THE CLAUDE BERNARD DISTINGUISHED LECTURE

The Claude Bernard Distinguished Lectureship honors both its namesake and its recipient for their outstanding contributions to physiology education. The American Physiological Society established the Lectureship in 1994, when the Teaching of Physiology Section of the Society selected Dr. Arthur J. Vander as its first Lecturer. The lecture was presented by Dr. Vander on April 27, 1994, at the Experimental Biology 94 meeting in Anaheim, California.

Arthur Vander has had a dedicated and fruitful association with the University of Michigan. He earned an M. D. degree there in 1959 and returned as an Instructor in the Department of Physiology after an internship in Internal Medicine at the Cornell Medical Center (New York Hospital). He quickly rose through the academic ranks and is now Emeritus Professor of Physiology.

He has distinguished himself in all areas of academic life — as a teacher, researcher, participant in collegial work at his institution, and contributor to the international advancement of physiology. His contributions have been recognized repeatedly with honors and awards, including the Richard Bright Award from the American Society of Hypertension for his research on renin secretion, the University of Michigan Lifetime Achievement Award for Excellence in Teaching, the Kaiser Permanente Award for Excellence in Teaching of the Basic Sciences, and Visiting Professorships in Israel and Uganda. He has to his credit a long list of papers and book chapters reporting his investigations of, among others, the control of renin release, renal handling of heavy metals, and most recently, the role of interleukin-1 in thermoregulation.

Arthur Vander’s textbooks of physiology have extended his masterful teaching beyond his own students. His ability to probe beneath the surface of pedagogy has allowed him to discern the best ways of helping students learn physiology. This insight has resulted in exceptionally clear explanations of complex ideas and a welcome emphasis on the integrative aspects of human physiology. His widely used Human Physiology: The Mechanisms of Bodily Function, written with James Sherman and Dorothy Luciano, is in its sixth edition, and his Renal Physiology is in its fifth edition.

KENNETH B. ROBERTS
Faculty of Medicine, Memorial University
St. John’s, Newfoundland A1B 3V6, Canada
Let me say first how deeply honored I am to be selected as the Claude Bernard Distinguished Lecturer by the Teaching Section. What makes it so special is that it comes from colleagues who themselves have devoted great efforts to teaching, despite the unfortunate value system that pervades academia. Since accepting the invitation I have felt like the professor whose favorite topic was the Johnstown flood; when he died and went to heaven St. Peter told him that he would be allowed to give a lecture on any subject he wished to the assembled angels, and he of course selected the Johnstown flood. St. Peter told him that would be fine, but he ought to know in advance that Noah would be in the audience.

What can I say to all you Noahs? Something hopeful — like God has revoked the countercurrent system and we’ll never have to teach it again. But what I decided on is my own hopes for the future and how badly needed all of you are. I’ll start with my theme concerning the central role of teaching in the future of physiology and then describe how two crucial attitudes will shape that future. Following this diagnosis, I’ll give prescriptions for some of the specific things I’d like to see done.

THEME AND TWO ATTITUDES

It is doubly appropriate that this lectureship bears Claude Bernard’s name, since I want to proclaim that the physiology he did so much to create is still very much alive and could be entering a new golden age. I stress “could” because just the opposite fate is also possible: Gabriel and Vera Pinter, in their provocative News in Physiological Sciences Perspective (21), asked whether physiology is dying “not . . . of old age, exhaustion, or other natural cause . . . [but] from incomprehension and neglect.”

My basic theme today is that the quality and breadth of our teaching, even more than our research, will decide the future of physiology. My reasoning is simple: in this era of molecular biology and profound reductionism all basic biomedical research looks homogeneous; therefore, it is our teaching that must convey our uniqueness to the young people from whose ranks will come the next generation of physiologists; it is our teaching that must convince our institutions that physiology is truly a distinct discipline and that physiology departments perform a central unifying role in the training of medical students; it is our teaching that must convey physiology’s special research achievements to the public, upon whom we depend for funding and permission to perform animal research.

For our teaching to achieve these happy goals, two overarching attitudes must be reshaped: one concerns the importance that we attach to teaching in our careers and the other how we view the very
nature of physiology. To put it bluntly: first, we must be willing to take our teaching as seriously as our research, and second, we must be capable of doing what is required — teaching integrative physiology. Let’s look at these in turn.

