Human situations: a course introducing physiology to medical students

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HANSEN, PENELOPE A., AND K. B. ROBERTS. Human situations: a course introducing physiology to medical students. Am. J. Physiol. 261 (Adv. Physiol. Educ. 6): S7–S11, 1991.—A block course of 12 days is described. It is considered to be appropriate for both physiologically naive and sophisticated students entering either a traditional or a problem-based curriculum. It is adaptable for medical schools in both developed and developing countries. Six problem-based small-group sessions, based on everyday human situations, are the core of the course. They are supplemented by a lecture series, laboratory experiments using student volunteers as subjects, laboratory demonstrations, and patient presentations. Student assessment is carried out by criterion-referenced examinations using take-home assignments, oral examinations, and a multiple-choice test containing context-dependent questions. The course is well received by students and faculty. Pre- and posttesting show that all students acquire a basic understanding of physiological control systems and of homeostatic mechanisms as they operate in intact human beings.

physiology teaching; human physiology; curriculum planning; problem based learning

THE MEDICAL STUDENT needs to become familiar with the subject of human physiology for four reasons: 1) to understand the integrated functions of the body systems in everyday normal situations: resting, exercising, responding to cold, etc.; 2) to understand the extent of physiological variability that occurs within a population of healthy individuals; 3) to understand the disturbances of function that occur in unwell humans; and 4) to understand normal function as a basis for therapeutic intervention. With such an education, the physician will be capable of giving advice to individuals and groups concerning healthy living, recognizing deviations from normality, understanding disordered processes in sick individuals, and prescribing drugs on the basis of known physiological responses.

We report in this descriptive paper a short introductory course in which medical students become familiar with the main physiological systems and begin to understand how these are integrated in health and react to perturbations in the external and internal environments. This 12-day course would be appropriate for students in the first year of either a traditional or a problem-based curriculum.

We have presented the course to 56 students once a year for the past five years. It was planned by physiologists with PhD and MD degrees on the basis of their experience of teaching in medical schools in North America and Europe. The educational justification we give in this paper is a result of later reflection. Popper (9), Medawar (5), and others have shown that the structure of scientific papers is often a late rearrangement of ideas and findings imposed after most of the work was complete.

The factors that have determined details of the course are, naturally enough, particular to the local circumstances of our medical school. Our students have diverse educational backgrounds, some entering without experience of any biological subject and others having a degree, for example, in biochemistry or physiology.

In brief, our curriculum is as follows. During the first four months of our four-year program, students study community medicine and behavioral science; they start acquiring clinical skills, alongside a consideration of ethical problems. Concurrently there are courses in biochemistry, immunology, physiology of excitable tissues, pharmacology, histology and embryology, cell biology, and genetics. The situational physiology course that we describe in our paper occurs in the second four-month block and is followed by seven weeks of gross anatomy teaching, while community medicine and clinical skills training continues. This second block is completed by courses in hematology, microbiology, general pathology, and a four-week elective period. One week is spent in residence at a rural hospital. This eight months of study constitutes the first phase of the MD program.

The second phase of the program consists of eight months of integrated learning in which preclinical, paraclinical, and clinical aspects of each body system are considered in a series of block courses. Physiology is a major aspect of this systems-based teaching.

The third phase of eight months is devoted to an integrated system-based study of disease, a continuing development of clinical skills, and an elective period.

The fourth phase of 16 months is a clinical clerkship, which includes experience of rural family practice.

The curriculum of our medical school (founded in 1968) has elements of innovation embedded in what now is regarded as a traditional program: disciplinary teaching and systems teaching coexist with a problem-based approach.

In this paper we present 1) a description of the organization of the course, 2) an analysis of those elements that are key to its apparent success, and 3) an assessment of those modifications that would make the course suitable for a wide range of educational, economic, and social circumstances.
ORGANIZATION OF THE COURSE

Objectives. The course is designed to influence students toward a physiological approach to medicine, one of problem solving and experimentation. To this end, the students should acquire an understanding of physiological control systems and of homeostasis as it operates in the intact human, so preparing themselves to place later-acquired detailed knowledge of pathophysiology within a clearly understood physiological framework. The instructors recognize that factual information is a prerequisite for understanding concepts; one of the most important purposes of the course is to help students learn to recognize the sorts of information necessary and appropriate when considering aspects of functions and malfunction. Our experience has shown that students completing the course are well motivated and confident that they will be able to use physiological concepts in their future studies and practice.

Format. Six problem-solving sessions are the core of the course. Students in groups of five to seven discuss the physiology of selected human situations with which the students are probably already familiar (Table 1). The course handbook outlines each situation in some detail, indicating useful library reading. Successive problems increase in complexity, thus recognizing the students’ developing sophistication.

