What makes physiology hard for students to learn? Results of a faculty survey

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Michael J. What makes physiology hard for students to learn? Results of a faculty survey. Adv Physiol Educ 31: 34–40, 2007; doi:10.1152/advan.00057.2006.—Teachers of physiology at all post-secondary levels were asked to participate in a survey about the possible sources of students’ difficulty in learning physiology. Sixty-three physiology teachers responded to the 18-question survey; 35 of the respondents also responded to a request for written comments about this issue prior to taking the survey. Three categories of possible factors contributing to physiology being hard to learn were defined: 1) the nature of the discipline, 2) the way it is taught, and 3) what students bring to the task of learning physiology. Respondents thought that characteristics of the discipline (it requires causal reasoning, it uses graphs and mathematics, and it is highly integrative) and characteristics of students (they believe that learning and memorizing are the same thing, they cannot or will do attempt to integrate, and they compartmentalize) were significantly more important than any aspect of teaching in making physiology hard to learn. Recommendations are offered in this article to help students deal with the sources of difficulty that were identified.

What do students mean when they say that physiology is difficult? Students find it “hard” to learn to physiology; if not all of them, then certainly a great many of them. This assertion is based on many years of teaching physiology to first-year medical students, conversations with students, and interactions with fellow physiology teachers at all levels. A very informal survey at the completion of the winter quarter Medical Physiology course (2005–2006 academic year) for which I am the Course Director yielded the following results. When presented with the statement “I found physiology hard to learn,” 29/61 students agreed or strongly agreed, whereas 27/61 students disagreed or strongly disagreed with this statement (the remaining 5/61 students were neutral). Thus, almost half of the students indicated that they thought physiology was hard.

What do physiology teachers mean when they claim that students find physiology hard? In thinking about learning any discipline, scientific or otherwise, we need to consider three things: 1) the nature of the task and the capabilities of the person attempting to accomplish the task.

What do physiology teachers mean when they claim that their students find it hard to learn physiology? Alternatively, we can ask what is it that leads physiology teachers to believe that their students find physiology hard? It seems likely that two phenomena are at work here. First, teachers see too many of their students NOT mastering physiology at the level that they expect, and, second, teachers discover that students need more help than expected to master concepts that were thought would be easily mastered. Howard Kutchai (University of Virginia School of Medicine) offered a more specific diagnosis of this problem in an e-mail message (February 15, 2005) in which he said “…current first-year medical students are less comfortable with basic math and physics concepts and skills than was the case some years ago.” He went on to say that “…these deficits …are diminishing their ability to understand physiology.” This hypothesis about a possible source of the difficulty that students have in learning physiology was the stimulus for the present study.

To find out what a more diverse population thought about the sources of difficulty that students encounter in learning physiology, I surveyed a wide sampling of physiology teachers about this issue. Some of these data have been first presented at the symposium “How Prepared Are Your Students to Learn Physiology” at the 2006 Experimental Biology Meeting (12).

What factors might make physiology hard for students to learn? In thinking about learning any discipline, scientific or otherwise, we need to consider three things: 1) the nature of the discipline being learned, 2) the ways in which we teach the discipline, and 3) what students bring to the learning of that discipline. These three categories of factors interact with one another in a way that is shown in Fig. 1A.

By the nature of the discipline, I mean the characteristics of the subject matter, how it relates to other subjects, how experts study that subject matter, how they reason about it, and how they communicate their knowledge and understanding of the discipline.

The ways in which we teach the discipline refers to all of the usual practices that students encounter in our classrooms as we attempt to help them to learn the discipline.

What I mean by what students bring to learning the discipline is the prior knowledge and skills to which they have access, their beliefs about learning and what it means to

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understand something, and the “student skills” they have accumulated over their years of schooling.

This model (Fig. 1A) for learning a discipline (in this case, physiology) formed the basis for the survey that I wrote and administered in the summer of 2005.

