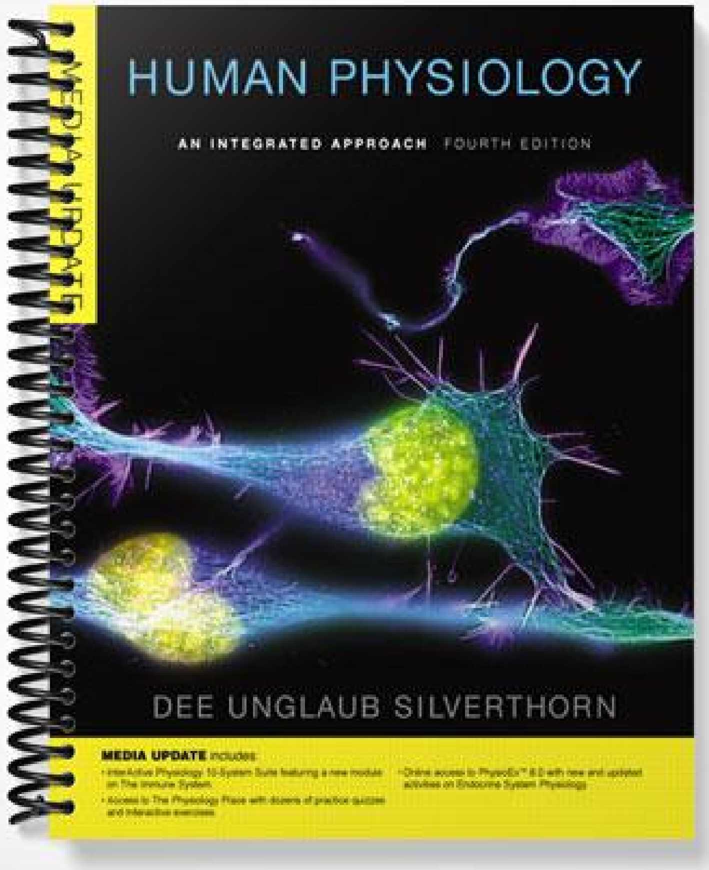
SOLUTIONS MANUAL



INSTRUCTOR'S RESOURCE MANUAL

HUMAN PHYSIOLOGY

AN INTEGRATED APPROACH FOURTH EDITION

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Welcome

Welcome to the Instructor's Resource Manual for *Human Physiology: An Integrated Approach*, 4th edition. We have written this manual with the hope that it will make teaching your physiology class easier and more fun!

FEATURES OF THE INSTRUCTOR'S RESOURCE MANUAL

Key features include the following:

- **Chapter at a Glance** uses conversational headings and subheadings from each chapter as a quick summary of chapter organization and contents.
- A **Teaching Summary** highlights key themes within each chapter. When appropriate, suggestions are offered for material that can be omitted if time is limited.
- **What's New?** offers a quick summary of material that has been added to or removed from this edition.
- The **Teaching Outline** includes references to relevant figures and key words to emphasize the main points within each chapter. There is also space at the end of many chapters for taking notes.
- Within some sections, you will find **supplemental lecture material**, **activities**, **examples**, and **analogies** you might find useful; these segments are preceded by an arrow (▶).
- **Talk the Talk** is a list of important vocabulary words for each chapter.
- **Focus on Physiology** contains additional quantitative and higher level problems to use as class activities or as test questions.
- **Focus on Graphing** features exercises that develop your students' graphing abilities and understanding of quantitative physiological data.
- **Running Problems** give additional background information and resources for exploring Running Problem cases presented in the textbook.
- **Quantitative Physiology** provides questions (and rationales) you can use to assess your students' understanding of quantitative aspects of physiology.
- **Maps** suggest additional mapping activities.
- **Reading** suggests additional literature and online resources.

INTRODUCTION TO RESOURCES

A list of resources including websites, articles, books, and organizations that you might find particularly useful follows.

FREE ACCESS INTERNET RESOURCES

In recent years free access to primary scientific literature has increased thanks to electronic publishing. Some journals and databases are available at the date of publication, while others open their access one year after the original publication date. In addition, there are helpful websites published by professional societies and the government.

MEDLINE (www.ncbi.nlm.nih.gov/entrez) is the National Library of Medicine's database, and is free of charge on the Internet through PubMed. MEDLINE is one of the most significant worldwide databases tracking medical research and has extensive search capabilities. Most citations include an abstract, and many of them have direct links to the full text of articles.

American Physiological Society publications are cited in this manual in many instances. *Advances in Physiology Education* (see below) offers free access from the date of publication, while all other APS journals have free access one year after their publication date.

- ***Advances in Physiology Education*** (advan.physiology.org) is a peer-reviewed journal that offers free access to published review articles and articles on physiology teaching.
- ***Physiology*** (formerly ***News in Physiological Sciences****;* nips.physiology.org) publishes review articles and commentaries on the latest developments in physiology. Access is free one year after publication.
- ***American Journal of Physiology, Journal of Applied Physiology***, and ***Journal of Neuroscience*** (www.the-aps.org/publications/journals) offers access to articles, and is free one year after publication.
- ***Highwire Press*** (www.highwire.org), the online publisher for many scientific journals, maintains a public access site that allows both free and paid access to research articles.

RESOURCE ARTICLES ABOUT PHYSIOLOGY EDUCATION

The following articles and books about physiology education have been grouped by topic.

Teaching Philosophy

DiCarlo, S.E. "Research or retrench: the teaching profession challenged." *Advances in Physiology Education 26*(137) (June 2002): 1043–4046.

Hansen, P. "Physiology's recondite curriculum." *Advances in Physiology Education 26* (Sept. 2002): 139–145.

Herreid, C.F. "Teaching in the year 2061." *Advances in Physiology Education 24* (Dec. 2000): 1–7.

Michael, J. "In pursuit of meaningful learning." *Advances in Physiology Education 25* (Sept. 2001): 145–158.

Sefton, A.J. "The future of teaching physiology: An international viewpoint." *Advances in Physiology Education 275* (1998): S53–S58.

Improving Teaching and Learning

Carroll, R. "Sharing what works—the archive of teaching resources." *Advances in Physiology Education 26* (Mar. 2002): 4.

Correa, B.B., *et al.* "How do learning issues relate with content in a problem-based learning pathophysiology course?" *Advances in Physiology Education 27* (June 2003): 62–69.

Goodman, B.E. "Evolution of a partnership to improve K-16 science education." *Advances in Physiology Education 26* (Sept. 2002): 168–173.