With regard to the importance afforded teaching, I like to think of myself as a “despairing optimist,” a term Rene Dubos, one of my heroes, coined. One reason for optimism that attitudes can change stems from recent actions taken by our own organization, the American Physiological Society (the Society, APS). A bit of history should make this clear.

Before World War II the APS was strictly a research organization. It provided no forum whatever for discussion of teaching at either the medical school or the undergraduate level. This began to change in the early 1950s, particularly with the establishment of the Education Committee (in 1953). A decade later E. F. Adolph wrote (1): “No evaluation of the Society’s efforts on education can be made... . Certain results can be seen in the changes of attitudes on the part of Society members, tending toward the feeling that teaching is an important activity.”

Twenty-five years later, Orr Reynolds and I reached essentially the same conclusion (26). We were impressed by the hundreds of people who had participated in the Society’s educational activities and the sheer number of individual educational programs that the Society had sponsored. But we were also struck by the number of projects that seemed to fade away and the many excellent ideas that appeared in the minutes of the Education Committee meetings but were never acted on or implemented. As Norman Staub put it recently (23): “Our dabbling in education indicated desire but not much staying power, partly because so many of our efforts were the personal objectives of an individual, not Society priorities.”

As a result of the Society’s 1992 Strategic Plan this should all change. At last we have a full-time Education Officer1, and for the first time in its history the Society has formally accepted the fostering of excellence in physiology education as a major goal: “The intention is to involve the Society in education at all levels from kindergarten to medical and graduate schools as well as in education for the public (3).”

Well before this Strategic Plan, of course, the Society had already taken another extremely important step: the creation in 1985, thanks to the initiative of Harold Modell and others, of this Teaching Section, followed by the birth of Advances in Physiology Education.

Modell and Joel Michael are absolutely correct in arguing that we need a community, within the life sciences, whose primary scholarly pursuit is in the realm of education (19). Such a group could constitute a powerful force for change. However, if physiology is to thrive as a discipline, the much larger group of traditional faculty, who will continue, quite properly, to devote most of their time to bench research, must also act on the belief that teaching is an important part of their professional careers. And this has made me think of what those who love and value teaching should say to a young physiologist just starting out. Every religion needs a credo, so here goes.

Good morning. I enjoyed reading your thesis research on renal signal transduction mechanisms for parathyroid hormone; I was pleased that you pointed out how these findings will help explain why certain diuretics don’t increase calcium excretion. But I really want to talk about your teaching, not your research. I have never tried to calculate what fraction of my professional life has been spent on teaching and research, but I would guess it’s been about 50:50. I enjoyed the research greatly and it has provided me with moments of true joy; indeed I am certain that any nonscientist onlooker would question the sanity of a grown man going into ecstasy over an increase in the number of drops emerging from a uterine catheter. But, overall, it has been my day-to-day classroom teaching and my textbook writing that have been the greatest continuous source of pleasure and pride for me.

1 The emphasis here is on “full-time.” Orr Reynolds had been appointed education officer in 1970 and remained so until 1981 when the education office was disbanded. However, on the retirement of Ray Daggs in 1972, Orr, while remaining education officer, also took on the immense duties of executive and secretary-treasurer.
And that’s why I wanted to talk to you, before you fall victim to some of the unfortunate attitudes prevalent in this school.

You’re about to enter a rather Kafka-esque situation. If you are like most of us, you were attracted to this field not by any desire to teach but because you loved its scientific content and you were excited by the research possibilities in it. You probably did little or no teaching in graduate school — maybe helping out in a lab here and there — and you certainly got no formal training in the science of teaching and learning. You became aware even then that there are very few institutional rewards for good teaching in high-powered places like this, despite what the school’s hypocritical guidelines for promotion and tenure may say. By the way, I think that this situation is starting slowly to change, as a result of declining research funds, angry state legislatures, and changes in life-science curricula.

It’s no wonder that so many young faculty conclude that teaching is a price we pay in order to do our research. But how can this be? Teaching is, after all, the unique and central mission of institutions of higher learning. That is certainly what you and your parents believed when you set off for college. To quote a recent eloquent book (22): “Teaching is not just an addendum to research. It is not an obligation that comes along with the job. Teaching is the continuation of a culture, the continuity of what we have done and known, the sustenance of our intellectual life. . . . What kills a subject is the lack of good teaching, the inability to communicate whatever once gave it vitality.”

