A PERSONAL VIEW

Selected omissions and capstone presentations: a new approach to student-centered integrative physiology education

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Curtis KS, Benjamin B, Curtis JT, Finn W, Rouch AJ. Selected omissions and capstone presentations: a new approach to student-centered integrative physiology education. Adv Physiol Educ 44: 448–452, 2020; doi:10.1152/advan.00080.2020.—Here, we describe a pedagogical approach that combines didactics with active learning to facilitate integration across physiological systems in a team-taught, graduate-level physiology course. We covered the major physiological systems, with each system preceded by an overview of its evolution/ontogeny to provide a broader perspective. Lectures provided a framework for integration by giving examples of how each system interacted with systems that preceded and followed. In lieu of a final exam, the course culminated in capstone presentations by small groups to promote student-centered learning of integrative physiology. At the beginning of the semester, students were assigned to groups; each group chose from predetermined topics. This allowed them to accumulate information throughout the semester and required them to attend to lecture content to assess how the material applied to their topic, thereby facilitating learning and retention. Faculty were deliberate in choosing material that was presented in each system, and material that was strategically omitted, establishing “gaps” that students filled in their capstone presentations. The final week was dedicated to student preparation for their presentations, which promoted peer-to-peer teaching and problem solving by the group, assisted by faculty as necessary. Capstone presentations demonstrated students’ mastery of basic physiological principles and their ability to integrate among physiological systems, and they rated capstone presentations highly in helping with integration and critical thinking. Thus students showed a better understanding of systems physiology and the importance of integration across systems in normal function and in responding to homeostatic challenges.

INTRODUCTION

Technical advances and applications have changed the face of biology teaching, including the teaching of graduate biomedical sciences. Specific courses targeted toward genetics/genomics, cell biology, and molecular biology have been added to curricula, whereas “classic” biomedical courses like physiology incorporate these elements as a way of understanding physiological functioning in more depth. However, with increased content in semester-long courses, other aspects may be given less emphasis. One such aspect is integration: the principle that, although comprised of separate organ systems and reliant on molecular and cellular mechanisms, physiology requires cooperation and communication among systems, tissues, and cells to achieve coordinated function necessary for continued existence. The challenge for physiology educators is how to emphasize this principle in physiology courses currently jam-packed with content. This paper describes an approach taken to promote integrative physiology in a graduate Biomedical Physiology course.

Organizational Strategies

This 5-credit-hour, team-taught course is a requirement for our newly developed “post-bac” Biomedical Sciences Graduate Certificate Program, as well as an elective offered to Masters and PhD students in our Biomedical Sciences Graduate Program. As a result, it was necessary to understand the needs of the various student demographics to incorporate integrative physiology into the course. Specifically, we had to tailor the content to cover foundational physiology material for students with aspirations of medical school and other healthcare professions, who comprised the majority of students enrolled, as well as for those who would build on that material in subsequent Biomedical Sciences graduate courses and in their research programs. Clearly, foundational material was important to both groups of students; however, we sought to cover content in ways that would be of interest, regardless of career goals. Thus we included implications for human health, as well as incorporating activities that illustrated how published research illustrates foundational material. At the same time, it was necessary to take into account the diverse backgrounds of the students. Only ~50% of the students in this class had taken a physiology course as undergraduates; ~30% were “nontraditional” students who were returning to school after an extended interval of working and/or starting families. Thus we included brief overviews/reviews for each system to ensure that all students were “on the same page.”

Our delivery of the content was guided by the premise that physiology rests on specific principles (Table 1). Accordingly, we structured the course so that the first lectures to be delivered covered these principles. Moreover, given the concentration on cell and molecular biology in undergraduate courses, as well as in other courses in our Biomedical Sciences Certificate Program and Biomedical Sciences Graduate Program curricula, we elected to reduce that material except for aspects that directly pertained to function within individual systems. For example, we discussed how neuronal communication depends on specific ion channels; we described how hormone effects require binding to receptors that activate different intracellular signaling pathways. This functional focus complemented our more-or-less traditional systems-based course organization.
with the nervous system, followed by cardiovascular, then respiratory, renal, gastrointestinal, endocrine, and reproductive systems. The systems varied somewhat in length, with more hours devoted to the nervous, cardiovascular, and renal systems (12–16 h) than to respiratory, gastrointestinal, endocrine, and reproductive systems (7–9 h), and each system was taught as a module by faculty content experts. With these foundational concepts in place, the overarching concept underlying our delivery of this physiology course was that of integration, and we incorporated a number of approaches to promote understanding of integrative physiology.

