ANATOMY & PHYSIOLOGY

Elizabeth Mack Co

Cengage

Australia • Brazil • Canada • Mexico • Singapore • United Kingdom • United States

ANATOMY & PHYSIOLOGY

Elizabeth Mack Co

Cengage

Australia • Brazil • Canada • Mexico • Singapore • United Kingdom • United States

***Anatomy & Physiology*, 1st Edition**
Elizabeth Mack Co

SVP, Product: Erin Joyner

VP, Product: Thais Alencar

Product Director: Maureen McLaughlin

Product Manager: Diana Baniak

Product Assistant: Emily Loreaux

Learning Designer: Kristin Meere

Senior Content Manager: Brendan Killion

Associate Digital Project Manager: Jessica Witczak

Developmental Editor: Julie Scardiglia

Senior Director, Product Marketing: Jennifer Fink

Product Marketing Manager: Adam Kiszka

Senior Product Development Researcher: Nicole Hurst

Content Acquisition Analyst: Ann Hoffman

Production Service: MPS Limited

Designer: Chris Doughman

Cover Image Source: Irina Shi/Shutterstock.com

Library of Congress Control Number: 2022909327

ISBN: 978-0-357-80221-2
ISBN: 978-0-357-96964-9

Cengage
200 Pier 4 Boulevard
Boston, MA 02210
USA

Cengage is a leading provider of customized learning solutions with employees residing in nearly 40 diffe ent countries and sales in more than 125 countries around the world. Find your local representative at **www.cengage.com.**

To learn more about Cengage platforms and services, register or access your online learning solution, or purchase materials for your course, visit **www.cengage.com.**

Printed in the United States of America
Print Number: 01 Print Year: 2022

Dedication

In many ways, I have tried to package my classroom self into the pages of this book. I started teaching years ago, but answering questions, writing case studies, telling stories, and—most importantly—being inspired by the curiosity and wonder of thousands of students changed me. It was because of the students that I became the teacher that I am today. And so, I dedicate this, my first book, to them.

For my students, thank you.

Brief Contents

Table of Contents

Unit 1 Levels of Organization

Unit 6 Deviations from Homeostasis

About the Author

Dr. Elizabeth Mack Co is Assistant Clinical Professor in the Departments of Biology and Health Sciences at Boston University (BU). She teaches Gross (cadaveric) Anatomy, Human Physiology, and Physiology of Reproduction. Her teaching career spans a variety of courses, including Human Infectious Diseases, Introductory Biology, Cellular and Molecular Biology, Human Biology, Human Pathophysiology, and Histology. Dr. Co received her Ph.D. in Biomedical Sciences (with a focus on Immunology) from the University of California, San Francisco; she earned her BA with High Honors in Biology and Education at Mount Holyoke College in Massachusetts.

Outside of teaching, Dr. Co holds positions in a number of science organizations, including:

- The HAPS (Human Anatomy and Physiology Society) Learning Objectives Panel
- Principal Investigator of Assessing Student Engagement and Efficacy of Remote Learning, BU
- Independent Contractor and Presenter for Howard Hughes Medical Institute (HHMI) BioInteractive
- Society for College Science Teachers
- National Science Teachers Association
- American Association of Anatomists
- American Physiological Society

As a professor, Dr. Co is renowned for her passion—both in regard to the human body and about learning itself. In 2018 she was nominated by students and members of the faculty at BU and received the Metcalf Award for Excellence in Teaching, Boston University's highest teaching award.

Dr. Co's current research focuses on learning, particularly critical thinking skills development. She puts this research into practice by integrating an active learning and study skills curriculum in her courses. One of the focal points she investigates is how "student awareness about their learning impacts their assessment performance."

Preface

As I move around in the world from doctors' offices to dinner parties, I occasionally am asked what I do for work. When I reply "I teach Anatomy and Physiology," people tend to have very strong reactions. From "Oh! I absolutely LOVED that course in college" to "A&P almost ended my interest in medicine" to "Oh, wow, you must have a very hard job." Everyone has intense feelings about A&P. I typically reply "Actually, I have the BEST job in the world because everyone has a body and so there is a common baseline of shared curiosity." But the fact of the matter is that A&P can be intimidating for students (and for us teachers, too!) because there is a lot of information that can be taught. One of the keys as an instructor to having students leave with *positive* intense feelings is finding a balance in how much information to present and how to present it.

One of the goals I had for this book was to lighten and streamline the content. Instructors are in a perennial push-pull with the desire to reduce the burden on our students and the desire to prepare them for their future exams and courses. If we sacrifice anatomical structures by not teaching enough of them, we might leave our students underprepared; if we sacrifice the interesting connections, our students may lack the passion and excitement for the subject; and if we keep everything in, they might be overwhelmed. In the writing of this book, I wanted to give instructors and learners the choice whether to explore deeper into the interesting connections and content. I separated these topics into "Cultural Connections" and "Digging Deeper" features. **Cultural Connections** are usually ways that the topics being covered connect to everyday health, or the way that history impacts health or science today. **Digging Deeper** features often discuss relevant diseases or the science behind healthcare technology.

