Introducing the HAPS Physiology Learning Outcomes

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Abstract

The Human Anatomy & Physiology Society (HAPS) has published a set of learning outcomes to be used for curriculum design of a one-semester introductory physiology course. The outcomes are competency-based and are mapped to core concepts and skills students should develop as undergraduates. This paper is an introduction to how the physiology learning outcomes are organized and how they can be used. https://doi.org/10.21692/haps.2023.010

Key words: learning objectives, core concepts, skills, competency-based education, physiology, curriculum design

Introduction

The mission of the Human Anatomy & Physiology Society (HAPS) is to promote excellence in teaching of anatomy and physiology, and, as part of that mission, HAPS members have been working for decades to create standardized guidelines for anatomy and physiology courses. The first set of learning outcomes (LOs) for combined two-semester anatomy and physiology courses was published in 1992, with major revisions in 2010 and 2019. In 2019, HAPS also published a set of LOs for the one-semester undergraduate anatomy class (Human Anatomy & Physiology Society 2019).

The final piece in the development of learning outcomes was to create a set of LOs for the one-semester undergraduate physiology course. Work on the physiology learning outcomes (PLOs) began with appointment of an expert panel in 2019, members of which are the authors of this paper. Completion of the PLOs was scheduled for 2020 but progress came to an abrupt halt with the onset of the COVID-19 pandemic. The panel persevered, however, and it is with great pleasure that we announce the publication of the physiology learning outcomes (Human Anatomy & Physiology Society 2019). The PLOs are published under a Creative Commons CC BY-NC-SA License [https://creativecommons.org/licenses/by-nc-sa/4.0/]. This license is described as "Attribution-NonCommercial-ShareAlike," and means that non-commercial users may adapt, edit, and add to the published PLOs by crediting HAPS and publishing their adaptation under the identical license.

This article explains the philosophy behind creation of the PLOs and includes some helpful hints on how to use the PLOs in your teaching. An abbreviated version of this article, "How to Use the HAPS Physiology Learning Outcomes (PLOs)," is available on the HAPS website (http://www.hapsweb.org) for download. A more detailed description of the development process is being prepared for later publication.

About the PLOs

The underlying philosophy of the PLOs is that we want students to develop a conceptual and long-lasting understanding of how the body works. One of the ways we did this when developing the PLOs was by focusing on core concepts. The core concepts of physiology (Michael et al.

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2017; Michael and McFarland 2020; Modell 2000) are ideas central to the discipline of physiology.

The learning outcomes in the PLO modules also use a competency-based approach, which means that students should be developing skills at the same time they are learning content. We created a list of basic skills we believe every undergraduate life science student needs to acquire, based on the core competency recommendations in the 2011 AAAS *Vision and Change* report as adapted and expanded by Clemmons et al. (2019; 2020). These skills are often synergistic with institutional guidelines and therefore may be helpful in curriculum assessment for accreditation. Individual PLOs are linked, when appropriate, to the six skills that best lend themselves to practice in a physiology course (Table 1).

Process of Science (PS)

PS-1 Draw conclusions based on inference and evidence-based reasoning.

PS-4 Formulate testable hypotheses, make predictions from data, and draw appropriate, evidence-based conclusions.

Quantitative Reasoning (QR)

QR-2 Select and use appropriate mathematical relationships to solve problems.

QR-5 Create and/or interpret graphs and other quantitative representations of physiological processes.

Modeling and Simulation of Physiological Processes, Systems and Diseases (MS)

MS-3 *Use* conceptual models (e.g., diagrams, concept maps, flow charts) and simulations to describe the important components of the model, summarize relationships, make predictions, and refine hypotheses about a physiological process, system, or disease.

MS-4 *Create and revise* conceptual models (e.g., diagrams, concept maps, flow charts) to propose how a physiological process or system works.

Table 1. *Skills mapped to physiology learning outcomes. The full list of skills is posted on the HAPS website:* https://www.hapsweb.org/page/Learning_Outcomes

The PLOs are an exhaustive list of topics that might be included in a one-semester introductory undergraduate physiology course. The PLOs are much more comprehensive and detailed than any student can learn in one term or semester, so instructors using them will need to select the topics and outcomes that are appropriate for their course and their students.

The expert panel followed the accepted principles for writing good learning objectives as laid out by Orr et al. (2022a; 2022b). We have been cognizant of writing learning outcomes that require more than rote memorization and that incorporate higher level Bloom's taxonomy skills (Crowe et al. 2008; Dirks et al. 2014). The PLOs with higher level skills can usually be recognized by verbs such as "compare and contrast" or "predict." Most of the modules end with a section on application of the concepts from the preceding sections.

