A NEW PhD TRAINING TRACK: A PROPOSAL TO IMPROVE BASIC SCIENCE TEACHING

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There has been increasing criticism of medical basic science teaching; much of this has focused on overcrowding of the curriculum, inadequate application to clinical medicine, and the limited commitment of the faculty to teach. We have analyzed some of the factors that may contribute to these complaints, such as the fragmentation of physiology and the conflicting roles of the medical basic scientist. We have also reviewed some previous suggestions for improving basic science teaching. We suggest that a basic scientist with a background of integrative physiology, pharmacology, anatomy, and pathology, with a special emphasis on pathophysiology, would be well qualified to assume an important role in the medical education of the future. Because there is at present no established training program of this type, we have proposed a PhD training track with this objective and have listed some of the advantages and disadvantages of such a program.


Key words: medical education; graduate training; physiology; pathophysiology

There have been critical comments on basic science teaching in medical schools. Our objectives in this article are 1) to review some of these comments, 2) to analyze the problems involved in teaching basic science, with particular reference to physiology, 3) to briefly review some previous suggestions for improving medical teaching, and 4) to venture a proposal for a new graduate training track in pathophysiology, which, we believe, might better prepare PhD students as medical teachers and researchers.

CURRENT BASIC SCIENCE TEACHING IN US MEDICAL SCHOOLS

Fueled by the military demands of World War II, the US, since 1940, has experienced an unprecedented growth of the biological and medical sciences. Incorporating this additional information into an already crowded curriculum posed a considerable problem; medical schools resisted further lengthening of an already prolonged period of study, so the curriculum became further overrun.

Although medical schools have in the last two generations undoubtedly made great contributions to scientific medicine, certain concerns have arisen. Medical education has been termed "a brutal experience, the curriculum rigid and bloated, the experience inhuman" (22). The basic science curriculum was said to be overloaded, with undue reliance on the lecture method and too little integration between basic and clinical material (2, 13, 18, 19). There have also been adverse comments on the quality of teaching. Presentations of the faculty were described as unimaginative and geared to the lowest common denominator of ability (20). It was said that the faculty had no formal
training in pedagogy and were unskilled in teaching (25).

The above complaints should not obscure the fact that a number of serious efforts have been made over the years toward improved medical teaching. There have, for example, been extensive, long-term curricular experiments aimed at reducing lecture hours and improving basic clinical integration at Case Western Reserve, Duke, Harvard, and more recently at Johns Hopkins, Kentucky, New Mexico, Oregon, and Yale (23). These schools and others have made serious efforts to initiate basic clinical teaching sessions, small class tutoring programs, and closely monitored student laboratories. Most of this effort did not, however, induce widespread, long term curricular reform. It should also be mentioned that the great majority of medical schools are aware of teaching problems and almost all have standing curricular committees. Unfortunately, in many cases, individual departments strongly defend their own hours and methods of presentation so that real curricular reform is difficult. Some observers believe that an important reason for curricular rigidity is the examination system. The National Board Exams, developed in the 1950s are the national standard against which all students and schools are measured and have become the dominant factor determining course content and maintenance of the curricular status quo (17).

On the assumption that these critiques have some validity, we sought reasons for the comments. We have briefly analyzed the evolution of basic science teaching in the US, the fragmentation of physiology, the career prospects for basic scientists, and the role of pathophysiology in the medical curriculum. All of these, we believe, are relevant to basic science teaching and its improvement.

EVOLUTION OF BASIC SCIENCE TEACHING IN THE US

An auxiliary to the often-asked question, "Who will teach basic science?" is, "Who is best qualified to teach it?" In most medical schools of Europe and the rest of the world, basic science is taught predominately by MDs. In the US, beginning in the 1920s, after the Flexner Report, there was a rather sudden increase in the demand for basic science teachers; PhDs were recruited because of insufficient numbers of qualified MDs for this purpose. PhDs were, in any event, career scientists and usually better trained in that field. At present, ~86% of the faculty in US departments of physiology are PhDs, ~6% are MDs, and ~5% are MD/PhDs (24). With the increasing complexity of basic science, it seems evident that the traditionally trained MD is not really qualified to teach modern basic medical science.

