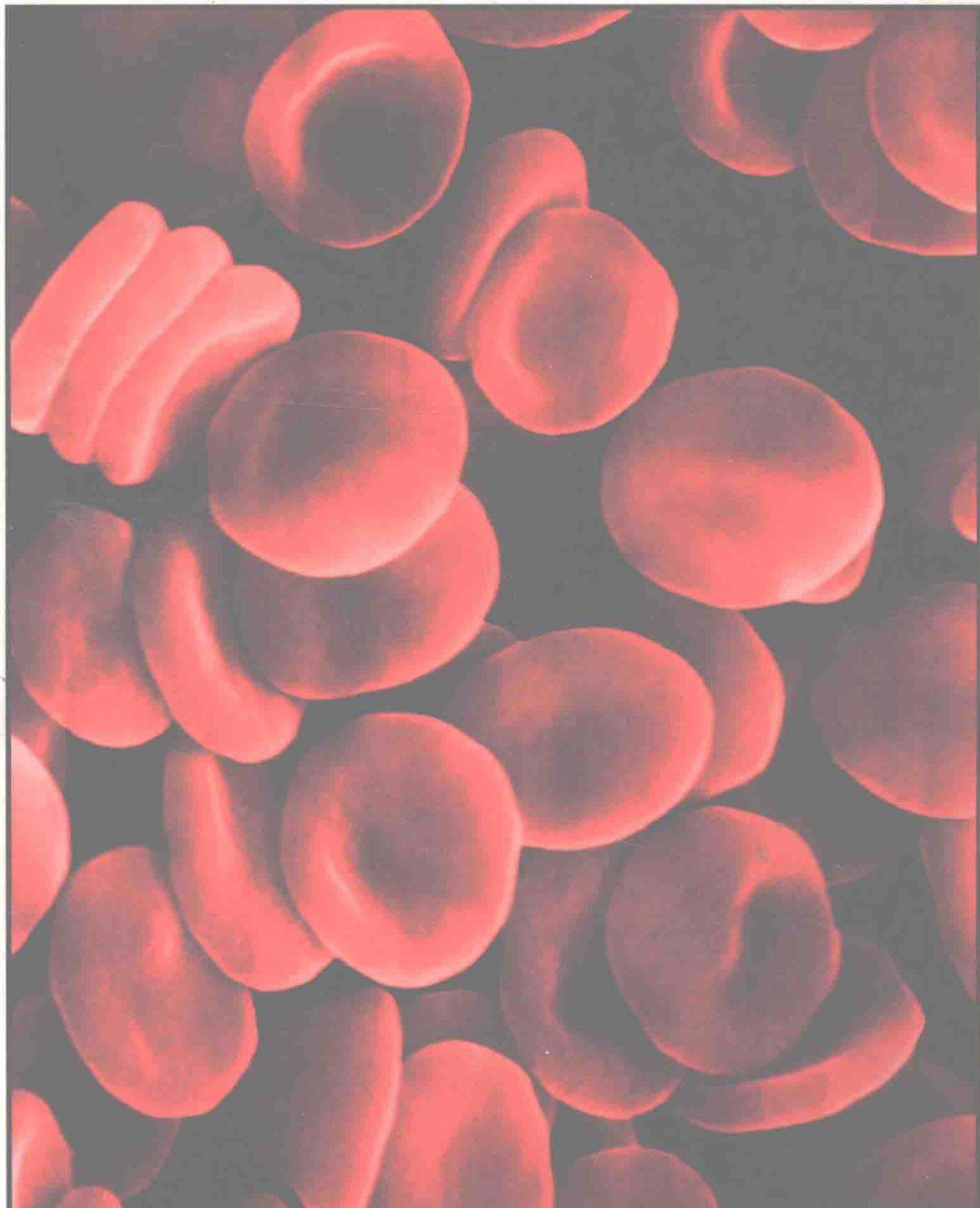
PROBLEM SOLVING IN PHYSIOLOGY



JOEL A. MICHAEL • ALLEN A. ROVICK

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JOEL A. MICHAEL
Rush Presbyterian St. Luke's Medical Center

ALLEN A. ROVICK
Rush Presbyterian St. Luke's Medical Center

PRENTICE HALL, Upper Saddle River, NJ 07458

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Printed in the United States of America

10 9 8 7 6 5 4

ISBN 0-13-2441047

Prentice-Hall International (UK) Limited, *London*
Prentice-Hall of Australia Pty. Limited, *Sydney*
Prentice-Hall Canada, Inc. *Toronto*
Prentice-Hall Hispanoamericana, S.A., *Mexico*
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Simon & Schuster Asis Pte. Ltd., *Singapore*
Editora Prentice-Hall do Brasil, Ltda., *Rio de Janeiro*

Preface

If asked, teachers of physiology will state that their primary educational objective is to help their students "understand" physiology. And there will be near unanimous agreement that "understanding" physiology means acquiring some knowledge and developing the skills to apply that knowledge to accomplish certain tasks (predict the behavior of physiological systems, solve problems, design and carry out experiments, etc.).