For physiology teachers there can, in fact, be many rewards, both emotional and intellectual. There is the pride of passing on to the next generation a unique way of looking at living organisms, all the way from individual molecules to an entire person. There is the excitement of learning whole new areas, indeed of finding that you never really understood your own field until you had to teach it to others. There is the pleasure of interacting with bright interested students, knowing that you can make a real difference in their lives and, at the very least, in the way they practice medicine.

There is also the simple egoistic satisfaction of feeling your students’ gratitude for doing a good job, of sensing their excitement and their looking up to you as someone important to them. Think how you felt about the all-too-few teachers who inspired you, probably you’re in this field now because of one of them. You are doubly fortunate to be teaching physiology, for of all the basic medical sciences physiology is the one medical students know they must learn; even though they may be exhausted and frustrated by the overall load laid upon them, they still try desperately to do so. I hope you will also teach undergraduates some day, for you will be amazed at their intense interest in learning how their bodies work.

I know it’s hard to say such things without sounding maudlin, but teaching, if you allow it to, just makes you feel good about yourself. I’d better quickly add that it will help your research too.

Your expression conveys your “this is all very idealistic but totally impractical” feelings. Well, let me play my trump card, citing a Nobel Laureate. Here is what the great theoretical physicist and renowned teacher Richard P. Feynman had to say (8).
“I don’t believe I can really do without teaching. The reason is, I have to have something so that when I don’t have any ideas and I’m not getting anywhere I can say to myself, ‘At least I’m living; at least I’m doing something; I’m making some contribution . . .’

“If you’re teaching a class, you can think about the elementary things that you know very well. These things are kind of fun and delightful. It doesn’t do any harm to think them over again. Is there a better way to present them? Are there any new problems associated with them: Are there any new thoughts you can make about them? . . . If you do think of something new, you’re rather pleased that you have a new way of looking at it.

Think how you felt about the all-too-few teachers who inspired you; probably you’re in this field now because of one of them.

“The questions of the students are often the source of new research. They often ask profound questions that I’ve thought about at times and then given up on, so to speak, for a while. It wouldn’t do me any harm to think about them again and see if I can go any further now. The students may not be able to see the thing I want to answer, or the subtleties I want to think about, but they remind me of a problem by asking questions in the neighborhood of that problem. It’s not so easy to remind yourself of these things.

“So I find that teaching and the students keep life going, and I would never accept any position in which somebody has invented a happy situation for me where I don’t have to teach. Never.”

What Feynman says about students and research has happened to me many times. For example, during a small-group discussion I was helping the students construct a massive flow-diagram of all the things they thought psychological stress might do; a student amazed me by calling out “increase in renin secretion.” She had put together two facts, presented to her on two different days, that renin secretion is stimulated by the renal nerves and that the renal nerves are activated during stress. I told her it was a great idea, which to my knowledge had never been tested, and I jokingly asked her to spend the summer in my lab and find out if it was true. She did and it was. I went on to do stress-related research for the next 10 years.

But I am digressing and you are looking at your watch; I won’t burden you much longer. I’m sure you’re worried that teaching will detract in a major way from your research career. Horace Davenport, my own teaching mentor, wanted me to be sure to emphasize to you that there is absolutely no conflict between being a good teacher and doing good research. Just look at his CV and, with all due modesty, mine too. Yes, I know that the world has changed since Horace’s and my day, that you feel you must spend every moment writing grants to keep your research career afloat. I empathize with your plight, but the solution to this monomaniacal system, which is bad for body and soul, is not to give in to it but to work to change it. One way we can do this is to make ourselves invaluable to our schools through our teaching.

One last point and then I’ll let you go. You must approach your teaching with the same seriousness and effort you devote to your research. You will be interacting with several hundred students a year; nothing you will ever do in the research lab is as likely to impact on so many lives. Treat the students as colleagues, as partners in learning. You do this by interacting with them; there are plenty of ways to do this, even while lecturing, and I’ll give you some tips at our next meeting.

Several nights ago I was greatly moved by bearing the Dalai Lama speak of the power of compassion and affection in teaching. These feelings cannot be faked, but if you feel them don’t hold back; your students will respond accordingly. E. M. Forster wrote, “Connect, only connect!” You have a real opportunity to enrich your life through your teaching.
Well, thanks so much for listening to me; next time let's do this kind of thing over pizza and beer, and maybe I'll even let you say something. Right now I have to get back to my audience in Anaheim.

Of course, we all know it is not what we say but what we do that counts, for the usual way in which young faculty learn their attitudes toward teaching is by observation of their own teachers. I know, because I had the immense good fortune to have Horace Davenport as my role model both as a student and as a faculty member in his department; indeed, by honoring me today, you are also honoring him. I want to tell you a little about this experience to illustrate the power of role models to shape attitudes and behavior.