First, we introduced each of the systems with a 1-h overview of the evolution/development/comparative physiology of that system. That is, there was a “prequel” for each system that rested on the evolution of that system, the ontogenetic “recapitulation” of that system, and/or the comparative aspects of how that system functions. These overview lectures provided a consistent framework in a team-taught course and were delivered by the same two content experts, which enhanced the consistency. For many of these students, human physiology was crucial to career goals in healthcare; therefore, in this approach, our aim was to describe physiological functioning across a scale that was larger in terms of both time and biology so that students might better understand “how we got to where we are.” To illustrate, the gastrointestinal system module was preceded by an overview of the evolution of the alimentary tract, along with a consideration of the variation in gastrointestinal processes in extant species. This approach allowed us to build to the functional complexity within systems of more phylogenetically recent species, including humans. At the same time, exposure to the variation in structures and processes that subserve gastrointestinal function across species enabled us to reinforce, not only the overall function of each individual system, but also how structures and processes are integrated to perform that function.

Second, although systems were taught by different faculty, we integrated across systems in lectures. Thus the respiratory system built on the cardiovascular system by discussing the influence of the respiratory cycle on heart rate variability and set up the renal system by introducing the regulation of blood gases. This approach was facilitated by the course faculty’s familiarity with their colleagues’ lectures, which enabled each content expert to integrate across systems using a “preview-review” technique. For example, the faculty member who covered renal physiology previewed aspects of the endocrine system in discussing vasopressin and aldosterone (“Dr. Smith will tell you more about receptors for these hormones and how their release is controlled in the endocrine system”). Subsequently, the faculty member who covered endocrine physiology did a quick review of aspects of renal physiology in discussing the sites of action of vasopressin and aldosterone (“As I’m sure you remember from Dr. Jones’ discussion of the renal system, the various parts of the nephron have different functions, for which the actions of vasopressin and aldosterone are important”). This approach helped to lay the groundwork to better understand the importance of material to be introduced in subsequent lectures, as well as reviewing and reinforcing content previously covered. More to the point, it emphasized the interaction among systems—the integration across systems—and the way such interactions may occur.

Finally, in addition to emphasizing integrative physiology in lectures and discussions, faculty were committed to facilitating students’ ability to integrate as well. To do so, we utilized a small-group capstone presentation (12–15 min with 5 min for questions) over topics developed specifically for this purpose (Table 2). Several aspects were critical to maximize the effectiveness of this approach:

- The capstone presentation served as a final exam and was worth 20% of the course grade. The grade reflected the performance of the group, and of each student in the group, as evaluated by all course faculty. Expectations were detailed in a grading rubric (Fig. 1).
- Students were randomly assigned to small groups by the second week of the course. At that time, a list of topics also

### Table 1. Physiological principles: understanding of integrative physiology rests on physiological principles

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| 1. | Physics explains many biological phenomena |
| 2. | Homeostasis |
| 3. | Feedback loops |
| 4. | Individual organs, integrated systems |
| 5. | Opposing modulation |

### Table 2. Capstone topics

|   |   |
|---|---|
| 1. | As with many hormones, angiotensin II has multiple actions on multiple tissues. Describe those actions and discuss the overall impact on body fluid balance. |
| 2. | Obesity has a broad range of effects on numerous physiological systems. Discuss how cardiovascular, hormonal, and reproductive systems may contribute to obesity-related hypertension. |
| 3. | Estrogen receptors are located in numerous sites in the central nervous system, including the organum vasculosum of the limina terminalis, the nucleus of the solitary tract, and the hypothalamic supraoptic nucleus. Discuss the physiological processes that may be affected by activation of these receptors, how they differ across the reproductive cycle, and the overall impact on body fluid balance. |
| 4. | Why is dehydration such a problem among the elderly? Discuss the physiological systems that contribute to this problem. |
| 5. | A car backfires (A); a person nearby passes out (B). Describe the events that happened between A and B. |
| 6. | People are advised to stay hydrated when moving to high elevations. However, each year, people who have moved to high elevations die, but not from dehydration. Explain how this could happen. |
| 7. | Describe the adaptations to exercise. |
| 8. | Describe the physiological/structural adaptations of diving mammals. |
| 9. | Why does blood pressure change with age? |
| 10. | Describe mechanisms that underlie blood pressure differences between men and women. |
| 11. | Describe the adaptations to being in space for a short time frame (<1 wk) and the consequences of those adaptations on returning to Earth. |
| 12. | Describe the adaptations to being in space for a long time period (~1 yr) and the consequences of those adaptations on returning to Earth. |