Increasing student persistence is a core need shared across community colleges and universities in the United States, with 30–50 percent[1,2]of students never completing the two-semester Anatomy & Physiology course. Recognizing that the course can be extraordinarily challenging due to its expansive depth and breadth of coverage, I address this lack of student persistence by improving student preparedness and helping students see themselves and the world around them reflected in what they are learning to engage them in the learning process. Increasing student confidence in both these areas will allow them to tackle the rigors of this course and lead to greater persistence in their education—and hopefully their career path.

Learner Support

As an instructor, how often are you asked "So, what will be on the test?" When we stop to think about the job of a student, they are not only trying to learn the material, but trying to learn how the instructor teaches and assesses their students. One effective mechanism for conveying the expectations of the course is through the use of learning objectives. **Learning Objectives** (LOs) can be used by an instructor to frame their pedagogy, as a list of goals for your students to make sure that you prepare them for. Sharing these same LOs with your students communicates to them what you are going to be assessing them on. In other words, it effectively answers the question "What will be on the test?" before it is even asked.

The Human Anatomy and Physiology Society (HAPS) has set out to define a set of learning outcomes (LOs) for Anatomy, Physiology, and A&P courses. As a member of the Physiology LO panel, I have participated firsthand in the careful process through which these LOs are created. The LOs are honed over months through the collaboration of some of the colleagues I respect most in our field. It is no exaggeration that some of these LOs have individually taken hours to write or improve. They are the most thorough, well-considered and well-crafted set available. I have written this text almost completely tailored to the LOs provided by HAPS. On occasion I provide additional LOs specific to the content I have created; often these are higher-order LOs.

Chapter 1 is dedicated entirely to helping each student build a learning framework so they are more prepared to engage with all the content that follows. This chapter explains the science behind learning and introduces the concept of metacognition to set the foundation for learning A&P in a systemic way. From there, each chapter orients students around the metacognitive aspects of the content to help them tie the concepts to the wider world around them.

Features in each chapter that support student learning and success in A&P include:

- **Learning Checks:** This feature provides periodic section assessments throughout the chapter to check your learning.
- **Student Study Tips:** These tips are written by *actual students* who have been successful in A&P.

[1] Gultice, Amy, Ann Witham, and Robert Kallmeyer. "Are your students ready for anatomy and physiology? Developing tools to identify students at risk for failure." *Advances in Physiology Education* (June 2015): 108-115. Doi:10.1152/advan.00112.2014, https://pubmed.ncbi.nlm.nih.gov/26031727/

[2] Vedartham, Padmaja B. *Investigating Strategies to Increase Persistence and Success Rates among Anatomy & Physiology Students: A Case Study at Austin Community College District*. 2018. National American University, Ed.D. dissertation. *ERIC*, https://eric.ed.gov/?id=ED583935

- **Learning Connections:** Chapter 1 details different ways to learn the material in A&P. Throughout the book, Learning Connections suggest learning approaches.
- **Chapter Review:** At the end of every chapter are assessment questions for each section, including a Mini Case with questions. LOs, questions, and a brief summary are provided for each section.
- **Cultural Connections:** Sometimes the things that we fall in love with in A&P are the ways that the material connects to our everyday lives. Cultural Connections are small features in each chapter that attempt to do just that. Consider these topics the ones you are most likely to share with others at the dinner table.
- **Digging Deeper:** The content in this text is streamlined, but sometimes you may want to know more about a given topic. This feature provides that deeper exploration.
- **Apply to Pathophysiology:** In most of scientific history we have learned about how the body works by studying the times when it doesn't! We did not understand blood sugar regulation until we studied diabetes; we did not understand much about how viruses affect our cells until the HIV pandemic. The Apply to Pathophysiology feature helps students strengthen their understanding of physiology by examining a disease state.
- **Anatomy of:** This feature describes different concepts graphically.

Critical Thinking

A 2017 study of Google employees[3] found that among the qualities of the most successful workers, STEM expertise comes in last. The top skills were listening well, teamwork, and critical thinking. Fostering critical thinking in the classroom is often cited as a goal of instructors, including myself. When I first began measuring my students' critical thinking skills using Bloom's taxonomy and my own exam data (Co, 2019),[4] I was shocked that, despite this being a top priority of mine, my students performed poorly on higher-order cognitive skill questions. I realized that my pedagogical approach had been to *show* critical thinking, to *tell* them how important it is, but that, as with any skill, I needed to give them supported opportunities to *practice*.

Based on these findings, I developed a new pedagogical approach in my classroom. I teach critical thinking practice through multiple choice questions that build upon each other, concept by concept, to arrive at an understanding of a complex system or pathology. Blood pressure, for example, is a factor in the body with many layers (osmosis, Starling's forces, capillary dynamics, vasoconstriction, neural control). To create a critical thinking activity on blood pressure, I start with simple concepts such as osmosis, which helps the students to remind themselves of the fundamental ideas and build confidence. From there we move on, like steppingstones in a path, to more and more complex ideas.

In this text I provide stepwise practice for students to build their critical thinking skills in each chapter. These **Apply to Pathophysiology** features first ask students to recall fundamental information and then apply it in a new situation.

To give students additional practice in critical thinking, Chapter 28 is composed entirely of case studies. The 10 cases within can be assigned at the end of the semester or at intervals as the instructor chooses.

