REFRESHER COURSE FOR TEACHING
RENAL PHYSIOLOGY

This report presents highlights of a refresher course presented at Experimental Biology '98 on Saturday, April 18, 1998, in San Francisco, California.

The Education Committee of the American Physiological Society has recently reinstituted the presentation of refresher courses on teaching specific aspects of physiology at the annual Experimental Biology meeting. This year, the half-day Workshop focused on teaching renal physiology to health science students. Because of the ever-increasing research specialization of the Society membership, faculty often face the responsibility of teaching physiology, a discipline still usually taught using a systems approach, even though they are not trained in systems physiology. Therefore, the major purpose of the Workshop this year was to provide an update on major advances in specific topics in systems renal physiology as well as to present examples of teaching approaches.

The Workshop itself consisted of two major portions. It began with a poster session, which included presentations of submitted abstracts as well as exhibits of instructional computer software and textbooks. Abstracts of the posters are reproduced within this issue. E-mail addresses are provided in case further information is desired. The second segment included four lectures by prominent teachers of renal physiology. The first three speakers presented updates on areas of renal physiology that students and teachers can find difficult. Dr. J. A. Schafer spoke about recent developments in our understanding of renal water and ion transport mechanisms; Dr. B. M. Koeppen discussed the role of the kidney in acid-base balance; and Dr. F. G. Knox presented an overview of the renal handling of potassium in the context of an instructional clinical case. All of these speakers presented new material as well as teaching strategies. The topic of the last talk, given by Dr. A. J. Vander, was unique in that it covered a number of areas of renal physiology, specifically those that are difficult to teach. Because there is a seemingly never-ending plethora of factors that both mediate and regulate kidney function, Dr. Vander’s presentation also included strategies for organizing and teaching the layers of complexity inherent in the subject of renal physiology.

All of the speakers prepared manuscripts that summarize these presentations, and these papers are also included in this issue. However, because time constraints allowed only a narrow selection of topics and speakers for didactic lectures, additional authors were recruited to present their views on the teaching of other important areas of renal physiology. Thus this issue contains a fairly comprehensive coverage of renal physiology teaching. Again, the goal of these additional papers is to present topic updates or teaching strategies.

We would like to express our gratitude to all of those who have participated in this endeavor. We believe that such refresher courses play an important role in achieving the educational mission of the APS, and we particularly thank the editor of Advances in Physiology Education (Penny Hansen) for allowing expansion of the scope and audience of the course.

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ABSTRACTS OF POSTERS AND DEMONSTRATIONS

Structure and function of the mammalian kidney: a multi-use computer module
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An interactive computer program was developed for Windows 95 and Macintosh operating systems to aid with teaching renal physiology to graduate and professional veterinary medical students. The program incorporates microscopy (electron and light), comparative gross anatomy, animations of cellular events, explanatory text, and interactive problems. The navigation permits either a linear presentation for first-time users structured like a classic lecture or individual components that can be accessed in a nonlinear manner for quick review or for use in lecture. The flexible nature of this program empowers a lecturer with the ability to easily use the animations in a classroom. The use of numerous animations is intended to enhance the learning process by allowing students to visualize complex cellular events. The canid is used as the primary physiological model. Bovine and equine kidneys are shown for comparative gross anatomy. The majority of the program is dedicated to physiology, and a basic level of cell biology is a prerequisite.

An opinion survey conducted in the fall of 1997 on first-year veterinary medical students was very favorable. Students were surveyed after seeing the program in lecture and on personal computers outside of class. Over ninety percent of the students indicated that the program aided them in understanding lecture and assisted them in learning outside of the classroom. When asked about the accompanying text support of the animations and figures, over eighty percent felt it was useful. The answers, along with a description of how the answer could be derived, are given on subsequent pages. The given values are varied so that students must logically analyze each separate situation to determine the correct solution. The section on body fluids uses modified Darrow-Yannet diagrams to illustrate the fluid shifts that occur due to changes in solute or water balance. Once again, the students are required to complete a chart that describes the osmolar and volume changes that occur during dehydration, overhydration, solute loss, or solute gain. It is felt that this technique could be applied to other areas of physiology with equal success.

