# Creating the HAPS Physiology Learning Outcomes: terminology, eponyms, inclusive language, core concepts, and skills

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**Abstract:** Learning outcomes are an essential element in curriculum development because they describe what students should be able to do by the end of a course or program, and they provide a roadmap for designing assessments. This paper describes the development of competency-based learning outcomes for a one-semester undergraduate introductory human physiology course. Key elements in the development process included decisions about terminology, eponyms, use of the word "normal" and similar considerations for inclusivity. The outcomes are keyed to related physiology core concepts and to process skills that can be taught along with the content. The learning outcomes have been published under a Creative Commons license by the Human Anatomy and Physiology Society (HAPS) and are available free of charge on the HAPS website.

**New and Noteworthy:** This paper describes the development of competency-based learning outcomes for introductory undergraduate human physiology courses that were published and made available free of charge by the Human Anatomy & Physiology Society (HAPS). These learning outcomes can be edited and are keyed to physiology core concepts and to process skills that can be taught along with the content.

## INTRODUCTION

The teaching of physiology in higher education and professional schools in the United States has been changing rapidly in recent years, even before the chaos created by the onset of the SARS-CoV2 pandemic in 2020. Physiology content has been truncated in many medical schools as curriculum design shifts away from discipline-based courses to integrated curricula that mix basic science with clinical topics (1-4). Established medical schools now have fewer traditional physiology departments than in 1980, having replaced them with interdisciplinary departments (5), while newly created medical schools are eschewing traditional basic science departments in favor of departments of medical education with education-focused instructors or departments of biomedical sciences organized around cellular and molecular biology research groups rather than systems-based physiology (6). At the same time, there has been growing interest in physiology at the undergraduate (baccalaureate) level, with an increasing number of U.S. institutions creating majors, concentrations, and even programs in human physiology to meet the demands of students seeking careers in the health professions (7, 8). The result has been the formation of an organization dedicated to communication among undergraduate physiology programs, the Physiology Majors Interest Group (P-MIG; 9), and an increased focus on developing program standards and curricular guidelines for undergraduate physiology education (10, 11).

One of the critical elements in curriculum design is the creation of clearly defined, assessable learning outcomes (LOs) that students should achieve by the end of a course or program (12, 13). Learning outcomes are an established mechanism for creating transparency between educators and their students about the goals of an academic course. They are most valuable to students and instructors when written clearly, concisely and consistently (14).

Learning outcomes generated by professional societies can help unify a field and remove the burden from instructors to generate their own.

Until recently, there were only two published sets of learning outcomes for physiologists: medical physiology learning objectives created in 2000 and revised in 2012 by the American Physiological Society (APS) and the Association of Chairs of Departments of Physiology (ACDP) (15, 16), and learning outcomes for two-semester undergraduate combined anatomy and physiology (A&P) courses created between 2010 and 2019 by members of the Human Anatomy and Physiology Society (HAPS) (17). Neither set of learning outcomes is appropriate for undergraduate physiology courses and programs, as the former focuses on medical-level objectives and the latter includes numerous anatomical learning objectives that would not typically be covered in a stand-alone undergraduate physiology course.

In 2019, a small group of HAPS members (the authors of this paper) were selected for a expert panel to begin work on a new set of physiology learning outcomes (PLOs) designed for a one-semester undergraduate introductory human physiology course (selection process discussed later). The panel started with the APS-ACDP and HAPS A&P documents and through multiple rounds of streamlining, eliminating, writing, and editing created a collection of resources (17). The PLOs have several unique features, including mapping individual learning outcomes to core concepts of physiology and to skills that students should be acquiring along with content knowledge. This paper describes the process and rationale for the creation of the HAPS Physiology Learning Outcomes, which we hope will provide guidelines and suggestions for others as they develop their own learning outcomes.

## The role of HAPS in curriculum development

HAPS, the Human Anatomy and Physiology Society (*www.hapsweb.org*), started as a grassroots organization in 1987 in response to a perceived need for professional development opportunities for educators teaching anatomy and physiology, especially in community colleges and 2-year colleges. By 1992 HAPS had become an incorporated non-profit society whose goal is to "enhance the quality of human anatomy and physiology instruction at colleges, universities, and related institutions" (*https://www.hapsweb.org/page/AboutHaps*). The early HAPS Core Curriculum Committee developed *Learning Goals for Students in Human Anatomy and Physiology* and *Course Guidelines for Undergraduate Instruction of Human Anatomy and Physiology* (18, 19) to create a roadmap for instructors and institutions planning a high-quality two-semester combined anatomy and physiology course. By 2010 the original course guidelines had evolved into a set of *HAPS Anatomy & Physiology Learning Outcomes* (17). In 2018 a HAPS panel of anatomy experts developed a new set of learning outcomes for a one-semester undergraduate introductory human anatomy course, and a panel of A&P experts revised the A&P learning outcomes to reflect current best practices for writing LOs. In 2019, both the HAPS Human Anatomy Learning Outcomes and the revised HAPS A&P Learning Outcomes were finalized and published on the society's website (free to HAPS members). Both sets of learning outcomes form the basis of questions for two validated standardized national exams offered by HAPS, one for A&P and one for anatomy (20, 21).

The third arm in the HAPS curriculum support plan was to create learning outcomes for a one-semester undergraduate introductory human physiology course, with the eventual intent to develop a standardized exam for human physiology, similar to the HAPS exams for A&P and human anatomy. Following the development pattern for the A&P and human anatomy learning outcomes, volunteers were recruited from the HAPS membership to form an expert panel for the creation of physiology learning outcomes (PLOs). The final set of PLOs and associated documents was published on the HAPS website in early 2023 (17) and the files are available to anyone for download and re-use under a Creative Commons CC BY-NC-SA License. This license allows non-commercial users to adapt the learning outcomes as long as they credit HAPS and publish under the same license. An introduction to the PLOs with notes for how to use them was published in Spring 2023 (22).

In the subsequent sections of this paper we describe the process of creating the physiology learning outcomes: how we started, the rationale for the organization of the PLOs, and decisions we made about language as we worked through the iterations.

## THE HAPS PHYSIOLOGY EXPERT PANEL

In July 2019 the HAPS Exam Program Leads (authors DUS and VO) sent out a call for volunteers to the HAPS membership to apply for selection to a HAPS physiology expert panel that would begin work on developing the physiology learning outcomes. We received 35 completed applications, then faced the difficult task of selecting only 8 for the panel. We were looking for participants with expertise in physiology content and physiology teaching, as well as attention to detail. We selected as diverse a group as possible from the pool, with a mix of career levels (new assistant professors to full professors), institutions (community colleges to professional schools), and geographic locations (Pacific Northwest to Scotland, which created a challenge for in-person and Zoom meetings). Volunteers who were not selected were invited to become a part of a Physiology Learning Outcomes Advisory Board.

