THE FUTURE OF TEACHING PHYSIOLOGY: AN INTERNATIONAL VIEWPOINT

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The discipline of physiology is challenging to teach. It has ill-defined boundaries and no agreed sequence for learning; students' needs depend on the goals of the specific degree programs in which they are enrolled. Internationally, it is taught under many different conditions, using a range of strategies, to a wide variety of groups. All teachers are subject to local constraints and the availability of resources. Newer educational methods emphasizing active and integrated learning provide novel challenges. Computer-based educational strategies offer promise but do not represent easy solutions, particularly when they are unaffordable in many parts of the world. Particular difficulties in teaching arise for some when they are not themselves broadly educated in physiology and related disciplines and for others when they have only limited access to up-to-date knowledge and resources. Sessions and workshops on modern physiology and educational issues should be included in national, regional, and international conferences at which the participation of teachers is encouraged and supported.

KEY WORDS: curriculum; educational philosophy

Throughout the world, those of us engaged in the teaching of physiology find ourselves increasingly challenged by a number of important and difficult questions. What are the boundaries and core elements of physiology? Are there national and international differences in the conceptualization of the discipline? How is the subject shaped by the different contexts in which it is taught and researched?

We cannot omit the characteristics of the teachers from considerations of teaching physiology. What are their backgrounds and interests? How well equipped are they for the task? Can teachers keep abreast of current issues in both physiology and teaching practice? With changing patterns of education, including the move to greater integration between disciplines, how do teachers adapt and cope?

In this article I will attempt to review some of these issues. This article represents a personal view, evolved over many years of experience as a teacher of physiology, but informed by my participation in many debates and discussions in Australian, regional, and international contexts. I aim to raise the questions; solutions will have to come from the practitioners wherever they are teaching the subject.

THE DISCIPLINE OF PHYSIOLOGY

A historical view. Physiology emerged as a distinct entity in medical training, whether in university settings or in apprenticeship, in the latter years of the last century. During this century, physiology generated lusty offspring: biochemistry early and pharmacology generally later. Now physiologists may also be working in departments, for example, of neuroscience, cell
science, pathophysiology, or developmental biology. The field of study called physiology has never been static or clearly bounded, suggesting that the notion of distinct disciplines in the medical sciences is inappropriate or at least represents an inadequate description.

The limits of physiology are further blurred in that, in their research and in some teaching, physiologists adopt techniques and strategies from a wide range of disciplines, from histology to electrical engineering, from molecular biology to computer science. In medicine and the health sciences, an understanding of the normal is often identified as a necessary precursor to interpreting issues arising from disordered function, yet aspects of normal physiology are often understood through reviewing the abnormal. Thus the barriers separating physiology from related disciplines are permeable and, in many cases, poorly defined.

**Physiology and related disciplines.** Figure 1 shows some of the relationships between physiology and allied disciplines from an Australian perspective; for different countries and situations, additional or alternate relationships, as represented by circles, may be appropriate. Thus, for example, pathophysiology is a recognized subdiscipline in many parts of Europe, but it is less commonly identified elsewhere; those studying the properties of cell membranes may have more in common with plant scientists than with colleagues in systems physiology.

The implications for designing appropriate courses in a subject that lacks sharp borders are clear. In departmentally organized institutions, territorial disputes are many and often hotly fought. Without sensible coordination of courses, and when assumptions are made about who is teaching what, there are redundancies, unnecessary duplication (often with confusing minor differences of emphasis), or substantial gaps. Clear statements of goals and expectations from each related course may overcome some of the problems, but interdisciplinary and interpersonal differences can impede the rational development of students’ knowledge and understanding.

**CONTEXTS FOR TEACHING PHYSIOLOGY**

**Educational structures.** Educational philosophies and organizations differ across the world. Thus the institutions in which physiology is taught in Great Britain are distinct from those in continental Europe; both differ from those in the U.S. Educational organizations in former colonial societies, although based on those originally imposed, are undergoing considerable modification and adaptation to local needs. Perhaps the differences are most sharply illustrated by comparing teaching physiology to medical students who have only recently left school (as in most of the world) or who are already graduates (as in North America). With a greater exchange of scholars and teachers, there is a better understanding of the international similarities and differences.
Student needs. The common goal of all teachers is to enhance learning. Those attending recent workshops held in conjunction with the Congresses of the International Union of Physiological Sciences (IUPS) have spanned a wide range of countries and responsibilities. Teachers of medicine, dentistry, nursing, pharmacy, and other health sciences dominate, teaching students for whom the subject is compulsory. Some teach similarly required physiology to students of veterinary science or agriculture, including aquaculture. Some are involved in more general science or liberal arts programs in which students choose the subject from interest rather than utility. Others are developing programs for those with an interest in biomedical engineering. In many countries, higher degree postgraduate training involves very little coursework outside the research laboratory. By contrast, in North America, formal classroom requirements are substantial, requiring the design and presentation of appropriate courses.

