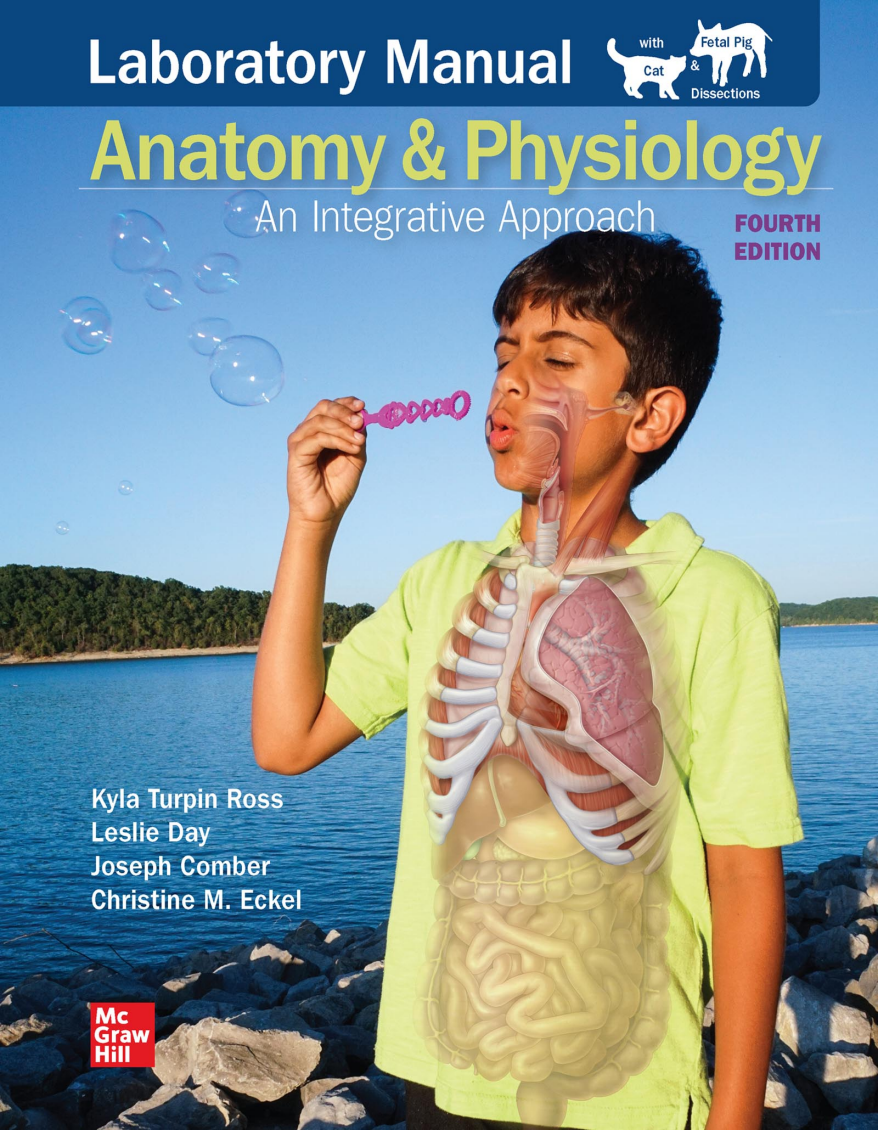
Laboratory Manual

with Cat & Fetal Pig Dissections

Anatomy & Physiology

An Integrative Approach

FOURTH EDITION



Kyla Turpin Ross
Leslie Day
Joseph Comber
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Mc Graw Hill

LABORATORY MANUAL—
with Cat and Pig Dissections

Anatomy & Physiology: An Integrative Approach

Fourth Edition

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LABORATORY MANUAL—ANATOMY & PHYSIOLOGY: AN INTEGRATIVE APPROACH, FOURTH EDITION

This book is printed on acid-free paper.

1 2 3 4 5 6 7 8 9 LMN 26 25 24 23 22 21

ISBN 978-1-264-26544-2 (bound edition)
MHID 1-264-26544-1 (bound edition)

Portfolio Manager: *Matthew Garcia*
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Compositor: *MPS Limited*

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brief contents

about the authors

To my husband Jim, daughter Ella, and son Cameron: I treasure your constant love and unending support.