METHODS

Participation in the survey was solicited with an e-mail message sent out on two listservs, and recipients of the e-mail message were asked to do two things. Respondents were first asked to “... in as many, or as few, words as you need, tell me why you think students find physiology a hard subject to master.” The answer to this question was generated before the respondents saw the survey. This is relevant because the survey (see Table 1) quite explicitly reflects the model of the situation that is shown in Fig. 1A, and I was seeking the respondents’ spontaneous, unprompted answers. Respondents then were directed to the URL of the Physiology Educational Research Consortium (PERC) website, at which they could log into the survey and answer the questions found there (Table 1).

The survey consisted of three sets of questions, each dealing with factors contributing to one of the categories of difficulties shown in Fig. 1A. These questions are shown in Table 1. Respondents were asked to rate each of the 18 factors using a 5-point Likert scale with 1 as a MAJOR contributor, 3 as a MINOR contributor, and 5 as NOT A SIGNIFICANT contributor to student difficulty learning physiology; ratings 2 and 4 had no label associated with them. Note, however, that in reporting the results of the survey (see Fig. 2 and Table 5), the scale has been reversed so that the more important factors have higher numbers; this makes it easier to understand the data presented.

Data from responses to Likert scale questions are ordinal in nature, and statistical treatment of such data must reflect this. There is, however, continued controversy about what tests are appropriate to apply to Likert scale data, and the issue has been much discussed in the social science and education research literature (7). Statisticians assert that ordinal data cannot properly be analyzed with parametric tests (such as the t-test) but must be analyzed with nonparametric methods (21). Nevertheless, researchers continue to apply parametric tests to such data, often with attempts at justification for this, but often without any discussion of the issues (7). In comparing the responses to different questions or groups of questions on the survey, nonparametric tests (χ²-tests or Wilcoxon signed-rank tests) were employed (25, 27).

RESULTS

Who responded. Responses to the survey were obtained from 63 physiology teachers: 56 teachers from the United States and 7 teachers in 7 different foreign countries (Australia, Canada, India, Italy, The Netherlands, Switzerland, and Thailand). Collectively, the respondents taught physiology at all postsecondary levels (community colleges, undergraduate programs, and graduate and professional programs).

Written comments. Thirty-five of sixty-three respondents provided answers to the question “... why do you think students find physiology a hard subject to master” before they saw the survey. Responses ranged in length from 24 words (a
What is it about the nature of physiology as a discipline to the difficulty students have finding it hard to learn (understand)?

<table>
<thead>
<tr>
<th>Question</th>
<th>Categories</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Understanding physiology is based on (built upon) an understanding of physics and chemistry.</td>
<td>Understanding physiology is based on (built upon) an understanding of physics and chemistry.</td>
</tr>
<tr>
<td>2. Physiological phenomena need to be understood at a number of different organizational levels simultaneously (from the molecular to the whole organism).</td>
<td>Understanding physiology is based on (built upon) an understanding of physics and chemistry.</td>
</tr>
<tr>
<td>3. Understanding physiology requires the ability to reason causally (mechanistically).</td>
<td>Understanding physiology requires the ability to reason causally (mechanistically).</td>
</tr>
<tr>
<td>4. Understanding physiology requires at least some limited ability to think about dynamic systems.</td>
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</tr>
<tr>
<td>5. Physiology, like other life sciences, seems to encourage the tendency of teleological thinking.</td>
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<tr>
<td>6. Much of our understanding of physiological mechanisms is communicated graphically or in other mathematical ways.</td>
<td>Much of our understanding of physiological mechanisms is communicated graphically or in other mathematical ways.</td>
</tr>
<tr>
<td>7. The language of physiology is a mixed one, with many commonly used words taking on specific, scientific meanings that are different from (some times opposite from) their lay meanings.</td>
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Sixty-three physiology teachers responded to the survey.

The initial reading of these responses made it clear that physiology teachers expect more than simple memorization from their students. Teachers expect “understanding” or the ability to “think” about physiological mechanisms.