As basic scientists became more basic, the research interests of PhDs and MDs became increasingly divergent. One group was trained and worked as scientists, the other was essentially trained in the practice of medicine (21). A further significant difference is that most MDs in their training years were subjected mainly to teacher-centered, passive education. PhDs were usually exposed to small-group, laboratory- and discussion-type education and to student-centered, problem-based learning (PBL). In any event, some observers have decried the intellectual isolation of the two groups (25).

It might be theorized that MD/PhD training could best bridge the gap between basic science expertise and clinical knowledge. This idea received considerable impetus through the Medical Scientist Training Program (MSTP) begun by the National Institutes of Health (NIH) in the 1950s. The NIH has continued its support and, as of July 1994, was funding 837 fellows in MD/PhD training programs at 33 schools (37). One report on the fate of MD/PhDs after training stated that 95% went into residencies rather than postdoctoral fellowships (12). Another indicated that, although clinical research was the stated objective of the MD/PhD program, only 13% were engaged in some type of clinical research and only 2% were directly studying human beings (1). A recent analysis provides further confirmation that MD/PhD research interests are more closely aligned with laboratory than clinical projects (38). It appears, therefore, that this group is not a significant force in applied human physiology nor in career teaching of basic science.

FRAGMENTATION OF PHYSIOLOGY AND THE CONFLICTING ROLES OF THE BASIC SCIENTIST

The increasing preoccupation of basic scientists with molecular biology and the relative neglect of human
system and organ physiology (integrative physiology) has been discussed by other authors, but because the question is central to medical teaching, we have briefly reconsidered this subject. Undoubtedly, recent developments in molecular physiology have opened research vistas and promising new ideas for the understanding of certain disorders, particularly of genetic origin. But however revolutionary this may be for the future, systemic and human physiology have much more medical and curricular relevance for the present. Vander (40) says that greater emphasis should be placed on integrative physiology. Hansen and Roberts (15) have stated that “whole body physiology is at the center of both medical science and clinical medicine.” Rosenberg et al. (36) point out that “the extrapolation of findings at the cellular level is not always meaningful, because the whole is inevitably not the sum of its parts”; they state that physiology “should emphasize the study of organ systems and especially that of the intact body.” Follow (11), the noted Swedish physiologist, believes that the “avalanche of molecular-cellular information only increases the importance of integrative physiology.” He finds that some leaders of physiology “have been so carried away by the molecular-cellular bandwagon—as to vanish below the cell membrane with their coworkers in a deep dive, presumably never to emerge again.” Because of this reductionism, he believes some physiology departments are no longer able to provide medical students with an acceptable course in human physiology.

As pointed out in two recent articles, this fragmentation has resulted in increasing divergence between the expertise of the basic science faculty and what the student needs to know to become a physician. Science faculty are increasingly proficient in their specialization areas, particularly cellular and molecular physiology, but less adept at teaching simpler, broader aspects of their subjects to the novice medical student. These authors make the analogy that the experts in the branches and leaves are not preparing the student to navigate in the forest. The important element in this mismatch, they emphasize, is that the basic science teacher, hard pressed by research commitments, simply does not have the necessary time to devote to his/her teaching (19, 45).

**PREVIOUS SUGGESTIONS FOR IMPROVEMENT OF MEDICAL TEACHING**

**A. How To Learn: General Approaches**

We will not review the extensive literature on this subject but mention only a few representative previous reports. Some general learning principles have been reiterated by previous reviewers. Carroll (8) emphasizes that adults learn best when material is tied to previous experience and that motivation is the key factor. Koeppen (19) believes strongly that the full depth of physiology teaching should not be telescoped into one semester or one year; instead, it should be revisited in the clinical years and extended in the form of pathophysiology into the residency training years. This is a restatement of an ancient principle, viz, that repetition plus amplification in somewhat different context is the golden rule of learning. Koeppen also believes that this can only be done by a faculty who devote more time and interest to teaching. At his school (University of Connecticut), a new organization is being formed, a “Committee of Scholars of Medical Education,” who are charged with the development, organization and teaching of basic science material unrelated to the main focus of the basic science faculty.