There are 14 lectures of basic information on the body systems (Table 2). The first six lectures are given before the first tutorial so that students have established a foundation of knowledge with which to work. All lectures are given by the same professor, who can thereby ensure that the material presented is accumulative. Each lecture has a clear logical structure, a précis of which is given in the course handbook along with reproductions of diagrams used as overheads. These lectures emphasize the physiological concepts shown by the 1987 survey of Dawson-Saunders et al. (2) to be important to the practice of medicine in the view of 346 faculty members of North American schools.

There are two laboratory experiments that the students carry out as a class, with themselves as subjects (Table 3). The results of their investigations are collated, are statistically analyzed by faculty members, and the figures generated are returned to the class to be the basis of a whole class critical evaluation of the data and of subsequent take-home assignments used as part of the evaluation. Each year the experimental protocols are varied in certain respects so that the outcome is not entirely predictable. In this way we create in these laboratories a genuine experimental setup.

The students participate in six sets of laboratory demonstrations (Table 4) that reinforce other parts of the course.

To make clear the clinical relevance of physiology, there are three patient presentations in which carefully chosen experienced clinical teachers interview patients about their problems and carry out, with commentary, a focused clinical examination appropriate to the circumstances of the course. In 1990 the following three clinical demonstrations were given: a 63-year-old woman with multiple sclerosis, showing loss of power and defects of sensation; a 72-year-old woman in heart failure, with dyspnea and ankle edema; and a 40-year-old man with

TABLE 1. Small-group sessions on situational physiology

1. Fainting: a soldier faints while standing to attention
2. Exercise: oxygen supply to the muscles in a 1,500 m runner
3. High altitude: physiological problems of climbing Everest
4. Dehydration: pathophysiology of a Ugandan 7-mo-old infant with diarrhea
5. Hemorrhage: a healthy adult donates two units of blood
6. Lactation: a 3-mo-old baby is put to the breast and is satisfied

TABLE 2. The lecture course

| Organization of the central nervous system |
| Autonomic nervous system                |
| Cardiac cycle and cardiac output       |
| Control of blood pressure              |
| Microcirculation                       |
| Energy and temperature regulation      |
| Respiration: mechanisms and controls   |
| Delivery of oxygen to tissues          |
| Functional anatomy of the kidney       |
| Kidney’s role in body fluid homeostasis|
| Gastrointestinal absorption            |
| Acid base homeostasis                  |
| Endocrine concepts: hypothalamic-pituitary axis, the adrenal |
| Aspects of female reproduction          |

TABLE 3. Class laboratory experiments

1. Exercise laboratory
   a. Volunteers undertake a prescribed routine of light exercise followed by moderate exercise
   b. Other medical students measure the volunteers’ heart rate, blood pressure, respiration rate, and oxygen uptake during a control period before and after exercise
   c. Data are collated and analyzed by a faculty member, and class results are critically evaluated by students
2. Fluid balance laboratory
   a. Volunteers control fluid and salt intake for 12 h preceding experiment
   b. Control samples of urine are collected; volunteers then drink measured volumes of water or isotonic saline
c. Diuresis is followed over the next 4 h, with measurements of rates, osmolarity, specific gravity, and Na⁺, K⁺, and Cl⁻ concentrations
   d. Each year the protocol is varied in a third group of volunteers to show effects of exercise, or antiaduretics, or immersion in water, or (in habitual users) coffee or alcohol drinking or smoking

All protocols are approved by the Medical School Human Investigation Committee.

TABLE 4. Laboratory demonstrations and exercises

<table>
<thead>
<tr>
<th>Nerve and muscle</th>
<th>Including electromyogram recording from human gastrocnemius muscle during elicitation of ankle jerk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heart</td>
<td>Including isolated rabbit heart preparation</td>
</tr>
<tr>
<td>Microcirculation</td>
<td>Including observations in anesthetized rat mesentery preparation</td>
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<tr>
<td>Respiration</td>
<td>Including spirometry</td>
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<tr>
<td>Gut</td>
<td>Including observations on peristalsis in animal preparation</td>
</tr>
<tr>
<td>Reproduction</td>
<td>Including microscopical examination of fresh semen</td>
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</tbody>
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In each demonstration there are gross and microanatomic preparations showing relevant morphology in humans.
end-stage renal disease, previously on dialysis, now with kidney transplant. The course chairperson has previously outlined the objectives of the course as a whole and discussed the purpose of the demonstration with the clinical presenter, explaining that there are both physiologically naive and sophisticated students in the class. There has been always a lively exchange of question and comment from the students. The affect created by these presentations is a potent motivation for student learning.