After majoring in history as an undergraduate, I decided to go to medical school for one reason only: to become a psychiatrist. I remember telling my wife the night before starting medical school that I would not allow my dislike of science to prevent me from reaching my career goals. How was I to know that Horace had just come to Michigan as chairman of physiology and that I would be in the first course to be taught under his aegis. Horace is one of the great teachers of physiology, a living example of the false dichotomy between teaching and research. He had inherited a department that was, to be kind, in disarray. To show his faculty, both old and new, the way he thought modern physiology should be taught to medical students, Horace gave a majority of the lectures himself that first year. From him I came to see the nonsense of pronouncements that one can't be a good teacher unless one is actively involved in bench research in that field, a view that drives the counterproductive system of teaching by "superspecialists on parade."

I found out only later that Horace had also designed the host of new student laboratories we did, actually putting together much of the equipment himself. On Saturday mornings the entire faculty would convene to work through the lab with him (5). It was quite an experience to attend Horace's lectures and to participate in the labs he taught; most striking were his enthusiasm, love of the material, and absolute commitment to our learning it. This model has been with me ever since. Horace also stimulated the development of our undergraduate course at Michigan, a course that at its peak attracted more than 1,000 students a year. The textbook that Jim Sherman, Dorothy Luciano, and I wrote grew out of the course but only because Horace legitimized textbook writing by his own example and by his enthusiasm and support for our own efforts. After reading, as a student, his classic "ABC of Acid-Base Chemistry" I remember thinking how thrilling it would be to write a book that people all over the world would read and learn from.

The moral of this story is that each of us has immense potential to move others, even within a system that itself may seem immovable.

Now I'd like to turn more briefly to the second attitude that will determine the success of our future educational endeavors and, very likely, our survival as a discipline: our image of physiology. We cannot succeed in our teaching unless we are clear who we are and are convinced of the uniqueness and vitality of our discipline. Our teaching cannot thrive if the gap between how members of physiology departments view the world and what they are called upon to teach becomes insurmountable.

Physiology has been going through a severe identity crisis, brought on by the extraordinary breakthroughs in molecular biology and the equally extraordinary drive to apply its techniques to physiological research. The significance of this reductionist revolution for physiology has caused much confusion, even among some misguided chairmen of physiology departments, as illustrated by Fig. 1. Our young hero should not heed this advice. He should remember that, no matter what techniques he may use, his unique mission as a physiologist is always the "enlightenment" of function. He also needs to be reminded of Claude Bernard's advice (4): "After carrying out an analysis of phenomena, we must ... always reconstruct our physiological synthesis, so as to see the joint action of all the parts we have isolated . . . ."

And most important, he also needs to read the 1990 report of the Society's Long-Range Planning Commission (10). This report recommended that "for the
"Forget enlightenment. I want you to concentrate on the structure of the protein molecule"

FIG. 1
My interpretation of misguided advice to a young physiologist. The cartoon and its legend have not been changed from the original. [From: Sidney Harris, \textit{Einstein Simplified: Cartoons on Science}. New Brunswick, NJ: Rutgers Univ. Press, 1989.]

first time in its history the APS officially adopt and promulgate a definition of physiology: 'Integrative Biology,' the biology of the future.” The report went on to state that physiology is “a unique branch of biology that deals with syntheses and integration and ultimately seeks to understand the functioning of whole organisms.”

I want to be clear that, at least to me, the view of physiology as integrated biology is not antireductionist, the “top-down” and “bottom-up” approaches are both important in physiological research. Nor does it deny the important insights and techniques that molecular biology has contributed and will continue to contribute to research in physiology. Rather, this view reasserts physiology’s unique point of view and unique mission (9, 10, 17, 20), which many seem to have forgotten.

The Long-Range Planning Commission Report also stated that “...the next revolution in biology will be in the integrative organismic domain,” with physiologists leading the way. I fully agree with this prediction, and I don’t think it is simply whistling in the dark. Far from dying, physiology should be entering its most fertile period, for it is physiologists who must integrate the findings of cellular and molecular biology in a great synthetic movement back up the levels of biological organization. And the challenge will be for teachers to capture the excitement of all this, to revel in the complexities of function, communication, and control in multiple hierarchies, everything connected and interacting with everything else. My wife teases me that, to paraphrase Will Rogers, I never met a flow-diagram I didn’t like. I might add that it was the excitement of finding new ways to describe these interactions that first motivated me to write textbooks.