KYLA TURPIN ROSS received her undergraduate degree from Louisiana State University in biological and agricultural engineering and her Ph.D. in biomedical engineering from Georgia Institute of Technology and Emory University. Kyla then served as a postdoctoral fellow in the Fellowships in Research and Science Teaching (FIRST) program at Emory University, a National Institutes of Health (NIH)-funded program that provides training in both research and teaching. In 2008, she joined the Department of Biology at Georgia State University, where she mentored faculty and students, and worked closely with administrators to improve instructional effectiveness in anatomy and physiology courses. She directed teaching assistant training, ensuring quality training in ethics, instructional effectiveness, and risk management. She also taught in a wide range of courses and classroom environments at both the undergraduate and graduate levels.

In 2016, Kyla joined the Wallace H. Coulter Department of Biomedical Engineering (BME) at Georgia Institute of Technology and Emory University as the Director of Graduate Training. In 2019, Kyla transitioned to the role of Assistant Vice Provost for Advocacy and Conflict Resolution at Georgia Institute of Technology, where she works closely with administrators, faculty, staff, and students to resolve conflicts in accordance with Institute policies and procedures. Kyla has more than 13 years of experience in physiology education and program development. In addition to teaching undergraduate physiology courses, she provides training opportunities for faculty and students that promote positive lab, work, and class environments. She has been an active member of the Human Anatomy and Physiology Society (HAPS) since 2012, hosted an annual conference, served as HAPS steering committee chair, and will assume the role of HAPS president in July 2021. In addition to academic endeavors, Kyla enjoys traveling and spending quality time with her family and friends. She views life experiences through an optimist's lens, and always looks for opportunities to reflect and grow.

With love to my husband Brian and my dogs Mia and Rigby. Thank you for your unconditional support.

LESLIE DAY earned her B.S. in Exercise Physiology from University of Massachusetts at Lowell, an M.S. in Applied Anatomy & Physiology from Boston University, and a Ph.D. in Biology from Northeastern University with her research on the kinematics of locomotion. Starting in 2002, she worked as a Lecturer in the Biology Department of Northeastern University in Boston, Massachusetts, teaching several sections of anatomy and physiology. In 2008, she transferred to the Department of Physical Therapy, Movement and Rehabilitation Sciences at Northeastern University to run the Cadaver Laboratory and teach gross anatomy and neuroscience to undergraduate and graduate students in a wide range of majors. In addition, she coordinated and taught postgraduate continuing education courses. During her time, she was promoted to Associate Clinical Professor and served as the Associate Department Chair. In 2019, she moved to Texas A & M University as Instructional Associate Professor to join a new program in the College of Medicine called Engineering Medicine (ENMED). The program combines medicine and engineering degrees utilizing nontraditional, innovative teaching methods. In her role, she is the course director for medical gross anatomy, teaches in the neuroscience course, and aids in the innovative curricular development.

She has received Northeastern University's teaching with technology award three times and in 2009 was awarded the Excellence in Teaching Award. In 2017, she received national recognition for her teaching by being the recipient of the ADInstruments Sam Drogo Technology in the Classroom Award from the Human Anatomy and Physiology Society (HAPS). She has been an active part of HAPS for several years, and currently serves as Treasurer on the Board of Directors. She is also a member of the American Association for Anatomy and the American Association of Clinical Anatomists. Her current research focuses on the effectiveness of different teaching pedagogies, including the flipped-classroom and TBL, and its effect on students' motivation and learning.

To my wife Kelly and son Liam, thank you for your never-ending love, support, and encouragement.

JOSEPH COMBER received his B.S. in Biology from Neumann University, his M.S. in Biology from Villanova University, and his Ph.D. in Immunology and Microbial Pathogenesis from Thomas Jefferson University. While completing his graduate degrees, he served as a teaching assistant in the anatomy and physiology course at Villanova University and as an instructor in anatomy and physiology laboratories at Neumann University. After finishing his Ph.D., he completed a postdoctoral fellowship in vaccine immunology, where his research focused on identifying T-cell epitopes generated during infection. He joined the faculty at Villanova University in 2014 and is currently an Associate Teaching Professor in the Biology Department. In this role he teaches anatomy and physiology for pre-health profession students, histology and human anatomy for Biology majors, and a course in vaccines and public perception for nonscience majors.