Michael (26), who has carefully studied basic science teaching, reminds us that much progress has been made in the analysis of methods of teaching science and that the relationships between teacher behavior and student achievement are now much better understood. He has detailed some basics in this area, such as the proper reading of text material, the domain specificity of certain learning abilities, and the skills required in problem solving. He deplores the fact that such accumulated knowledge has been largely ignored by teachers of basic science (26). The General Professional Education of the Physician report of the Association of the American Medical Colleges of 1984, a thorough evaluation of American medical education (5), listed 27 recommendations for improvement of medical education, nine of which pertained to basic science. However, few of those recommendations have been generally applied (26); the primary problem apparently lies in the scarcity of basic science teaching.
faculty properly prepared and with the time to carry out the task.

B. Types of Learning

1) Teacher-centered (passive) learning. Teacher-centered (passive) learning, revolving primarily about the lecture approach, is the usual norm in college and medical school curricula. The faculty generates the learning objectives.

2) PBL. In classical PBL (active, student-centered, self-directed learning), the students generate the objectives and define the content to be mastered. The student learns primarily on his own, with only guidance from the tutor (facilitator). PBL may take different forms. It often involves small groups of students who attempt to solve a problem by discussing possible approaches among themselves, then try to consolidate their ideas, use the library, and gradually move toward solutions. The process may be slow and not have any definitive end points. Rangachari (30) has made an excellent analysis of this process and has described his experiment with a PBL course in pharmacology; he notes that self-directed PBL is not easy and is not a panacea. Success depends on proper selection of students, tutors, and problems; students should be able to relate to others, to critically evaluate information, to be honest, and to have self-appraisal ability. Tutors should be knowledgeable, enjoy tutoring, and be capable of self-effacement (30). In a later reevaluation, Rangachari (32) echoed the previous comment of Richardson (33) that PBL is an “attitude” and not a “method.” Whatever the form, the main objective is a critical, reflective attitude in the student that may promote lifelong learning (32).

3) A mixed PBL and regular curriculum. A mixed PBL and regular curriculum program falls somewhere between the teacher and student-centered program in terms of who defines the content to be mastered (7). In 1984, in addition to its standard curriculum, Rush Medical College developed a parallel, Socratic problem-based method of teaching basic science material termed the “alternative curriculum,” open each year to 18 volunteers from an entering class of 120. Results indicated that “alternative” and regular curriculum students scored about equally on written exams but the former scored higher than the latter in oral exams (14). Further analysis showed that in the “alternative” program, which included significant teacher-centered components, the students acquired behaviors reflecting self-directed learning skills (7).

Richardson and Birge (35) have also compared the results of the usual “passive learning” approach with one in which part of the course involved “active learning” elements. Although there was no statistical difference in overall performance between the two, the active learning group seemed to prefer this approach and gave it a higher rating.

Participants at a recent International Physiology Teaching Conference agreed that student-centered education has many desirable features but that success depended heavily on the motivation of students and teachers, on the content of the problem, and the context of the situation (6, 42). Because the scores on PBL tests often correlated highly with traditional measures, such as multiple choice tests, it was suggested that the main emphasis should be on the educational or professional relevance of test content rather than the advantages of any particular method of teaching (41). The necessity for greater faculty participation, more curricular hours, and some uncertainty about its actual value have apparently discouraged a more widespread application of PBL in basic science teaching.

C. Improving Individual Teaching Proficiency

Although teachers often agonize over their course content, it has been said that how a course is taught is more important than what is taught. Success is achieved mainly if the student is intellectually engaged and active learning is encouraged (27). Written and oral communication are, of course, basic to all education. Hansen (16) has commented on the art of writing, and Rangachari and Mierson (31) have assembled a checklist to help students analyze scientific articles. To improve oral communication, a common method is assessment by colleagues or experts in education. Casteel et al. (9, 10) have described a voluntary multiphase experiment at the University of South Alabama; with the help of a teaching consultant,
perspectives were evaluated, written analyses were submitted, and the results were discussed (9). Critiques of follow-up lectures indicated definite improvement in teaching effectiveness (10).

At Kentucky, a graduate course in teaching was instituted for PhD students in physiology; the course has a theoretical component, with presentations by outside experts on lecture preparation and delivery, etc. There is also an experiential component involving direct participation by the students in the teaching of an elementary physiology course for undergraduate students; there was a positive feedback from the graduate student enrollees (34).