Michael, J. "Misconceptions—what students think they know." *Advances in Physiology Education 26* (Mar. 2002): 5–6.

Modell, H.I. "How to help students understand physiology? Emphasize general models." *Advances in Physiology Education 23* (June 2000): 101–107.

Mowy, M.E. and Matyas, M.L. "Ben portal—your doorway to a broader range of teaching material." *Advances in Physiology Education 26* (June 2002): 67–68.

Palaez, N.J. and Gonzalez, B.L. "Sharing science: Characteristics of effective scientist-teacher interactions." *Advances in Physiology Education 26* (Sept. 2002): 158–167.

Report of workshop presented at Experimental Biology '99 Conference, in Washington, DC. "Teaching critical thinking skills in physiology." *Advances in Physiology Education 277* (Dec 1999): 268–270.

Rovick, A.A., *et al.* "How accurate are our assumptions about our students' background knowledge?" *Advances in Physiology Education 276* (June 1999): S93–S101.

Active Learning

Howard, M.G., *et al.* "'Survivor' torches 'who wants to be a physician?' in the educational games ratings war." *Advances in Physiology Education 26* (Mar. 2002): 30–36.

Huang, A.H. and Carroll, R.G. "Incorporating active learning into a traditional curriculum." *Advances in Physiology Education 273* (Dec. 1997): S14–S23.

Mierson, S. "A problem-based learning course in physiology for undergraduate and graduate basic science students." *Advances in Physiology Education 275* (Dec. 1998): S16–S27.

Sabyasachi, S.S. and Tandon, O.P. "Involving students in question writing: A unique feedback with fringe benefits." *Advances in Physiology Education 277* (Dec. 1999): S84–S92.

Svinicki, M.D. "A theoretical foundation for discovery learning." *Advances in Physiology Education 275* (Dec. 1998): S4–S8.

Tong, E.Y. "Learning physiology through service." *Advances in Physiology Education 277* (Dec. 1999): S100–S110.

Collaborative, Cooperative, and Peer-Peer Learning

Cudd, T.A. and Wasser, J.S. "Biomedical device design discovery team approach to teaching physiology to undergraduate bioengineering students." *Advances in Physiology Education 277* (Dec. 1999): S29–S41.

Lake, D.A. "Peer tutoring improves student performance in an advanced physiology course." *Advances in Physiology Education 276* (June 1999): S86–S92.

Palaez, N.J. "Problem-based writing with peer review improves academic performance in physiology." *Advances in Physiology Education 26* (Sept. 2002): 174–184.

Rao, S.P. and DiCarlo, S.E. "Peer instruction improves performance on quizzes." *Advances in Physiology Education 24* (Dec. 2000): 51–55.

Rao, S.P., *et al.* "Collaborative testing enhances student learning." *Advances in Physiology Education 26* (Mar. 2002): 37–41.

Seals, D.R. and Tanaka, H. "Manuscript peer review: A helpful checklist for students and novice referees." *Advances in Physiology Education 23* (June 2000): 52–58.

Teaching and Learning with Technology

Goldberg, H.R. and McKhann, G.M. "Student test scores are improved in a virtual learning environment." *Advances in Physiology Education 23* (June 2000): 59–66.

Machart, J.M. and Silverthorn, D.U. "Mailing lists are preferred to newsgroups as teaching tools for undergraduate biology classes." *Advances in Physiology Education 23* (June 2000): 67–71.

Rodenbaugh, D.W., *et al.* "Creating a simple PowerPoint multimedia game." *Advances in Physiology Education 26* (Dec. 2002): 342–343.

Weaver, D.A., *et al.* "Evolution of a student model-building program." *Advances in Physiology Education 26* (Dec. 2002): 288–298.

Laboratory Teaching

McNeal, A.P., *et al.* "Involving students in experimental design: Three approaches." *Advances in Physiology Education 275* (Dec. 1998): S28–S34.

Myers, M.J. and Burgess, A.B. "Inquiry-based laboratory course improves students' ability to design experiments and interpret data." *Advances in Physiology Education 27* (Mar. 2003): 26–33.

Rivers, D.B. "Using a course-long theme for inquiry-based laboratories in a comparative physiology course." *Advances in Physiology Education 26* (Dec. 2002): 317–326.

Classroom Assessment

DeSantis, M. and McKean, T.A. "Efficient validation of teaching and learning using multiple-choice exams." *Advances in Physiology Education 27* (Mar. 2003): 3–14.

Hiebert, S.M. "Information age testing: Making rigorous exams fun to write and easy to grade." *Advances in Physiology Education 23* (Jun. 2000): 96–100.

Holladay, C.J. "Book review: *Classroom Assessment Techniques* by Thomas Angelo and K. Patricia Cross. San Francisco: Jossey Bass Publishers, 1993." *Advances in Physiology Education 26* (Mar. 2002): 57.

Paschal, C.B. “Formative assessment in physiology teaching using a wireless classroom communication system.” *Advances in Physiology Education 26* (Dec. 2002): 299–308.

Program Design and Assessment

Harrison, J.F., *et al.* “Evaluating the impact of physical renovation, computerization, and use of an inquiry approach in an undergraduate, allied health human anatomy and physiology lab.” *Advances in Physiology Education 25* (Dec. 2001): 202–210.

Krilowicz, B.L. and Downs, T. “Use of course-embedded projects for program assessment.” *Advances in Physiology Education 276* (June 1999): S39–S54.

Lemons, D.E. and Griswold, J.G. “Defining the boundaries of physiological understanding: The benchmarks curriculum model.” *Advances in Physiology Education 275* (Dec. 1998): S35–S45.

McCleary, V.L. “Assessing pre-baccalaureate human physiology courses.” *Advances in Physiology Education 275* (Dec. 1998): S106–S113.

McCleary, V.L., *et al.* “Predictors of success in undergraduate human physiology.” *Advances in Physiology Education 277* (Dec 1999): S119–S126.

Richardson, D. and Birge, B. “Effects of an applied supplemental course on student performance in elementary physiology.” *Advances in Physiology Education 24* (Dec. 2000): 56–61.

Zolman, J.F. and Ott, C.E. “Students’ colleges and achievement in an advanced course.” *Advances in Physiology Education 26* (Dec. 2002): 282–287.

EDUCATION RESOURCES

The following articles and books are provided as resources on the subjects of teaching and learning:

Journal of College Science Teaching publishes articles about college teaching in all sciences.

The American Biology Teacher publishes articles about teaching in all areas of biology.

Dictionary of Word Roots and Combining Forms, by Donald Borror (Mayfield Publishing Co.) is a comprehensive reference for biological terms and scientific names.