Physiology, however, is a difficult subject for most students to understand: physiological systems are made up of many components; complex concepts are required to describe the functions of these components; and there are important interactions between components. Thus, it is also a difficult subject to teach. The number of facts to be learned is enormous and grows larger every day. Authors of textbooks of physiology select those facts that they believe are appropriate to ask a particular student audience to master, and as teachers of physiology, we select the texts that we think best meet the needs of our students. But textbooks are, in general, not an optimal medium to provide students with practice applying these facts to master the process of solving physiology problems.

Problem Solving in Physiology contains a set of physiology problems and answers to be used in assisting students to develop the problem-solving skills that we all believe are an essential part of "understanding" physiology. The problems are a learning resource with which teachers of physiology can engage students in applying their physiology knowledge.

Active Learning and Problem Solving

All too often, reading a textbook or listening to a lecture is a passive process for the student. The primary mental process being engaged is rote memorization. But, if we expect students to organize the facts being memorized so that they can build an understanding of bigger and bigger ideas about the functioning of the body, if we expect students to retain what they memorize, then we must encourage them to make the learning process a more active one. We must provide them with opportunities to consciously build mental models of physiological systems, and we must provide them with opportunities to test the validity of the models that they are building. Accurate mental models give students tools with which to reason about the behavior of physiological systems.

There are many avenues to assisting students to develop active learning skills and many learning environments in which they can practice their developing skills. Traditionally, the laboratory has been one learning environment in which to engage students in an active learning process. Discussion groups, tutorials, and workshops have provided other kinds of environments in which active learning could be stimulated. Solving problems—whatever the physical setting in which this occurs (the laboratory or the small group classroom)—provides students with practice in developing important skills of applying physiology information, helps students integrate the facts of physiology into conceptual models of physiological phenomena, and provides a means for students to test their developing mental models.

Developing a New Approach to Using Problems to Teach Physiology

When we assumed responsibility for teaching physiology to first-year medical students in the 1970s, we immediately began to develop approaches to using physiology problems to foster problem-solving skills and to facilitate student integration of facts. Over the years, we have written problems dealing with essentially all areas of human physiology. Equally important, we have experimented with a variety of procedures for structuring the problems and the problem-solving sessions, with some sessions taking place in the lecture hall with large numbers of students and others occurring in small-group settings. In each of these situations, we have discovered that seemingly small differences in how we do things materially affect the learning that occurs and the student response to their experience. We have shared the problems we have used in our classroom with colleagues at a number of different educational institutions in this country and abroad, and we have discussed how these problems worked (or did not work) with their students. Our ideas about using problem solving in teaching physiology have been presented in a number of national and international forums. The discussions arising from such presentations have helped us further to refine what we do and how we do it. We do not have a universally applicable prescription for how to use problem solving in teaching, but we do know some things that seem to work well in our classroom and in our colleagues' classrooms.

Using This Learning Resource to Achieve Your Objectives

There is a common feature to the format for each of the problems we have written. Each problem is presented in stages. Students are expected to complete each part and discuss the solution to that part before proceeding to the next part of the problem (presented on the next page). Thus every student begins the solution of subsequent parts of the problem with an understanding of the physiology underlying the preceding part. In this way, errors are not allowed to compound, avoiding the danger of students being led astray by an initial failure to understand some aspect of the problem. We have found this organization of our problems to be very important. Compounding failure quickly discourages students from continuing to grapple with the underlying physiology inherent in the problems.

As students discuss parts of the problem and build their mental models, it is important to provide mechanisms with which they can test these models. Two frequently used tools employed in many of our problems are the use of predictions tables and the drawing of concept maps.

The prediction table is a simple way of requesting students to make qualitative predictions (increase, decrease, no change) about the responses of specified components that result from a situation described in the problem. This process requires the students to "exercise" their mental model(s). Then, if their predictions are correct, students gain confidence in the utility of their model(s). If their predictions are incorrect, students can clearly see that their current model(s) need to be changed.

Similarly, constructing a flowchart or concept map of the events involved in a problem requires the students to extract information from their model, and the correctness of their concept map reveals something about the correctness of their models.

The answers we have provided for each problem are intended to be complete in the sense that each step in the solution is developed as explicitly as possible. How one thinks about a physiological issue and the reasoning steps that one must undertake are every bit as important as the answer itself. But, this is *not* a textbook of physiology, and it is not meant to be used like one. When students have difficulties understanding a physiological phenomenon or when questions remain after consulting the answers, it is time to go back to the textbook or the instructor for a more comprehensive discussion of the relevant physiology.