We started the physiology expert panel with ten members but one volunteer withdrew early on. Only two panel members (DUS, VO) had prior experience with developing HAPS learning outcomes and writing questions for the HAPS combined A&P exam. One member (VO) is an anatomist and used her non-physiologist perspective to question the clarity and intent of the LOs created. The remaining panel members teach a variety of courses including combined A&P, introductory biology, and different levels of introductory and advanced physiology. The panel includes three physiology or A&P textbook authors, one member of the original physiology core concepts team, and multiple members with substantial physiology curriculum development and/or bench research credentials.

The panel first convened in September 2019 using email and a shared Google Drive as our primary means of communication. We worked remotely until January 2020, when we had a 2.5 day in-person gathering. The panel was making rapid progress on refining the learning outcomes, and we planned to complete our work in another in-person session just before the May 2020 HAPS annual conference. However our plans derailed in March 2020 with the onset of the SARS-CoV2 pandemic. Panel members needed to focus on shifting to remote teaching and personal concerns, so work on the PLOs paused until September 2020. From then until publication of the completed document in early 2023, we primarily worked virtually. An in-person gathering scheduled for January 2022 was canceled because of COVID concerns, and our final in-person meeting in July 2022 was missing three panelists because of illness and personal concerns (although one was able to participate remotely for some key discussions). A near-final draft of the learning outcomes was reviewed by the diverse 13-member Advisory Board in November 2023, and the final PLOs were published in March 2023. In total, the development process stretched out over more than three years, with the delay due primarily to the SARS-CoV2 pandemic (Table 1).

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**Table 1: Physiology learning outcomes development timeline** LO = learning outcome or learning objective

| | | |
|---|---|---|
| July 2019 | HAPS Exam Program Leads *Call for Applications* sent to HAPS members. | |
| August 2019 | Applicants sorted into 2 groups. | A. Physiology Expert Panel (working group)<br>B. Advisory Board (reviewers) |
| September-December 2019 | Rounds 1 & 2. Panel met virtually/worked asynchronously to review and triage the 2012 APS-ACDP Medical Physiology LOs (16) and 2019 HAPS combined A&P LOs (17) and generate a new set of physiology learning outcomes. | |
| January 2020 | Panel met in person to establish LO template, establish a consistent voice, and generate foundational documents (Skills, Entering Competencies, Core Competencies). | |
| March 2020 | SARS-CoV2 pandemic disrupted higher education and diverted the panel's attention as they were forced to transition to remote instruction. | |
| February 2020- August 2022 | Rounds 3-6. Panel authored and revised LOs using a combination of asynchronous editing, synchronous editing via web conference, and one in-person gathering (July 2022). | |
| November 2022 | Round 7. Draft was sent to Advisory Board for peer-review. | |
| January 2023 | Round 8. Expert Panel incorporated Advisory Board edits into final draft. | |
| February 2023 | Round 9. Expert Panel mapped LOs to Core Competencies and Skills documents. | |
| March 2023 | Physiology LOs published to HAPS website under Creative Commons License. | |

There has been debate over whether virtual collaborations over Zoom can be effective, and authors of a 2022 *Nature* article concluded that there was greater creativity during in-person meetings (23). We found that our two in-person meetings were more productive and facilitated brain-storming and consensus building better than time-limited Zoom gatherings, but the virtual meetings were also effective. We were fortunate to have had the January 2020 in-person meeting at the start of the project as it allowed the diverse group, living together in a rental house, to get to know each other on a personal level and to establish a level of trust and collaborative spirit that facilitated the later virtual discussions.

## PLO DEVELOPMENT PROCESS

This section describes the process by which the HAPS physiology expert panel created the published physiology learning outcomes. The timeline for development of the PLOs is shown in Table 1 and summarized below. We worked using shared Google drive documents and spreadsheets hosted by HAPS, and in total we went through nine rounds of revision.

### Goals and Assumptions

The goal of the PLO project was to create a comprehensive list of learning outcomes appropriate for a one-semester undergraduate introductory human physiology course, using a competency-based approach (24) that includes promoting skills and creating conceptual understanding of physiology using core concepts. Defining our target audience was the first challenge the panel faced, given the wide variability of student populations, institution types, and course and career goals of one-semester physiology courses across the United States. We concluded that our target population in a typical one-semester undergraduate introductory physiology course was pre-health professions students, especially those applying to professional programs that require eight credit hours of human anatomy and physiology with laboratory for admission (for example, physical therapy, physician assistant/associate, optometry, nursing). Secondary populations include students majoring in exercise physiology/kinesiology, biology, anthropology, neuroscience, psychology, biochemistry, and engineering.

**Topics**

The next decision for the physiology expert panel was to establish the topics to be included. We settled on 18 topics, starting with the ten traditional physiological systems. We divided neurophysiology into cellular neurophysiology and systems neurophysiology, and we separated blood from the cardiovascular system. We chose four integrated topics: cell physiology and membrane processes; cell-cell communication and control systems; fluid-electrolyte and acid-base balance; and integrated functions and special environments. Three topics introduce the collection: entering competencies (prerequisite knowledge), skills, and physiology core concepts, all discussed below.

Each topic was put into a separate *module*, the terminology used in the HAPS A&P and Anatomy Learning Outcomes (17). A module consists of the list of learning outcomes plus introductory and explanatory sections. The format of the modules is discussed in detail in the Development Process section below.

**Prerequisite Knowledge**

The third challenge the panel faced was to find a solution to the problem that student background and course prerequisites at various institutions range from little background and few or no prerequisite courses to foundational knowledge and prerequisite courses in introductory biology and chemistry. We decided to write our learning outcomes with the assumption that students would enter introductory physiology with one semester of general chemistry and at least one semester of introductory biology. We then created a document of "Entering Competencies" that lists 57 concepts across ten topic areas that we assumed students had learned prior to starting physiology (Table 2).