Clearly, the goals of these varied curricula and thus the demands on teachers are very different. Thus the expectations in terms of understanding and the application of basic normal mechanisms for a medical student may be quite distinct from those for a student embarking on a scientific research career in physiology. Even within the various health professions, the principal emphasis and ultimate levels of professional responsibility differ. Contrast, for example, the different learning needs of a doctor, pharmacist, or speech pathologist. Comparative physiology assumes a greater importance for those in veterinary science or agriculture, and sophisticated measurement techniques loom larger for those undergoing research training. Of course, local constraints often lead to the mixing of different groups within the same class, with the inevitable result that the program offered, however professionally designed and presented, can never be entirely appropriate for all.

The different needs of students of physiology largely determine the educational strategies. Thus, in medicine and the various health sciences, an emphasis on traditional body systems is common. That is how textbooks are commonly organized and how specialist practice is usually defined. For science students learning physiology alongside pharmacology, a cellular and molecular approach may be more appropriate.

By contrast, those teaching physiology to students who seek to apply the subject more generally in medical sciences or in research increasingly rely on more integrative, process-related themes such as homeostasis, signaling, and epithelial transport, using examples and stressing common issues across systems. Interestingly, this tension between themes and systems also arises for the Council of the International Union, which is debating the place of new special interest groups (e.g., epithelial transport) that seek commission status, intersecting with the more traditional systems-based definitions.

Political and economic contexts. The realities of academic life are inseparable from the political, social, and economic environments in which institutions are embedded. In some parts of the world, selection is not always on the basis of academic merit or appropriateness for the program, and students may not be equally proficient in the language of instruction. Societies have different expectations of the graduates that emerge from educational institutions. Financial and political support for universities is never adequate. Few institutions even in wealthy countries can provide resources for small-group teaching or for all students to use state-of-the-art equipment in practical exercises, particularly when class sizes are large. Thus an “ideal” course in physiology is probably unaffordable anywhere.

Political impediments abound. Curricula are under stress from pressure groups arguing to include or exclude particular elements. For example, those opposed to experimentation on animals (whether in research or teaching, or both) seek to impose their views; internationally, the levels of their concerns vary from indifference to active interference. Thus new classes need to be designed and resourced. Even in those countries in which animals are still used, greater accountability and security measures impose additional costs. Recourse to human experimentation is not universally appropriate because the presence of new infectious diseases limits the use of human blood and other tissues in the classroom. Furthermore, the costs of sensitive, noninvasive instrumentation are often prohibitive. A reasonable but increasing emphasis on written informed consent for participation in even the simplest human experiments adds layers of complexity to the classroom.
TEACHERS OF PHYSIOLOGY

A diversity of backgrounds. At the 1997 international teaching workshop in Russia, an intense debate developed on issues relating to the backgrounds and skills of teachers of physiology. Those from developed countries, particularly the U.S., expressed concerns that physiology teachers are increasingly appointed on the basis of their research skills, whereas few are recruited from amongst medical or other more broadly educated graduates. Their interests are more likely to focus narrowly on molecular biology or biophysics than on broader, more traditional systems. Many have little experience or education in physiology, although they may be expected to teach medical and health science students. Not only are many unfamiliar with the basic topics but also they are limited in their capacities to provide examples and applications. There is a risk of such physiology programs becoming overladen with research-relevant detail, ignoring both essential integrating insights and a desirable emphasis on broad and applicable principles.

On the other hand, many students in undergraduate programs in both developed and developing countries are being taught by those who may well have been broadly educated in physiology but who may have no opportunities to undertake research and only limited access to recent advances in the subject. Such teachers are denied the opportunity to engage with recent advances and to incorporate newer ideas into their courses. Particularly when institutions can offer only outdated texts and few if any journals, keeping up to date is a major problem.

Interchanging ideas. Only a small minority of physiology teachers are supported by their institutions to attend conferences, workshops, or even activities related to the modern teaching of their subject. Intensive specialized research conferences are often too detailed to be particularly useful. More general conferences should include up-to-date keynote speeches and symposia that synthesize information by addressing broader and more integrative issues. New strategies for teaching challenging areas of physiology can be included and discussed. I see it as a priority. The IUPS has shown the way since 1983 with its successful teaching workshops and the raising of some important general issues in symposia at its congresses to update knowledge. Regional bodies, such as the Federation of Asian and Oceanian Physiological Societies, and some national societies have followed that lead. Advances in Physiology Education and News in Physiological Sciences represent important components of such an interchange, but accessibility to them is not assured throughout the world.

DESIGNING PROGRAMS: AN INTERNATIONAL PERSPECTIVE

Introduction and sequence. Internationally, there is no agreement on the most appropriate strategy for introducing and developing the subject, even for a well-defined group such as medical students. In the various international workshops held since 1983, various participants have described successful courses in physiology, each of which starts by considering a different system or with more integrative themes, such as cell membranes. Perhaps this observation is not surprising in a subject in which all systems are interdependent.