American National Research Council (www7.nationalacademies.org/cfe/CFE_Publications.html) publishes excellent books on learning and on assessing learning. You can read them online at no cost (though there are hundreds of pages) or order them directly.

- Brown, A.L., Cocking, R.R., and Bransford, J.D. (eds) *How people learn: Brain, mind, experience, and school,* Expanded Edition. Committee on Developments in the Science of Learning with additional material from the Committee on Learning Research and Educational Practice, National Research Council. 385 pages, 2000.
- Olson, S. and Loucks-Horsley, S. (eds.) *Inquiry and the national science education standards: A guide for teaching and learning.* Committee on the Development of an Addendum to the National Science Education Standards on Scientific Inquiry, National Research Council. 224 pages, 2000.
- Pellegrino, J., Chudowsky, N. and Glaser, R. (eds.) *Knowing what students know: The science and design of educational assessment.* Committee on the Foundations of Assessment, Center for Education, National Research Council. 450 pages, 2001.
- Committee on undergraduate science education. *Science teaching reconsidered: A handbook.* National Research Council. 104 pages, 1997.

New Directions For Teaching and Learning (series). San Francisco: Jossey-Bass Publishers.

- Bateman, W.L. *Open to question: The art of teaching and learning by inquiry.* 1990.
- Brookfield, S.D. *The skillful teacher.* 1990.
- Svinicki, M. (ed) *The changing face of college teaching.* 1990.

Angelo, T. and Cross, K.P. *Classroom assessment techniques.* San Francisco: Jossey-Bass Publishers, 1993. (See review in *Advances in Physiology Education* at advan.physiology.org/cgi/content/full/26/1/57)

Bonwell, C.C. and Eison, J.A. “Active learning: Creating excitement in the classroom.” *ASHE-ERIC Higher Education Report No. 1.* Washington, DC: The George Washington University, School of Higher Education and Human Development, 1991. (Order from: ERIC Clearinghouse on Higher Education.)

Johnson, D.W., Johnson, R.T., and Smith, K.A. *Active learning: Cooperation in the college classroom*. Edina, MN: Interaction Book Co., 1991.

Rangachari, P.K. "Active learning: In context." *Advances in Physiology Education 268* (June 1995): S75–S80.

Uno, G.E. (ed.) *Handbook on teaching undergraduate science courses: A survival training manual*. Belmont, CA: Thomson Brooks/Cole, 1999.

The Visible Human Project. The Visible Man was a 39-year-old prisoner who donated his body to science after he was executed. It was embedded in gelatin, frozen, and sliced crosswise into 1878 slices 1 mm thick. The slices were photographed, digitized, and colored. The entire set occupies about 14 gigabytes. To view this project, go to www.nlm.nih.gov and look under Biomedical Research.

ORGANIZATION RESOURCES

The **American Physiological Society** (APS), founded in 1887, is devoted to fostering scientific research, education, and the dissemination of scientific information. Membership is open to individuals who have an interest in physiology. APS meets annually in April at the Experimental Biology meeting and has additional specialty meetings throughout the year. APS members receive free subscriptions to *News in Physiological Sciences*, *Advances in Physiology Education*, and *The Physiologist*. For information about becoming a member of APS, go to www.the-aps.org.

The **Human Anatomy and Physiology Society** (HAPS) was founded in 1989 to promote communication among teachers of human anatomy and physiology in colleges, universities, and related institutions. HAPS presents national and regional workshops and conferences where members can obtain information about the latest developments in the health and science fields. The annual HAPS meeting takes place in late May or early June. HAPS members receive the quarterly publication *HAPS-EDucator*. For membership information, see the HAPS website at www.hapsweb.org.

The **Association for Biology Laboratory Education** (ABLE) was founded in 1979 to promote information exchange between university and college educators actively concerned with teaching biology in a laboratory setting. ABLE meets annually (early June) in a workshop format that includes 3-hour hands-on laboratory experiences and shorter 1-hour demonstrations or discussions. The exercises are published in the conference proceedings that all members receive. For membership information, see ABLE online at www.zoo.utoronto.ca/able.

The **National Association of Biology Teachers** (NABT) started in 1938 to support teachers of biology at all grade levels. NABT meets annually in the autumn and sponsors professional development seminars and workshops during the summer. Members receive eight issues of *The American Biology Teacher* and five issues of *News and Views*. In addition, members receive discounts on NABT publications. Monographs of interest include *Teaching Critical Thinking Skills in Biology*, *Biology Labs That Work*, and *Favorite Labs*. Learn more about NABT at www.nabt.org.

The **Society for Integrative and Comparative Biology** (SICB; formerly American Society of Zoologists) is a multispecialty group with a Division of Comparative Physiology and Biochemistry. The goal of SICB is to foster advances and facilitate communication among life scientists working at all levels of biological organization, on all kinds of organisms, and with comparative as well as experimental approaches. The organization meets annually in early January. For membership information, visit their website at www.sicb.org.

TEACHING HIGHER THINKING SKILLS

One objective of many physiology courses is to teach students to use what is sometimes called "higher-level thinking." But what does that term mean? Originally it referred to the higher levels of "Bloom's taxonomy," a 1956 classification that divided cognition in six levels.[1] In 2001, a new team of learning scientists expanded and modified Bloom's scheme.[2]

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[1] Bloom, B.S. (ed.) *A taxonomy of educational objectives: The classification of educational goals, handbook I: Cognitive domain.* New York: McKay Publishers, 1956.

[2] Anderson, L.W., *et al.* (eds.) *A taxonomy for learning, teaching, and assessing.* New York: Longman, 2001.

The revised Bloom's taxonomy is now a table. The Knowledge Dimension recognizes four types of knowledge:

1. **Factual** facts, terms, vocabulary, details
2. **Conceptual** principles, theories, models, generalizations, categories: "the big picture"
3. **Procedural** how to do things: skills, research methods, algorithms
4. **Metacognitive** understanding how people in general learn and how you learn

Each type of knowledge has a range of cognitive levels associated with it. These levels of knowing and understanding are given below, ranked from lowest to highest:

1. **Remember** An ability to recognize or recall information. ("I know this material...")
2. **Understand** A deeper understanding of the information than simple memorization. Examples include the ability to classify items into similar groups, summarize information, explain a process, and give examples.
3. **Apply** An ability to solve or explain a problem by applying what the person has learned to the problem.
4. **Analyze** An ability to solve a problem by systematically examining facts, and looking for patterns and relationships.
5. **Evaluate** An ability to make a judgment based on some standard or criteria.
6. **Create** An ability to use original, creative thinking to create something.