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**Table 2: Ten prerequisite knowledge topics for introductory physiology.** For the detailed list of Entering Competencies, see (17).

| |
|---|
| 1. Atoms and molecules |
| 2. Biological energy |
| 3. Chemical bonds and reactions |
| 4. Organic compounds |
| 5. Biological reactions |
| 6. Solutions and solubility |
| 7. General organization of a cell |
| 8. Cellular membrane structure and function |
| 9. Genes, genomes, and gene expression |
| 10. Cellular respiration (introduction) |

We recognized that at some institutions students may never have learned these concepts or may not remember them, so the introduction to the Entering Competencies document notes that instructors in physiology classes with no prerequisite courses may need to teach some of these concepts at the beginning of their course.

**Skills**

Competency-based teaching promotes skills and behaviors in addition to content knowledge (24). The panel adapted core competency recommendations first presented in the 2011 *Vision and Change in Undergraduate Education*: *A Call to Action* report (25) and elaborated upon by Clemmons et al. (26, 27). Our final list contains skills in 7 broad domains that instructors should consider reinforcing in their undergraduate physiology courses (Table 2). These skills overlap, in part, with previous work on professional skills for physiology (28). We considered some skills, such as *Quantitative Reasoning-1: Correctly perform basic calculations (e.g., percentages, frequencies, rates, means, unit conversions, exponents, logarithms)* to be entering competencies for introductory physiology students. As part of the PLO process we mapped individual learning outcomes (when appropriate) to six key skills listed in Table 3. These skills fall into three domains that are critical for success in physiology courses: process of science, quantitative reasoning, and modeling and simulation.

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**Table 3: Physiology Learning Outcome Skills.** Six skills in three domains were selected to be mapped to learning outcomes. The full list of skills can be found in the "Physiology Skills Summary" (17).

| |
|---|
| **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. |

**2. 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.

**3. 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.

**4. Interdisciplinary Nature of Physiology (I)**

**5. Communication and Collaboration (Com)**

**6. Metacognition (Me)**

**7. Science and Society (SS)**

## Physiology Core Concepts

Over the past forty years, knowledge in biology and biomedical sciences has increased exponentially, and it has become impossible to teach students everything we know about human physiology. At the same time, educators have come to recognize the importance of teaching students to develop and use higher level cognitive skills in addition to acquiring factual knowledge. Mastery of introductory physiology requires the ability to apply a set of central concepts or models — the core concepts — to explain processes and phenomena, solve problems, and make predictions in novel situations (29-31).

The core concepts our physiology expert panel selected to use in the PLOs (Table 4) are informed by a number of reports, projects and papers, including *Vision and Change: A Call to Action* (25), *Scientific Foundations for Future Physicians* (32), the American Society for Biochemistry and Molecular Biology's foundational concepts (33), physiology general models (30), and core concepts for undergraduate physiology education (31, 34-36). Most of these core concepts were the result of input from communities of faculty and a consensus process.

Core concepts can serve as guides or scaffolds to help students build their understanding of critical, recurrent themes in physiology. Core concepts are general and transferable, can be used to explain phenomena in many biological disciplines, and reflect expert reasoning. Once understood, students retain core concepts longer than memorized "facts" (34).

We propose that the core concepts be introduced at the start of a one-term (semester or quarter) introductory physiology course. Then, each time a concept reoccurs in the course, students are explicitly reminded of the core concept in the new context. Explicit recall of core concepts throughout a physiology course helps students simplify their understanding of processes in different organ systems by providing repeating patterns. Pattern recognition is a key element in developing expertise in a field (37), especially when combined with deliberate practice that matches unfamiliar content to a previously learned pattern (38).

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**Table 4: The Physiology Learning Outcomes core concepts**. Learning outcomes for the core concepts can be found in (17).

**Structure-Function Relationships**

- Anatomy and Levels of Organization
- Compartmentation
- Mass balance
- Molecular structure & function
- Properties of physical systems

**Homeostasis and Control Pathways**

- Homeostasis
- Control Pathways

**Gradients and Flow**

**Energy Types, Storage, Use and Conversion**

**Communication**

**Systems Integration**

## Writing the Physiology Learning Outcomes

In developing our learning outcomes, we followed best practices (14, 39) and created carefully written learning outcomes that were designed to be specific, measurable, achievable, relevant and time-bound, a.k.a. "SMART" (40, 41). We paid particular attention to the verbs used in the outcomes to ensure that they were assessable (for example, "understand" is not an assessable verb) and asked "what do we expect a student to do to demonstrate mastery of the learning outcome?"

We were purposeful about including physical action verbs such as *graph* or *diagram*. Research has shown that having students draw or diagram their mental model of a concept is helpful in uncovering their misconceptions, errors, or areas of uncertainty (42-44). Graphing, creating, and interpreting diagrams are three of the skills we want to promote with the PLOs (see Table 2, skills QR-5, MS-3, and MS-4). We chose to use the verb *diagram* rather than *draw* because diagrams can include flow charts and concept maps in addition to anatomically accurate representations of processes. To accommodate students who are unable to create visual representations of their understanding, these learning outcomes all say “Diagram or describe…”, with *diagram* being the preferred action.

One criticism of learning outcomes is that they often focus on lower levels of Bloom’s taxonomy (45, 46), overemphasizing the use of verbs such as *define, describe*, *list*, and *explain*. We intentionally wrote LOs that incorporate higher levels of cognitive thinking (Bloom’s levels) and that require more than rote memorization (47-49).  Table 5 lists the verbs used in the PLO, divided into lower order and higher order cognitive skills. When a learning outcome had more than one verb, such as “Define ..., then describe...”, only one verb (the highest level) was counted. Depending on the context, the instruction to either “compare” or “contrast” is counted as low level, versus the combined directive to  “compare and contrast,” which is considered higher level. Our calculations show that 44% of the PLOs fall into higher level Bloom’s taxonomy categories.

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**Table 5: Occurrence of verbs associated with cognitive thinking levels in the Physiology Learning Outcomes (PLOs)**

| **Cognitive level (Bloom's)**<br>Verb | **Number of PLOs using each verb** |
|---|---|
| **Lower level cognitive skills**<br>**(remember, understand)** | **56%** |
| List | 31 |
| Identify, classify | 21 |
| Define, state (an equation) | 46 |
| Describe | 306 |
| Explain | 219 |
| Compare OR contrast (low) | 29 |
| **Higher level cognitive skills**<br>**(apply, analyze, evaluate, create)** | **44%** |
| Compare and contrast (analysis) | 174 |
| Diagram or describe | 143 |
| Apply | 25 |
| Predict | 132 |
| Create/interpret/evaluate | 14 |
| Calculate | 17 |
| Relate | 17 |

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Higher level learning outcomes require students to analyze or apply what they have learned, and instructors often use medical or pathophysiological situations as examples for practice and assessment of higher-level learning outcomes. After discussion, we decided to write two broad application learning outcomes rather than trying to think of every possible pathological or physiological scenario for application problems. This format allows instructors to choose their own specific and relevant examples.