CAREER PROSPECTS FOR PHYSIOLOGISTS

Of serious concern is the future employment of PhD graduates. Despite a steady decrease in the number of physiology PhDs awarded to US citizens since 1980, there is a significant oversupply of PhDs and postdoctoral fellows in relation to job openings in physiology departments; the discrepancy is increasing (24) and improvement is not in sight. With increased financial pressure on universities and uncertainties in the medical commercial markets about the future costs of health care, there may be a further decrease in opportunities for research careers in both academia and in the pharmaceutical industries (37). Williams (43) believes that PhD programs in basic science departments need to increase their emphasis on integrative physiology to enhance job opportunities in academic, industry, and government labs. At Michigan he has instituted a combined cellular-integrated biology training program with practice teaching for the trainees (43).

There has recently been a disappointing development in medical schools, i.e., a tendency for medical physiology to be taught by other basic science or by clinical departments. This has perhaps been hastened by the growing scarcity of physiologists qualified to teach human physiology. Whatever the reason, this seems to be accompanied by an actual or “de facto” abolition of some physiology departments. Some medical educators have privately predicted that if this trend continues, departments of medical physiology may gradually disappear. We believe this, if it occurs, will be a highly unfortunate development.

Our concern is not based solely on our regret at the disappearance of such an ancient and honorable discipline from the academic rolls, as painful as this disappearance would be. Rather it is because we believe that normal and pathological physiology is and always will be the cornerstone of the practice and teaching of medicine. In all of biology, the study of integrated function is, after all, paramount. It would also seem evident that the normal and disordered function of the human body and its parts can best be taught by those whose primary dedication is to this study. Furthermore, it should be recognized by its proper name, physiology, and should be taught by an identifiable, departmental, physiology faculty (3).

RECENT EFFORTS AT CURRICULAR REFORM

As mentioned above, there have been, over the last 30 years, serious efforts at improving medical teaching (23). Reference has also been made to specific experiments at Rush (7, 14) and Connecticut (19) and attempts to improve teaching skills at South Alabama (9, 10) and Kentucky (34). In the last 10 years other schools have made intensive, large-scale curricular revisions. Although there are some variations, one pattern, followed at Harvard (28, 39) and Northwestern (44), featured certain common objectives. One of these was to improve student attitudes and skills in communication, medical ethics, human values, and doctor-patient relationships. Other objectives focused on the preclinical areas and included 1) replacement of most lectures with small-group, student-directed, and (in some cases) PBL instruction, 2) emphasis on intersubject (horizontal) integration, and 3) promotion of clinical (vertical) integration. These were not minor corrections. They consisted of nothing less than complete overhaul of the entire basic science program.

The changes at Harvard and Northwestern were implemented by a centrally directed administrative team headed by the dean, many faculty administration conferences, retreats extending over months and years, establishment of a Central Medical Education Center to support the program, and a two- or three-
fold increase in faculty participation. There was a clear message that teaching had become a highly important mission of the medical school and an implication that faculty status (and presumably remuneration) would now depend on teaching as well as research. It seems likely that other universities will also respond to the often-repeated criticisms, but probably in an individual manner.

RATIONALE OF OUR TRAINING TRACK PROPOSAL

Although horizontal and vertical integration have often been made an essential part of curriculum reform, it seems strange that very little attention has been given to the training of teachers in interdisciplinary integration. Many of the present curricular changes have involved intensive mobilization of basic science faculty to teach in their individual areas but apparently rely on the students to do the integration. But interdisciplinary integration is one of the most difficult and demanding of academic tasks. Medical students, especially in their first two years, are neophytes exploring uncharted waters. Unfortunately, as mentioned above, many basic science teachers, especially those recently trained, have been increasingly immersed in molecular biology. A number of them may have had little training in systemic and human applications of their own specialty and may have limited background in other basic sciences. This could be a handicap to them in assisting medical students. We believe it would be important to provide a training ground for some teachers to fill this gap.

It is the primary purpose of this report to suggest a training track designed to improve the skills of basic science teachers in 1) horizontal and vertical integration and 2) the ability to teach. We believe that taking most of the medical basic science courses (in addition to the graduate courses in their own specialty) will be a good preparation for horizontal integration of the basic sciences. The most important element in clinical (vertical) integration is, we believe, pathophysiology; an indispensable element in mastering pathophysiology is, in turn, a good course in medical pathology. Also highly important, is at least one course in basic science teaching.