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So much for shaping attitudes. Let us assume that physiologists will take their teaching seriously and that they will be secure in the identity of their unique research and teaching domains. We have now the tasks of attracting great young people to our discipline, training them to be effective, knowledgeable teachers, and playing our role with them...
Introducing the topic in this way makes undergraduate teaching seem to be only self-serving, a way of recruiting new people, and this is not my belief at all. We ought to be teaching physiology to undergraduates in and for itself, because a knowledge of how one’s body works is an essential part of a liberal education. Happily, in performing our mission of teaching physiology to all comers we can also achieve our goal of attracting the best of them into physiology.

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In undergraduate life-sciences education we have a real challenge to be a bridge between the esoteric reductionism of molecular biology and the most holistic aspects of organismic function, to which the students are intrinsically attracted. In the construction of introductory human-physiology courses, the challenges are to have students see that physiology, in its focus on function, spans the full range of organizational levels, that physiologists pursue both reductionist and integrating strategies, and that physiology is a living experimental field uniquely committed to looking at the whole person. It’s important to think about novel ways of structuring undergraduate courses (and the textbooks designed for them) so that they best accomplish these objectives. For example, Penny Hansen and Kenneth Roberts have described a course built around ordinary human situations rather than the traditional organ systems (13).
I’d like to tell you about the most enjoyable course I have ever given at any educational level. It was in the 1970s, and the course was called, rather ostentatiously, “Environmental Challenges: The Physiology of Human Survival.” It dealt with traditional environmental physiology, but also with the body's adaptations to nutritional challenges, noise, psychological stress, and toxic chemicals (25). Its only prerequisite was our undergraduate human physiology course (or a college course in Biology), and it attracted 75–100 students a year. In addition to several exams, based entirely on problem solving, each student’s major responsibility was to generate a research proposal — to pick a highly specific question, review 10–15 original research articles dealing with it, and then generate a testable hypothesis; at the end of the term the students held a mini Experimental Biology (FASEB, in those days) meeting, in which they presented 15-min summaries of their papers to the other students and then fielded questions. Crucial to this end point were weekly small-group conferences, whose major function was to help the students learn how to look up literature, analyze research articles, and formulate hypotheses. I was pleased that several students, after taking the course, decided to go into physiology and eventually entered our department as graduate students. One of them had been majoring in the humanities, and I will always remember him musing out loud the day of the presentations: “I can’t believe I’m doing this, sitting here and talking about research and loving it.” An instructor can live on that for a long time.

Claude Bernard has provided another excellent approach to course design (4):

*I am devoting my whole course at the College de France this year to the study of curare, not for the sake of the substance itself, but because this study shows us how the simplest single determinism, such as the lesion of a terminal motor nerve, re-echoing successively from all the other vital units, leads to secondary determinisms, which grow more and more complicated till death ensues.*

At this point, to avoid being stoned to death, I must say to my colleagues in liberal-arts colleges and smaller universities that I am not advocating that you do more teaching; you are already doing your share and then some. I do make that plea, however, to the faculty of medical-school departments. I am certain that in most large universities the numbers of potential students for human physiology courses far exceed the present number of undergraduate faculty available (or motivated) to teach them. I would urge every medical school physically connected with an undergraduate institution to offer at least one undergraduate course in human physiology. Our own course, open to all students, has no prerequisites, and I believe this is essential so as not to put up unnecessary barriers for the students, especially those not in the sciences. The offering of such a course has to be done not in competition with the undergraduate biology faculty but in a spirit of cooperation, which has certainly existed in my own university. The Biology departments have more or less deserted the field of integrative physiology teaching, and there is a large pool of students waiting to sample our wares. In the words from a recent movie: “If you build it, they will come.”

This kind of interaction might also stimulate thinking on another extremely important issue: the appropriate relationship between undergraduate and medical-school physiology. As more medical schools move to curricula that decrease or even eliminate disciplinary courses in physiology, a bizarre situation is emerging: the physiology course taken by a student as an undergraduate frequently has the same or greater content than the student's first-year medical course. And the contents are organized in the same way.