A more detailed reading was then undertaken to determine whether the comments provided could be sorted into the categories of factors described in the model shown in Fig. 1A. Thirty-two of thirty-five of the written responses contained one or more comments about the nature of the discipline of physiology, 18 of 35 responses contained comments about the way in which we teach physiology, 31 of 35 responses contained comments about what student bring to the learning of physiology, and 16 of 35 responses contained comments from all three of the categories identified in the model.

There were also comments that fell into a fourth category of factors (one that was not included in the model shown in Fig. 1A) that might contribute to students finding physiology hard to master. Nine of the thirty-five responses contained comments about factors related to the personal lives of students and the academic environment outside of the physiology classroom.

Not only did respondents’ comments map onto the model (Fig. 1A) with surprising frequency, but many comments mirrored specific questions that make up the survey. Tables 2-4 show examples of the comments made by respondents, with many of them clearly related to the indicated survey question.

Five of seven factors about the discipline of physiology were found in the written comments, two of six factors about teaching were mentioned, and one of five factors was mentioned about the students (but this was one of the most frequent comments made by respondents).

Responses to survey questions. The collected responses to each of the 18 questions were first tabulated by counting the number of responses in each rating (5 through 1). The higher the rating, the more important the factor was thought to be in contributing to making physiology hard to learn (as previously indicated, Likert scale numbers were reversed to make it easier to understand the results). The responses to questions pertaining to the discipline, teaching, and students were counted separately, and average numbers of ratings for each category were calculated (the number of questions in each category was different). Averages are shown in Fig. 2. Based on these results, it appeared that factors related to the nature of the discipline of physiology and factors related to the students were regarded as more important (there were more high ratings) than factors related to teaching (there were fewer high ratings).

χ²-Tests were carried out to compare the distribution of ratings (how many 5s, 4s, etc.) on questions in each of the three categories. The distribution of responses for questions about the discipline and for questions about student characteristics were each compared with the distribution of responses to questions about teaching. The comparison between discipline...
Table 3. A sample of comments about the contribution of the typical teaching of physiology as a discipline to the difficulty students have

“Although we like to think that we teach only concepts, there is a goodly amount of jargon and facts that novices must master.” (Question 12)

“Like many (most) science teachers we tend to focus on the details at the expense of the big picture.” (Question 11)

“In my opinion, the biggest problem is the use of language by the lecturers.” (Question 12)

“Perhaps the problem lies with us as educators, in that we are not doing a good enough job of integrating the material.”

“Current teaching practices do not do a good job of identifying students misconceptions . . . ”

Questions on the survey that correspond to the contents of a particular comment are indicated.

and teaching yielded a $\chi^2 (4, 63) = 14.0$ ($P < 0.01$). The comparison between students and teaching yielded a $\chi^2 (4, 63) = 11.2$ ($P < 0.05$). Respondents to the survey thought that teaching practices are less important than the characteristics of the discipline and student characteristics in making physiology hard for students to learn.

The ratings for each question from all 63 respondents were summed, and the aggregate sums were used to rank order the 18 factors described in the survey, starting with the most significant ($S =$ MAJOR contributor) to the least significant ($I =$ NOT A SIGNIFICANT contributor). The factors in rank order can be seen in Table 5. (The rank ordering is essentially unchanged when different procedures are used; for example, calculating the average ratings for each questions does not change the top 10 rankings.)

If we focus on the “top 10” reasons faculty members think physiology is hard for students to master, we see that 5 factors (questions 1–4 and 6) describe the discipline of physiology, 4 factors describe student characteristics (questions 14–16 and 18), and only 1 factor in the top 10 relates to the teaching of physiology (question 8).

It is worth noting that the highest rated factor shown in Table 5 is related to the need for students to be able to do causal (mechanistic) reasoning to understand physiology (question 3). Howard Kutchai originally asserted that the dependence of physiology on mathematics (question 6), which is ranked number 5 on the list, and the dependence on physics and chemistry (question 1), which is ranked number 8, were the principle sources of the difficulties that students exhibit in learning physiology.