Inclusivity and Diversity—and Accuracy

The need to include more diverse content in the Anatomy and Physiology course was one of my biggest inspirations for writing this text. An example of how this issue came into my awareness occurred about 10 years into my teaching career. I attended a science museum with an exhibit on the human body that, naturally, I gravitated toward. One feature used a size measurement to estimate the volume of blood in each museum visitor. My body, the exhibit computer told me, contained 4.6 liters of blood. I walked away shaking my head. I'd been teaching physiology for a decade and everyone knows the human body contains 5 to 5.5 liters of blood. How many times had I said that in class? All the calculations we use in class on the cardiovascular system are based on this range.

It dawned on me that I, a slightly smaller-than-average woman, may not necessarily be represented in physiological estimates. I dug into the background on this and discovered that most of the average numbers we teach came from studies of men—young men, probably mostly white men, with an average weight of 150 pounds. Since then, when I teach, I introduce the idea of "average man," a mythological 150-pound white man on whom we base our calculations. The students and I look around our classroom (which is a large auditorium) and reflect that average man is not usually among us. We are beautifully diverse and require a wider range of numbers. In this book I have tried, when possible, to research and provide more accurate and representative numbers for us. In other cases I provide the anatomical and physiological factors that influence the value range.

This text will not only prompt students to think deeper about their learning; it will also challenge them to take a broader look

[3] https://www.washingtonpost.com/news/answer-sheet/wp/2017/12/20/the-surprising-thing-google-learned-about-its-employees-and-what-it-means-for-todays-students

[4] **Co, E.** (2019). "The power of practice: adjusting curriculum to include emphasis on skills." *Journal of College Science Teaching* **48** (5): 22–27.

at the cultural assumptions that have an impact on anatomy and medicine. For example, Hoffman et al. (2016)[5] explored biases held by medical students and revealed deeply racist beliefs that could affect their patient care—ideas such as the one that Black Americans have higher pain tolerances and therefore require less treatment for their pain. I believe that no one holds onto racist or bias-laden beliefs because they want to; rather, racist ideas persist because they haven't been sufficiently challenged. There hasn't been, in the education of these medical students, enough accurate information about the diversity and unity in function that exists among human bodies. Anatomy and Physiology is often the threshold into health education that our future clinicians pass through, and so this subject represents especially fertile ground to facilitate critical thinking when it comes to biases within scientific information.

In developing this text, I benefited from the reviews of a number of instructors, including Inclusion and Diversity (I&D) advocate Dr. Edgar Meyer, author of "Diversity and Inclusion in Anatomy & Physiology Education, Degree Programs, and Professional Societies."[6] My goal was to create an inclusive and diverse textbook in Anatomy & Physiology. Taking into consideration Dr. Meyer's feedback, I created a seven-point I&D plan, including:

1. More diverse models and imagery throughout the text
2. "Cultural Connections" features that link science with culture
3. In-class active learning opportunities to maximize inclusive and diverse academic experiences
4. Curriculum and anatomy pertaining to transgender and gender nonconforming individuals
5. Inclusive language that is sensitive to diversity in students
6. Clinical examples detailing the predispositions of certain racial and socioeconomic groups to display health care disparities, such as sickle cell anemia
7. Defining "average" values and providing comparative data, where applicable

Organization of the Text

Chapter 1, "The Art and Science of Learning in Anatomy and Physiology," is devoted to explaining methods students can use to approach learning. Dr. Co's commitment to her students comes through as she explains the proper mindset needed to study Anatomy & Physiology. She shares study tips from her previous students to offer a peer perspective to learners.

Chapters are organized as follows:

- **Unit 1 (Level of Organization)** contains chapters that examine the levels of organization of the structures of the human body.
- **Unit 2 (Support and Movement)** includes the chapters of the musculoskeletal system.
- **Unit 3 (Regulation, Integration, and Control)** contains chapters about systems that contribute to homeostasis through control over other systems.
- **Unit 4 (Fluids and Transport)** examines the systems that regulate fluids and fluid flow throughout the body.
- **Unit 5 (Energy, Maintenance, and Environmental Exchange)** is all about exchange with the external environment.
- **Our last unit, Unit 6 (Deviations from Homeostasis),** contains two chapters that are beyond the homeostatic function of the body: reproduction and the changes that occur in our bodies in disease.

Art

Throughout my teaching career I have spent a lot of time and energy observing how students interact with instructional art. Often illustrations, symbols, or representations that seem easy to understand using our expert eyes are not intuitive for an introductory learner. In designing each figure, I drew the structures and concepts as I would do and have done while talking to students in office hours. Our amazing illustrators then took what I produced and turned it into art. This instructional art approach is infused throughout the book but especially prominent in our "Anatomy of…" features.

Years ago, I learned in an undergraduate educational psychology class that science students often had trouble developing a scientist identity because they didn't see images of scientists that looked like them. The idea of representation has wide ranging ripple effects. Clinicians see a variety of patients; students see a variety of possible selves. When we choose a limited palate of representative humans in instructional art, we limit the scope of what students are exposed to in several ways. Therefore, I asked our art team to work with me on creating and sourcing images that represented a spectrum of bodies from young to old, across different sizes, gender expressions and ethnicities.

