NOTE: (added by the Program Chairman:)

This paper, "Representation of Medical Knowledge" and PROMIS, is the result of the creative efforts of the staff of the PROMIS Laboratory, under the direction of Lawerence L. Weed, M.D. Dr. Weed is the principal author, but wishes that the PROMIS Laboratory be listed on the actual publication. Because of the significance to this work I requested the names of the PROMIS Laboratory Staff Members:

Carolyn F. Barnes (Librarian)
Ann Cravens Buller (Librarian)
Stephen V. Cantrill, M.D. (Medical Content & Software)
Suzanne M. Clark (Librarian)
Layton Davis (Documentor)
Brian J. Ellinoy, Pharm. D. (Pharmacist)
Genevieve Gilroy, R.Ph. (Pharmacist)
Stuart M. Graves, M.D. (Medical Content)
Richard Hertzberg (Software)
Ron R. Holland, M.D. (Medical Content)
Donna Kaynor (Medical Content)
Kurt Lauenstein, M.D. (Medical Content)
James LeMay (Software)
Susann Lyon (Secretary to Dr. Weed)
Diane L. McGee (Administrative Assistant)
David A. Miller (Administrator)
Keith Morgan (Software)
Pati Naritomi (Medical Content)
Stephen Reynolds (Software)
Jan R. Schultz (Software)
Pete Walton, M.D. (Medical Content/Software)
James F. Wanner (Hardware)
Lawerence L. Weed, M.D. (Director, PROMIS Laboratory)
Lawerence I. Wolf (Software)