One point that students often miss is that to use the higher level thinking skills, they must master the first two levels. In other words, they must have a memorized database of information upon which to act and they must really *understand* it, not just *know* it.

MAPPING STRATEGIES FOR PHYSIOLOGY

INTRODUCTION

Mapping is a nonlinear way of organizing material, similar to making flowcharts. Some instructors create maps to give to their students, but the real benefit of using maps occurs when students prepare the map themselves. Student-constructed maps force the students to organize the material themselves, look for similarities and differences, and question the relationships between terms. This active processing of information results in a "big picture" that is retained in long-term memory. Mapping requires students to think about the importance and relationship between items, tasks that are essential when trying to master analytical skills.

KEY ELEMENTS OF MAPS

A map has only two parts: the concepts and the linkages between them. A concept is an idea, event, or object. Concepts do not exist in isolation; they have associations to other relevant concepts. In this Instructor's Resource Manual and in the Student Workbook, we have provided some groups of words to be mapped. You will probably want to develop your own groups of words to fit the material you teach.

When you create a physiology map, think about three aspects: normal homeostatic control processes, response pathways to abnormal (pathophysiological) events, and anatomical structures where the processes are occurring. Each map drawn in physiology has one or more of these three focuses. Physiology maps are often more useful and informative if they include anatomical diagrams and graphs.

There are general types of associations between concepts: cause/effect, structure/function, and description/characteristic. Ask students to label the linking lines of their maps so that you can understand what they think the relationship is between linked terms. Some of the most important arrows on a map are those that connect laterally and over long distances, as these are the relationships that cannot be represented by a written outline or branching tree structure.

TEACHING STUDENTS TO MAP

Teaching students how to map is essential for student success. In the initial instruction, I describe the theory of maps and construct a very simple map. I then give the students a familiar topic such as "the cell" and ask them to make a map. If the students are beginning level, you may elect to give them a nonscience topic such as "the city." Give them 5–10 minutes to work on the map. I walk around and select several student maps for diversity, then ask the students to draw them on the chalkboard. By comparing several different maps, the class can see that 1) there is no "right" way to draw a map as long as the relationships are correct, and 2) maps are as individual as the people who construct them. If a map has errors in it, I ask the students how they would change the map. This removes the instructor from the role of "grader" and makes the process less threatening. Emphasize that maps made by an individual are more likely to be remembered than maps made by the instructor and memorized by the student.

Many students require follow-up instruction and encouragement before they become comfortable with mapping. With beginning level students, the instructor may provide lists of concepts to be mapped. I often do this as an active learning exercise in class, as I have found that the difficulties students have in rank-ordering concepts often reflect their confusion or misconceptions about the material. After a few weeks of mapping, the students gain confidence and can make their own lists. Since some students feel that they cannot construct good maps, we offer to look over their maps and make suggestions if they bring them to office hours. I also encourage students to take their maps to their study group and compare them. In this way, the students get positive reinforcement when they see the similarities between maps, and peer assistance for any errors or omissions.

Physiology lends itself to the construction of what I call "system maps." These are giant maps drawn on a piece of poster board and containing everything of importance about a physiological system, such as the cardiovascular system. I tell my students to put everything in their notes somewhere on the map. The system map then becomes a self-contained study guide. Students can see the physiology (and anatomy) of the entire system at a glance and gain an appreciation for the complexity of the relationships between parts and processes.

Students who use mapping consistently are enthusiastic about its usefulness in both science and liberal arts classes. Maps allow them to organize large volumes of material and see complex relationships. Students who use mapping feel that they understand the material better and retain the information longer. Often, system maps have become part of a student's permanent reference material.

The next page is a handout on mapping that you can copy for your students.

HOW TO MAKE A MAP (FOR STUDENTS)

The advantage of using maps as a study technique comes from the theory that each person has a unique mental organization of previously learned material. New learning occurs when you are able to attach new ideas to this preexisting framework. By organizing the material yourself, you question the relationships between terms, organize them into a hierarchical structure, and look for similarities and differences between items. Such interaction with the material ensures that you process it into long-term memory instead of simply memorizing it.

1. **Choose the concepts to map**. If you are trying to map a large number of terms, write each term on a separate small piece of paper or sticky note.
2. **Begin with the most general, important, or overriding concept.** It goes at the top of your map.
3. **Organize the remaining terms** into progressively more specific parts or follow the passage of time. The downward development of the map reflects a process or increasing levels of complexity.
4. **Think about the association between concepts.** Arrows will point the direction of the linkage, but you should also label the kind of linkage. You may label the line with linking

words or by the type of link, such as CE (cause or effect). Color is very effective on maps. You can use colors for different types of links or for different sections.

Try arranging the papers on a table and rearrange them until you are satisfied with your map. Even an experienced physiologist may draw a map several times before being satisfied that it is the best representation of the information.

5. **A good way to study with maps is to compare your map to those of classmates.** Don't panic when they look different ... they're supposed to! There is no "right" map for a group of concepts, only correct associations. By comparing maps you will see if you forgot a linkage or left out a term.

6. **Practice making maps**. The study questions in each chapter of your textbook will give you some ideas of what you should be mapping. You should always feel free to add additional terms or drawings to your maps.

REFERENCES ON MAPPING

Cliburn, J.W. Jr. "Concept maps to promote meaningful learning." *Journal of College Science Teaching.* (Feb 1990): 212–217.

Novak, J.D. *Learning, creating and using knowledge: Concept maps™ as facilitative tools in schools and corporations*. New Jersey: Lawrence Erlbaum Associates Publishers, 1998.

Small, P.A. Jr. "Consequences for medical education of problem-solving in science and medicine." *Journal of Medical Education 63* (1988): 848–853.

Silverthorn, D.U. "Teaching concept mapping." *Annals of the New York Academy of Sciences 701* (1993): 139–141.

Wallace, J.D., Mintzes, J.J., and Markham, K.M. "Concept mapping in college science teaching—what the research says." *Journal of College Science Teaching.* (Nov. 1992): 84–86.

Zeitz, H. and Pinto, A. "Concept mapping: A strategy for meaningful learning." *Basic Science Educator 4* (1994): 6–8 (Part 1) and 11–13 (part 2).

ACTIVE LEARNING IN THE PHYSIOLOGY CLASSROOM

Active learning is loosely defined as any activity in which a student engages other than listening to a lecture. Behaviors that characterize active learning include writing (other than lecture-based note-taking), reading, discussion, and problem solving. Students learn best when they use the higher-order thinking skills of analysis, synthesis, and evaluation. Active learning can take place in the classroom (including large lectures and tests), in the laboratory, and outside formal instructional settings when students work individually, in pairs, or in small groups. Some examples of active learning are listed below.