Considerable study time is protected during the course; no other basic medical science teaching occurs concurrently.

The recommended textbooks for this course have been by Bray et al. (1) and Jennet (4), although the students are told that any elementary text written for medical students will suffice.

Assessment. We evaluate student performance using three criterion-referenced (11) methods. 1) Written take-home assignments measure application of knowledge and understanding of elementary scientific design and analysis. These assignments are based on physiological concepts arising from the experimental laboratories. 2) The penultimate small-group session is an oral examination based on a discussion of physiological responses to hemorrhage: a healthy person donates two units of blood. Each student’s performance in this tutorial is evaluated by tutors on a four-point scale: outstanding to unsatisfactory. There are no selected readings recommended for this tutorial, thus encouraging independent library work. This oral examination assesses knowledge and its application and evaluates problem-solving ability. The small group format gives confidence to students unfamiliar with oral examinations and prepares them for the open discussions that are part of everyday clinical practice. 3) A 1-h examination comprised of multiple-choice questions given at the end of the course measures knowledge and its application. This examination includes context-dependent questions (8).

KEY ELEMENTS OF THE COURSE

Content. The course emphasizes situational physiology, paying particular attention to the concepts of homeostasis and the interrelationship of the body’s systems. This engenders a physiological whole body approach to clinical medicine. Although the lectures of the course present a rational continuum of information, there is no attempt to cover the whole of physiology; rather, the content of the course is highly selected to support the students’ understanding of the physiological situations presented. For example, tutorial 3, on climbing Everest, is held after all but one of the lectures have been given, so the students have a basic knowledge of the following: partial pressures; the “oxygen cascade” from inspired air to mixed venous blood; the oxygen dissociation curve of blood; the role of buffers, respiration, and renal function in H+ concentration regulation; the ventilatory responses to pH and partial pressures of CO2 and O2 mediated centrally and peripherally; the effects of hypoxia and hypocapnia on pulmonary vessels and cerebral function; and the control of erythrocyte numbers. The functional organizations of the respiratory center and of the carotid body are, for example, not considered (unless raised specifically by students in the tutorial) and neither are endothelial derived vasoactive factors or the details of erythropoietin production or acid-base regulation by the kidney.

The human situations of the tutorials are familiar to most students, and each has a bearing on clinical medicine; the depth of inquiry is determined by each student’s interest, ability, and previous education, but a satisfactory knowledge base at this level, as determined by physiologists who plan and teach physiology in our MD program, must be acquired by each student. An understanding of basic physiological concepts must be achieved, including those of homeostasis, the integrative actions of physiological systems, adequate controls in physiological experimentation, and the centrality of quantitation.

Teaching. The methods used are appropriate for adult learners and accommodate students with different learning styles (3); the teaching and learning methods used are intentionally diverse. Students find the combination of lectures and small-group problem-solving sessions particularly effective, as noted also by Mitchell (6). The experiential nature of much of the course encourages critical appraisal and familiarizes students with research methodology.

The small-group format of the problem-solving tutorials and the laboratories gives an opportunity for mentoring relationships to develop between teachers and students and for students to receive informal feedback on their performance throughout the course.

On average, about 15 faculty members, physiologists, clinicians, pharmacologists, and anatomists, take part in the course each year. Five of these act as tutors, and one acts as lecturer; the others conduct laboratories and demonstrations. Total faculty time spent in contact with the students is ~150 hours. Faculty members find participation in this course to be highly acceptable. They have an opportunity to teach in ways in which they are most effective: as lecturer, small-group tutor, laboratory demonstrator, curriculum planner, or examination marker. Teachers’ awareness of the course content is achieved by having course handbooks distributed well in advance and by meetings of all participants. The teachers enjoy the interactions with students that occur in laboratories and small-group sessions; this gives many opportunities for discussion with every student.

Assessment. The methods used are diverse, each assessing some different aspect of the student’s performance. All are criterion referenced (11), an approach that students say encourages cooperation and reduces competition. Part of each assessment is on material that the faculty has identified as essential at this level; students must have a satisfactory performance to earn a passing mark. Another part of each assessment tests the students’ understanding of additional material considered to be important but not essential at this level. Performance on these questions allows outstanding students to identify themselves. This arrangement helps motivate students to explore where the subject will lead and then gives them the opportunity to demonstrate to themselves and their teachers what they have accomplished.
Educational Outcome. These arrangements have resulted in an excellent educational outcome for both physiologically naive and sophisticated students. All but 3 of 280 students who have so far taken the course have attained a level of knowledge felt by the faculty sufficient to enable them to proceed in their studies, i.e., they have met the criteria for a pass mark. The 50-item multiple-choice exam that forms part of the assessment was used also as a pretest in 1990: the average mark for naive students at the beginning of the course was 32%, with an increase to 85% at the end, and for physiologically sophisticated students it was 43%, increasing to 89%.