To see if the respondents to the survey did, in fact, disagree with Kutchai, Wilcoxon signed-rank tests were performed to determine whether the distribution of responses to questions 1 and 6 were different than the distribution of responses to question 3. The comparison between the distribution of ratings for question 1 and 3 yielded $z = -3.953$ ($P < 0.001$) (two-tailed). The comparison between question 6 and 3 yielded $z = -3.172$ ($P = 0.002$) (two-tailed). There is thus support for the assertion that while respondents thought that the dependence of physiology on math and physics and chemistry was important, they thought that the need to be able to apply causal reasoning was more important.

Table 4. A sample of comments about the contribution of the what students bring to learning physiology to the difficulty students have

“They are much too inclined just to memorize ‘facts’ and ‘answers’ to old test questions . . . ” (Question 14)

“. . . understanding tends to be viewed as secondary to memorizing.” (Question 14)

“Not all students have the appropriate prerequisite knowledge, and physiology borrows from a lot of sciences.”

Questions on the survey that correspond to the contents of a particular comment are indicated.

DISCUSSION

The written comments provided by slightly more than half of the respondents offer considerable support for the three-factor model shown in Fig. 1A. The comments consistently could be assigned to the three categories of factors constituted the survey: 1) the nature of the discipline of physiology, 2) the teaching of physiology, and 3) what students bring to the learning of physiology. In addition, however, many of the respondents’ comments suggested a fourth factor that needs to be considered in thinking about why physiology is hard for students: the influence of the world outside of the physiology classroom. The final model incorporates this factor and is shown in Fig. 1B.

It is interesting to note that while I wrote this article, support for the three-factor model was discovered from two quite different sources. Carter and Brickhouse (2) surveyed students taking a general chemistry course for science and engineering majors about “what makes chemistry difficult.” The written comments from 300 students clustered around three factors: 1) students’ behaviors, 2) the course itself (what faculty did), and 3) the nature of chemistry. While the specific factors cited by the students were not identical to those included in the survey used here, the model that is implied is the same as that shown in Fig. 1A. In a discussion of the impact of research on cognition to instruction (teaching), Siegler (26) organized his comments around a very similar model.

The results of the survey clearly indicate that teachers of physiology believe that the nature of the discipline and what students bring to the task of learning physiology are the most important determinants of physiology being hard. The way we teach physiology, while not unimportant, is clearly viewed as being significantly less important that the other two factors.

Are there objective data about the difficulties of learning a science? Physiology teachers have identified what they believe to be the sources of student difficulties in learning physiology. Are there any objective data that might suggest the sources of these difficulties? There are, unfortunately, little data directly addressing this issue from students learning physiology. It is known that students commonly enter the physiology classroom lacking the expected prerequisite knowledge and skills (8, 23). It is also well known that transfer, the ability
as making the learning of physiology difficult. More research is clearly needed to determine the extent to which the factors identified as contributing to student difficulty in learning physiology actually affect learning outcomes.

What is the impact of our teaching on student difficulties? Respondents to the survey appeared convinced that the ways in which we teach physiology were NOT a major source of the problems that students have learning physiology; this is evident in the distribution of ratings shown in Fig. 2 and in the χ²-tests that were performed.

However, there are many reasons for believing that this is not the case. That is to say, there is considerable evidence that at least a major source of students’ failure to master science at the expected level is due to current teaching practices. From the publication of A Nation at Risk: the Imperative to Reform (19) in 1983 to the more recent BIO2010: Transforming Undergraduate Education for Future Research Biologists report (20) published in 2003, there have been numerous calls for reform in teaching, and specifically the teaching of the sciences, to raise student achievement to levels that are thought to be acceptable. Halpern and Hakel (5) recently observed that “…it would be difficult to design an educational model [the way we currently teach] that is more at odds with current research on human cognition than the one that is used in most colleges and universities.” We are, in general, not doing as good a job of helping the learner to learn physiology as could be done. If students are not reaching the goals we have set for them, the cause of this failure lies with the ways we teach as much as it does with the difficulties of the discipline or the students.