The prescribed curriculum. It has sometimes been asked of the Teaching Commission to develop “the curriculum for Physiology.” Given the diversity of students and degree programs of which physiology is a component, that is clearly not only impossible but also undesirable. Teachers of physiology must actively identify the needs of the different cohorts of students, clarify the goals of the educational process, and respond to significant local imperatives. Only then can they design an appropriate program and fully realize their educational responsibilities. I hope that, when the process is worked through, they will share their experiences both locally and with the international community of physiologists through writing or by attending workshops. In those ways we can learn from each other and, together, enhance the effectiveness of the students’ learning in physiology.

NEWER EDUCATIONAL APPROACHES AND STRATEGIES

Active learning. New challenges arise from advances in methodologies of teaching that enhance students’ learning. One major issue, however, is that busy teachers of physiology do not always have the time or
the means to access the relevant educational literature that emphasizes active learning. The importance of goals that extend beyond the recall of specific knowledge is now acknowledged, and appropriate strategies have been well reported. The limitations of passively sitting in class and memorizing by rote are well documented. Techniques can be applied in lectures and practical sessions to enhance active participation by students individually or in groups.

Computers in learning. Active learning can also be encouraged by well-designed, interactive computer-based programs. So far, the promise of computer-aided learning has not generally been realized (with a few notable exceptions), but some recent applications encourage both individual and group learning. Such programs are effective only when the education, rather than the technology, is paramount. They are expensive to produce, and those developed in other locations need careful evaluation to ensure their relevance and appropriateness for a particular class. The goals of each program, the level of complexity, accuracy and quality of the content, the quality of the educational strategies, the degree of interactivity, and the ease of use must all be taken into account. The explosion of resources on the Internet will have a profound impact on learning physiology, but teachers will need the skills and the time to search for the various offerings and evaluate and integrate them appropriately. Computers not only offer simulations to provide access to otherwise unattainable hands-on experiences but also are effective when used with powerful recording instruments to enhance experimental work and the subsequent analysis of results.

The costs of infrastructure, however, are far from trivial. I am thus acutely aware that the perspective from which I am writing assumes adequate and equitable access for staff and students to sophisticated computers, the Internet, and instrumentation; for teachers in many parts of the world that is an unrealizable dream. There is a very real risk that the uneven distribution of appropriate technology will drive even greater wedges between those in affluent societies and those unable to share in the benefits.

Assessment. New commentaries on assessment emphasize the setting of clear criteria to be met, the effectiveness of timely feedback as an aid to student learning, the need for fairness and validity as well as reliability in tasks, and the necessity of ensuring that all the significant goals of a program are tested. We can all achieve our teaching aims more effectively by harnessing effective, nonpunitive assessment to encourage the development of more sophisticated understanding, problem-solving, analysis, and synthesis of ideas. Time spent on planning, implementing, and marking assessments has to be factored into the whole teaching effort. The greater sharing nationally and internationally of information about assessment strategies and the design of challenging questions appropriate for different groups of students would reduce the overall burden on all teachers.

Integration and problem-centered learning. For many health science and related programs, integration is increasingly emphasized. Thus physiology, with its obvious relationships with other disciplines, is often featured within integrated courses. The most obvious example of integrated learning is problem-based learning, as described elsewhere in this issue. Problem-based learning as most commonly used in medical curricula involves integration vertically through the curriculum (clinical and preclinical) as well as horizontally between related medical sciences. Problem-based learning encourages the process of reasoning, provides a context for learning, and enhances students' abilities to recall and to use knowledge. For many teachers of physiology it represents a very effective means of ensuring that learning is student-centered and independent. It is, however, threatening to those who are unfamiliar with the (usually clinical) context in which the problems are set. Some are uncomfortable because they lose control of the ways in which students learn physiology (although, as noted above, there is no prescription for an "ideal" sequence) and because timetables become somewhat unpredictable. When well implemented, however, problem-based learning puts the key emphasis on self-direction, teamwork, reasoning, and the application of integrated knowledge, thus laying the foundations for lifelong learning.

A problem-centered approach is also becoming a feature of physiology courses that are not themselves parts of fully integrated and problem-based programs. For example, physiological problems are being effec-
tively used to stimulate and challenge the students to explore scientific issues. In such potentially open-ended explorations, the boundaries are blurred between physiology and other related subjects, aiding the integration of knowledge.

CONCLUSIONS

We are standing at an unprecedented time of change and challenge for the teaching of our discipline. New methods and ideas abound, both in traditional educational settings and in the use of the newer technologies. The opportunities are many but will be enhanced with greater national and international sharing of ideas and active cooperation. In those ways we can enhance the professionalism of physiology teachers, whatever their local circumstances.

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