In deciding what terms to include in a PLO statement, we would often research the current undergraduate human physiology textbooks (for example, Fox and Rompolski 2018; Sherwood 2015; Silverthorn 2019; Widmaier et al. 2018) to see what level of detail is included. Some instructors using the PLOs may be teaching combined anatomy and physiology, and those instructors might want to provide more anatomical detail than is given in the PLOs.

How to use the core concepts

In the last forty years scientific discoveries have grown exponentially, and it is no longer possible for an instructor to cover all of what we know in an introductory survey course, whether it be physiology or general biology. One way to simplify the content of a course is to use the core concepts as the organizing structure.

- First, look at the core concepts in module CC (Core Concepts in Physiology) and decide what big ideas you want to emphasize.
- Ask yourself which concepts you want your students to be able to explain 5 years down the road.
- Then ask: "How can I use those concepts to guide the content for the semester?"
- Choose a few examples of PLOs that reinforce each chosen core concept and emphasize those.

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Students should be introduced to the major core concepts at the start of the course and alerted to the fact that these concepts will appear repeatedly throughout the course. Many of the detailed PLOs presented in Modules CC, A, and B can be introduced as needed at any point in the semester, when related content occurs for the first time.

For example, consider core concept *CC.3.3: Predict how changes in a gradient will affect flow*. There are multiple PLOs across the physiological systems (modules) that map to this core concept, including:

- G.7.5 *Diagram or describe how blood pressure (BP) changes as blood flows from the aorta to the venae cavae*.
- I.2.7 *Graph or describe the change in intrapleural pressure, alveolar pressure, airflow, and lung volume during a normal quiet breathing cycle,* identifying the onset of inspiration, cessation of inspiration, onset of expiration, cessation of expiration, and the timepoints where atmospheric pressure is equal to alveolar pressure.
- J.3.13 *Predict the effect of changes in the resistance of the afferent or efferent arteriole on renal blood flow and glomerular filtration rate (GFR).*

Each module begins with a table showing which core concepts are related to the module. Individual PLOs are mapped to those core concept(s) when relevant. Users can search for PLOs related to each core concept by using the final index document that shows all PLOs that mapped to a concept.

It is important to remember that you will need to be explicit about the core concepts and to point out the examples of core concepts in action each time they occur. Patterns that are obvious to experts often elude novices. By the end of a course, students should be familiar enough with the core concepts that they will recognize them when they encounter them in their later studies. Ultimately, a student may not remember a specific example, but we hope they will remember the core concept.

What is the value of using LOs to help guide your teaching?

The use of learning outcomes (LOs) in higher education has gained traction in the past 15-20 years, and Orr et al. (2022b) have reviewed the evidence supporting writing instructional learning objectives. Using LOs for teaching has an abundance of benefits for both faculty and students. For the instructor, the LOs provide a framework for the design of a course from the chapter level to the unit level and ultimately to the entire course level. Once instructors create a list of LOs, they can then align assessments, both formative and summative, to the LOs (Jalloh et al. 2020). Carefully constructing LOs with action verbs for measurable outcomes makes the creation of assessments follow logically. For students, being provided with LOs and instructed how to use them can increase their confidence and success (Osueke et al. 2019; Thanprasertsuk et al. 2021).

Applying the physiology learning outcomes (PLOs) to your teaching should help inform the organization and rigor of your course as well as reduce your workload. Suggested steps for utilizing the PLOs effectively are based on the principle of backward design (Bowen 2017):

- Select the PLOs you wish to cover in your course, knowing that it will not be suitable to cover all of the PLOs.
- Decide the level of detail that is appropriate for your student population and include the terminology you want students to know in your course version of the PLOs.
- Generate assessments, both formative and summative, that align with each PLO.
- Generate and/or curate teaching resources specific to each PLO.
- Clearly communicate the PLOs and how to use them to students.
- Gather and evaluate the results of the assessments and adjust the instructional strategy if needed.

In subsequent sections of this paper, you will learn more about how to use the PLOs.

Organization of the PLOs

The physiology learning outcomes, like the A&P and anatomy learning outcomes, are organized into modules, but the topics and lettering schemes are different (Table 2).