Lecture: Problem-solving, questioning, writing, debating, collaborating, demonstrations, role-playing, mapping exercises

Small group work in lecture: Problem-solving, student-to-student teaching

Individual/group studying: Mapping, student posters and projects

Tests: Problem-solving, creative thinking, writing, debating

Laboratories: Prediction of results; explanation of procedures; design, execution, and analysis of experiments

Active learning can be incorporated into all settings, even the large lecture class. I routinely use these techniques with my class of 200 students. All active learning takes time away from lecture, but I gain this time by making my students responsible for learning certain straightforward factual material *before* coming to class. (And I reinforce the importance of doing the work before class with an occasional pop quiz covering that information.) I do not lecture on the assigned material unless someone has a specific question about it, and I work on active learning exercises with the time saved.

One of the new innovations that has facilitated this teaching style is the **wireless personal response system**, which consists of handheld remote controls that allow students to record their choice of answer for a multiple-choice question onto the classroom's computer. (Think of audience voting on "Who Wants to Be a Millionaire?") The students and instructor get instant feedback and the software records the student responses, which can then be used for grading or attendance records.

For a paper describing use of the system, see Paschal, C. B. "Formative assessment in physiology teaching using a wireless classroom communication system," *Advances in Physiology Education 26* (Dec. 2002): 299–308.

To ensure that students read and think about material before class, I developed a workbook for my class in which they answer questions as they read (**guided note-taking**). Some of these questions can be found in the textbook as concept check questions and end-of-chapter questions. Others are found in the optional Student Workbook that accompanies this text. If you are interested in trying to save time in lecture so that you can incorporate problem-solving activities, you may wish to consider adopting the Student Workbook. Each chapter in the Workbook contains a section called "Teach Yourself the Basics" that consists of an outline of the chapter headings accompanied by factual questions about the material contained in each section. Students can use the outline for guided note-taking, answering the questions as they read through the chapter. In this way, they will come to class prepared to ask questions about material that was unclear when they tried to answer the questions.

In class, the simplest small-scale activity is interactive questioning between the instructor and student, or between student and student. The questions may be factual or may require higher-level thinking. Pathophysiology-based and open-ended questions are examples of the latter. Some formalized active learning techniques are described below.

1. **Begin lecture by soliciting student ideas about the day's topic.** Write them down and use them as the starting point. This technique is an excellent way to uncover student misconceptions, and you can use the student responses as a quick way to check attendance. In my large lecture class, I require students to bring 3×5 cards to each class for small in-class assignments, saving myself the chaos of 200 pieces of odd-sized paper torn from spiral notebooks.

2. **Questioning.** When you ask the class a question, you should pause for at least five seconds to allow students to think. Studies have shown that most instructors do not wait this long and often end up answering their own questions. Questioning can be done at different levels (factual recall, analysis, synthesis, evaluation). A questioning sequence that covers all levels follows:

   a. Recall factual information about a situation or example.
   b. Given this situation, what will happen if ...?
   c. Support your prediction of what will happen, using factual information.
   d. Are there alternate possibilities? What?
   e. If your prediction is correct, what will happen next?
   f. Based on the facts and your predictions, what are the possible consequences/sequelae?

   Walking students through this type of questioning sequence models problem solving for them. Often we expect our students to be able to solve problems, but we neglect to teach them the process.

3. **Student "debates" are an extension of questioning.** Ask the class as a whole: "Do you think A or B is more likely to occur/be the right answer?" Select one student supporting A and one student supporting B. Students defend their choices and critique the other student's choice. This method is less threatening to the students because the instructor acts as the moderator rather than the critic.

4. **Ungraded writing exercise followed by discussion.** This is a variation of questioning except that it actively involves all students rather than the one who answers a question aloud. Students are asked to write the answer to a question, either in their notes or on a 3×5 card that can be traded with a neighbor. Students are more likely to read another student's wrong answer aloud since they know that they will not receive the "blame" for it. This is another good technique for uncovering student misconceptions.

5. **Mini-problem solving.** If you expect students to solve problems on exams, it is essential that you give them practice with equivalent questions. Some ideas are below.
    a. Quick quantitative problems. Students pay more attention to the process if they do it themselves. Think about having students do the work when calculating GFR or cardiac output rather than working the problem for them.
    b. Pathophysiology as it reflects alterations to normal physiology. Case studies are a good example of this (see "Using Case Studies to Teach Physiology" on page 11).
    c. Research topics. Present the class with conflicting models for a physiological process and have them evaluate the models. Give them data from an experiment and ask them to interpret the results and integrate that information with what they already know about the physiology involved.
    d. Open-ended creative questions: "Design an alien to fit the habitat that has ...," "Design a cell to function as an osmoreceptor." Questions like this should be graded on whether the answer fits the model of physiology that the students have learned. Thus, incorrect but logical answers can be given as much credit as the correct answer.
6. **Guided lecture**. Class begins with a list of the objectives of the day, followed by a 20–30 minute lecture. Students *do not* take any notes, just listen. After the lecture, they spend the next five minutes writing down what they remember of the main concepts and supporting data. For the remainder of the class session, students form small groups to compare notes and collaborate on a group summary. Advantage: students think about the material while it is fresh. Disadvantage: not as much material can be covered as in a traditional lecture.
7. **Feedback lecture**. Students have a study guide that includes learning objectives, reading list, lecture outline, and self-paced tests. The instructor lectures for 20 minutes, then gives the class a discussion question related to the lecture. The students work in pairs to answer the question. The final 20 minutes of the class are used in a group discussion of the answers. Disadvantages: Requires a lot of preparation by the instructor. Cannot cover as much factual material.
8. **Pause technique**. Instructor lectures for 12–18 minute blocks. During two-minute pauses between lecture blocks, students work in pairs to compare notes. At the end of the class, students take the final 3 minutes to write down all the significant points they remember from the lecture. This technique is based on the research finding that student attention to lectures deteriorates after 15 minutes.
9. **Responsive lecture:** a class session dedicated to answering open-ended student questions pertinent to the class material. The questioner must explain the importance/relevance of the question. To avoid surprises, the instructor may prefer to have the questions submitted in advance. In one variation, all questions are asked at the beginning and the class ranks them so that the most important questions are answered first. This technique could also be done in discussion/tutorial or review sessions.
10. **Demonstrations** break up the lecture and keep student interest. Throughout this Instructor's Guide you will find suggestions for demonstrations to use in class.
11. **Role playing** requires careful thought and scripting. Students take the role of various physiological components and act out a process, such as sliding filaments in muscle contraction or the opening and closing of gates in a sodium channel. Often, making an abstract concept concrete through use of demonstrations or role-playing improves student understanding.
12. **Poster sessions** can be used to replace library research papers. (Students cannot cheat as easily because they must stand before classmates and talk about their subject.) Students select physiological or medical topics and research them in the literature. Each student or student group then prepares a poster on the subject to educate classmates on the topic. The poster should include good visual aids (graphs, diagrams), a two-page abstract, and a list of references. Posters are presented in "sessions." Each student is scheduled to present in one session and to evaluate assigned posters in the others. We use three 15-minute sessions for a group of about 30 students. The instructor also evaluates the posters. Students feel that they have an opportunity to master a subject and enjoy teaching it to their peers during their poster session.