Whether you are a student or an instructor, please know that I have written this book for *you*. I hope that it helps you learn or teach and that you find it helpful in your A&P journey. I would love to hear back from you about it, whether it is typos, constructive suggestions, ideas for enrichment or, perhaps you'd

[5] Hoffman, K.M., Trawalter, S., Axt, J.R., and Oliver, N.M. (2016). "Racial bias in pain assessment and treatment recommendations, and false beliefs about biological differences between blacks and whites" *Proceedings of the National Academy of Sciences* **113** (16): 4296–4301. Doi: 10.1073/pnas.1516047113, https://www.pnas.org/content/113/16/4296

[6] Meyer, E. R., and Cui, D. (2019). "Diversity and inclusion in anatomy & physiology education, degree programs, and professional societies." *HAPS Educator* **23** (2): 396–419. Doi: 10.21692/haps.2019.012, https://files.eric.ed.gov/fulltext/EJ1233545.pdf

like to suggest your own study tips. Please know my virtual door is always open and I would love to chat with you.

I hope you develop the most positive feelings about A&P!

Liz Co, July 2022
eco@bu.edu

MindTap

MindTap is the online learning platform that gives you complete control of your course. Craft personalized, engaging learning experiences that boost performance and deliver access to eTextbooks, study tools, assessments, and student performance analytics—whether you are teaching an in-person, online, or hybrid course.

To provide a personalized, engaging digital learning experience, you can deliver your course in MindTap integrated with your institution's Learning Management System (LMS). MindTap supports your instruction by teaching students core concepts using a prebuilt, customizable learning path that progresses from understanding to application with readings from the eTextbook, study tools, interactive media, auto-graded assessments and more, including:

- **Learn Its:** 15-minute activities that pair concise narrative and multimedia with assessments to improve students' conceptual understanding of difficult concepts.
- **Case Studies:** Engage students with clinical scenarios and challenge them to higher-level understanding with auto-graded assessments.
- **Mastery Training** (powered by Cerego): Use cognitive science principles to help students learn key terms faster and more effectively by utilizing retention, distributed learning, and retrieval practice.
- **Virtual Labs:** Includes 3D models and Institute of Human Anatomy cadaver dissection videos, with assessment content for pre- and post-lab.
- **Practice Tests:** Mimics exam questions so students can confidently prepare on their own. Students choose the chapters they want to study and generate a test with the desired number of questions.
- **Chapter Quizzes:** Measures how well students have mastered material after completing chapter readings and activities. Students see feedback explaining the correct answer after they submit the quiz.
- **Flashcards:** Students can use ready-made, mobile-friendly flashcards, or create their own, to learn key terms and concepts.

Instructor Resources

- **Test Bank:** Build your exam from a list of multiple-choice and short-answer questions.
- **Lecture PowerPoints:** Key points from the text are outlined, along with images and active-learning activities to keep students engaged.
- **Image PowerPoints:** These slides give instructors easy access to all images from the text.
- **Instructor Manual:** Each chapter's Instructor Manual includes a chapter outline, key terms list, suggested activities, discussion questions, video links to share with students, and answers to Apply to Pathophysiology questions from the text.
- **Labeling Worksheets:** Students can practice labeling anatomical structures during class, while studying, or for a grade.

Cengage Unlimited

Boost Access and Affordability

Cengage Unlimited is the cost-saving student plan that includes access to our entire library of eTextbooks, online platforms and more—in one place, for one price. For just $124.99 for four months, a student gets online and offline access to Cengage course materials across disciplines, plus hundreds of student success and career readiness skill-building activities. See www.cengage.com/unlimited/instructor for more information.

HAPS

We created both print and digital content in this product with direct ties to HAPS learning outcomes. Each piece of information was intentionally chosen to support A&P student learning. Throughout the text and MindTap, students and instructors can see which content is tied to each learning outcome. The Human Anatomy and Physiology Society includes more than 1,700 educators who work together to promote excellence in the teaching of this subject area. The HAPS A&P Learning Outcomes measure student mastery of the content typically covered in a two-semester Human A&P curriculum at the undergraduate level. The full Learning Outcomes are available at https://www.hapsweb.org.

OpenStax

Certain content in this product was developed using open-source content from OpenStax's Anatomy & Physiology product. OpenStax (www.openstax.org) is part of Rice University and is a 501(c)(3) nonprofit charitable corporation. We would like to thank the contributing authors and editorial team for their work on Openstax's Anatomy & Physiology, which can be accessed here: https://openstax.org/details/books/anatomy-and-physiology.

Acknowledgments

Writing a book is an enormous and consuming task. As I sit here writing the acknowledgments, I feel as though I could write for days because there are so many people who have helped either directly or indirectly.

I'll start with my family. In many ways, this book is my third child, I feel as though I dreamed about it, hoped for it, and poured my heart and soul into it. It also, at times, interrupted my life in the ways that a newborn can. Therefore, my first acknowledgment is to my two human children, Talia and Eliot, who had to be patient and understanding and occasionally got less of their mom's time for the duration of the writing cycle. For all the times you sat next to me writing your books as I wrote mine, drew bones on the floor of my office while I finished a paragraph, and generally cheered me on, thank you. You are the loves of my life.

Sam, thank you for describing my early morning typing as a "steady pitter patter" instead of disruptive, for all the things you took on or waited for when I needed to write, for all of your listening, but most of all, for your steadfast and contagious belief in LFC, I do not think this book could or would exist without you.

I need to thank my work wife, who patiently answered my exasperated phone calls, took walks with me when I needed to get out of my head, edited many sentences, brought clarity and insight to biological concepts, and who has always been in my corner, thank you. I wouldn't have wanted to share this work journey or all those nachos with anyone else.