Students selected one of the topics for small-group capstone presentations. The list of topics was given during the second week of class.
was provided, along with the grading rubric. Groups selected their topic on a “first-come-first-serve” basis from a list of topics that included ~50% more topics than needed so that no group “settled” for a topic. Importantly, selecting a topic at the beginning of the course encouraged students’ engagement throughout the course.

- Faculty made a deliberate decision to selectively omit content related to those topics so that students would have to investigate the integrative physiology necessary to understand and present those topics.
- Throughout the semester, additional graded assignments were given to prepare students for working in small groups and for critical thinking/analytic skills, both of which would be crucial for the capstone presentations.
- The final week of class was devoted to preparation of capstone presentations. All small groups met during each class session, affording opportunities for peer-to-peer teaching within the group, as well as problem-solving by the group. All faculty members were in attendance at these sessions to answer questions and to provide guidance and advice, as needed. It should be noted that many of the groups had met with faculty at least once before the last week of class, as they were encouraged to do.

Outcomes and Evaluation

All faculty agreed that students were fully engaged in the course. Not only did they attend class sessions, they asked questions during class, and they took advantage of faculty members’ office hours to explore concepts in greater depth, in addition to requesting clarification. Nowhere was this engagement more apparent than in students’ performance during the capstone presentations. It was clear that students did more than cursory investigations of the topics. Rather, the presentations were thorough and demonstrated a sophisticated grasp of integrative physiology, including content that had been strategically omitted. As one example, the renin-angiotensin system (RAS) was not covered in endocrine or cardiovascular system lectures and only briefly in renal system lectures. Nonetheless, students who selected capstone topics 1 and 4 (Table 2) clearly demonstrated understanding of RAS, as did those who had selected topics 9 and 10. Even students who chose a topic less obviously involving RAS, such as topic 3, discussed the impact of central angiotensin receptors, which had not been covered in the nervous system. Students integrated across systems in these presentations and did not limit themselves to information found in textbooks. Indeed, students frequently prefaced information they gave during presentations with “According to a paper I read...”. In addition, other students in the class asked questions during the presentations, so that the students presenting became de facto content experts, not only teaching others within their group while preparing the presentations, but also instructing other students in the class. In short, the capstone presentations exceeded our expectations, and responses from other faculty and staff who attended these presentations were invariably positive.

But aside from grades, especially on the capstone presentations, which were uniformly high, and the more subjective assessment of class participation, what was the concrete evidence that these approaches/strategies were effective in promoting integrative physiology? Here, course evaluations were invaluable. We worked with personnel in the Office of Educational Development (OED) to design a series of questions intended to elicit information specific to our course goals, along with information about whether other goals that were “sandwiched in” also were accomplished. We used a Likert scale in these surveys, with responses about specific statements rated on a 5-point scale, ranging from “strongly disagree” to “strongly agree.” The evaluations were electronically distributed by the OED as anonymous surveys during the last week of the course; students were given 2 wk to respond. To maintain confidentiality, completed surveys were returned to the OED, which then compiled the results and conveyed that information to the course faculty. The survey and procedures were reviewed by the Oklahoma State University, Center for Health Sciences Institutional Review Board (IRB) and were adjudged to be exempt from further review by the IRB.