The problems can be used in a variety of different classroom settings. We have used them in small-group problem-solving sessions and in whole-class problem-solving workshops. In both settings, we have worked to ensure certain common features: instructor modeling of problem solutions; instructor facilitation of the students' problem-solving efforts; and active, cooperative problem solving by the students. We have provided descriptions of these classroom formats in the "Owner's Manual" that follows. We do not mean to imply that the approaches we describe are the only way it can done; rather, they are suggestions that can be used and adapted by each instructor. There is no one right way to teach physiology, although there certainly are some broad principles that seem applicable in any course (see Chapters 1 and 2).

Many of the problems are couched in what may seem to be very clinical terms. Yet, these are all problems about physiology, frequently physiology that has been perturbed either by an experimental procedure or by an experiment of nature represented by pathophysiology or pathology in some system. *The problems are not meant to teach medicine and they do not do so*; you do not have to be an M.D. nor does your course have to be part of a medical or allied health curriculum to use these problems in your physiology course! But that such problems are about human physiology or pathophysiology (i.e., they may describe situations in which disease is present) serves to motivate students who are always interested in the processes at work in their own bodies or those of friends and relatives. Where relevant, we have included some information about the clinical context of these as an aid to both the instructor and the student.

Acknowledgments

We want to acknowledge the contributions of current and past colleagues in the Department of Molecular Biophysics and Physiology, specifically Drs. F. Cohen, T. DeCoursey, R. Eisenberg, G. Gottlieb, C. Hegyvary, R. Levis, F. Quandt, E. Rios, and J. Zbilut. Some of the problems were written by other faculty participating in our course. Our faculty colleagues also assisted us in trying out these problems and often suggested revisions that have been incorporated into them. We also appreciate the feedback we have received from the many Rush Medical College students who have used these problems as they attempted to learn physiology.

About the Authors

Joel A. Michael (left) was trained as a neurophysiologist and conducted research in the neurosciences for twenty years. His involvement in medical education, including thirty years of experience as a physiology teacher, led him to conduct research on the applications of cognitive psychology and computer science to teaching and learning. The worldwide demand for him to conduct faculty development workshops on computer-based education, active learning, and problem solving attests to his expertise in these areas where he has conducted groundbreaking research.

Allen A. Rovick (right) has relied upon forty years of experience as a physiology teacher to develop problem-based laboratories, small-group workshops, and computer-based exercises. His educational research, including studies of tutoring, has culminated in computer teaching programs and a host of other projects, all of which have informed his work on this innovative text.

Contents

What Does It Mean To Understand Physiology? 1

Physiology is a discipline taught at a variety of educational levels. In colleges and universities, the courses in which physiology is taught range from introductory or advanced biology to ones that emphasize comparative, insect, general mammalian, or human physiology. Such courses are taught at the most elementary levels to freshmen or sophomores, at more advanced levels to juniors and seniors, and at still more advanced levels to graduate and professional students. These courses may be solely lecture based, may incorporate laboratory work, or may be solely laboratory based.

The instructor for any course is likely to be asked,"What do you expect a student in your course to accomplish?" Students will ask, "What am I expected to learn?" The answers to these questions, whether long and detailed (a list of educational or learning objectives; Bloom, 1958) or brief, is likely to include some statement to the effect that "the student is expected to gain an understanding of physiology."

What exactly does it mean to "understand physiology"? Can one provide some operational or behavioral definition so that a student can tell when he or she has succeeded in meeting this expectation? Equally important, having a definition is essential if it is to be possible to measure whether the students have achieved that goal.

"Understanding physiology" may mean any or all of the following (see Box 1-1) depending on the particular course being taught and the goals of the particular teacher: (1) knowing facts, (2) being able to solve problems, (3) having the skill to carry out certain procedures in the laboratory, (4) being able to design experiments to study physiological phenomena, and analyze the results of experiments to define the components of physiological systems and their behavior, or (5) having the ability to analyze certain problems from a physiological perspective.

Let us attempt to define more precisely what each of these components of understanding involves.

BOX 1-1 "UNDERSTANDING PHYSIOLOGY" MEANS

Possible Components of a Student's Understanding of Physiology

- **Knowing "facts":**
  - **vocabulary**
  - **data**
  - **concepts**
  - **relationships**
- **Being able to solve problems**
- **Being able to "do" physiology as an experimental science:**
  - **carry out laboratory procedures**
  - **design experiments**

What Are the Facts of Physiology?