For example, the two broad application learning outcomes from Module G on cardiovascular physiology are shown below:

| | |
|---|---|
| G.10.1 | Given a factor or situation (e.g., left ventricular failure), predict the changes that might occur in the cardiovascular system and the consequences of those changes (i.e., given a cause, state a possible effect). |
| G.10.2 | Given a disruption in the structure or function of the cardiovascular system (e.g., pulmonary edema), predict the possible factors or situations that might have created that disruption (i.e., given an effect, predict possible causes). |

In most modules, these broad statements are part of an APPLICATIONS section at the end of the module, along with additional learning outcomes that focus on student understanding of physiological concepts or that require students to use evidence-based reasoning.

**<u>Reference Documents</u>**

As the starting point for our physiology learning outcomes, we used two existing documents: the *HAPS A&P Learning Outcomes* (17) for 2-semester undergraduate A&P classes, and the APS-ACDP *Medical Physiology Learning Objectives* (16). A summary of the two reference documents is in Table 6. A number of years ago there was a distinction between "learning outcomes" and "learning objectives," with learning (educational) objectives being much more granular (13, 50), detailed, and focused on a single class session, while outcomes referred to course or program achievements. Currently the two terms are often used interchangeably and their definitions overlap. We use the abbreviation *LOs* for both terms and consider outcomes and objectives to be equivalent.

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**TABLE 6: Summary of the HAPS A&P learning outcomes (17) and APS-ACDP medical learning objectives (16) that served as the reference documents, compared to the final HAPS Physiology Learning Outcomes.** The APS-ACDP document divides its topics into chapters, the approximate equivalent of the HAPS modules. The abbreviation LO is used for both outcomes and objectives.

| | **HAPS Physiology LOs** | **HAPS A&P LOs (2019 version)** | **APS-ACDP Medical Physiology LOs (2012 revision)** |
|---|---|---|---|
| **How many modules/ chapters?** | 18 modules | 20 modules | 9 chapters |
| **How many numbered outcomes?** | 1174 | 824 | 860* |

* The APS-ACDP learning outcomes often have more than one outcome listed under a single number.

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We copied the APS-ACDP and HAPS learning outcomes into spreadsheets, along with their reference document number. Multiple APS-ACDP learning objectives (16) have as many as four learning objectives under one LO number, so we separated those into distinct items, limiting each learning objective to one sentence. For example,

*APS Cell and General LO CE 16: Explain how the resting membrane potential is generated and calculate membrane potential by using either a) the Goldman-Hodgkin-Katz equation or b) the chord conductance equation. Given an increase or decrease in the permeability of* $K^+$, $Na^+$, *or* $Cl^-$, *predict how the membrane potential would change.*

Was divided into

*APS LO CE 16.1: Explain how the resting membrane potential is generated.*

*APS LO CE 16.2: Calculate membrane potential by using the Goldman-Hodgkin-Katz equation*

*APS LO CE 16.3: Calculate membrane potential by using the chord conductance equation.*

*APS LO CE 16.4: Given an increase or decrease in the permeability of* $K^+$, $Na^+$, *or* $Cl^-$, *predict how the membrane potential would change.*

At this point we began the work of triaging the reference documents.

## Rounds 1 and 2: Triage HAPS and APS-ACDP LOs

The first step in our development process was to triage each of the reference documents to remove learning outcomes that we did not feel were appropriate for a one-semester introductory physiology course. The numbering of LOs in the original documents served as the identification code for each item. At least two panel members looked at all LOs in a given chapter or module and keyed them to indicate whether the reference LO is unsuitable for an introductory physiology-only course (i.e., too high-level or anatomy-focused), should be an entering competency (students with introductory biology and chemistry should already know the information), is more appropriate for an advanced undergraduate physiology course, or is suitable with editing (e.g., the anatomy specified is more than we would want students to know for physiology, but a more basic level might be appropriate). Comments and explanations were encouraged. Table 7 compares the topics and numbers of learning outcomes in the final HAPS document to those of the two reference documents.

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**TABLE 7: Comparison of topics in the Physiology Learning Outcomes (PLOs) and reference documents.** The number in parentheses after each topic is the number of learning outcomes (LOs) in that topic.

| HAPS PLOs | HAPS A&P LOs | APS-ACDP Medical Physiology LOs* (2012 revision) |
|---|---|---|
| EC. Entering competencies (57) | | |
| CC. Core concepts in physiology (62) | A: Body Plan & Organization (15) | |
| | B: Homeostasis (11) | |
| A. Cell physiology and membrane processes (58) | C: Chemistry & Cell Biology (50) | Cell and General (49) |

| | | |
|---|---|---|
| | D: Histology (14) | |
| | E: Integumentary System (24) | |
| | F: Skeletal System & Articulations (32) | |
| B. Cell-cell communication and control systems (26) | | |
| C. Endocrine physiology (95) | J: Endocrine System (34) | Endocrinology & Metabolism (107) |
| D. Cellular neurophysiology (50) | | Neurophysiology (281) |
| E. Systems neurophysiology (83) | H: Nervous System (103) | |
| | I: General & Special Senses (42) | |
| F. Muscle physiology (43) | G: Muscular System (36) | Muscle (39) |
| G. Cardiovascular physiology (128) | K: Cardiovascular System (103) | Cardiovascular (132) |
| H. Blood (39) | | |
| I. Respiratory physiology (81) | M: Respiratory System (65) | Respiration (67) |
| J. Renal physiology (67) | P: Urinary System (44) | Renal (79) |
| K. Fluid-electrolyte & acid-base homeostasis (64) | Q: Fluid/Electrolytes & Acid-Base Balance (29) | |
| L. Digestive physiology (111) | N: Digestive System (69) | Gastrointestinal (91) |
| M. Metabolism and its control (38) | O: Nutrients & Metabolism (27) | *(Metabolism included with Endocrine)* |
| N. Reproductive physiology | R: Reproductive System (52) | *(Reproduction included with* |

| | | |
|---|---|---|
| (86) | | *Endocrine)* |
| | S: Introduction to Heredity (7) | |
| | T: Embryology (17) | |
| O. Immune system (39) | L: Lymphatic System & Immunity (50) | |
| P. Integrated functions and special environments (47) | | Exercise and Environmental Physiology (15) |
| **TOTAL LOs: 1174** | **TOTAL LOs: 824** | **TOTAL LOs: 860*** |

* The APS-ACDP learning outcomes often have more than one outcome listed under a single number.