Now for the book team, first, thank you, Julie Scardiglia, for being the maven of details and always patiently redirecting me to my priorities. Brendan Killion patiently kept us all on task and driving forward, and we all owe him thanks that this book is being published in 2022, instead of 2032.

Akshat Mehta, Angelina McNulty, and Emily Ackerman, you each brought your own strengths to the book and I am so very grateful. Akshat, I've always said that there is a teacher in you! Thank you for sharing that teacher with the world in the pages of this book. Angelina and Emily, many, many students will be helped by the student study tips you've shared with them. You are learning assistants through and through. Thank you for providing your unique insights the process of learning A&P. I am not only grateful for your contributions to the book, but for the privilege of getting to a part of your journey as you transitioned from my students to my colleagues. I cannot wait to see what you do next in the world.

Nanette Tomicek, thank you for your insights on the hardest of the chapters. Janet Brodsky, your precision is unparalleled, I am thankful for your partnership throughout the book.

Hilary Engebretson, your comments as a reviewer were always spot on. You corrected content, adjusted my voice, and lent a perspective that always helped me bring things back in check. I very much appreciate your contributions.

This text would not make half as much sense as it does and would have commas in all the wrong places, if not for the careful editing of Christopher Chien. Thank you.

One of the most important things to me in conceiving this book was that the images within it represent a diverse set of bodies. I dreamed that we could fill the pages of the book with beautiful images of people of different shapes, sizes, ages, and appearances. Dragonfly brought that dream into vivid color and created a book that is more magnificent than I could have dreamed. I owe the amazing artists a huge thank you.

To Kelsey Kerr, Katherine Caudill-Rios, Maureen McLaughlin, and Diana Baniak. You saw an author in me. When I believed that a book would be a dream, you picked me out, coached me along, and willed it into reality. I am a person of many, many words, but I am not sure if I will ever find all of the right ones to be able to thank you for helping me make this transition. You are the birth coaches of this book baby. I am forever thankful.

This text, MindTap content, and instructor supplements were improved thanks to the insights of many Anatomy & Physiology instructors who shared their ideas, concerns, and feedback with the product team at Cengage. Thank you to the following participants who dedicated their time to improving the product through focus groups, surveys, interviews, and product testing.

Special thanks to the following reviewers:

Janet Brodsky, *Ivy Tech Community College*
Stephen Burnett, *Clayton State University*
Mary Colon, *Seminole State College of Florida*
Hilary Engebretson, *Whatcom Community College*
Stephen Henry, *Houston Community College*
Austin Hicks, *The University of Alabama*
Nathaniel King, *Palm Beach State College*
Ann LeMaster, *Ivy Tech Community College*
Edgar Meyer, *University of Mississippi Medical Center*
Andrew Nguyen, *CUNY Queensborough Community College*
Julie Posey, *Columbus State Community College*
Rosemary Stelzer, *University of Wisconsin-Milwaukee*
Nanette Tomicek, *Thomas Jefferson University*
Padmaja Vedartham, *Lone Star College System*
Kelsha Washington, *Florida A&M University*
Theo Worrell, *Delgado Community College*

1

The Art and Science of Learning in Anatomy and Physiology

Rawpixel.com/Shutterstock.com

Chapter Introduction

In some ways learning can be discipline specific. However, in many ways learning is learning, regardless of the content. In this chapter we will explore some of the science behind how we learn in order to help you foster success in Anatomy and Physiology (A&P).

1.1 The Science of Learning

1.1a Foreign, Familiar, and Mastery-Level Understanding

Let's take an example of a person who is learning a new language. We could also use an example of a spectator trying to learn about the game of baseball, or a student studying physics, or an architect learning about building construction, but let's take a new language. Let's say our learner's name is Talia. Talia goes to Spanish class for the first time. The teacher speaks in Spanish and Talia understands none of it. She guesses as to the instructions based on the instructors' gestures and tone of voice. After a few classes, Talia begins to pick up on some of the vocabulary of the class. She is learning Spanish words in her own time, using flashcards, online quizzing apps, recognizing phrases. She eventually becomes very familiar with Spanish words. After a few years, Talia travels to Mexico. She finds she is able to recognize enough Spanish words to be able to understand signs and ads that are printed in Spanish. However, Talia now sits in a café in Mexico City. A friendly stranger approaches her and begins to make conversation in Spanish. Will Talia be able to converse with the stranger?

Probably not, because there is a difference between being familiar with a language and being able to converse in it. Conversation is a skill, a dynamic skill that involves listening, decoding, recall, comprehension, and creativity. Talia has not yet practiced these skills. She has the content she needs but will need to practice the skill of conversation before she can employ it with ease.

Learning A&P (or really most anything) can be thought of the same way: there is the content of what you are learning, and the skills involved in its mastery and application. In terms of A&P, we have vocabulary, concepts, functions, structures, and locations, and then we need to learn how to connect ideas and apply knowledge in a new context, analyze new data. For example, if you were to become a clinician and a patient had a pain in their abdomen, it would not be sufficient to list off a memorized set of organs in the abdomen. You, the clinician, must apply your knowledge of the area and an understanding of the symptoms that the patient is experiencing and analyze the data from clinical tests to diagnose and treat the patient. You must think critically about the information you know and apply it in a new circumstance, one that may be nuanced or unique. Therefore, it is insufficient to simply memorize in A&P; we must learn the life-saving skills of application, analysis, and critical thinking.