The interplay of physiological, pathological, and pharmacological factors and the necessity for comparative judgments of the relative importance of these factors are constant problems for the physician in caring for his/her patients. One’s ability in this area is an important determinant of success in one’s profession.

ROLE OF PATHOPHYSIOLOGY IN THE MEDICAL SCHOOL CURRICULUM

The most important untaught course in the medical school curriculum is pathophysiology. The normal functioning of the human body and its parts are unquestionably the underpinning to the study of medicine; but it is also true that pathology, which is essentially the study of the causes and effects of disease, is crucial to the physician and to his/her comprehension of the diagnosis, prognosis, and therapy of illness. Pathology lends a perspective to the understanding of disease that is unmatched by any other single course in the medical curriculum.

Pathophysiology is the understanding of how and why disease alters the physiology and how the pathological process disrupts normal function. Pathophysiology gives the physician a clue as to how important (or relatively unimportant) the inroad of a particular disease may be from the standpoint of the patient’s total welfare; it points the way to the advisability (or not) of further diagnostic procedures and therapy. It is the background for the assessment of signs, symptoms, and laboratory findings, the daily preoccupation of the practicing physician.

It is obviously of critical importance that the physician have a good understanding of normal physiology so he/she may correctly estimate the degree of threat the disease process poses to the normal functioning of the body. But the pathophysiology, the estimate of the degree of derangement inflicted by the pathology, although always important, has recently become increasingly so. This is because the remarkable advances in imaging and other diagnostic techniques now permit earlier diagnosis of potentially severe disorders than ever before. The earlier symptoms and earlier physiological derangements are correspondingly more subtle, requiring an even better understanding of the pathophysiological processes and how they begin. We suggest that an understanding of pathophysiology is
now as important to the physician as normal physiology.

It has been said that if pathophysiology were offered, it would be the most popular course in the curriculum (8). It may be recalled that in the 1940s and 50s, weekly "clinical-path" conferences were held at many University hospitals. Students and faculty jammed the large amphitheaters to hear the detailed histories of one or two selected patients, the pathologist's review of the autopsy findings, and the clinicians' explanations of their diagnostic and therapeutic rationale in the cases (whether correct or incorrect). It was a fascinating educational exercise in retrospective pathophysiology.

These clinical-path conferences illustrate another important reason for the basic science graduate student to take the pathology course. Through its insistence on gross and microscopic examination of all body organs and parts and its demand for a calculated analysis of the relative importance of all organ systems in causing disease or death, it is one of the few medical courses that forces the student to focus on interorgan, intersystem, and whole body function.

Human pathophysiology is an immense subject and would be difficult to contain in a single course. It is more likely that it would evolve as a series of systems courses, e.g., pathophysiology of the respiratory, cardiovascular, gastrointestinal systems, etc. It is also likely that such courses would be taught as a joint venture of physiologists, pathologists, and clinicians. But who would lead or organize such an effort? We believe that training in normal human physiology is not really sufficient preparation for this role. The normal physiologist is at a disadvantage in meeting with medical students and physicians to discuss disease processes.

Prompted by such factors, Arias (4) designed a course in pathobiology at Tufts for basic science graduate students. Patients are presented, and gross and microscopic pathology are discussed and studied. The course has been very successful and is consistently overscheduled. Dr. Arias states that the students are enthusiastic and that the course has definitely improved the students' employability.

We agree wholeheartedly with the principles enunciated by Dr. Arias. We believe, however, that the addition of a good medical pathology course and its necessary prerequisites, along with a course in medical teaching, would be preferable. Although it would prolong the training period, it would, for the student willing to pursue it, provide a stronger background in pathophysiology and a better preparation for a career in medical research and teaching while also expanding the future occupational options. In the following section we have outlined a possible training track to that end.