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**Round 3-9: Combine LOs into modules and topics**

Once all the reference documents were triaged, we merged the two documents into a single document using our 18 module topics as headers and keeping the original source numbers, triage notes, and comments. Sub-topic headers were created within each module, with a final OMIT section where we parked the LOs that were triaged as unsuitable.

**Module template development**

The first in-person meeting allowed us to design a template we could follow as we worked remotely, with each learning outcome limited to a single sentence. The template for the modules, shown in the infographic (**Figure 1**), includes ancillary information in addition to the learning outcomes themselves.

Introductory information Each module begins with an introductory table that explains the content and organization of the module, with notes about terminology choices. It includes the core concepts students need to know and should be able to apply in order to be successful in the module, along with a list of necessary skills and the LOs that pair with each skill.

<u>Learning outcomes keyed to core concepts and skills</u> The table of learning outcomes follows the introductory table. This table has columns for the LO number, the LO text, and when appropriate, the core concept(s) or skill linked to that particular LO. More advanced LOs are marked with an asterisk to indicate these LOs may not be suitable for all students. For example, the basic LOs for autonomic innervation of the heart say:

| | |
|---|---|
| G.3.11 | Compare and contrast innervation of myocardial autorhythmic and contractile cells by sympathetic and parasympathetic neurons. |
| G.3.12 | Compare and contrast the influence of sympathetic and parasympathetic divisions on heart rate and contractility, specifying which division is dominant at rest or with increased heart rate. |

The more advanced LO on the same topic adds complexity that may be beyond the scope of some introductory classes:

| | |
|---|---|
| G.3.13* | Compare and contrast the neurotransmitters, membrane receptors, and ionic mechanisms by which sympathetic and parasympathetic neurons influence heart rate and contractility. |

<u>Supplementary information</u> The closing table of each module has Background Basics, additional knowledge a student might need before attempting the module. The sequence of major

topics varies from course to course, and users might not use modules in our sequence, so each module contains needed information about background knowledge a student requires to be successful, both from prior courses (entering competencies) and from previous work in a physiology course.

A final section lists learning outcomes readers might expect to find in the module but that we chose to put elsewhere. For example, discussion of the integrated control of blood pressure occurs in Module K on fluid-electrolyte homeostasis rather than with the cardiovascular topics in Module G. In this way, we were able to ensure that a given learning outcome only appears once in the collection of modules.

The final documents produced for the PLO collection are two indexes: one that lists our core concepts with all of the individual LOs that address each core concept (from Module CC), and a second index for the Physiology Skills Summary, showing all of the LOs that require students to use a particular skill. These indexes allow users to see every place a particular core concept or skill appears in the entire set of learning outcomes.

**COMING TO CONSENSUS**

The summary of our development process makes it appear that the process was simple and straightforward; however, in reality it was complex and highly iterative. The many variations in how introductory physiology is taught at the undergraduate level were reflected in the backgrounds and approaches of the nine members of the expert panel. There were many extended discussions about how we would come to consensus on points of divergence.-When there was disagreement, one strategy we used to come to consensus was to consult the introductory physiology textbooks most commonly used in the United States (51-54). The iterative nature of this collaborative process allowed the panel to reflect on differences, revisit the LOs multiple times, and agree on final wording for each LO that was acceptable to all.

**Sequencing of topics**

Deciding the number, titles, and sequence of the modules was not simple. For example, where would we put the immune system? Some instructors teach it when they discuss the blood but we decided, particularly after what we learned from the pandemic about the influence of the immune system on multiple physiological systems, to give the immune system its own module.

Even deciding where certain topics would go within a module could be a topic for discussion. Many of us teach stress, but some do it with the autonomic nervous system, others teach it in the endocrine system with glucocorticoids, and a third group includes stress when they teach the immune system. Our conversations on stress were instrumental in the decision to have a final module on integrated functions that includes the topic of stress.

**Level of detail**

The wide range of different student populations to whom introductory undergraduate physiology is taught in the United States results in considerable variability in the level of detail students are expected to learn. It became obvious during our Advisory Board review of the draft PLOs that some instructors wanted more detail than we had included, while others wanted less. Our solution was to provide broad learning outcomes, like *K.1.2 Label the structures in a cross-sectional diagram of a kidney*, then provide representative examples of some structures that an instructor might want students to label.

To do this, we put the examples in an (e.g., ...) statement, indicating the list of terms is not all-inclusive – it is simply an incomplete sample to give readers an idea of what we intended. In these LOs we were not trying to be prescriptive about what should be taught, leaving the decision about details up to individual instructors. This allows instructors to adapt the PLOs to fit their course and program goals and best serve their unique student populations. For learning outcomes in which we did have a specific set of terms we wanted students to know, we used (*i.e.,* ...) to indicate *in other words*.

**Terminology**

The need for inclusive teaching and inclusive terminology fueled many of our discussions and influenced our writing (55-60). For example, all learning outcomes that ask a student to diagram a concept are worded as "Diagram or describe..." to permit alternate action for students who for any reason are unable to diagram.

To explain terminology decisions, the introduction section to some modules includes notes about terminology use related to that particular topic. For example, in all modules we chose to use the term *cell membrane* instead of *plasma membrane*. The word *plasma* in physiology/medicine means the fluid matrix of the blood, and some students mistakenly think there are membranes in the blood when they hear "plasma membrane." As a result, we decided to restrict the term *plasma* to the body fluid compartment and simply refer to *cell membranes* when discussing phospholipid bilayers of cells.

We also recognize that in many instances there are multiple terms that refer to a single physiological process or anatomical structure, and that the terms used in different books may not be the same. Our solution was to include common alternatives in parentheses after our preferred term. For example:

> *J.1.4 Diagram or describe the segments of the nephron in the order in which a filtered solute encounters them (i.e., glomerular capsule [Bowman's capsule], proximal*

*convoluted tubule, nephron loop [loop of Henle], distal convoluted tubule).*

**Eponyms**

The example for alternate terminology above points out a particularly sticky point we had to contend with: should we use eponyms? An eponym refers to an individual (real or fictitious) for whom something is named; medical eponyms often refer to body structures or diseases that were named in honor of an individual who first discovered or reported the structure or disease. For example, Alzheimer disease was named for Alois Alzheimer, the German physician who first identified and described neurofibrillary tangles and amyloid plaques found in the brain of a deceased psychiatric patient (61). The motor speech area of the frontal lobe (called the Broca area) was named after Paul Broca when he described the language impairments of two patients who had lesions in this brain area (62).