We have found the following criteria to be helpful in evaluating posters:

a. Appearance: Is it too crowded? Neat and readable?
b. Content: Is the material well organized? Good scientific content? Did the author try to cover too much? Too little? Is everything well explained? Good use of visual aids?
c. Author: Was the author able to talk intelligently about the subject? Able to bring in information that is not on the poster? Able to answer questions about the poster?
d. Reviews: Organization, correct spelling and grammar, and content. Does the review show that the author has a good grasp of the subject and has done his/her homework on the subject?
e. References: correct citation of references according to instructions. Good selection of references. Balanced between scientific publications, books, articles, and websites, and must include recent references.

Student instructions for preparing a poster follow.

Physiology Poster Projects

The purpose of a library-research poster is to summarize concisely what is currently known about a selected topic. The poster is like a research paper in that it should have an introduction that gives a summary of background information, a middle portion with the detailed information on the topic, and a conclusion that states the "bottom line." This is very much like the old saying on how to give a good talk: "Tell them what you are going to tell them, tell them, then tell them what you have told them."

Posters differ from term papers in several ways. First of all, you will probably do just as much reading for a poster as you would for a written paper. However, you distill that information so that it can be summarized in a two-page review and on the poster. Posters can include lots of visual material such as graphs, photos, and diagrams. In addition, you will stand beside your poster during a 10- to 15-minute "poster session" to talk about the topic and answer questions for viewers.

Posters should be presented on poster board (minimum 22" × 28") or may use several small mat boards that fit into a 24" × 30" space as an alternative. The poster should be easily readable from a distance of several feet. Most lettering should be at least 3/8" high (typed abstract and references are an exception). The poster should have the following:

The **title** goes across the top. Your name should be on the front of the poster somewhere. The title should represent the contents of the poster. Informative titles that summarize the paper's main conclusion are preferred. *Example:* "Studying Physiology Raises Blood Pressure in Biology Students." Keep the title free of superfluous words.

The **review** is a short paper that summarizes the essence of the poster. It should have between 600–700 words or about two pages, typed, double-spaced. It should contain a summary of the major points and/or conclusions of the poster.

Book and journal/magazine **references** should be the basis of your posters, and you should turn in a reference list with citations in the requested format. You may also use websites, but these should not be the only source of information, and you must cite them in correct format. Your instructor will provide the format s/he wishes you to use.

One section of the poster should be an **introduction** and another section should be a **conclusion**. Other material may include **statistics**, **diagrams**, or **tables**. The poster should attract people's attention and should be informative without being overwhelming. It should not have too much small writing. Keep illustrative material simple. Show facts and/or statistics as figures or graphs, but make sure that they are well labeled and/or explained in words. If charts or diagrams are copied from a reference source, cite the reference under the diagram as (author's name, 19XX). The citation does not have to be in lettering as large or as dark as the informative lettering on the poster. Color images (copied, scanned, etc.) can really dress up the appearance of the material and improve its visual effectiveness.

Ten Tasks for Faculty in Classes That Use Active Learning

Written by Marilla Svinicki, Ph.D.
Director, University of Texas Center for Teaching Effectiveness

1. Identify the *real* objective of learning specific content, the objectives that go beyond memorizing, and use those as the basis for the learning (e.g., being able to assess any biases of an author's writing as opposed to simply knowing what a particular author said).
2. Be able to articulate the process skills that students should be learning (e.g., just what do we mean by "making a clear argument" and how does a student go about doing it?) [*In the sciences, these skills might include graph reading and interpretation, problem solving, application of basic physiology to clinical situations.*]
3. Be patient with students' struggling and missteps, and direct the feedback at the response rather than the ability of the students.
4. Be able to think on your feet so that you can turn any outcome into a learning opportunity.
5. Be willing to entertain alternate solution paths or explanations.
6. Step out of the center of attention and act as a facilitator of learning rather than a deliverer of content.
7. Have a very *deep* understanding of the particular content and of how a student might go about learning it so you can see where students have been and where they're headed.
8. Be willing to have less breadth of coverage in the interest of greater depth of understanding.
9. Alter the testing and evaluation procedures of the class to reflect what was learned in the active learning format.
10. Be able to accept when it doesn't work the first time, and keep on trying.

USING CASE STUDIES TO TEACH PHYSIOLOGY

Many physiology students are preparing for careers in the health professions, and one way to capture their interest is to show them how a thorough knowledge of physiology is essential for success in the clinics. But not all instructors have a clinical background themselves. One way to bridge the gap is with published clinical problems or case studies that come with detailed explanations.

A wonderful resource for case studies is the National Center for Case Study Teaching in Science (ublib.buffalo.edu/libraries/projects/cases/case.html) at the State University of New York at Buffalo. You can also find case studies on the Internet by doing a Google search (www.google.com) for *case studies physiology*.

The following books contain useful clinical problems. Sometimes, the more advanced problems may need to be simplified to match the depth in which you cover a particular topic, but this generally involves only a small amount of work.

Alexander, R.S. *Case studies in medical physiology.* Boston, MA: Little, Brown & Co., 1977.
Berne, R.M. and Levy, M.N. *Case studies in physiology*. St. Louis, MO: Mosby Year Book, 1993.
Blumenfeld, H. *Neuroscience casebook*. Stamford, CT: Appleton & Lange, 1997.
Freed, H.A. *Case studies in emergency medicine*. Boston, MA: Little, Brown & Co., 1991.
Haist, S.A, Robbins, J.B., and Gomella, L.G. *Internal medicine on call*. Stamford, CT: Appleton & Lange, 1996.
Johnson, S.M. *Case studies in neuroscience critical care nursing*. New York: Aspen Publishers, 1991.
Kowalski, J.T. and Totten, M.A.. *Case studies in primary care for nurses and nurse practitioners*. Baltimore, MD: Lippincott Williams & Wilkins, 1990.
Michael, J.A. and Rovick, A. *Problem solving in physiology*. Upper Saddle River, NJ: Prentice Hall, 1998.