A PROPOSED NEW TRACK FOR BASIC SCIENCE
PhD TRAINING

Pathophysiology is a complex subject and requires two quite different skills: first, a good grounding in modern basic medical science and, second, an understanding of the dynamics of disease and its effects on the human. The best learning ground for the latter is, we believe, medical pathology. Pathophysiology will not achieve its proper place in the medical school curriculum until we have adequately trained teachers. It is rare for clinicians to undertake the rigors of advanced training in basic science; it is a hard upstream swim. More logical would be for interested basic science graduate students to take medical pathology and the necessary prerequisites, gross and microscopic anatomy and pharmacology, or at least the major portions of these courses. This is also not an easy undertaking: it involves commitment to some major courses somewhat different than those to which the basic science student may be accustomed. However, we believe this to be a logical training route in preparation for pathophysiology.

The following outline of a proposed PhD graduate training program is based on the graduate school and medical school course structure at the Medical College of Wisconsin (MCW); we believe the MCW course program to be reasonably representative but must of course be adapted to individual school curricula. At MCW, there are currently two choices in the physiology graduate training program: an "integrative physiology" track and a "molecular physiology" track. The integrative track ordinarily takes 4-5 years to complete and includes the following courses
A PROPOSED
"INTEGRATIVE-PATHOPHYSIOLOGY
TRAINING TRACK"

This consists essentially of the current integrative track plus four additional courses, i.e., 1) microanatomy, selected elements; 2) clinical (gross) anatomy, major elements; 3) medical pathology, major elements; and 4) a course in "teaching of basic science." Because these courses are not ordinarily included in a graduate physiology curriculum, we have described them in some detail.

1) Microanatomy

The integrative track at MCW includes Integrated Medical Neurosciences (205) (a combined neuroanatomy and neurophysiology course) and Cell Physiology (Phy 261). For Medical Pathology, it may be necessary for students to have some additional training in microanatomy of some special tissues.

2) Clinical Human Anatomy

At MCW, the "gross" anatomy course extends over 18 wk and is divided into four units: Unit I, upper limbs and back (4 wk); Unit II, head and neck, cervical region, pharynx, larynx, skull, and brain (6 wk); Unit III, thorax and abdomen (4 wk); and Unit IV, pelvis and lower limbs (4 wk). The course consists of 12 assigned hours per week of lectures, conferences, and dissection laboratories. We would recommend that Units I and II be obligatory as well as the auditing (lectures and associated readings) of either Unit III or IV.

3) Medical School Pathology 200

At MCW, this course consists of two one-semester courses of 16 wk each (fall and spring). Students in this track should study human genetics, cell injury and inflammation, neoplasia, immunopathology (to the extent it is covered in major pathology texts), and three major organ systems, preferably respiratory, circulatory, and renal. The human genetics, cell injury and inflammation, neoplasm, and immunopathology present very basic concepts. Hematopathology should be included if it can be worked in. These elements, which are usually included in the first semester of pathology, will give the student a firm foundation in systemic pathology and the application of systemic concepts to the disease process in each of these areas. The course should be vigorous and use a good pathology text e.g., Cotran's Robbins Pathologic Basis of Disease (10a) or Essential Pathology by Rubin and Farber (36a).

Format. At MCW there are extensive handouts; slide collections; reading assignments; and 9-11 assigned class hours per week including lectures, case-based learning (CBL) sessions, a computer-assisted, self-assessment learning experience, laboratory exercises, an autopsy experience, and seven units and one final examination. The course elements described above will introduce the student to the methods and literature of pathology and, most importantly, to the pathologist's approach to disease. We recommend the first semester course.

4) A Course on “Teaching of Basic Science”

We believe this to be an important element and that it should include both formal and experiential instruction in pedagogy by outside experts with skill and experience in this field. One course of this type, instituted by Richardson at the University of Kentucky
(34), has been described in C. Improving Individual Teaching Proficiency.

SAMPLE PROGRAM: “INTEGRATIVE-PATHOPHYSIOLOGY” TRAINING TRACK

**Year 1**
- Biochemistry (Biochem 201)
- General Medical Physiology (Phys 202)
- Integrated Medical Neurosciences
- Selected Portions of Microanatomy
- Clinical Anatomy (1st half)
- Laboratory Rotations

**Year 2**
- Pharmacology (Pharm 201)
- Medical Pathology (1st semester)
- Respiratory Physiology (Phys 266)
- Cell Physiology (Phys 261)
- Form Graduate Committee

**Year 3**
- Advanced Cardiovascular (Phys 263)
- Complete Qualifying Examination
- Molecular Genetics (Biochem 250)
- Endocrinology (Phys 271)
- Laboratory Research

**Year 4**
- Special Topics in Molecular Biology
- Present Thesis Proposal
- Laboratory Research

**Years 5 and 6**
- Course in Teaching of Basic Science
- Laboratory research
- Defend Dissertation

The “Integrative Physiology” Graduate Program at the Medical College of Wisconsin typically takes ~4½-5 years. We believe that the “Integrative-Pathophysiology” track will take ~1 year longer, i.e., on average, 5½-6 years to complete.