What should we do to help our students? I would argue that a belief that the characteristics of physiology as a discipline that make it hard for students to learn physiology must be based on the belief that those very characteristics are hard for students to deal with. This point was made explicitly in the following comment by one of the respondents: “Physiology depends crucially on chemical and physical principles that students find hard to master . . . [emphasis added].” This, of

![Distribution of Ratings of All Questions](image-url)

Table 5. The 18 survey question in rank order of faculty members’ perceived contribution to making physiology hard for students to learn

<table>
<thead>
<tr>
<th>Rank Order</th>
<th>Aggregate Rating</th>
<th>Question Number and Category</th>
<th>Factor Contributing to Difficulty Students have in Learning Physiology</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>292</td>
<td>3 (D)</td>
<td>Requires the ability to reason causally (mechanistically)</td>
</tr>
<tr>
<td>2</td>
<td>286</td>
<td>14 (S)</td>
<td>Students believe that “learning” is the same as “memorizing”</td>
</tr>
<tr>
<td>3</td>
<td>280</td>
<td>4 (D)</td>
<td>Ability to think about dynamic systems</td>
</tr>
<tr>
<td>4</td>
<td>269</td>
<td>6 (D)</td>
<td>Understanding is communicated graphically or in other mathematical ways</td>
</tr>
<tr>
<td>5</td>
<td>268</td>
<td>2 (D)</td>
<td>Students fail to appreciate the integrative nature of physiological mechanisms</td>
</tr>
<tr>
<td>6</td>
<td>267</td>
<td>16 (S)</td>
<td>Students compartmentalize (pigeon-hole) everything</td>
</tr>
<tr>
<td>7</td>
<td>261</td>
<td>15 (S)</td>
<td>Based on (built upon) an understanding of physics and chemistry</td>
</tr>
<tr>
<td>8</td>
<td>253</td>
<td>1 (D)</td>
<td>Students tend to ignore graphs, tables and figures</td>
</tr>
<tr>
<td>9</td>
<td>250</td>
<td>18 (S)</td>
<td>Textbooks are typically descriptive not mechanistic</td>
</tr>
<tr>
<td>10</td>
<td>231</td>
<td>8 (T)</td>
<td>The language of physiology is a mixed one</td>
</tr>
<tr>
<td>11</td>
<td>217</td>
<td>7 (D)</td>
<td>No stress on commonalities of function across organ systems</td>
</tr>
<tr>
<td>12</td>
<td>214</td>
<td>11 (T)</td>
<td>Teachers expect too many memorized facts and too little understanding</td>
</tr>
<tr>
<td>13</td>
<td>211</td>
<td>13 (T)</td>
<td>Teachers talk too much and students talk too little</td>
</tr>
<tr>
<td>14</td>
<td>208</td>
<td>5 (D)</td>
<td>Encourages the tendency to teleological thinking</td>
</tr>
<tr>
<td>15</td>
<td>196</td>
<td>10 (T)</td>
<td>Poor job of defining and communicating learning performance objectives</td>
</tr>
<tr>
<td>16</td>
<td>189</td>
<td>12 (T)</td>
<td>Teachers and authors use language imprecisely</td>
</tr>
<tr>
<td>17</td>
<td>173</td>
<td>17 (S)</td>
<td>Students assume ALL physiological responses benefit organism</td>
</tr>
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</table>

D, properties of domain; T, teaching; S, what students bring to class.

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course, reinforces the idea that there is an important interaction between the nature of the discipline and what students bring to the learning of that discipline. It also means that if, as teachers, we believe that our job is to “help the learner to learn” (13), then we must find ways to help students bridge the gaps between what mastery of physiology requires and what students come into our classrooms knowing and able to do.