Understanding any discipline requires that students learn the language of that discipline. Thus one particularly important class of facts consists of the specialized *vocabulary* with which experts in the discipline label the objects and behaviors of their study (for example, the resting potential, renal clearance, cardiac contractility). Students must also learn that many words used in everyday discourse may have a special meaning when used to describe physiological phenomenon (force, elasticity). Finally, students need to learn how to use this vocabulary to describe the phenomena encountered in the discipline. Learning the language of physiology involves memorizing the definitions of words but also acquiring the skill to use these words in ways that correctly communicate their intended meaning (whether that meaning is physiologically correct or not).

Another class of facts consists of *data*, the numbers that describe the state of the organism (average, normal blood glucose concentration is 100 mg/100 ml, normal blood pressure is 120/80 mm Hg). *Facts*, isolated pieces of physiology knowledge, must also be acquired (the sinoatrial node is the pacemaker of the heart, digestion of fats requires micelle formation in the small intestine). *Concepts*, larger and more organized pieces of information describing physiological function, are also facts to be acquired (osmotic movement of water, oxygen transport by hemoglobin, the specificity of membrane receptors for hormones). Finally, one must learn the *relationships* between variables (mean arterial pressure = cardiac output × total peripheral resistance; renal clearance of substance A = urine concentration of A × urine flow rate/plasma concentration of A).

Although the manner in which students acquire these facts may vary (and one role of the teacher is to provide a number of different ways for students to accomplish this), students are ultimately expected to have these facts available in their memory for retrieval (recall), even if only to answer examination questions, but certainly to use in solving problems.

What Do We Mean by Problem Solving?

Everyone has an intuitive notion of what a "problem" is and what it means to "solve a problem." Nevertheless, it is useful to consider a formal definition of a problem such as the one offered by Smith (1991):

> A problem is a task that requires analysis and reasoning towards a goal (the "solution"); [it] must be based on an understanding of the domain from which the task is drawn; [it] cannot be solved by recall, recognition, reproduction, or applicability of an algorithm alone; and [it] is not determined by how difficult or by how perplexing the task is for the intended solver. (page 14)

Problem solving thus entails having the ability to recognize that you want to "get from here to there," having and being able to access the knowledge required, and having the skills to use that knowledge appropriately to complete the task.

BOX 1-2 PHYSIOLOGY PROBLEMS

Three Different Kinds of Problems Commonly Presented to Students in Physiology Courses

- **Quantitative problems**
  - **Calculate the value of something**
- **Qualitative problems**
  - **Predict the changes that will occur**
- **Explain**
  - **Describe the causal relationships that lead to some state**

The problems to be solved in physiology courses are of three kinds (see Box1-2).

1. In *quantitative problems*, the solver must calculate the value of some variable given certain information.
2. Some problems request the solver to make *qualitative predictions* about the direction in which some physiological parameter or parameters will change when a perturbation is introduced in a physiological system.
3. Finally, students are often asked to *explain* some phenomenon, such as to provide a stepwise description of the causal sequence of events that results in an observation to be explained.

We are, of course, distinguishing didactic "problems" or exercises (intended to assist students to learn some part of existing physiological knowledge) from the "problem" that confronts a researcher attempting to gain new knowledge about the functioning of the body or some part of it. The former problems have, arguably, more clearly definable answers (however fuzzy some of the boundaries might be), whereas the latter problems, by definition, do not yet have known answers. We commonly assign problems of the first type to students in courses at all levels, although in advanced undergraduate, graduate, or professional courses we might also pose less structured problems or problems requiring physiological investigation to reach an answer.

Physiology as an Experimental Discipline

Physiology is one of the natural sciences in which it is possible to manipulate nature as a way of uncovering its laws (unlike disciplines such as geology or astronomy, which are largely observational sciences). An instructor might therefore argue that a true understanding of physiology requires that the student gain the skills required to conduct a physiological experiment.

This requirement might only mean that the student is expected to learn how to use common pieces of experimental apparatus (oscilloscopes, amplifiers, strip-chart recorders or polygraphs) or to perform certain procedures (anesthetizing a preparation, preparing it surgically, making up solutions). It can also mean that the student is expected to learn how to design an experiment, starting with the generation of a hypothesis and carrying the process through to the writing up of the results in an acceptable format.

The ability to "do" physiology, to actually carry out experiments, is certainly an important objective of many physiology courses. It is impossible to imagine a student achieving this goal without at the same time learning the vocabulary, facts, and concepts of physiology. It is impossible to imagine that a student could generate and validate a hypothesis without the ability to "solve problems" in physiology. Yet, only a relatively small number of students are expected to "understand" physiology in this way.