Let's go back to Talia, the Spanish language learner, for a moment. Talia needs to engage in separate processes of memorizing vocabulary and practicing the skill of conversation. She cannot dive first into practicing the skill, nor is it sufficient to stop at memorization. If we were to diagram Talia's learning it would look something like **Figure 1.1**. Talia's stage 1 of learning happened in the classroom when she was a beginning learner. She is currently at an advanced level of stage 2; she has a lot of vocabulary

Figure 1.1 Stages of Learning

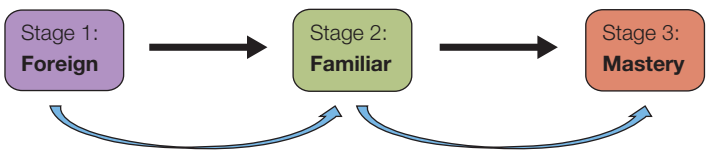
and is able to understand written text and recall meaning. If she practices the skills involved in conversation, she will reach stage 3—mastery of Spanish—and able to converse with ease.

The science of learning tells us that the transition between foreign and familiar is one that is best achieved through repetition and exposure. The methods of repeat exposure may look different from one type of learning to another, but in A&P learning, this may look like: reading/rereading your notes, copying your notes over, watching and rewatching lectures, reading and rereading your textbook, and using flashcards to memorize terminology.

The transition from familiarity to mastery, however, is a bit different. Here, the difference in our language-learning example is between being able to translate printed words or being fluid in a conversation. In A&P, mastery means not only being able to identify the deltoid muscle but being able to predict functional deficits with deltoid injury, or being able to identify, based on a set of symptoms, the location of an injury. In further mastery, you may find, as a clinician, that you need to communicate about A&P on a variety of levels. For example, you may use one set of terms to discuss a case with a colleague who is also a clinician, but you may need to translate information when conveying it to others in ways that are respectful of their level of knowledge and understanding.

In A&P, examples of practice might include: teaching or explaining the material to someone else, drawing a structure or structures, writing out an explanation of a concept, recreating a graph with explanations, completing practice problems, or answering the question *what happens if these components don't work?* (**Figure 1.2** and **Table 1.1**).

Figure 1.2 Transitioning Between the Stages of Learning Using a Variety of Learning Techniques



Transition from foreign to familiar through repetitive exposure to the material:

- Reading/rereading your notes
- Copying your notes over
- Watching and rewatching lectures
- Reading and rereading your textbook
- Using flashcards to memorize terminology

Transition from familiarity to mastery through practice:

- Teaching or explaining the material to someone else
- Drawing a structure or structures
- Writing out an explanation of a concept
- Recreating a graph with explanations
- Completing practice problems
- Answering the question *what happens if these components don't work?*

Table 1.1 Learning Strategies That Build Familiarity and Those That Build Mastery

Familiarity-Building Learning Strategies	Mastery-Building Learning Strategies
Reading	Drawing a representation of an anatomical structure
Looking over notes	Teaching someone else the material
Copying notes over	Quizzing yourself
Flashcards	Having a friend quiz you
Listening to/watching lectures	Explaining a process
Labeling an unlabeled drawing	Ordering the parts of a process after mixing them up
	Looking at a process you've learned, ask yourself about each component "what would happen if this was broken, how would that impact the entire process?"

1.1b Memory Formation and "Chunking"

Everyone has limits to their learning and memory. People who enter memorization competitions (yes! There are such things!) have a variety of different strategies for learning vast quantities of information quickly. The first technique is quite easy to employ. It is storytelling. Let's say that you have been asked to remember four words and recall them back four hours later. The four items are *cookie, staircase, yellow*, and *music*. Imagine you go about the rest of your day for the next four hours and then are asked to recall these four random words. Few people would be able to do so easily. But what if you paused for a moment, after getting your list of words, and created a quick story or visual for learning (*Cookie monster is sitting on the bright yellow staircase listening to his favorite music*)? If you paint this image in your mind, it is much more likely that you will be able to remember the four words a long time from now. Similarly, in A&P we can create short stories known as *mnemonic devices*. For example, there are 12 nerves that exit the brain and innervate structures mostly found in the head and neck. These 12 nerves are known as cranial nerves. Their names are: olfactory, optic, oculomotor, trochlear, trigeminal, abducens, facial, vestibulocochlear, glossopharyngeal, vagus, accessory, and hypoglossal. You got that? What was the fifth one? It's a challenge. However, what if, in order to remember them, we take just their first initials: OOOTTAFVGVAH and make a story such as *On, on, on they traveled and found Voldemort guarding very ancient horcruxes*? If you have read the Harry Potter books (or seen the movies) you will remember this mnemonic pretty easily. You still have to learn the names of the cranial nerves and that the second V, for example, stands for vagus, but it makes the process easier.

Chunking is the term for grouping items together as you learn them. It's a way to cheat your working memory into holding onto more information. Let's take an example. Please remember the following numbers—4195082637—in order, and repeat them back in five minutes. It seems like a challenging task. What if, instead, we chunk them like this: (419) 508-2637? That form of chunking is widely employed for memorizing telephone numbers. Birth dates are another example; instead of 10152004 you may remember a birthday as 10/15/2004. So how do we chunk information in A&P? One great example is learning structure and function together. Forms of chunking you might use could be:

- similarities and differences.
- structure and function.
- structures in order, for example, from top to bottom or superficial to deep.
- structures that are together in one location—for example, the three layers of protective tissue, called *meninges*, over the brain—can be learned together in one chunk.