I can’t leave the topic of undergraduates without giving those of you who have never taught at that level my favorite example of how creative these young people can be. My first experience with undergraduates, soon after I came on faculty, was through a summer program for them doing research in our labs. I was somewhat leary about what I could have them do since they had had only limited coursework in physiology (our own undergraduate course was not fully developed at that time). My worries proved groundless, for the students read
voraciously and I had my first experience of being a facilitator of active learning. At the end of the summer the two young women who had worked in my lab presented me with a board game they had created: "Nephron," complete with kidney-bean counters. The goal of the game was to move along pathways according to the roll of the dice and to be excreted ahead of the other players. To do this, of course, you had to be filtered or secreted, and you had to avoid pulling from the stack of monopoly-style cards the ones that read, "You have been reabsorbed," or "go to the descending limb of Henle's loop and be recycled in the medulla," or "you have just become bound to plasma protein and are no longer filterable." These beginning students had developed for themselves a model that contained all the essential basic components of renal physiology. I wish I could show you a picture of the game, but much to my sorrow it was lost during a departmental move.

PREPARING GRADUATE STUDENTS FOR TEACHING

One of our greatest challenges is to train graduate students to be effective teachers; to give them the confidence, knowledge, and motivation to teach integrative physiology and be facilitators in the newer types of curricula.

One component of such training is the providing of supervised teaching experiences as well as formal didactic instruction in teaching methodology. For at least 25 years the Physiology Department at Michigan has required graduate students to teach in the laboratories and small-group conferences of all our courses. They have also functioned as tutors. The entire faculty has participated in this program in a small way, by sitting in on one or more of the students' conferences and providing both evaluation and feedback to the student. Some additional instruction in teaching techniques is given in a weekly session. In general, the students have enjoyed their experiences, and it was an important factor in causing several of them to choose teaching, rather than bench research, as their primary professional mission. Unfortunately, with the disappearance of labs and the small-group conferences in our medical course, the opportunities for teaching in our department have been decreased greatly, and I suspect this is true nationwide.

I would urge the APS to set up a task force to do a full survey of such training activities in all departments that offer the Ph.D. in physiology and then make recommendations as to how to achieve Joel Michael's goal of applying "the kind of rigor to this (training) effort that (we) expect in (our) research and that is increasingly possible in pedagogy (16)." It is mind-boggling that many faculty, who expend huge efforts training their students to do research, somehow have concluded that teaching, a no-less-difficult activity, requires no special training. The notion that good teachers are born, not made, is a counterproductive myth, often a self-fulfilling prophecy.

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In addition to specific training, another goal is important: to inculcate graduate students with an appreciation of integrative physiology, to help them to be well-rounded and adaptable enough to teach in a variety of settings in the future. The reality, of course, is that the graduate curriculum of most schools has become quite narrowly focused. It has followed the same evolution as the physiologists delivering it. After an introductory course in classical organ-system physiology, most additional courses, departmental research seminars, and thesis problems emphasize the techniques and approaches of cellular and molecular biology.

My hope is that departmental faculty will recognize that training programs need to reflect the many
potential future roles of the graduates, not just the immediate research interests of the faculty. This is true not only for our graduates’ future careers as teachers but also as researchers. We must not make the same mistake as generals who are always preparing for the last war, or economists who are always preparing for the last depression. As physiology research comes to deal again with more integrative questions, the problem of narrow training will naturally fade. But while we are waiting, I’d like to suggest a few small measures that could help.

1) Faculty should make more of an effort to seek out for some departmental research seminars persons whose work is in an integrative area, even though no one in the department is doing this type of research. For example, one of our most exciting (and best attended) recent departmental seminars dealt with protein metabolism and urine formation in hibernating grizzly bears.

2) There could be a formal course based on the analysis of real case histories, as espoused by Joseph Engelberg. He has described how valuable such experience could be for those destined to teach in the health professions and also what a wonderful vehicle cases are for sparking interesting scientific discussions that transcend the usual organ-system boundaries (7).

3) Similar benefits could be achieved by analysis of classic papers that display the power of systems thinking. For example, I would have every student discuss Arthur Guyton’s brilliant synthesis of the complex interacting pathways that can lead to hypertension and the logic that led him to implicate the kidneys as major contributors (11).

4) Lab experiments. I think it important to have graduate students do at least some of the classic ones, specifically those done on themselves. I was interested to read that high-school teachers and students at last year’s Past President’s Symposium were most excited by the mini-experiments they did with their own pulse and respiration rates, and I found myself wondering who would know how to demonstrate them twenty years from now.

In ending this section I want to emphasize another important benefit from providing broad training to graduate students: it will inevitably influence the development and views of the younger faculty, who themselves were narrowly trained or come, as is often the case now, from different disciplines altogether.