Developing problem-solving skills using active learning techniques
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The concepts covered in renal physiology present a challenge for both teachers and students. The cognitive skills required to develop a working knowledge of these concepts go far beyond rote memory. Active learning techniques can be used to help students analyze the concept of clearance, tubular transport, filtration, fluid balance, renal concentrating mechanisms, etc. A technique used in our physiology program presents a series of scenarios in a workbook format. Each scenario provides limited information for students regarding flow rate (ml/min), concentration (mg/ml), or amount (mg/min) of a compound appearing at selected points along the nephron. The students are then required to determine the omitted values. The answers, along with a description of how the answer could be derived, are given on subsequent pages. The given values are varied so that students must logically analyze each separate situation to determine the correct solution. The section on body fluids uses modified Darrow-Yannet diagrams to illustrate the fluid shifts that occur due to changes in solute or water balance. Once again, the students are required to complete a chart that describes the osmolar and volume changes that occur during dehydration, overhydration, solute loss, or solute gain. It is felt that this technique could be applied to other areas of physiology with equal success.

Problem-oriented learning: emphasizing the need for integrative physiology
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The approach we advocate as the most efficacious way to learn core concepts of physiology, and of physiological derangements that lead to disease, is one focused on the study of problems in integrative physiology. This requires a consideration of inputs from multiple interacting body systems recognizing that a challenge may require greater responses from particular organ systems. We began with a problem rather than a list of facts, with rich contextual variables to enhance the likelihood of their being recalled in future comparable situations, a strategy consistent with principles of adult learning theory. The relevance of the issues considered to clinical situations is emphasized, and the ability to generalize the principles learned to broader contexts is fostered. We shall illustrate an in-depth analysis for surviving without water or caloric intake for several days. The first organ challenged is the kidney because it must maximally conserve salt and water. This obvious answer becomes the next problem: how to ensure a large enough urine volume in the presence of ADH to avoid the formation of kidney stones in general and uric acid stones in particular, given the need for production of ketoacids and the resulting metabolic acidosis. This approach will be illustrated by an interactive, self-directed computer program created for this purpose.

**Problem-based learning using computer simulations**

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Problem-based learning (PBL) has gained increasing success in medical education. PBL is recognized as an approach that stimulates a positive attitude toward learning and fosters motivation of medical students. We have modified the standard PBL format by using computer simulations instead of a preset clinical case on paper. Classic paper-based PBL format has several limitations: there is a limited number of selected parameters; “real-time” follow up and changing the course of the case report are usually impossible. In contrast, whole body computer models offer a quasi-real-time simulation. The changes occur dynamically in front of the student and are subject to his or her interventions and manipulations. At the same time the student can choose among numerous variables to follow or influence and is thus enabled to assess and analyze the complex pathophysiological process and reveal its mechanisms.

Computer-based PBL is conducted in the following four steps.

**Step 1: Getting familiar with the software.** In our computer lab and in classroom lectures, the students first become familiar on several occasions with two whole body computer simulation programs developed at the University of Mississippi Medical School: Quantitative Circulatory Physiology (QCP) and Guyton’s model. Both programs allow access to several hundred variables with the ability to stop the simulation at any time.

**Step 2: Discussion of learning objectives in small groups (30 min).** In groups of six to eight students plus a tutor, the students first discuss a short paper-based clinical case. Under guidance they are rapidly directed toward the disease process and the learning objectives. At this time, they are also given instructions if necessary on how to handle the computer programs to run the desired simulation.

**Step 3: Running the simulation independently (2.5 h).** The students are then left on their own (2 students per computer) with no tutorial assistance. During that time they run specifically assigned simulations of known clinical problems. Three different themes are proposed on separate sessions: 1) Regulation of Arterial Blood Pressure and Sodium Excretion (renal artery stenosis, arteriovenous fistula, congestive heart failure); 2) Oxygen Transport in the Blood (high-altitude adaptation, pulmonary shunt with and without oxygen therapy, carbon monoxide poisoning); and 3) Electrolyte Disorders (mineralocorticoid excess, Addison’s disease). In each case, the student must run the model to observe which changes may result from the selected disturbance and must decide which variables should be followed, as if dealing with a private patient or an experimental animal. Interactions within the group are encouraged.
Step 4: Discussion of the results (1.5 h). On a separate day, the students present the results of their simulations and discuss in small groups what they have learned. Questions raised are answered by students under guidance of the tutor.

Although PBL with paper-case study is very helpful for self-learning, a complementary approach using computer simulations offers additional advantages. The student follows the selected disturbance on a real-time basis with the ability to stop the simulation at any time to interrogate a wide choice of variables. A clear distinction between acute and long-term manifestations of the disease can be made by observing the sequential development of abnormalities. In addition, mechanisms of disease and their importance can be analyzed via the ability to rerun the simulation with specific variables locked at a fixed value. Finally, such an approach promotes an integrative understanding of the human body.