Table 1.2 Examples of Chunking

Example 1: Chunking structures by shared functions	**Cellular Structures and Their Functions**		**Recycling Functions**	**Protein-Building Functions**
	• Lysosomes break down material through enzymes • Peroxisomes break down material through hydrogen peroxide • Smooth endoplasmic reticulum breaks down some toxins • Nucleus holds the instructions for building proteins • Ribosomes build proteins • Golgi apparatus modifies proteins	**chunked**	• Lysosomes • Peroxisomes • Smooth endoplasmic reticulum	• Nucleus • Ribosomes • Golgi apparatus
Example 2: Chunking structures by similarities	**Structures within the Abdominal Cavity**		**Organs**	**Membranes**
	• Stomach • Greater omentum • Small intestine • Large intestine • Lesser omentum • Liver • Mesocolon	**chunked**	• Stomach • Small intestine • Large intestine • Liver	• Greater omentum • Lesser omentum • Mesocolon

Two examples of chunking in A&P are provided in **Table 1.2**. Chunking is a great tool to incorporate as you move from foreign to familiar in your learning.

1.1c Retrieval Practice

Retrieval practice refers to memory strengthening. The more often you are asked to recall information, the easier it becomes to remember. Let's say that you change the passcode to your new mobile phone, email account, or favorite website. The first few times you enter this passcode it may be difficult to remember, but after the thirtieth time you've logged in, the passcode becomes rote, or habitual. The learning concept of retrieval practice is part of the philosophy behind assigning homework or quizzes or in-class questions during a course. The more times you are asked about a concept, a structure, or an idea, the more habitual it becomes to recall that piece of information. Your instructor may provide opportunities for you to practice retrieval, such as quizzes, but you can do this for yourself as a learner as well.

Examples of retrieval practice in studying can be:

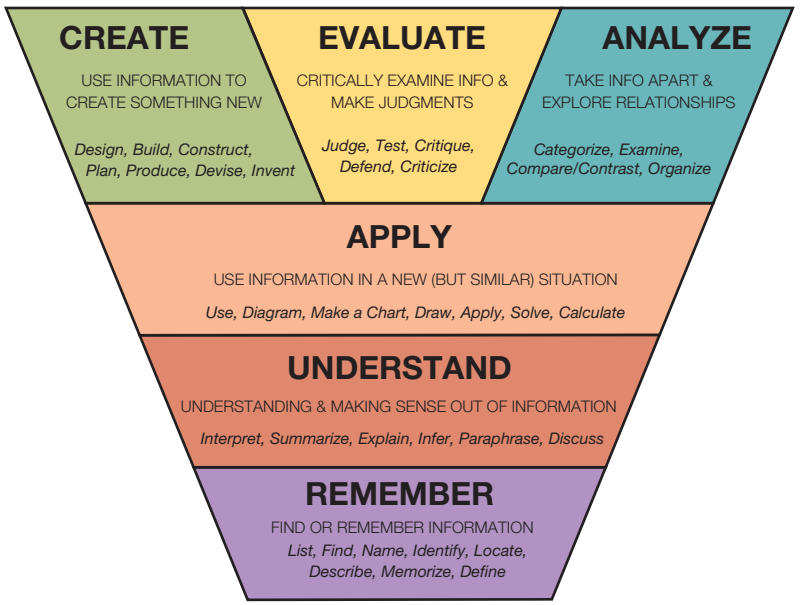
- using flashcards, redrawing, or rewriting from memory.
- labeling an unlabeled diagram.
- paraphrasing a process or idea (especially effective if you are trying to tell someone else about this process or idea).
- predicting what questions could be asked of you about a structure/concept/idea.
- summarizing information at the end of a section or chapter.

Retrieval practice is a great tool to use as you move from foreign to familiar in your learning.

1.2 Bloom's Taxonomy

In our example of learning a new language, we differentiated between content (words, concepts, ideas) and skills (application, analysis, and so on). In education there is a well-accepted framework for considering the skills involved in a question or task. The framework is called **Bloom's Taxonomy** (**Figure 1.3**).

Figure 1.3 **Bloom's Taxonomy**



The framework conveys a few central points:

- Different assessment questions or tasks target different skills. If you are asked, "which of the following words best defines the term *tissue*?" You are being asked to *recall* the definition of tissue. If, instead, you were asked "You are looking through the microscope at a tissue that has a high degree of cellularity, with every cell contacting another cell except for a free edge at the top of your view. What type of tissue are you most likely looking at?" You are being asked to *apply* what you know about tissue types to a new situation you have never encountered before. These tasks and the skills involved are different from each other.
- These skills are iterative. You cannot *apply* information in a new context if you cannot remember it. Therefore, application depends on knowledge.
- The skills build on each other, but one is not necessarily harder than another. It could be more challenging to apply knowledge than to remember something, but if you were asked a remembering question about a tiny obscure tidbit of knowledge, or asked to apply a general concept, the application question in this case would be easier than the remembering question.
- Everyone is working with a different brain. Some students are natural memorizers; these students need to work on their skills of application and analysis. Some students struggle with memorization, but problem solving comes easily to them. To be the most successful, you need to *learn about yourself as a learner* first, then work on the skills that need the most building.