Mims, B.C. *Case studies in critical care nursing*. Baltimore, MD: Lippincott Williams & Wilkins, 1990.
Mlynczak-Callahan, B. *Care studies in emergency nursing*. Baltimore, MD: Lippincott Williams & Wilkins, 1990.
Oelerich, R. *Case studies in anatomy & physiology*. St. Louis, MO: Mosby Year Book, 1992.
Raskova, J., *et al*. *Laboratory medicine case book: An introduction to clinical reasoning*. Stamford, CT: Appleton & Lange, 1996.
Sims, S.L. and Boland, D.L. *Pathophysiology case studies*. St. Louis, MO: Mosby Year Book, 1996.
Schwinghammer, T., *et al*. *Pharmacotherapy: A patient-focused approach*. Stamford, CT: Appleton & Lange, 1996.
Shapiro, B.A. *Case studies in critical care medicine*. St. Louis, MO: Year Book Medical Publishers, 1985.
Stoddard, F.J. *Case studies in obstetrics & gynecology*. Philadelphia, PA: Saunders, 1964.
Van Wynsberghe, D. and Cooley, G.M. *Case histories in human physiology*. New York: McGraw-Hill, 1999.
Welsh, M.D. and Clochesy, J.M. *Case studies in cardiovascular critical care nursing*. New York: Aspen Publishers, 1990.

In addition to the books referenced above, there is a series of paperback books called *Case studies in ... for the house officer* (Lippincott Williams & Wilkins). The books are written by a variety of authors, and the subjects include endocrinology, neurology, cardiology, psychiatry, and neurosurgery.

Other references that include case studies or useful background:

Cutler, P. *Problem solving in clinical medicine*. Baltimore, MD: Lippincott Williams & Wilkins, 1985. (Good background on problem solving plus case studies.)
Herreid, C.F. "Case studies in science—a novel method of science education." *Journal of College Science Teaching 23* (Feb. 1994): 221–229.
Hershman, J.M. *Management of endocrine disorders*. Philadelphia, PA: Lea & Febiger, 1980. (Case studies.)
Kassirer, J.P. and Kopelman, R.I. *Learning clinical reasoning*. Baltimore, MD: Lippincott Williams & Wilkins, 1991. (The first two chapters have useful background on problem-solving strategies and generation of hypotheses.)
Lawry, J.V. *Essential concepts of clinical physiology*. Sunderland, MA: Sinauer Associates, 1977. (Case studies.)

CREATING YOUR OWN CASE STUDIES AND PROBLEMS

Not all case studies need to be full-blown patient-oriented problems. If you are trying to have students apply what they have learned, you can create your own problems. Sources for information include physiology, pharmacology, and medical texts; newspaper and periodical articles; or medical and research journals.

PATHOPHYSIOLOGY AND PHARMACOLOGY

Many therapeutic interventions are being developed based on what we have learned about the physiology of particular systems, especially at the molecular level. Drugs that target enzymes, receptors, ion channels, transporters, and protein synthesis are among the most common. Make sure that the problem is explained using the same terms and at the same level that the students have been taught. If you introduce new terms, be sure to define them. *Examples*: Describe a disease. Ask students to explain how the pathophysiology and symptoms are related to the normal physiology. Explain the rationale for a treatment, based on the normal physiology. For example, why are calcium-channel blockers used for hypertension?

RESEARCH DATA

Research data from animal and human experiments may provide you with information to create problems. For graphing practice, extract the numerical data from which a graph was constructed, then have students reconstruct the graph.

GRAPHS

Graphs from textbooks or research papers can make interesting problems. Delete the axes and ask students to place the axis labels in the correct axis; this tests whether students understand the proper cause/effect relationship between two terms. Leave off the caption and ask the students to interpret the information presented by the graph. Or simply ask questions about how the graph relates to what they know of physiology. Good books for clear graphs include Ganong's *Review of medical physiology* (Appleton-Lange), Boron and Boulpaep's *Medical physiology* (Saunders), Guyton and Hall's *Textbook of medical physiology* (Saunders), Johnson's *Essential medical physiology* (Raven), and Berne & Levy's *Physiology* (Mosby).

ALIENS AND IMAGINARY DRUGS

Physiological processes can be made up from aliens and imaginary drugs. Be sure that students understand that they are not limited by the information they have learned about human physiology.

CLASS EXAMPLES

Here are some examples of questions I wrote for my class.

Quantitative problem based on imaginary data: You are working for a pharmaceutical company trying to develop a drug that will increase sodium excretion by the kidney. The long-term goal of this research is a new anti-hypertensive drug. You come up with a new compound 300ZX that enhances sodium excretion by acting on sodium transport mechanisms in the proximal tubule. In animal studies you find that 300ZX is freely filtered by the rat kidney. You administer 300ZX so that the rat has a constant plasma level of 0.2 mg 300ZX/mL of plasma. In 24 hours the rat has excreted 2.88 g of 300ZX. The GFR in this rat is measured as 1 mL/min. Can 300ZX be used to accurately estimate GFR? Show your work and defend your answer.

Physiology taken from an actual experiment: In experiment 1, a section of excised arteriole is placed in a perfusion chamber with saline. When the oxygen content of the saline perfusing (flowing through) the arteriole is reduced, the arteriole dilates. In experiment 2, an isolated section of arteriolar smooth muscle is stripped away from the other layers of the arteriole wall, then placed in saline. When the oxygen content of the saline is reduced as in the first experiment, the isolated smooth muscle shows no response. What do these two experiments suggest about how low oxygen exerts local control over arteriolar diameter?

Question derived from newspaper article: The following paragraph is a summary of a recent newspaper article:

> *A new treatment for atrial fibrillation due to an excessively rapid discharge rate at the SA node has been described. The treatment involves administering a high voltage electrical pulse to the AV node to completely scar it. A ventricular pacemaker is then implanted in the patient.*

Briefly and succinctly explain the physiological rationale behind this treatment. Be as complete and specific as you can.

WRITING CHALLENGING TEST QUESTIONS

The following types of test questions may help you be more creative in your test writing.

Trace questions ask students to trace a molecule or ion anatomically through a process or through a system. For simpler grading, do not allow students to write sentences. Have them use words connected by arrows (a map). *Example:* Trace a drop of blood from the right atrium to the big toe. Trace a water molecule from a capillary in the hand directly to the kidney and out through the urine.