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Physiology LO Modules	A&P LO Modules	Anatomy LO Modules
Skills summary EC: Entering competencies CC: Core concepts in physiology A: Cell physiology & membrane processes B: Cell-cell communication & control systems C: Endocrine physiology D: Cellular neurophysiology E: Systems neurophysiology F: Muscle physiology G: Cardiovascular physiology H: Blood I: Respiratory physiology J: Renal physiology K: Fluid-electrolyte & acid-base homeostasis L: Digestive physiology M: Metabolism & its control N: Reproductive physiology O: Immune system P: Integrated functions & special environments	A: Body plan & organization B: Homeostasis C: Chemistry & cell biology D: Histology E: Integumentary system F: Skeletal system & articulations G: Muscular system H: Nervous system I: General & special senses J: Endocrine system K: Cardiovascular system L: Lymphatic system & immunity M: Respiratory System N: Digestive system O: Nutrients & metabolism P: Urinary system Q: Fluid/electrolytes & acid-base balance R: Reproductive system S: Introduction to heredity T: Embryology	A: Body plan & organization C: Chemistry & cell biology D: Histology E: Integumentary system F: Skeletal system & articulations G: Muscular system H: Nervous system I: General & special senses J: Endocrine system K: Cardiovascular system L: Lymphatic system & immunity M: Respiratory system N: Digestive system P: Urinary system R: Reproductive system T: Embryology

Table 2. *Comparison of HAPS physiology, anatomy and A&P learning outcomes organization (See:* https://www.hapsweb.org/page/Learning_Outcomes*)*

The PLOs are organized into 19 modules.

- The first module (Skills summary) lists the skills that students should be acquiring during their undergraduate studies. We identified six skills that lend themselves to practice in a physiology course (Table 1), and individual PLOs are mapped to these skills if appropriate.
- The second module (EC) contains the entering competencies that we hope students have acquired prior to beginning their physiology course. For some student populations that lack pre-requisite courses, it may be necessary to teach or review some introductory biology or general chemistry concepts at the beginning of the physiology course.
- The third module (CC) focuses on the core concepts of physiology, those fundamental themes that appear repeatedly in different body systems. Each subsequent module begins with a table showing which core concepts from the CC list are related to that module. In addition, individual PLOs are mapped to the underlying core concept(s) when relevant.
- The next 15 modules (A-O) cover the organ systems or related concepts such as metabolism, cell physiology, and communication mechanisms. The final module (P) includes integrated functions and physiology of special environments.

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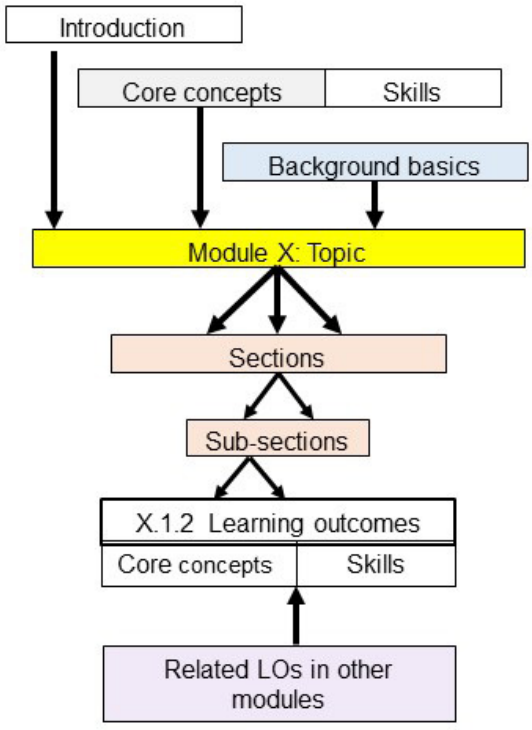
For a graphical overview of module organization, please see the infographic in Figure 1. Each module contains the following sections:

Introduction

- Introduction to the module: This section has a brief overview of the module that explains what is and is not included. Terminology notes are also included here.
- Core concepts from Module CC, with the annotation "Students need to understand and be able to apply these core concepts in order to be successful in this module."
- Skills: a key to the skills that can be practiced with the PLOs in the module, with PLOs matched to the appropriate skills.

A.



B.