Applying a Physiological Analysis to Solving a Problem

An enormous number of problems affect us as individuals and as a society, and many of these problems have a significant physiological component. Such problems are as diverse as personal dietary choices (low fat, low sodium, vitamin supplements) or personal sexual behavior, social issues such as school lunch programs (what is nutritionally sound, what are the consequences of poor nutrition), and environmental pollution. The ability to apply an understanding of the concepts and principles of physiology to problems such as these implies both a fund of knowledge and the skills to use that knowledge to understand still wider phenomena. Further, the ability to solve such problems correctly plays an important role in being able to make personal health decisions as well as contributing to decisions being made by local and national legislatures about health-related matters.

Setting Educational Objectives

We cannot emphasize too strongly that it is the responsibility of each instructor to define the goals for his or her course, goals that include some mix of the above objectives and that may include aspects of problem solving. If students are expected to develop problem-solving skills, it must be understood that these, like other skills, improve with practice. This book will provide a resource with which instructors can help students gain the experience needed to achieve the goals you have set.

References

Bloom, B.S. (editor). 1956. *Taxonomy of educational objectives. Handbook I: Cognitive domain.* New York: David McKay Company, Inc.

Smith, M. U. (1991). A view from biology. In M. U. Smith (Ed.), *Towards a unified theory of problem solving* (pp. 1–19). Hillsdale, NJ: Lawrence Erlbaum Associates.

Solving Physiology Problems 2

Physiology is a science that seeks to understand the myriad processes that are integrated in a living organism. The first step to acquiring an understanding of some particular physiological phenomenon is the determination of the "entities"—the system parameters and variables—that interact to produce it. As an example, let us consider what happens to a rat whose pancreatic islets (which contain the insulin-secreting β cells) are chemically destroyed with alloxan (a derivative of uric acid). Within a short time the rat will no longer behave normally. It will eat enormous amounts of food but nevertheless lose weight. As this process continues, other visible manifestations of some fundamental abnormality become evident. The rat will be observed to drink large quantities of water and to urinate frequently and copiously. Its breathing will be rapid and deep, that is, it will visibly hyperventilate.

After many years of physiology research, the "entities" involved in the phenomenon described above can now be listed. They include the plasma concentration of hormones such as insulin, glucagon, cortisol and epinephrine as well as the blood concentrations of metabolites such as glucose, free fatty acids, and amino acids. In addition, the rates of uptake (or release) of these substances by tissues such as muscle, liver, and adipose cells are relevant. Box 2-1 lists the "entities" that need to be considered to understand the phenomenon of the alloxan diabetic rat.

BOX 2-1 SOME OF THE "ENTITIES" INVOLVED IN GLUCOSE HOMEOSTASIS

To understand the maintenance of a more or less constant blood glucose level it is necessary to be able to relate the interactions of the entities listed here.

Hormones (plasma concentration):
- **insulin**
- **glucagon**
- **cortisol**
- **epinephrine**

Metabolites (plasma concentration):
- **glucose**
- **amino acids**
- **fatty acids**
- **ketones**

Transport rates of metabolites in and out of:
- **muscle**
- **liver**
- **adipose cells**

Furthermore, the qualitative, causal relationships between these "entities" (parameters and variables) can be specified (Figure 2-1) so that the consequences of a change in one parameter on other entities in the system can be predicted. Most textbooks of physiology have such diagrams or their textual equivalent. By understanding some aspect of physiology, we usually mean, in part, that the relationships between entities is known (is in memory) and is usable (can be recalled and applied).

Physiology as a science does not stop when it has determined what parameters and variables interact with each other. Once the causal relationships are understood, the next step is to determine the quantitative relationships between the relevant variables. These relationships may be represented by tables or graphs filled with data points as are quite common in our textbooks. Figure 2-2 is an example of such a graphical representation of the relationship between glucose concentration and stimulated insulin release and the additive effective of gastric inhibitory protein (GIP). Where possible, however, the exact relationships are expressed by mathematical equations relating the relevant variables and necessary physicochemical constants.

To turn to respiratory physiology for an example, the factors that determine the steady-state value of the partial pressure of oxygen in the alveolar space (P_AO_2) are the partial pressure of oxygen in the inspired air (P_IO_2), the alveolar ventilatory rate ($\dot{V}_A$), and the rate at which oxygen is being consumed by the cells of the body ($\dot{V}O_2$). The alveolar gas equation for oxygen expresses these relationships in a most compact form:

$$P_AO_2 = P_IO_2 - \frac{k\dot{V}_2}{\dot{V}_A}$$

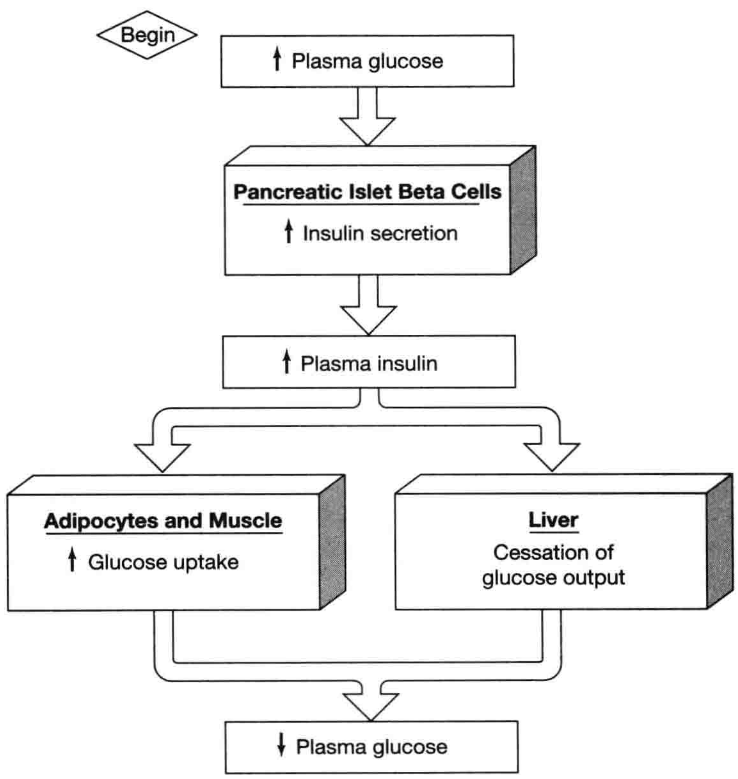

Figure 2-1. A representation of some of the causal relationships involved in maintaining a normal blood glucose concentration. (From Vander, Sherman, Luciano.)

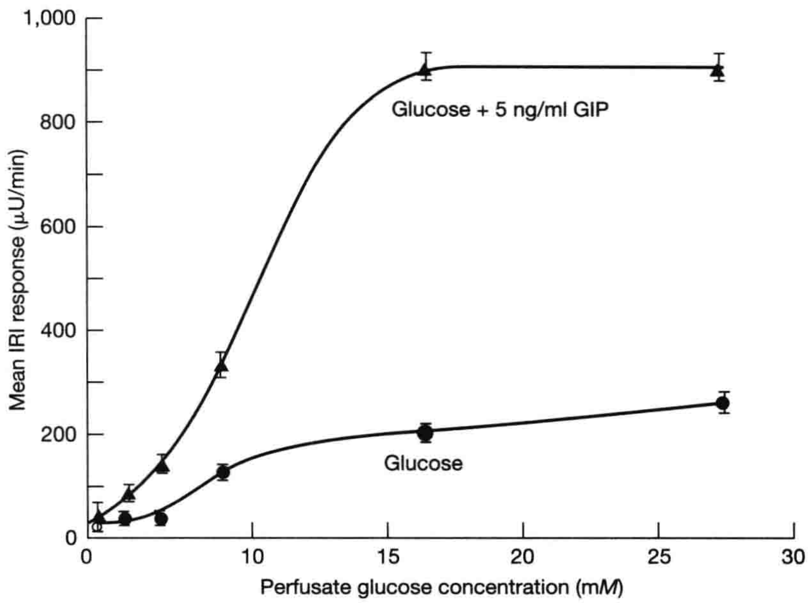

Figure 2-2. The relationship between blood glucose concentration, plasma concentration of gastric inhibitory protein (GIP) and insulin release. (From Patton et al.)

The advantage of having such an equation is that one can reason with it qualitatively (if alveolar ventilation changes, how will P_AO_2 change?) as well as use it to determine quantitative responses of the system to a particular disturbance (if the alveolar ventilation decreases by 25%, what value of P_AO_2 will be present?).

Given this description of physiology as a science, what can we say about the kinds of problems that are presented to be solved, whether as an exercise in problem solving for its own right or as a means of assisting solvers to consolidate their understanding of physiology? As described in Chapter 1, there are three types of problems to be solved, and each requires the solver to be proficient at somewhat different sets of skills to be successful.

1. Problems may involve reasoning about the qualitative, causal relationships between the "entities" making up a particular system. Such problems are frequently posed in terms of *predicting* the qualitative change (increase/decrease/no change) of the components of the system as they respond to some perturbation or disturbance acting on it (Rovick and Michael, 1992). The ability to make such predictions requires both a knowledge of the causal relationships between the entities of the system and the ability to use those relationships to solve the problem. The rules for solving such problems are addressed below.

2. A second kind of problem requires the production of an *explanation* of some physiological phenomenon. What this generally means is that the solver is to construct the sequence of causal steps between relevant "entities" that describes the phenomenon under discussion. Such a sequence of causal relationships can be described at different levels of organization (thus involving different "entities" such as cells, tissues, or organs), and one of the important skills to be acquired by students is identifying the appropriate level to use in making an explanation.