In some instances, prolific scientists lent their names to multiple structures, which can lead to confusion. A common eponymous structure most physiologists are familiar with is the “Purkinje fiber.” But Purkinje fibers in which organ? The reader must conclude from the context in which the term is used whether it means neurons in the cerebellar cortex or specialized myocardial conducting cells in the ventricle of the heart.

Eponyms have a troubled history in medicine, and there are numerous reasons to not use eponyms in the teaching of anatomy and physiology. The reasons NOT to use eponyms include the following:

- *Many eponyms incorrectly attribute the discovery of a structure to a particular individual.*

Our understanding of the workings of the human body may be attributed to the research and published findings of multiple individuals.  However, until relatively recently, much of this attribution has been given to Western and European scientists, most of whom were white and male. We have come to realize that the discoveries and findings of researchers who were from other countries or cultures or who were female often went unreported or overlooked in this Eurocentric representation of medical history. For example, the Circle of Willis (named by British Physician Thomas Willis in the 17th century) actually was first described by Muslim scholar Abubakr Muhammad Ibn Zakaria Razi (Muhammad al-Razi; 865-924) in the 9th century (63, 64). We do these unrecognized scholars a disservice by using the eponyms that perpetuate an inaccurate Eurocentric approach to medical history.

- *Some eponyms give honor to individuals who committed atrocities to other humans.*

Some of our understanding of how the human body works comes from experimental procedures on humans that were unethical and inhumane.  Marion Sims (formerly known as a Father of Gynecology and the inventor of the Sims speculum) was able to develop his eponymous tool and gain understanding of the female reproductive system by operating on female slaves without anesthesia and most likely without their consent (65, 66). Bronchiolar exocrine cells (club cells) used to be called Clara cells until individuals realized they were named for Max Clara, a Nazi anatomist who made his discoveries by examining the pulmonary tissue of executed prisoners (67).

- *Eponymous terms do not adequately describe or explain the structure in question, like the non-eponymous term does — and therefore they impede learning.*

For example, the term ‘Fallopian tube’ does not explain the location or structure as the non-eponymous term ‘uterine tube’ does.  (Side note: the uterine tube was first described by the Greek physician Soranus in 100 CE, but was later renamed by Vesalius in honor of his assistant, Gabriele Fallopio, an Italian Catholic priest (68).)

- *Professional organizations are moving away from the use of eponymous terms.*

In an attempt to standardize anatomic language, the Federative International Programme for Anatomical Terminology (FIPAT) of the International Federation of Associations of Anatomists developed and published *Terminologia Anatomica* in 1998, with a 2nd edition in 2020 (69). Their working group was charged with minimizing the use of eponyms as primary terms, as they often were culture-specific and interfered with the vocabulary standardization process. Most human anatomy and many combined anatomy and physiology textbooks have adopted the standardized, non-eponymous terminology published by FIPAT.

Thus, whenever possible, we chose to use non-eponymous terms as the primary terms in the physiology learning objectives, with the eponyms put in parentheses for reference. There are some instances in which there is not an adequate non-eponymous term for a structure or disease, in which case, we kept the eponym as the preferred term (for example, the interstitial cells of Cajal in the gut). In addition, there are some instances in which we retained the eponym because physiologists and medical professionals still use the eponymous term most commonly.

**"Normal"**

The word *normal* is found throughout the discipline of physiology. Normal value ranges, normal functioning, even the definition of physiology often incorporates the word ("physiology: study of the normal function of the human body"). It is common in medicine to refer to test results as being within normal limits (WNL), where the range for normal is determined statistically. But *normal* is at best ambiguous and at worst can be exclusionary. Philosophical debates about use of the terms *normal, normality,* and *normalcy* in relation to human health have been going on for decades (70, 71). Even statistical normality is situational and specific to the population used to determine a reference value or range (72). For example, in the 1970s the *lower* end of the range for "normal" blood cholesterol was 300 mg/dL plasma, based on statistical data from people in industrialized Western nations. By the end of the 1980s clinical trials aimed at decreasing cardiovascular disease had shown that the *upper* limit of cholesterol for health should be 200 mg/dL plasma (73). This example illustrates the ambiguity associated with the word *normal*.

Throughout our PLO writing process the panel discussed extensively when to use the term *normal*. We agreed we should try to avoid it if possible, substituting "healthy" or "typical" when appropriate to avoid the implication that if something is not normal, it must be abnormal. When the LO includes quantitative values obtained by laboratory testing, we opted to follow the still-common clinical practice of referring to the normal range for the parameter.

## Sex & Gender

Discussions about sex and gender in education and in everyday life have been among the most difficult conversations for the panel and in society at large. On one hand the panel members believe it is critical that students understand the variability in human sexual development and the difference between biological sex and gender so all students feel included in the discussion (74). At the same time, we acknowledge that most introductory physiology courses have very limited time in which to teach the biological aspects of reproductive physiology. Our solution was to have the learning outcomes in the module on reproductive physiology deal with the physiology of the prototypical sexes as commonly taught in introductory physiology. We selected the modifier *prototypical* to indicate that the traditional binary sexual assignment of male and female is only a model that serves as the basis from which all variability arises. We follow the guidelines of the American Academy of Pediatrics and recommend the term "differences of sex development" (DSD) when referring to congenital differences in sex development that result in changes to anatomic, gonadal, or chromosomal indicators of sex (75).

## CONCLUSION

Creation of the HAPS learning outcomes for a one-semester undergraduate introductory human physiology course was a multiyear project that relied on the expertise of many contributors, from the authors of the reference documents (16, 17) to the members of the expert panel and the PLO Advisory Board. The breadth of disciplinary expertise and range of experience in teaching environments and institution types represented by the members of the panel and advisory board ensured productive divergence and increased the potential utility of the final PLOs. The final product was far more comprehensive than we had envisioned at the start: 1174 LOs mapped to a list of core concepts in physiology and to skills students should be acquiring; a set of entering competencies for students to ensure they have adequate background knowledge at the start; and two indexes that allow instructors to find the LOs associated with a particular core concept or skill. A summary snapshot of the HAPS Physiology Learning Outcomes is provided in Table 8.