Students often "know" material, but only at the level where they could recognize it when presented to them. **Draw** questions ask students to draw something from scratch, such as the anatomy of the heart or the transporting epithelium of the kidney, and tests whether they know all the structures and their relationships.

Using knowledge of word **roots**, students are asked to figure out the meaning of words they have not studied. *Example:* reticulocyte, hypernatremia, hemostasis, myopathy

List, outline, or explain questions are usually straightforward questions designed to see if students have learned the material. *Example:* List the role(s) of ATP in muscle contraction/relaxation. Outline the structure of a muscle down to the level of the proteins.

However, these questions may also be application questions if students have not been taught pharmacology or pathophysiology. *Example:* In one sentence each, explain the mechanism that makes each of the following an effective treatment for hypertension: beta-blockers, calcium channel blockers, and angiotensin-converting enzyme inhibitors.

Compare-and-contrast questions ask students to compare two or more items. The best way to answer these questions is to make a chart or numbered list. Making up and answering their own compare/contrast questions is an excellent way for students to study. *Example:* Compare and contrast covalent and ionic bonds, and anterior and posterior pituitary.

Compare-and-contrast questions seem to give students the most trouble on exams. Weaker students may merely list the properties of each item in random fashion without analyzing and comparing the items. Often students need to be taught how to answer these questions effectively. One way to approach answering this type of question is to use a matrix to compare common properties of the items. Students might name the property being compared in the leftmost column of the matrix; see the example below.

	Cars	Bicycles
Number of wheels	4	2 (4 for trainers)
Power source	gasoline combustion	muscular energy
Protection for driver	good to excellent	poor to fair

Interpret **graphs**, **charts**, and **diagrams** that students have not seen before but that are based on the physiology that students have studied. To find suitable graphs and charts, turn to other physiology textbooks written for the same level or for higher levels, or make up your own data based on "experiments" done on aliens. Examples of some "alien" questions can be found in the Student Workbook.

On **true** or **false** and **DEFEND your answer** questions, students get no points unless their defense is correct. Students may get partial credit if their answer shows that they understand the process involved in the question. *Example:* Are the following statements true or false? Explain.

Growth hormone is carried in the blood on a binding protein that lengthens its half-life.
Alveolar ventilation is more effective with panting than with normal breathing.
Patients with anemia exhibit an increased ventilation rate.

A good understanding of the steps of a **homeostasis** and the **pathways** that maintain homeostasis are key aims of this course. Students may be given the stimulus and asked to fill in the rest of the pathway.

Explain **true statements** that have not been discussed directly, but that are related to material covered in class. Students are asked to explain the statement based on the physiology that they have learned. These questions give students practice in critical thinking. *Example:* Aplastic anemia is a disease in which, from a variety of causes (not relevant), the bone marrow is suppressed and unable to produce blood cells. Erythropoietin was first isolated in large quantities from the urine of patients with aplastic anemia. Using what you know about homeostasis and homeostatic control loops, explain why patients with aplastic anemia were a good source for erythropoietin.

1 Introduction to Physiology

CHAPTER AT A GLANCE

TEACHING SUMMARY

This chapter introduces your students to key themes in physiology and physiological research. Emphasize to your students that learning basic patterns, themes, and the "big picture" will simplify learning the details of physiology. Here are some ideas for teaching this chapter:

- Throughout this text, the focus is on integration of physiological function. Look for links in the text and in the lecture outlines. These will key you into topics previously discussed that you may choose to integrate into a current lecture.
- If you are interested in comparative physiology, this is a good place to point out that humans are animals, with special physiological adaptations that allow us to survive in a terrestrial habitat.
- If you plan to emphasize problem-solving skills, talking about experimentation and experimental design at the beginning of a course shows students how important this skill is in real life.
- Almost all students have difficulty reading and constructing graphs. Teach them the basics in the first week of class.
- Many students lack the ability to handle large amounts of detailed information. Teaching them how to map and encouraging them to continue mapping throughout the class will provide them with a tool for organizing material.

WHAT'S NEW?

Expanded introduction to homeostasis
New sections:
  Physiology: Moving beyond the genome (describes "-*omes*" and "-*omics*")
  Searching and Reading the Scientific Literature
Translational research (lab bench to bedside)
Streamlined physiological themes to four
New figure on control systems

TEACHING OUTLINE

PHYSIOLOGICAL SYSTEMS

Figs. 1-1, 1-2; Table 1-1

Key words: physiology, anatomy, integration, levels of organization, cell, tissue, organ system, integumentary system, musculoskeletal system, digestive system, respiratory system, urinary system, reproductive system, immune system, nervous and endocrine systems

- With increasing complexity in design and organization comes increased integration.

First day activity: Begin the first day by asking students what they know rather than by telling them what they should know. Some topics to ask them about might include:

What is physiology? How is it different from anatomy?

Name the 10 physiological organ systems.

What are the characteristics of living organisms?

Which organ systems carry out which functions of life?

If your students have had chemistry and introductory biology and you do not plan to teach Chs. 2–4 to your class, ask them some review questions, such as:

Where does energy for life processes come from? How is energy stored in animals?

List the four primary tissues of the body, their characteristics, and some examples.

Draw a cell, add as many organelles as you can, and give their functions.

List the steps of protein synthesis, including as many details as you can.

- Physiologists are interested in everything from the molecular level to how physiological adaptations affect an organism’s ability to adapt to and survive in particular environments.

- Some students will separate muscular and skeletal systems. The question sometimes arises about whether the lymphatics are a system. They are an anatomical system, but physiologically, the lymphatics function as part of three systems: circulatory (returning excess fluid and escaped proteins from interstitial space to the plasma), digestive (transporting fats from the intestine to the circulation), and immune (lymph nodes contain clusters of immune cells).

FUNCTION AND PROCESS

Key words: function, teleological approach, mechanistic approach, processes/mechanisms

- Discuss teleological vs. mechanistic approaches to science and life. See “A survey of students’notions of body functions as teleologic or mechanistic,” by D.R. Richardson, *Advances in Physiology Education 10* (1990): S79–S80.

    1. Ask the students “Why does blood flow?” or “Why do we breathe?” Analyze responses and determine if they’re teleological or mechanistic.
    2. Have students ask one of these questions to nonscience friends outside of class. Compile a list of teleological and mechanistic responses.

- Be careful not to write test questions that begin with “Why…” when you expect the students to answer with a mechanistic answer. Instead, ask “Explain the mechanism that is the basis for blood flow.”