THE TEACHING OF MEDICAL STUDENTS

We come now to one of the pressing questions in medical education: How is the medical curriculum to be structured, and what are to be the roles of basic scientists and basic science departments in it? This question raises considerable angst in physiologists, and for good reason. Both problem-based and highly integrated curricula are associated with large reductions in the time allotted to a separate physiology course, or they eliminate the course altogether. If, as I argued earlier in my talk, our survival is based on our teaching, then does not this process eliminate that base?

That certainly is a possibility, but one can also make a strong argument for the opposite view. The problem-solving skills and integrationist point of view that broadly trained physiologists have make them uniquely suited to be excellent teachers in these curricula, especially to be facilitators in problem-based ones, more suited even than the clinical faculty, who are too busy to do the job anyway. Because we can see the big picture and because physiology is so central to understanding disease, broadly trained physiologists can be comfortable in these situations. And, as Penny Hansen and Kenneth Roberts have brought out (12), physiology gives relevance to all the other basic sciences. Sooner or later, if we do our job, Academic Deans will come to recognize all this. This is why I have harped on the need to train physiology graduate students broadly.
To avoid any misunderstanding, I want to state as strongly as I can that the reason for favoring or opposing the newer types of curricula should not be based on our perceived needs but on those of our students. The problem is that most faculty simply don’t know what is best for the students in this regard. I certainly don’t. But what I do know is that the traditional way of delivering the curriculum is badly in need of alteration and the very least that physiologists can do is take a leadership role in doing it. Endless debate on exactly how it is to be repackaged should not distract physiologists in schools with traditional curricula from acting now.

Figure 3 illustrates nicely the present typical state of affairs. Horace Davenport, as usual, put it perfectly years ago when he wrote: “There is a great difference between teaching and learning; there is too much teaching and not enough learning.”

Happily, there is a growing consensus on what needs to be done: we should reduce the total amount of factual information students are expected to memorize, reduce our use of the passive lecture format, and devote much more effort to helping students become active, independent learners and problem solvers. Here is my prescription.

First and foremost, we should decide, as a discipline, exactly what the appropriate content of medical physiology should be. This content should be specified in the form of detailed learning objectives.

Second, we should further decide which of the fundamental concepts of this total content are difficult enough to warrant special treatment, requiring interaction between student and faculty. The rest of the content can be learned by the students from textbooks or other resources, the objectives serving as guide. In this way, the faculty can use classroom time to help the students learn the difficult material and to pepper them with problems.

This all sounds so simple — 1, 2, 3. But what do we really need to bring about this utopia? Obviously we need the decisions about total content and the designation of which portions need special treatment. There is no doubt in my mind that physiologists, clinicians, and cognitive scientists, working as a team, can actually make these decisions on rational grounds; there are already several published models of how to approach this task (6, 24). It is of such central importance that the APS should jump at the chance to initiate it.

A second requirement is the availability of appropriate textbooks and other resources for self-study. This is a very tough requirement to meet. I wrote my renal physiology textbook to serve this purpose, but...
I must confess that I have found it very difficult, as the editions mounted, to practice what I preach. The mechanistic details keep popping out on my computer screen as though they had a will of their own. Can I really not tell students which channels and transporters aldosterone influences? But is this really part of the core knowledge of physicians? Isn’t it enough for them simply to know that aldosterone stimulates sodium reabsorption and potassium secretion? To make decisions like this it would be invaluable to have the consensus on content that I described earlier.

The third requirement is a physiology faculty adept at promoting their students’ active learning and problem-solving skills. It is totally unrealistic to imagine that large numbers of physiologists will become experts in cognitive science, but that really isn’t necessary. To take a large leap forward, all one need do for now is obtain and study the first 95 pages of a small volume entitled Promoting Active Learning in the Life Science Classroom, edited by Harold I. Modell and Joel A. Michael (18). I am not being flippant; this volume is very useful. The APS should sponsor, at regular intervals, conferences and workshops of the kind that gave birth to it, and Advances in Physiology Education can meanwhile be a vehicle for the sharing of good simple problems and other practical applications of the basic ideas. What I’m trying to say is that even with a very modest effort, we can do a far better job than we have.