Joseph is a two-time semifinalist for the Lindback Award for Distinguished Teaching at Villanova University and serves on several departmental and college committees. He is a member of the Human Anatomy and Physiology Society (HAPS), the National Science Teaching Association, and the Society for College Science Teachers. When not in the classroom, Joseph enjoys coaching Little League baseball and spending time with his wife and son.

With love and thanks to my entire family, including the dogs.

©Christine Eckel

CHRISTINE MARIE ECKEL received her B.A. in Integrative Biology and M.A. in Human Biodynamics from the University of California, Berkeley, and her Ph.D. in Neurobiology and Anatomy at the University of Utah School of Medicine. She has taught a two-semester anatomy and physiology course for pre-nursing and pre-health-science majors, and an advanced dissection course for premedical students at Carroll College; stand-alone general biology, human anatomy, and human physiology courses at the University of California at Berkeley and Salt Lake Community College (SLCC); human gross anatomy and medical histology for medical students, and anatomy review courses for residents in orthopedic surgery and pathology both at the University of Utah School of Medicine (U of USOM) and the West Virginia School of Osteopathic Medicine (WVSOM). She has also advised pre-med, pre-PA, pre-nursing, and pre-PT students. Christine also headed the Body Donor Program at WVSOM.

Christine is the author of Human Anatomy Laboratory Manual, 3e (McGraw-Hill Education). She has also authored several supplements and individual chapters for textbooks in human anatomy and human physiology.

Christine is currently serving on the Board of Directors as Secretary for the Human Anatomy and Physiology Society (HAPS). Her previous service to HAPS includes two terms serving as Western Regional Director, and many years serving as Chair and member of the Cadaver Use Committee. Christine has also served on other committees for both HAPS and the American Association of Anatomists (AAA). She is an ad hoc reviewer for the journals *Anatomical Sciences Education* and *Medical Education*. Her research is in the field of teaching innovation and educational outcomes research.

With over 25 years of experience engaging with community college students, medical students and medical residents in orthopedic surgery, pathology, and gynecologic surgery, Christine has a unique appreciation for the learning challenges experienced by students at all levels. Christine's passions for human anatomy, classroom and laboratory teaching, biological dissection, and photography are evident throughout the pages of this laboratory manual.

In her spare time, Christine loves to take her English Setter, Zelda, hiking, mountain biking, cross-country skiing, and exploring the great outdoors—always with her camera in hand.

contents

preface

Human anatomy and physiology is a complex yet fascinating subject, and is perhaps one of the most personal subjects a student will encounter during his or her education. It is also a subject that can create concern for students because of the sheer volume of material, and the misconception that "it is all about memorization."

The study of human anatomy and physiology really comes to life in the anatomy and physiology laboratory, where students get hands-on experience with human cadavers and bones, classroom models, preserved and fresh animal organs, and histology slides of human tissues, and explore the process of scientific discovery through physiology experimentation. Yet most students are at a loss regarding how to approach the anatomy and physiology laboratory. For example, students are often given numerous lists of structures to identify, histology slides to view, and "wet labs" to conduct, but are given comparatively little direction regarding how to recognize structures, or how to relate what they encounter in the laboratory to the material presented in the lecture. In addition, most laboratory manuals on the market contain little more than material repeated from anatomy and physiology textbooks, which provides no real benefit to a student.

This laboratory manual takes a very focused approach to the laboratory experience and provides students with tools to make the subject matter more relevant to their own bodies and to the world around them. Rather than providing a recap of material from classroom lectures and the main textbook for the course, this laboratory manual is much more of an interactive workbook for students: a "how-to" guide to learning human anatomy and physiology through touch, dissection, observation, experimentation, and critical thinking exercises. Students are guided to formulate a hypothesis about each experiment before beginning physiology exercises. Diagrams direct students in how to perform experiments and don't just show the end results. The text is written in a friendly, conversational tone to put students at ease as they discover, organize, and understand the material presented in each chapter.