3. Finally, there are *quantitative* problems to be solved. Most of these problems require manipulating an equation, or set of equations substituting the known values, and carrying out the required mathematical operations to arrive at an answer. There are, however, also problems in which information must be obtained from a table or graph and then used to solve the problem. The students may have to first reason through a series of steps to define the relationship(s) to employ before the problem can be solved.

Solving Causal Reasoning Problems

To *predict* the consequences of a perturbation introduced in a physiological system (reduced blood volume) or to *explain* a particular physiological phenomenon (digestion and absorption of fats in the gastrointestinal tract), one must proceed through several problem-solving steps. First, there must be an identification of the organizational level at which an answer is being sought (membrane of sinoatrial node cells, the cardiac pacemaker, or the whole heart). Then the solver must determine which set of entities is involved in the problem (heart rate, stroke volume, mean arterial pressure) and what the relationship is between these entities. Finally, the interactions that actually occur must be determined. Each step involves a problem-solving skill that must be practiced to be learned.

Before elaborating on how these steps are carried out, we must discuss a "tool" whose use can greatly facilitate the solving of causal reasoning problems.

Pictorial or diagrammatic representations of physiological systems are quite common. These illustrations can range from the deliberately cartoonlike depictions of physiological phenomena (Smith, 1991) to more conventional pictorial representations (Mackenna and Callander, 1990; Ackermann, 1992) to highly sophisticated mathematical representations of our knowledge of quantitative physiology (Hopkins, Campbell, and Peterson, 1987). We have evolved a form of diagrammatic representation that we call the concept map (Rovick and Michael, 1992). These qualitative, casual representations can be used by students to solve problems or represent their solution to problems; they can also be used in computer teaching programs to represent the knowledge required to tutor students solving problems at the keyboard. Our approach is akin to that taken by developers of qualitative physics models (see Weld and de Kleer, 1990) rather than that of Novak and Gowin (1984), although our terminology is clearly similar to Novak and Gowin. It is important, however, not to mistake our concept maps for those of Novak and Gowin; ours represent causal relationships, whereas theirs most often represent hierarchical organization of knowledge.

A concept map is made up of three kinds of elements. Physiological parameters are represented by boxes, with the relationship between two parameters represented by an arrow connecting them; the origin of the arrow is on the **determiner** and the head of the arrow is on the **determined** parameter. Thus, in Figure 2-3a, the representation is to be understood to say that X determines the value of Y. It is important to note that such a representation cannot be read in the opposite direction; you cannot say, *given what is represented here*, that Y determines X. (If that were true, it would have to be represented with an arrow in the reverse direction.) The third element needed to describe a relationship between two parameters (Figure 2-3b) is a plus or minus sign indicating whether the relationship is a direct one (if X changes in magnitude, the value of Y will change in the same direction) or an inverse one (if X changes, the value of Y will change in the opposite direction). The plus and minus signs are often placed alongside the arrow head or can be placed in any obvious association with the arrow. (It is not uncommon for the plus sign to be omitted.) A parameter may have any number of determiners, and one parameter may determine any number of others.

A concept map is a useful tool for organizing your understanding of some physiological mechanisms and for making predictions about the behavior of such systems. Consider, for example, the thermoregulatory system that operates to maintain a nearly constant body temperature. This system can be described by the concept map seen in Figure 2-4.

Let us use this concept map to *predict* the changes in body function that will occur during the onset of a fever, when body temperature is increasing. Before reading ahead, predict how cutaneous blood flow, shivering, and sweating will be affected by this disturbance.

Function	Prediction
Cutaneous blood flow	
Shivering	
Sweating	

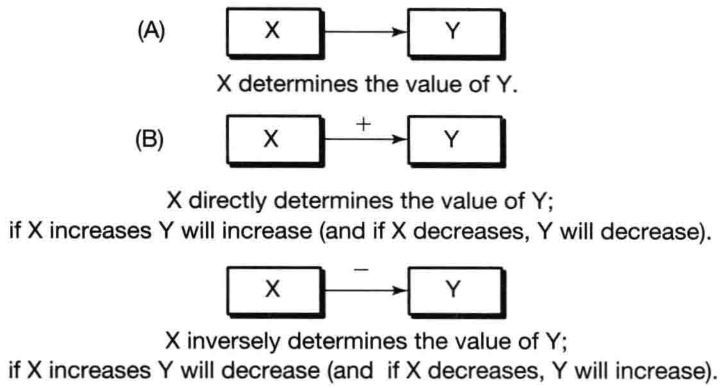

Figure 2-3. How to represent physiological cause-and-effect relationships in a concept map and how to read such a concept map.