You can talk with your instructor about what to expect on your assessments in your A&P course. Within this book we label the assessment questions with the Bloom's level the question is targeting to get you familiar with your skills and growth areas. It is common for 70–80 percent of the questions on an exam to be either remembering or understanding questions, and 20–30 percent of the questions to be applying or analyzing questions. Your instructor may also include questions or tasks that target the creating Bloom's level in your course. Study strategies that target each Bloom's level are summarized in **Table 1.3**.

Table 1.3 Learning Strategies and Question Examples That Target Each Bloom's Level

Bloom's Level	Skills	Example Question	Individual Strategies	Group Strategies
Remember	• Memorize • Define • Recall details	*Which of these is the correct definition of osmolarity?*	• Practice labeling diagrams • List characteristics • Flashcard practice/quiz • Draw, classify, select, or match items • Write out the textbook definitions	• Check a drawing that another student labeled • Create lists of concepts and processes that your peers can match • Place flash cards in a bag and take turns
Understand	• Recognize a concept in a new situation • Thoroughly understand a concept	*Which of the solutions in this diagram is hyperosmotic?*	• Describe a biological process in your own words • Provide examples of a process • Write a sentence using new vocabulary words	• Discuss content with peers • Take turns quizzing each other about definitions and have your peers check your answers
Apply	• Apply information in a new situation • Use a previous example to or model to understand a new example	*What will happen to interstitial fluid volume if the concentration of glucose increased there?*	• Review each process you have learned and then ask yourself: what would happen if you increase or decrease a component? • If possible, graph a biological process and create scenarios that change the shape or slope of the graph	• Practice writing out answers to practice questions (or write your own) and have your peers check your answers • Take turns teaching your peers a biological process while the group critiques the content
Analyze	• Assess a new piece of data or graph to make a conclusion	*The blood pressure readings of four patients can be found in this table. Which one might have the highest blood osmolarity?*	• Analyze and interpret data in primary literature or a textbook without reading the author's interpretation and then compare your analysis to the author's • Compare and contrast two ideas or concepts • Create a map of the main concepts by defining the relationships of the concepts using one- or two-way arrows	• Work together to analyze and interpret data and defend your analyses to your peers • Work together to identify all of the concepts in a paper or textbook chapter, create individual maps linking the concepts together with arrows and words that relate the concepts, and then review your peer's maps and defend your own
Evaluate	• Justify a conclusion • Choose a best among a group of plausible explanations	*Which of these diseases is likely to cause an increase in osmolarity of the blood?*	• Practice justification of each of the wrong answers for complex questions	• Justify your stance to your group on each answer of case study questions
Create	• Produce a new work, idea, or writing	*Design a solution that is hyperosmotic to blood plasma. Describe the effects on the tissues (and red blood cells) if this solution was injected into the bloodstream*	• Write a paragraph summarizing a major idea or process • Draw your own physiological diagram to illustrate a concept or process	• Design your own fictional case study and ask your peers to do the same. • Exchange case studies for each other to solve

Adapted from Crowe et al., 2008.

The activities that you use to study and learn can incorporate all these ideas. As you study you want to make sure you move from familiarity-building techniques to mastery-building techniques (Table 1.1). You also want to be sure to incorporate activities that target different Bloom's levels (Table 1.3). Remember that no two learners have the same brain; therefore, the ways that you learn best may very well be different from those of a friend or even your instructor! As you progress through your education, you will discover that some learning strategies work for you and some do not! You may also find that some strategies work better for some material, while other strategies are more adapted for other courses. For example, you may find differences in how you approach even A&P material within the same course. Ultimately, as you become more in tune with your learning processes, you will have a better sense of which strategies to apply when and in what order.

1.3 What Is a Learning Objective?

Learning objectives (LOs) are used as a means of transparency between the instructor and the learner. They are, essentially, a means of answering the age-old student question: What are we supposed to learn? In this book we have included LOs at the top of every section of text. The LOs appear again at the end of each chapter along with questions that target those objectives. The goal of this design is to help you to become familiar with anticipating the types of assessment questions you want to prepare for. The text indicates higher-order and lower-order Bloom's level LOs using different icons. Remember that you may want to use different learning strategies for different levels. Your instructor may have additional LOs that they include in their lectures or syllabus. Again, LOs are tools of transparency; your instructor is communicating with you about what they feel is important for you to learn. You can also ask your instructor questions when you are unsure of your objectives. An example of an LO and how to use it in your learning can be found in **Figure 1.4**.

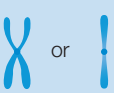
Figure 1.4 Anatomy of a Learning Objective (LO)

Example LO from Chapter 4 and one approach to learning the material it targets.

Anatomy of an LO

The verb: Compare and contrast

The content: chromatin, chromosomes, and chromatids.

	Drawing	Description	Timing	Function
Chromatin		Loosely wound DNA	Interphase	DNA (genes) accessible for transcription
Chromosome	 or	Compacted DNA	Mitosis Meiosis	Condense DNA for movement and sorting during mitosis and meiosis
Chromatid		One of two replicates	Mitosis Meiosis	One of two replicated sisters separates to daughter cells