Organization

Because observation of histology slides, human cadavers or classroom models, and "wet lab" experiments are usually performed in separate physical spaces or at specific times within each laboratory classroom, chapters in this laboratory manual are similarly separated into three sections: Gross Anatomy, Histology, and Physiology. Each exercise within these chapter sections has been designed with the student's actual experience in the anatomy and physiology laboratory in mind. Thus, each exercise covers only a single region of the human body, classroom model, histology slide, or wet lab experiment. At the same time, within-chapter Concept Connection and Clinical View boxes provide an opportunity to integrate the material from all three sections of each chapter. Learning Strategies boxes provide mnemonics, study tips, and other helpful hints to assist students in recall of pertinent information. In addition, Can You Apply What You've Learned? and Can You Synthesize What You've Learned? questions in Post-Laboratory Worksheets provide further opportunities for students to integrate the information and apply it to clinically relevant and practical situations. Organization of each chapter into a series of discrete exercises makes the laboratory manual easily customizable to any anatomy and physiology classroom, allowing an instructor to assign certain exercises while telling students to ignore other exercises. Post-Laboratory Worksheets are also organized by exercise and are coded to Learning Objectives within the chapter, which makes it easy for an instructor to assign questions that relate only to the exercises and/or Learning Objectives covered in their classroom.

Changes to the Fourth Edition

Anatomy & Physiology: An Integrative Approach Laboratory Manual, fourth edition, continues to serve as a resource for students both in and out of the lab, providing a "how-to" guide for learning anatomy and physiology. The interactive pages within serve as a stand-alone manual, while also complementing the textbook, McKinley/O'Loughlin/Bidle: *Anatomy & Physiology: An Integrative Approach*, fourth edition.

The fourth edition includes a consolidation of the MAIN, CAT, and PIG versions of the lab manual into a single, stand-alone resource. Having only one version of the lab manual makes textbook selection more straightforward for instructors and students. In this edition, chapter 28 covers the dissection of the cat (*Felis domesticus*), and chapter 29 covers the dissection of the fetal pig (*Sus scrofa domesticus*). Dissection provides the student an opportunity to view, feel, and explore the spatial relationships of anatomical structures. The exercises included in this combined lab manual contain detailed images, which are beneficial for relating content covered in earlier chapters to the anatomy of cats and fetal pigs. This comparative approach allows students to make connections and note similarities in vertebrate anatomy.

- Gross Anatomy has been moved prior to Histology in each chapter to allow students and instructors to explore macroscale structures before microscale structures.
- Exercises and labeled figures have been reviewed and revised for accuracy.
- The introductory text in each chapter has been revised to be more engaging and relatable for students and instructors.
- Content in Clinical Views has been revised to be more easily accessible and generally applicable for students and instructors.
- Concept Connections have been revised to review content covered in previous chapters rather than to preview content in upcoming chapters, so as to reduce confusion.
- Reference tables have been revised and reorganized for coverage and ease of learning.
- Content throughout the manual has been revised to align with rather than to duplicate coverage in the complementary textbook.
- Exercises throughout the manual have been revised to be more interactive with the addition of question prompts and fill-in tables.
- Pre-Laboratory Worksheets and Post-Laboratory Worksheets have been revised to include broader coverage of topics and to eliminate the use of true/false questions.
- BIOPAC exercises have been revised to include updated instructions that reflect updates in the software.
- Ph.I.L.S. exercises have been revised to include new screen captures that illustrate updates in the software.
- The number of labels in labeling activities has been reduced to decrease cognitive overload.

The fourth edition of this lab manual contains improvements and updates to text and figures throughout, and updated figures are added into Connect.

Changes by Chapter

The following is a list of the most significant changes made in each chapter in the fourth edition of this lab manual.