PLO X: Module topic

Introduction to the module *This section contains a brief overview of the module content plus notes on other modules with related content and specialized terminology.*

Core Concepts from Module CC: Students need to understand and be able to apply these core concepts in order to be successful in this module.
CC-1 Structure-Function Relationships (CC.1.8, CC.1.9, CC.1.12, CC.1.24)

SKILLS addressed in this module:
Quantitative Reasoning (QR) (D.2.8, D.2.9)
Modeling and Simulation of Physiological Processes, Systems and Diseases (MS) (D.1.1, D.1.2)

PLO D Cellular neurophysiology			
At the end of an introductory one-semester physiology course, a student should be able to do the following:		**Core Concepts**	**Skills**
D-1 Neurons, Glial Cells and Neurotransmitters			
D.1.1	Diagram or describe the major structures of a typical neuron.	CC.1.8, CC.1.9	MS-4
D.1.2	Compare and contrast the functional types of neurons with respect to their structure, location, and function.	CC.5.1	MS-1
	Glial cells		
D.1.3	List and describe the six types of glial cells, their structure, major functions, and locations.	CC.1.3, CC.1.9	
	Neurotransmitters		

Background Basics from other modules: Students need to understand and be able to apply these concepts in order to be successful in this module.
Entering competencies
EC-1 Atoms and molecules (EC 1.4)
Module A Cell Physiology & Membrane Processes
A-2 Movement of materials across cell membranes (A.2.7)

Related LOs covered in other modules. *These are LOs that instructors might expect to see in this module but that are covered elsewhere.*
F-3: Skeletal muscle excitation-contraction coupling
G-3: Cell physiology of cardiac muscle contraction

Figure 1. *Infographic showing the elements and organization of each module. (A) A map showing the elements that can be found in each module. (B) An abbreviated module showing how the different elements appear within the module.*

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Learning Outcomes for the Module

The physiology learning outcomes (PLOs) are organized into numbered sections, with the number preceded by the module letter. For example: Module A contains section A-2 Movement across membranes. PLOs within that section are numbered sequentially: A.2.1, A.2.2, A.2.3, etc. Sub-sections are indicated with colored headers and continue the section numbering sequence.

- Advanced learning outcomes are indicated with an asterisk, as in D.1.12*.
  - Advanced PLOs address higher level skills or additional detail that may appear in some physiology texts but that may not be appropriate for all introductory physiology classes.
- The two right-hand columns of the table indicate core concepts and skills related to specific learning outcomes.

Background Basics and Related PLOs

- Background Basics from other modules: These are lists of content that students should have mastered before attempting this module.
- Related PLOs covered in other modules. These are learning outcomes that instructors might expect to see in this module but that are covered elsewhere. For example, PLOs about blood types are in Module H *Blood*, where most physiology courses teach them, rather than in Module O *Immune System*. Each topic appears only once in the learning outcomes.

Terminology

The expert panel recognizes that there is considerable variability in the level of detail taught in introductory physiology courses. Our solution is to create broad learning outcomes, such as *K.1.2 Label the structures in a cross-sectional diagram of a kidney*, using a parenthetical (e.g., ...) to provide examples of some of the structures that an instructor might want students to label. The list of terms following an *e.g.,* is not all-inclusive, and the PLOs are not trying to be prescriptive about what should be taught. The decision about which details to teach is up to individual instructors so that they can adapt PLOs to fit their student populations.

Terminology conventions in this document

- (e.g., ...) in a PLO means *for example, ...*
- (i.e., ...) means *in other words, ...*
- When multiple terms can be used to refer to a single physiological process or anatomical structure, common alternatives are included in parentheses after our preferred term.
- We attempted to replace eponyms and use anatomical terminology as given in the *Terminologia Anatomica* 2e (FIPAT 2019), but we recognize that certain terms are entrenched in the clinical literature and used daily in healthcare. The PLOs use the preferred physiological term, followed by historical alternative terms in parentheses.
- *Draw* and *diagram* are considered to mean the same thing: a graphical representation that may be literal or abstract, such as a concept map. We chose to use *Diagram* as our preferred term in these outcomes.
- Numerous PLOs begin with the words "*Diagram or describe*." For these PLOs, the preferred student action is to draw or map a visual representation of the concept, but for students who have difficulty creating visual representations, the alternative action is to use words to describe the topic.

Inclusive language

The expert panel has been cognizant of trying to use inclusive language whenever possible. We have questioned whether the word "normal" in a PLO can be replaced with an alternative such as "healthy" or "typical," to avoid the implication that if something is not normal, it must be abnormal.