A structured active learning method for teaching osmolarity, tonicity, and fluid therapy
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When students are taught osmolarity and tonicity, they often have difficulty understanding the effects of penetrating solutes. To deal with this problem, we developed a structured teaching approach based on administration of intravenous (IV) fluids. After the introduction of osmolarity, tonicity, and penetrating and nonpenetrating solutes, students are given a worksheet to complete. The worksheet treats intracellular (ICF) and extracellular fluid (ECF) compartments as two boxes filled with nonpenetrating solutes. The students are also shown a systematic approach for calculating the effect of solutions added to the body compartments, using tables to calculate the volume, solute content, and osmolarity of the total body and of the ECF and ICF. Once students are comfortable with the concept of distributing volume based on the relative concentrations of nonpenetrating solutes, we introduce the theoretical red blood cell in an infinite volume of solution. This gives them practice dealing with volume changes during the equilibration period.

Finally, students are asked to predict what will happen to ECF and ICF volumes in a person who is given different solutions. This last step is the skill that they need when rationalizing IV fluid therapy in the clinics. Students taught by this method retain the information well enough to teach it to colleagues several years after the course has ended.

Integration of cardiorenal basic science concepts into the clinical education of medical students: the North Dakota experience
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The clinical sites (Fargo, 70 miles; Bismarck, 220 miles) for training third-year medical students are separated from the basic science campus in Grand Forks. In 1995, the Departments of Surgery and Physiology instituted a program designed to incorporate basic physiological concepts into the clinical setting of the third-year Surgery Clerkship. The process utilizes half-day interactive problem-solving sessions (4 times per year) with small groups of students (5–8 per group) at their respective clerkship sites involving both a basic scientist and a clinician in the discussions. The students are initially challenged to review important physiological principles relevant to body fluid compartments, fluid and electrolyte homeostasis, fluid resuscitation procedures, and acid-base balance. The following patient cases are then discussed, integrating basic science principles with the clinical management: 1) an 85-year-old, 55-kg male with a myocardial infarction due to extracellular fluid hypovolemia; 2) a 73-year-old, 90-kg female with acute bleeding from the gastroduodenal artery with a chronic history of epigastric pain, NSAIDs for osteoarthritis, and digoxin and furosemide for moderate congestive heart failure. Student response has been enthusiastic with respect to inclusion of the physiologist in the clinical small group session as a reinforcement of the importance of basic sciences in clinical reasoning and decision making. This program also demonstrates that irrespective of distance the integration of basic sciences into the clinical arena of the medical curriculum is feasible.
Unilateral nephrectomy in the rat as a teaching model for renal function in an undergraduate physiology setting
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The white rat offers a valuable teaching model to demonstrate the in situ anatomy, homeostatic control, and function of the mammalian renal system. Students in my upper-level physiology class are responsible for formulating a set of testable hypotheses as to the possible compensatory mechanisms, if any, that will result from a unilateral nephrectomy in the rat. To test their hypotheses, each group of students is made responsible for the induction of anesthesia, maintenance of anesthesia, removal of the right kidney, closure, and recovery of the animal in their experiment. Prior to nephrectomy and one week following the operative procedure, students collect blood samples via the caudal artery for measurement of hematocrit (microcentrifuge method) and plasma creatinine concentrations (spectrophotometric assay). Pooling data across all student groups (n = 6) for pre- and postnephrectomy hematocrit and creatinine values allows students to run pairwise statistical comparisons, testing their hypotheses. This laboratory experience in integrative physiology has proven to be a successful exercise in introducing students to the fundamentals of experimental design, the in situ anatomy of the rat abdomen, techniques in biochemical analysis, and, most importantly, an appreciation for the process of humane animal research. (Funded by a generous grant from the Merck Research Laboratories.)

An archive of teaching resources: a proposal from the Education Committee of The American Physiological Society (APS)
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An APS Long-Range Planning Committee report recently identified the need for an archive of physiology teaching-related resources (The Physiologist 39: 375, 378–388, 1996). “Time Demands: ...Another problem is the expansion of teaching loads. In this report, for example, we advocate the participation of medical school physiology faculty in the teaching of undergraduate courses. ...We might reduce the extra time required for this desired step by establishing archives of teaching resources, which can decrease the redundancy inherent in the redevelopment of courses by every new instructor.” On the basis of Internet searches, we concluded that such a resource devoted to physiology does not yet exist. The Education Committee is soliciting educational materials in electronic format, developed by members, which could be contributed to a central archive maintained by APS and available to all educators (http://www.faseb.org/aps/educatn/archive.html). However, if members wish, their materials could remain on their own servers with the APS Teaching Archive providing information on the materials and a link to the members’ servers. Participants will receive a list of suggested formats for materials for both IBM-compatible and Apple Macintosh computers. Examples covering the areas of renal physiology, body fluids, and acid-base balance will be presented.