Each year students complete an anonymous course evaluation questionnaire. Consistently, they give the course a high overall rating, averaging six on a seven-point scale. They perceive that the course material is presented at an appropriate level (averaging 4.2 on the scale of 1 = content too elementary and 7 = too difficult) and that the amount of material to be covered is satisfactory (averaging 4.5 on the scale of 1 = very little amount for the time allotted and 7 = too much). The students think that the learning objectives are clear (averaging 6.3) and that they have achieved those objectives (averaging 6.3).

Adaptability of the Course to Other Situations

Traditional curricula based on disciplinary teaching. Some students find that traditional courses given by physiology departments are academic, austerely indifferent to their previous experience, and difficult to relate to their future as medical doctors. If the course in situational physiology here described could be given to students soon after they arrive in such a school, we think that they would be able, on the one hand, to connect physiology with everyday experience and, on the other hand, to connect it to clinical medicine; this should motivate them to persist through a subsequent more detailed study of physiology.

Traditional curricula based on systems teaching. We have found that this course, in the context of our other first-year courses, forms a suitable lead into the systems teaching of our second year. The student remembers from this introductory physiology course the general principles of integration and regulation within the body systems in everyday human situations. This means that the discourse in the systems teaching may then be presented at a high level.

Problem-based curricula. Students without biological training may find themselves at first disadvantaged in a purely problem-based curriculum. It may be efficient to set the scene for problem-based learning by introducing basic physiological concepts. Educational principles would not be compromised by introducing situational physiology, since the central elements of the course are experiential and problem based; the lectures are given as an efficient way of creating a scaffolding for concurrent individual study and small-group discussion.

Applicability to Third World medical schools in developing countries. Canada is a relatively rich country, and its medical schools, including even ours in the poorest province, are comparatively well funded. Is it possible to take the better elements of this introductory physiology course and use them in poorly funded medical schools? The curricula of some schools in developing countries have continued to reflect the preindependence practices of a former colonial power; the physiology courses in some schools in India, for instance, are structured on the pattern of 1947 traditional medical education in Britain. [However, there have been remarkable developments in India with a willingness to look anew at physiological education with unprejudiced eyes (7).] The course here described may be adapted for use in such schools. The situations investigated can be chosen to be understood easily by the student. Such subjects as physiological responses to heat or to heavy work in heat, to dehydration, or to nutritional anemia may be developed into everyday situations suitable for small group discussions. Laboratory classes in which experiments are planned and carried out on humans, the students themselves, rather than on costly experimental animals, can be simply devised. Work, heart rate, blood pressure, temperature, and fluid balance may be measured, recorded, and analyzed in class experiments requiring little capital expenditure.

A satellite conference of the XXXI International Congress of Physiological Sciences on teaching physiology in developing countries was held in 1989; the principles underlying our courses on situational physiology are in accord with the recommendations arising from this conference (10).

Conclusion

This introductory course was designed to be appropriate for a mixture of physiologically naive and sophisticated students. The innovative use of common human situations to study physiology has been well received.

During the course students begin to acquire an insight into three aspects of physiology: 1) how body systems are controlled and integrated in health, 2) how measured physiological values vary, and 3) how physiology is relevant to understanding the problems of the patient. They leave the course confident and well motivated with respect to physiology in the medical curriculum.

Basic medical scientists and clinicians successfully collaborated with increased understanding of the other’s role in medical education. Mentoring relationships have been fostered in the seminar room and in the laboratory.

The efficiency and success of the course as judged by student performance and by student and teacher acceptance has led us to make this report in the hope that its better elements may be useful to other medical schools.

The course we describe has been a joint venture of faculty, staff, and students. The core group of physiologists have included Dr. B. W. Fayton, who coordinated the laboratories and the preparation of text handbooks, and Drs. S. Lodge, D. W. McKay, P. Moody-Corbett, A. Rankin, J. W. Snellen, and ourselves. We acknowledge valuable help from anatomists Drs. S. Chandra and J. Harris; pharmacologists Drs. D. Bieger and T. Hoekman; family physician Dr. R. Butler; and the clinical demonstrators Drs. H. Clarke, A. Goodridge, J. Harnett, F. Parfrey, M. Sadler, and F. Stone, and their patients.

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REFERENCES