A fever results from the presence in the body of substances called pyrogens. These cause the temperature setpoint in the hypothalamus to be reset to a higher value. As a consequence, the thermoregulatory center in the hypothalamus reacts as though the existing core temperature (signaled by the firing rate of the thermoreceptors) is too low. The hypothalamic thermoregulating system then causes changes that will result in the conservation of heat and increased heat production, thus increasing the core temperature. This increase in temperature is accomplished by reducing the rate of sweating and by causing shivering (increased metabolic heat production) and cutaneous vasoconstriction (reducing blood flow to the skin, resulting in less heat loss to the environment) to occur. These changes increase the core temperature; that is, they cause a fever to appear. These responses are illustrated in Figure 2-5.

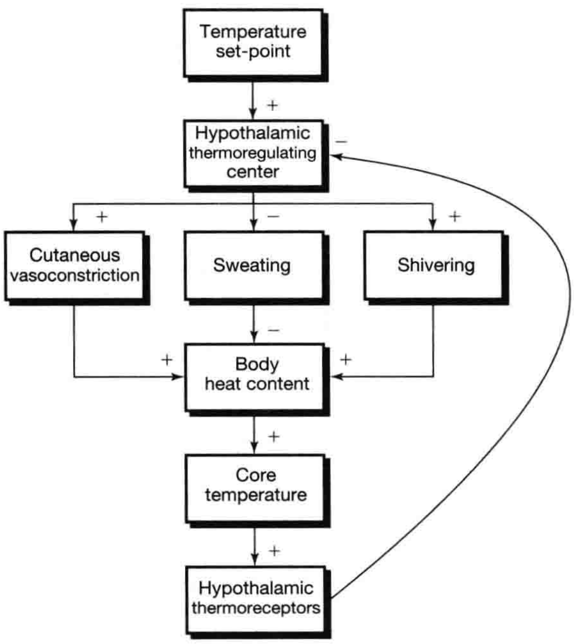

Figure 2-4. A concept map representing the thermoregulatory system.

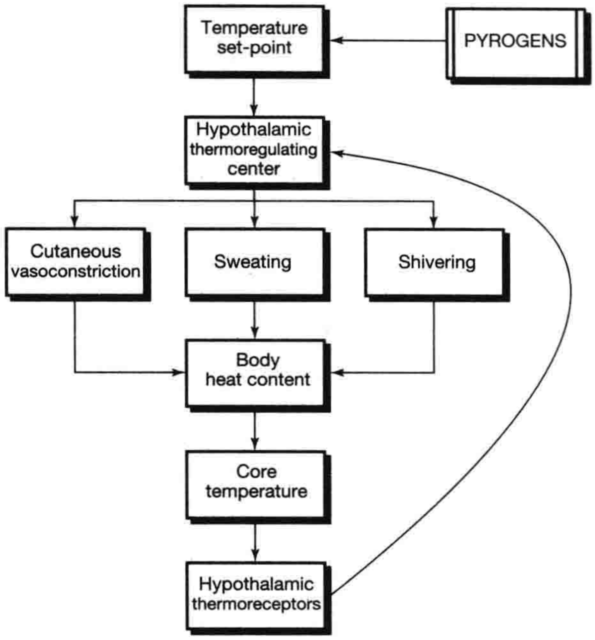

Figure 2-5. How to predict the responses of the thermoregulatory system to the onset of a fever (the period when body temperature is increasing).

A concept map can be used in another way as well. When a fever breaks and the body temperature returns to normal, the patient will sweat profusely, and a fair-skinned individual will appear quite flushed. If asked to *explain* these "signs," a concept map can be used to represent the responses that give rise to them (Figure 2-6) or to generate a verbal description of these events (Box 2-2).

Solving Quantitative Problems

Quantitative problems can appear deceptively easy to solve, certainly much easier than qualitative problems, due in part, to their greater familiarity. "Word problems" are routinely assigned in arithmetic or science. In addition, we are used to representing the quantitative relationships between variables with

BOX 2-2 AN EXPLANATION FOR THE EVENTS OCCURRING WHEN A FEVER BREAKS

Below is a verbal explanation for the responses that occur when a fever breaks and body temperature returns to normal. This explanation can be read from the concept map of Figure 2-6.

When the production of pyrogens ceases, the thermoregulatory setpoint is returned to its normal value. The hypothalamus now senses that the temperature of the body is higher than the (new, but normal) setpoint. It therefore terminates shivering (reducing heat production) and activates the two mechanisms that increase heat loss. The sweat glands secrete, and evaporation increases heat loss. In addition, cutaneous vasoconstriction is reduced; that is, a vasodilatation occurs. This process increases blood flow to the skin, resulting in a greater loss of heat by radiation, conduction, and convection. It also causes the individual to appear flushed.