Sex and gender

The HAPS Physiology LOs address biological aspects of sex and reproductive physiology in Module N, and we attempt to use a broader, more accurate, and inclusive approach to teaching this topic. All students should be aware of the biological variability that can occur during development and that creates diversity in human physiology and anatomy. We recognize that because of time constraints, most one-semester introductory physiology courses do not have time to go into the complex biopsychosocial topic of gender, but we feel that our students should be able to distinguish between sex and gender, and we have included one learning outcome (N.1.1) that asks students to do this.

Summary

The PLO expert panel (the authors of this paper) hope that you find the physiology learning outcomes and associated documents useful. Instructors who were looking for a short list of topics that are essential for a one-semester course will be disappointed by the extensive nature of the modules. However, our goal was to represent the broad range of topics encompassed in physiology courses taught to varied student populations (Wehrwein et al. 2020). The closest we can come to providing a single list is Module CC, the core concepts of physiology. These are the "big ideas" of physiology that should be included in every physiology course, no matter which organ systems are taught.

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We close with a short list of reminders for adopters of the PLOs.

- The entire PLO document is far more comprehensive and detailed than any student can learn in one term or semester. Instructors need to select the topics and outcomes that are appropriate for their course and their students.
- Users will need to decide the terminology appropriate for their students and edit the PLOs accordingly.
- Instructor-users should share their chosen and edited PLOs with their students to help guide student study.
- All assessments in the class and class activities should align with the chosen PLOs.

Documents such as the PLO are works-in-progress and subject to periodic revision. We welcome your feedback and suggestions.

About the Authors

The authors of this paper are members of the expert panel that wrote the HAPS PLOs. The panel was assembled from respondents to a HAPS call for volunteers in summer 2019. Members were selected to represent the broad range of institutions found in the HAPS membership. Patrick Cafferty, PhD, is Director of Undergraduate Studies and an associate teaching professor in the Department of Biology at Emory University in Atlanta, Georgia where he teaches courses in introductory biology, human physiology, and developmental neurobiology. He also serves as Southern Regional Director (2021-2023) for the Human Anatomy and Physiology Society (HAPS). Janet Casagrand, PhD, is an associate teaching professor in the Integrative Physiology Department at the University of Colorado Boulder, where she teaches human physiology, physiology lab, endocrinology and neurophysiology. She is also the Anatomy and Physiology Exam Program Lead for HAPS. Elizabeth Co, PhD, is a senior lecturer at Boston University, where she teaches Human Anatomy, Human Physiology, and the Physiology of Sex and Reproduction. She is the author of *Anatomy & Physiology* 1/e (Cengage). Meg Flemming, MS, Vet Phys. is a professor in the Biology Department at Austin Community College where she has been teaching anatomy and physiology for 22 years. Meg has contributed to the teaching ancillaries for Silverthorn's *Human Physiology: An Integrated Approach*, 2013 and 2016. She has been a member of HAPS since 2010. Jenny McFarland, PhD, is emeritus faculty and former department chair of the Biology Department at Edmonds College where she taught human anatomy & physiology and introductory biology courses for more than 20 years. Her research in biology education focuses on core concepts for undergraduate physiology. Valerie O'Loughlin, PhD, is a professor of anatomy, cell biology & physiology at Indiana University School of Medicine - Bloomington, where she teaches human anatomy to undergraduates, gross anatomy to medical students, and health sciences pedagogy to graduate students. She is the HAPS Anatomy Exam Program Lead and a HAPS president emeritus. She is co-author of *Human Anatomy 6e* (McGraw Hill Education) as well as co-author of *Human Anatomy & Physiology: An Integrated Approach* (McGraw Hill Education). Derek Scott, PhD, holds the Chair of Physiology & Pharmacology Education at the University of Aberdeen, UK. He teaches physiology to a variety of science and healthcare students at undergraduate and postgraduate levels. Derek was previously the Education & Teaching Theme Lead for the UK Physiological Society. Dee Silverthorn, PhD, is a Distinguished Teaching Professor of Physiology emerita at the University of Texas at Austin, where she taught physiology to students ranging from non-science majors to medical students for more than 30 years. She is the HAPS Physiology Exam Program Lead and a HAPS president emeritus. She is also the author of *Human Physiology: An Integrated Approach 8/e* (Pearson). Nanette J. Tomicek, PhD, is Director of Anatomy and Physiology Courses and an assistant professor in the College of Life Sciences at Thomas Jefferson University in Philadelphia. She co-authors *Physiology Laboratory Manual. 5/e (Macmillan Learning)* and teaches introductory anatomy and physiology, human physiology, and the biology of sex. She also serves as Eastern Regional Director (2020-2024) for HAPS.

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