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**Table 8. Snapshot summary of the Physiology Learning Outcomes (PLO) documents**

LO = learning outcome

| |
|---|
| **Content**<br>• 18 topical modules<br>  ○ 12 systems modules<br>  ○ 4 integrated topic modules<br>  ○ Entering competencies and core concepts modules |

- Skills document
- 2 indexes list all learning outcomes associated with a core concept or skill

**Key elements of the PLOs**

- LOs are broad with representative examples of included concepts to allow maximum flexibility so instructors can tailor the content to their student population
- When possible, LOs are keyed to the core concepts of physiology as presented in one of the introductory modules.
- LOs are linked to skills to promote competency-based teaching
- Nearly 45% of the LOs use verbs that require higher cognitive skills
- Special attention was paid to using inclusive language
- The LOs avoid eponyms as the preferred terminology when possible

**Supplementary information**

Each module includes supplementary information designed to inform instructors who plan to use the LOs in their teaching:

- Explanations of what is and is not included in the module
- Terminology notes
- Skills promoted in the module
- Core concepts students should know before starting the module
- Additional content students should have mastered before starting the module (Background Basics)

We cannot emphasize enough that the entire collection of PLOs is far more comprehensive than any one introductory physiology course could cover. Both the physiology learning outcomes and the core concepts are intended as guides or tools, not prescriptions or mandates, and instructors may choose to focus on a selected subset rather than trying to teach them all in a time-limited course. Our discussions frequently revolved around what is possible or optimal to teach in a one-semester physiology course and we consistently concluded that the best (and perhaps only) people to decide what to cover are the instructors or program directors themselves. Therefore we provide a wide array of LOs with the expectation that instructors and physiology programs will select those learning outcomes that are at the right level and include the best content for their course and student population. Future directions include creation of a HAPS Physiology Exam to assess the PLOs.

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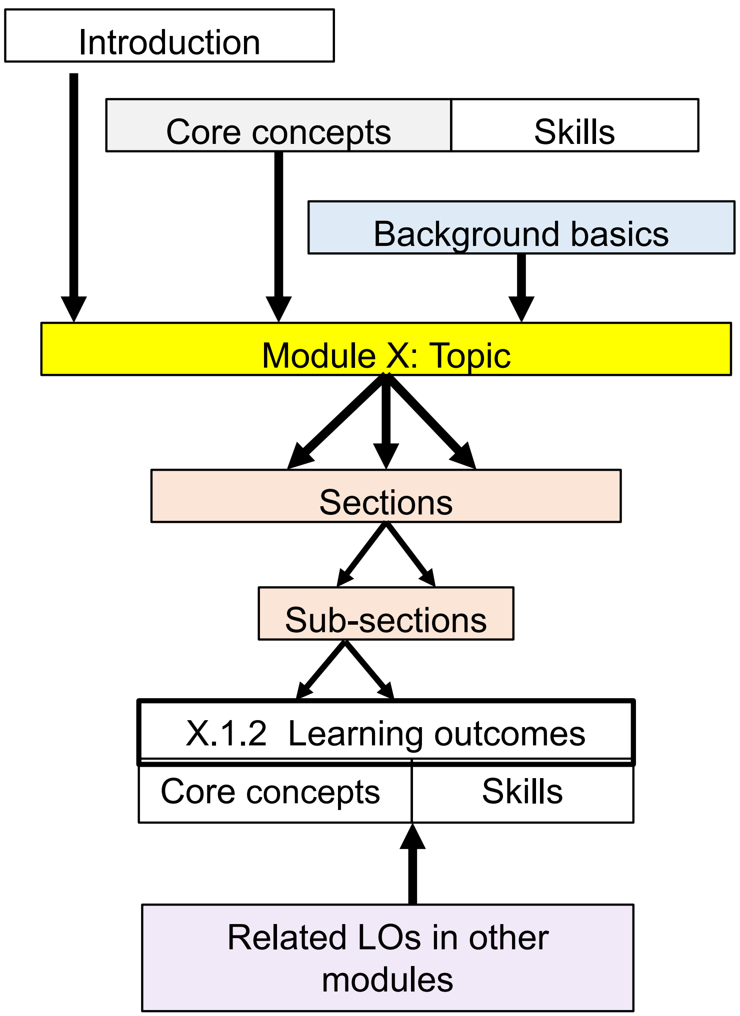
**Figure 1: Organization of a Physiology Learning Outcomes (PLO) module.** A. Map of the elements within a module. B. The arrangement of elements in the final version of a module. Reprinted with permission from (22).

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

**Table 1: Physiology learning outcomes development timeline** LO = learning outcome or learning objective

| | | |
|---|---|---|
| July 2019 | HAPS Exam Program Leads *Call for Applications* sent to HAPS members. | |
| August 2019 | Applicants sorted into 2 groups. | A. Physiology Expert Panel (working group) |
| | | B. Advisory Board (reviewers) |
| September-December 2019 | Rounds 1 & 2. Panel met virtually/worked asynchronously to review and triage the 2012 APS-ACDP Medical Physiology LOs (16) and 2019 HAPS combined A&P LOs (17) and generate a new set of physiology learning outcomes. | |
| January 2020 | Panel met in person to establish LO template, establish a consistent voice, and generate foundational documents (Skills, Entering Competencies, Core Competencies). | |
| March 2020 | SARS-CoV2 pandemic disrupted higher education and diverted the panel's attention as they were forced to transition to remote instruction. | |
| February 2020- August 2022 | Rounds 3-6. Panel authored and revised LOs using a combination of asynchronous editing, synchronous editing via web conference, and one in-person gathering (July 2022). | |
| November 2022 | Round 7. Draft was sent to Advisory Board for peer-review. | |
| January 2023 | Round 8. Expert Panel incorporated Advisory Board edits into final draft. | |
| February 2023 | Round 9. Expert Panel mapped LOs to Core Competencies and Skills documents. | |
| March 2023 | Physiology LOs published to HAPS website under Creative Commons License. | |

**Table 2: Ten prerequisite knowledge topics for introductory physiology.** For the detailed list of Entering Competencies, see (17).