Approximately 60% of the students completed the survey; their responses are summarized in Table 3. Responses to questions about the course as a whole showed that, overall, students were positive about how much they had learned in the
course, and that they understood the importance of the content for their career plans. Thus it appears that we presented foundational physiology material at a level that students could appreciate as relevant to their careers, regardless of whether they planned to pursue healthcare or further graduate training. Moreover, the content was presented at a level that was both informative and challenging, despite the students’ diverse educational experiences and background. Students also were positive about the organization of the course and agreed or strongly agreed with the statement that the faculty worked well together. Clearly, the course faculty’s familiarity with their colleagues’ lectures facilitated integration across systems. Moreover, specific faculty expertise in evolutionary/developmental/comparative physiology likely was useful in introducing the various systems with an overview of these elements, although sufficient information exists that should allow most faculty to incorporate at least some evolutionary, developmental, or comparative aspects into systems-based physiology. In any case, student responses to these questions suggest that our approach of introducing each of the classical systems with evolution/ontogenetic/comparative elements and our “preview-review” approach to integration across physiological systems were successful.

Responses to questions about the capstone presentations also were uniformly positive. Students not only recognized the value of this exercise for understanding integrative physiology, but they also acknowledged that organizing and evaluating the material that went into their presentations enhanced their critical-thinking skills. At the same time, given that oral communication and working as part of a team are increasingly acknowledged as critical to success as researchers, physicians, or teachers, among the reasons for including a capstone presentation was to enhance these “soft skills.” Thus, despite initial expressions of nervousness and/or concern about unequal effort in team exercises by some students, it was gratifying that students agreed or strongly agreed with the statements that the capstone presentations were helpful in terms of both working as part of a team and giving presentations. Undoubtedly, the weight of the grade for the capstone presentations, and the fact that students were evaluated based on both individual and group performance, facilitated their working together and taking the exercise seriously, and we opted for these strategies for that reason. It should be noted that students also were positive about the exams and assessments by which their grades were determined, with 84% strongly agreeing and 16% agreeing with the statement that testing/evaluation was fair. Nonetheless, expanded surveys may help to identify additional areas of strength and opportunities for improvement in subsequent deliveries of this course.

Conclusions

The ability to understand and apply principles related to integrative physiology is essential for graduate students with aspirations of a career in biomedical research and is critical for students with goals in healthcare professions. Most medical schools require upper level biology courses as prerequisites (1, 5). However, physiology (or anatomy and physiology) is only one of several options that also include microbiology, genetics, cell and molecular biology, biochemistry, etc. Moreover, undergraduate physiology courses now incorporate more genetics and cellular and molecular biology content. Thus students may be entering graduate or medical education with less background in organismal physiology. Although this lack is problematic for both groups, a further complication for students embarking on healthcare education is that medical schools and other healthcare professional schools increasingly have implemented curricula in which physiology is integrated into board certification-oriented clinical instruction (e.g., Refs. 2–4, 6, 7) rather than serving as the basis for understanding underlying causes and clinical manifestations of pathological conditions. Ironically, a survey of pharmacy schools showed that, when physiology is integrated into system-based curricula, the contact hours are <50% of those in standalone physiology courses (4), which suggests a reduction in physiology content, particularly content related to integration across systems. We are not aware of similar surveys of medical schools, but it is likely that differences in content hours exist there, as well (see Ref. 3). In any case, the net outcome is that students are receiving less physiology instruction at both the undergraduate and professional levels, and the instruction deemphasizes integrative physiology.

Accordingly, we sought to promote understanding of integrative physiology in our Graduate Biomedical Physiology course,
which is taken by students with career goals in healthcare, as well as in teaching and research. Based on faculty assessment, student performance, and student evaluations, the approaches we implemented appear to have been successful in accomplishing our aims. Extensive discussion and debate among faculty during planning for the delivery of the course were critical for the success of this approach. Our biggest challenge was to omit content that we knew (and that we knew was important) to allow students the responsibility, and the excitement, of discovering integrative physiology through their own efforts.

DISCLOSURES

No conflicts of interest, financial or otherwise, are declared by the authors.

AUTHOR CONTRIBUTIONS

K.S.C., B.B., J.T.C., A.J.R., and W.F. conceived and designed research; K.S.C. analyzed data; B.B., J.T.C., K.S.C., W.F., and A.J.R. interpreted results of experiments; K.S.C. prepared figures; K.S.C. drafted manuscript; B.B., J.T.C., W.F., and A.J.R. edited and revised manuscript; K.S.C., B.B., J.T.C., W.F., and A.J.R. approved final version of manuscript.

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