**DISCUSSION**

We realize that broadening of teacher training (as we suggest) is not the only need of preclinical medical education. The determination of the appropriate minimal curricular content for which the medical student should be responsible and the availability of proper textbooks for self-study, as suggested by Vander (40), are also important areas for improvement. But even more basic is the question of faculty priorities. Appointment, salary, and status of medical faculty are at present almost entirely dependent on skill and performance in research and/or the practice of medicine. Although teaching is required, the faculty member is neither paid nor trained nor rewarded for special effort or competence in teaching. Inasmuch as motivation is the prime driving force in human behavior, a rearrangement of faculty incentives is essential for any lasting reform in medical education. Fortunately at some universities, steps are being taken to alter this situation.

In our report, we have gone into some detail on pathophysiology, because it is not usually included in a graduate program. It should not be necessary to emphasize that medical physiology begins with normal physiology. It is axiomatic that the teaching of normal function comes first and must precede the abnormal. As others have recommended, we believe the normal should include a judicious emphasis on whole body, system, and organ function. The patho-or applied physiology is a second, albeit from a medical student standpoint an equally important, consideration.

Theoretically, students trained in the above proposed track would have a unique background in molecular, normal, and applied physiology, with some preparation in pathophysiology. It is important to emphasize that the research training in this program is fully as intensive as in the other physiology graduate programs. In actuality the students will have extended their research potential not only in clinical areas but in other areas of applied research, for example, in the rapidly growing field of exercise physiology, stress physiology, physiology of aging, and in environmental, underwater, space, and aviation physiology, etc.
It would seem likely that PhDs so trained might be well suited for employment, not only in academic fields but also in pharmaceutical, biotechnical, and government capacities. It may not be an exaggeration to suggest that basic scientists so trained may constitute a new breed. Some colleagues with whom we have discussed this program have suggested that such PhDs might receive special recognition, e.g., a "certificate in applied physiology" or perhaps the PhD itself might be awarded in pathophysiology. Of medical scientists being currently trained, these PhDs in pathophysiology would, we believe, be better prepared to bridge the gap between basic science and medicine to help adapt the scientific advances of the future into the mainstream of American medicine. As Folkow (11) has pointed out, in the world of increasing scientific fragmentation, integrators are desperately needed.

There are, on the other hand, some very real problems and disadvantages to this approach. It prolongs an already long training program. For this reason some might prefer the less-intensive, single course addition suggested by Arias (4). A common objection from department chairpersons and senior investigators to the longer program was the added cost. One more year would likely entail for each student an additional $12,000-20,000 in personal support plus an estimated $6,000-15,000 in tuition scholarship funds. It is clear that such a program would need outside grant support. Even so, some departments might be hesitant on the possibility that the added course work might distract students from their research program and thus decrease the value of students to the investigator's laboratory.

To gain some idea of the receptivity of graduate students to this plan, we circulated a questionnaire to the 17 current graduate students in physiology at MCW. We carefully explained the program, the additional courses, and added time required and asked how they would personally view such a program. They were told no commitment was involved, and it was not necessary to sign the form. Eleven students responded; seven signed the questionnaire. Six were favorably inclined, two unfavorably, and three were neutral. The distribution between the year of training (1st to 5th) was quite uniform. An MSTP student, who had already taken pathology, was the most enthusiastic, stating that "pathology would be by far the most valuable addition and should be included in the physiology curriculum." These results suggest that some basic science graduate students might not be averse to the suggested "integrative-pathophysiology training track."

Our primary intent in this report has been to suggest a somewhat broader training option for basic science graduate students with particular emphasis on pathophysiology. If this is a worthwhile objective, there may be other methods of achieving this goal than that described in the above.

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