1. Atoms and molecules
2. Biological energy
3. Chemical bonds and reactions
4. Organic compounds
5. Biological reactions
6. Solutions and solubility
7. General organization of a cell
8. Cellular membrane structure and function
9. Genes, genomes, and gene expression
10. Cellular respiration (introduction)

**Table 3: Physiology Learning Outcome Skills.** Six skills in three domains were selected to be mapped to learning outcomes. The full list of skills can be found in the "Physiology Skills Summary" (17).

| |
|---|
| **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. |
| **2. 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. |
| **3. 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. |
| **4. Interdisciplinary Nature of Physiology (I)** |
| **5. Communication and Collaboration (Com)** |
| **6. Metacognition (Me)** |
| **7. Science and Society (SS)** |

**Table 4: The Physiology Learning Outcomes core concepts**. Learning outcomes for the core concepts can be found in (17).

| |
|---|
| **Structure-Function Relationships** |
| Anatomy and Levels of Organization |
| Compartmentation |
| Mass balance |
| Molecular structure & function |
| Properties of physical systems |
| **Homeostasis and Control Pathways** |
| Homeostasis |
| Control Pathways |
| **Gradients and Flow** |
| **Energy Types, Storage, Use and Conversion** |
| **Communication** |
| **Systems Integration** |

**Table 5: Occurrence of verbs associated with cognitive thinking levels in the Physiology Learning Outcomes (PLOs)**

| Cognitive level (Bloom's)<br>Verb | Number of PLOs using each verb |
|---|---|
| **Lower level cognitive skills**<br>**(remember, understand)** | **56%** |
| List | 31 |
| Identify, classify | 21 |
| Define, state (an equation) | 46 |
| Describe | 306 |
| Explain | 219 |
| Compare OR contrast (low) | 29 |
| **Higher level cognitive skills**<br>**(apply, analyze, evaluate, create)** | **44%** |
| Compare and contrast (analysis) | 174 |
| Diagram or describe | 143 |
| Apply | 25 |
| Predict | 132 |
| Create/interpret/evaluate | 14 |
| Calculate | 17 |
| Relate | 17 |

**TABLE 6: Summary of the HAPS anatomy and physiology (A&P) and APS-ACDP medical learning objectives documents that served as the starting point for the learning outcomes (LOs), compared to the final HAPS Physiology Learning Outcomes.**

| | HAPS Physiology LOs | HAPS A&P LOs (2019) | APS-ACDP Medical Physiology LOs (2012 revision) |
|---|---|---|---|
| **How many modules/ chapters?** | 18 modules | 20 modules | 9 chapters |
| **How many numbered outcomes?** | 1174 | 824 | 860* |

* The APS-ACDP learning outcomes often have more than one outcome listed under a single number.

**TABLE 7: Comparison of topics in the Physiology Learning Outcomes (PLO) and reference documents.** The number in parentheses after each topic is the number of learning outcomes (LOs) in that topic.

<table>
<tr><th>HAPS PLOs</th><th>HAPS A&P LOs</th><th>APS-ACDP Medical Physiology LOs* (2012 revision)</th></tr>
<tr><td>EC. Entering competencies (57)</td><td></td><td></td></tr>
<tr><td rowspan="2">CC. Core concepts in physiology (62)</td><td>A: Body Plan & Organization (15)</td><td></td></tr>
<tr><td>B: Homeostasis (11)</td><td></td></tr>
<tr><td>A. Cell physiology and membrane processes (58)</td><td>C: Chemistry & Cell Biology (50)</td><td>Cell and General (49)</td></tr>
<tr><td></td><td>D: Histology (14)</td><td></td></tr>
<tr><td></td><td>E: Integumentary System (24)</td><td></td></tr>
<tr><td></td><td>F: Skeletal System & Articulations (32)</td><td></td></tr>
<tr><td>B. Cell-cell communication and control systems (26)</td><td></td><td></td></tr>
<tr><td>C. Endocrine physiology (95)</td><td>J: Endocrine System (34)</td><td>Endocrinology & Metabolism (107)</td></tr>
<tr><td>D. Cellular neurophysiology (50)</td><td></td><td rowspan="3">Neurophysiology (281)</td></tr>
<tr><td rowspan="2">E. Systems neurophysiology (83)</td><td>H: Nervous System (103)</td></tr>
<tr><td>I: General & Special Senses (42)</td></tr>
<tr><td>F. Muscle physiology (43)</td><td>G: Muscular System (36)</td><td>Muscle (39)</td></tr>
<tr><td>G. Cardiovascular physiology (128)</td><td rowspan="2">K: Cardiovascular System (103)</td><td rowspan="2">Cardiovascular (132)</td></tr>
<tr><td>H. Blood (39)</td></tr>
<tr><td>I. Respiratory physiology (81)</td><td>M: Respiratory System (65)</td><td>Respiration (67)</td></tr>
</table>

| | | |
|---|---|---|
| J. Renal physiology (67) | P: Urinary System (44) | Renal (79) |
| K. Fluid-electrolyte & acid-base homeostasis (64) | Q: Fluid/Electrolytes & Acid-Base Balance (29) | |
| L. Digestive physiology (111) | N: Digestive System (69) | Gastrointestinal (91) |
| M. Metabolism and its control (38) | O: Nutrients & Metabolism (27) | *(Metabolism included with Endocrine)* |
| N. Reproductive physiology (86) | R: Reproductive System (52) | *(Reproduction included with Endocrine)* |
| | S: Introduction to Heredity (7) | |
| | T: Embryology (17) | |
| O. Immune system (39) | L: Lymphatic System & Immunity (50) | |
| P. Integrated functions and special environments (47) | | Exercise and Environmental Physiology (15) |
| **TOTAL LOs: 1174** | **TOTAL LOs: 824** | **TOTAL LOs: 860*** |

* The APS-ACDP learning outcomes often have more than one outcome listed under a single number.

**Table 8. Snapshot summary of the Physiology Learning Outcomes (PLO) documents**

LO = learning outcome

| |
|---|
| **Content**<br>• 18 topical modules<br>  ○ 12 systems modules<br>  ○ 4 integrated topic modules<br>  ○ Entering competencies and core concepts modules<br>• Skills document<br>• 2 indexes list all learning outcomes associated with a core concept or skill |
| **Key elements of the PLOs**<br>• LOs are broad with representative examples of included concepts to allow maximum flexibility so instructors can tailor the content to their student population<br>• When possible, LOs are keyed to the core concepts of physiology as presented in one of the introductory modules.<br>• LOs are linked to skills to promote competency-based teaching<br>• Nearly 45% of the LOs use verbs that require higher cognitive skills<br>• Special attention was paid to using inclusive language<br>• The LOs avoid eponyms as the preferred terminology when possible |
| **Supplementary information**<br>Each module includes supplementary information designed to inform instructors who plan to use the LOs in their teaching:<br>• Explanations of what is and is not included in the module<br>• Terminology notes<br>• Skills promoted in the module |

- Core concepts students should know before starting the module
- Additional content students should have mastered before starting the module (Background Basics)

Learning Outcomes, Core Concepts, and Skills