My experience while preparing this talk has convinced me this is true. Now I will tell you that the light-bulb problem I gave you earlier (Fig. 2) is from one of the papers in the volume just cited (15), by a physicist, Lillian McDermott, whose group has been doing for physics exactly what we need done for physiology: studying student understanding and using the findings for developing curriculum. The correct answer to the problem is A=D=E>B=C. I certainly got it wrong. I’m in good company: only 15% of students in calculus-based physics courses, high-school physics teachers, and university faculty who teach other sciences and mathematics give the correct ranking. I presented it to you to as an inducement to read her article and ponder her conclusions concerning the great discrepancies between how faculty teach and how students learn. These conclusions, although made specifically for physics teaching, have considerable relevance for physiology.

It’s time to stop. In closing I want to say that I know how concerned many of my colleagues are about the future of physiology. One view of the future can take the form expressed by Woody Allen, in what he called his speech to the graduates (?): “More than any other time in history, mankind faces a crossroads. One path leads to despair and utter hopelessness. The other, to total extinction. Let us pray we have the wisdom to choose correctly.” Instead of this attitude let us adopt that attributed to another great American philosopher, Yogi Berra: “When you get to a fork in the road, take it!” I’d like to let Claude Bernard have the final word (4): “It is that which we do know which is the greatest hindrance to our learning that which we do not know.” Thank you all for this wonderful honor and the chance to speak to you.

References


This Distinguished Lecture honors not only the lecturer, but also the life and work of the physiologist Claude Bernard.

Claude Bernard was born in 1813 at St. Julien in Beaujolais, France, the son of a vineyard worker. He was apprenticed to a pharmacist in Lyons and then made his way to Paris with the intention of becoming a playwright. He took another route, however, managing with difficulty to support himself through medical school. Assisting Francois Magendie with his animal experiments at the College de France so excited Bernard that he committed himself entirely to physiology, physiological chemistry, and experimental medicine.

He earned an M. D. degree in December 1843 but continued to experiment in various laboratones, including his own private one funded by his wife’s dowry. He returned in 1847 to Magendie, at first as suppleant, or deputy lecturer to the professor. Then in 1852 on the retirement of his mentor, he took over the chair and the physiological laboratories at the Collège. These first years were remarkably productive, Claude Bernard reporting many major findings, including the vasoconstrictor nerves; he was later to discover vasodilator nerves. Although illness periodically interrupted, Bernard continued to investigate innovatively a remarkable range of phenomena, combining keen powers of observation with dexterity, curiosity, and intellectual rigor. When he came across something in his investigations that did not fit into current dogma, he would worry at it until he had a new concept. New experiments were tried and incorporated into the hypothesis, modifying and strengthening the generalization.

One such concept, the notion of milieu, environment, appeared first in 1851. By 1857 the idea had undergone further refinement: “The blood constitutes an actual organic environment intermediary between the external environment in which the complete individual lives and the living elements which cannot safely be brought into direct contact with this external environment” (5). The notion that there was a (relative) stability in this milieu intérieur came from Bernard’s own physiological experiments on the temperature and on the levels of oxygen, glucose, and salts of blood; blood was identified with the internal environment. There was a great imaginative leap to this seminal generalization, for the evidence for “stability” or “constancy” was at this stage meager. The concept was expressed poetically and memorably in Bernard’s last work: “The constancy of the internal environment is the condition for a free and independent life…” This statement is to be found on page 113 of the final volume of his lectures, published shortly after his death, Lecëons sur les phénomènes de la vie communs aux animaux et aux végétaux (Paris: J.-B. Baillière, 1878). Bernard continued:
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"...the nervous system is called upon to regulate the harmony which exists between all these [elements of the internal environment]" (4). We would now add to the nervous system the endocrine and paracrine systems.

The concept of an integrated control of the various internal environments of the body has undergone further evolutionary development, including Walter Cannon's ideas on homeostasis (3), it was further extended by the writings of Joseph Barcroft (1), by the concepts of cybernetics (6) and the application of control system theory to physiology, and by the growth of biochemistry and endocrinology. In this age of molecular biology, the hypotheses stemming from Bernard's ideas still remain one of the major challenges of biology (2).

Throughout his career Claude Bernard's experimental work, put into conceptual structures, was often presented first in public lectures, with actual demonstrations of animal experiments; these lectures were then published, to influence the subsequent course of physiology.

Bernard in later life bought the manor house at St. Julien and, until his death in 1878, returned each fall to assist in the grape harvest.

References

Further Reading

KENNETH B. ROBERTS, Associate Editor, Faculty of Medicine, Memorial University, St. John's, Newfoundland A1B 3V6, Canada.