For example, if physiology is hard because it requires the application of causal reasoning, and if students find it hard to apply causal reasoning to a physiological phenomenon, then we must first model this kind of reasoning for our students and then give them ample opportunities to practice it while they receive appropriate feedback. Michael and Rovick (15) have developed examples of paper-and-pencil problems (and answers) aimed at helping students develop the needed skills. In addition, computer tutors such as CIRCSIM and CIRCSIM-Tutor (4) have been developed with the expressed goal of assisting students to develop the ability to predict the responses of perturbed physiological systems. It is also important that we indicate to students what this ability by including it in our course objectives and assessing it on our exams.

If physiology is hard because it is based on physics, chemistry, and mathematics, and these pose challenges for our students at any postsecondary level (the hypothesis advanced by Howard Kutchai), then we must focus more attention on the fundamental physics and chemistry concepts and principles that are relevant, model the application of these to understanding physiological phenomena, and give the students opportunities to practice using these concepts and principles. Modell (17) has proposed that emphasizing the common themes or general models that apply to many physiological systems such as conservation of mass or mass and heat flow can also help students overcome their difficulties.

If physiology is hard because students believe that understanding a physiological phenomenon requires only memorizing something, then we have to do a better job of explicitly defining our expectations. We also need to openly discuss this issue to help students recognize what we mean by “understanding physiology” and “learning” (15). And, finally, we must demonstrate that we mean what we say by assessing their progress with exams that require more than the regurgitation of memorized information.

Another recommendation is that we need to spend more time finding out what our students know and don’t know, and can do or not do, when they enter our classroom. Assumptions about what students bring to the learning of physiology based on a list of prerequisite courses is known to be unreliable (23). We can do this in a “formal” way with a carefully crafted pencil-and-paper pretest such as the one described by Kutchai (8). The studies of misconceptions by Michael and colleagues (14, 16), and the study reported here, were all conducted using the PERC website. Such web-based tests are very easy to administer and require no class time. Another approach (and they are not mutually exclusive) is to monitor students’ prerequisite knowledge in every class session through the use of diagnostic questions (18). The use of student responder systems can greatly facilitate this process by allowing students the anonymity that encourages active participation in answering questions posed in a public setting. But, without knowledge of the “input” state of our students, it is difficult to plan an educational treatment to help them get to the desired “output” state (13).

We also need to examine our expectations. What do our students need to know and what should they be able to do when they complete our course? The answer to this question may be determined by the requirements of subsequent courses in the curriculum, or external licensing agencies, or our own sense of what students should know. Nevertheless, given what our students do bring to our classroom and all of the demands that are made of them, many of them from outside the classroom (the fourth factor in the model shown in Fig. 1B), it is possible that our expectations are simply unreasonable. Several respondents offered comments about the “time crunch” and “information overload” in our courses. Another respondent suggested that there are “other stressors competing for the student’s learning time and ability.” Finally, one respondent quite explicated voiced the opinion that “overall expectations placed on today’s college students are too high.” We all need to recognize that everything going on outside of our classrooms influence our students and, if nothing else, that our expectations must be tempered by the other academic demands being made on our students.

Where do we go next? Teachers of physiology have had a chance to voice their opinion about what makes physiology hard for students to learn. Next, we need to ask students in physiology classes to tell us what they think. Do they expect physiology to be hard as they start the course? When they get to the end of the course, do they think that it was hard? To what extent does their assessment of the degree of difficulty depend on how well or poorly they did in the course? Do students attribute their difficulties learning physiology to the same factors that faculty members have proposed? These are issues for future research.

Conclusions. Our job as teachers is to help students learn physiology. The more we understand about learning and the better we understand the sources of difficulty that students have in learning physiology, the better we can do our job.

ACKNOWLEDGMENTS

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REFERENCES

How We Learn

WHY IS PHYSIOLOGY HARD FOR STUDENTS TO LEARN?