Chapter 1

- Revised Learning Strategy on learning techniques
- New Clinical View on Common Safety Training by Healthcare Professionals
- Revised Figure 1.7 Scalpel Blade Handles and Blades

Chapter 2

- Moved Exercise 2.2 Regional Terms before Exercise 2.3 Directional Terms
- Revised Table 2.2 Directional Terms to include more terms
- Revised Exercise 2.3 to include integration of directional and regional terms
- Deleted Table 2.3 on Selected Regional Terms
- Incorporated Learning Strategy on directional terms into text
- Revised Figure 2.4 Regional Terms for accuracy
- Revised Figure 2.7 Body Cavities for accuracy
- Revised Exercise 2.4 on Body Cavities to include activity on membranes
- Incorporated Concept Connection on Serous Membranes into text
- New Figure 2.6 on Serous Membranes

Chapter 3

- Revised and moved to earlier chapter Concept Connection on viewing histological slides
- Revised Exercise 3.1 Parts of a Compound Microscope to include a table
- Revised Exercise 3.3 Measuring the Diameter of the Field of View to be more interactive
- Revised Figure 3.5 Estimating Specimen Size

Chapter 4

- Revised Introduction to better explain the overall structure and function of cells and tissues
- Reorganized Table 4.1 Parts of a Generalized Animal Cell to sort terms by membrane-bound and non-membrane-bound organelles
- Replaced Concept Connection on excitable cells with Concept Connection on plasma membrane proteins and membrane transport due to relevance to chapter content
- Deleted Concept Connection on molecular weight calculation to avoid duplicated content
- Replaced Clinical View on Hemodialysis with Clinical View on Dehydration due to relevance to chapter content

Chapter 5

- Revised Introduction to explain the process of preparing tissue samples for histological staining
- Revised Clinical View: Histopathology to move information about tissue preparation to the introduction
- Revised Learning Strategy on identifying epithelial tissue on a slide to help make this identification easier for the student
- Revised Table 5.3 Cell Surface Modifications and Specialized Cells of Epithelial Tissues to more clearly differentiate between surface modifications and specialized cells

Chapter 6

- Revised Introduction to include several important functions of skin
- Revised Gross Anatomy introductory text: Integument Model to discuss the layers of skin in more depth
- Revised Clinical View: Fingerprinting to highlight the contribution of dermal papillae to fingerprint formation
- Revised Clinical View: Melanoma to include evolution of a mole as a characteristic of melanoma clinical presentation
- Revised Figure 6.11 Longitudinal Section of a Nail
- Revised Table 6.5 Parts of a Nail

Chapter 7

- Revised Introduction to cite the relevance of chapter content to real-life scenarios
- Replaced the term *bone marrow cavity* with *medullary cavity* to align with the textbook
- Revised Exercise 7.3 Cow Bone Dissection for brevity
- Revised Figure 7.4 The Human Skeleton
- Revised Table 7.2 Types of Bone Cells
- Revised Exercise 7.5 Compact Bone for brevity
- Revised Figure 7.9 Spongy Bone
- Revised Concept Connection on the composition of bone for brevity
- Revised Concept Connection on hormones that influence bone growth to better relate to chapter content
- Revised Learning Strategy on five functional layers of the epiphyseal plate

Chapter 8

- Incorporated Learning Strategy on learning bony projections into Introduction
- Revised all tables for accuracy and brevity
- Revised Figure 8.1 Anterior View of the Skull
- Eliminated table on The Axial Skeleton: Anterior View of the Skull for redundancy
- Revised Exercise 8.1B The Orbit to be more interactive
- Revised Figure 8.2 The Orbit
- Revised Concept Connection on the nasal cavity
- Revised Figure 8.4 The Mandible
- New Table 8.3 Sutures and Craniometric Points
- Revised Figure 8.5 Lateral View of the Skull
- Revised Figure 8.6 Posterior View of the Skull
- Revised Figure 8.8 Inferior View of the Skull
- Revised Figure 8.11 Superior View of the Cranial Floor
- Revised Clinical View on Spondylolisthesis
- Revised Figure 8.21 Sacrum and Coccyx

- New Exercise 8.11 Radiographs
- New Figure 8.24 A Radiograph of Skull
- New Figure 8.25 A Chest X-Ray
- Revised Post-Laboratory Worksheet to include a labeling figure and some new questions

Chapter 9

- Incorporated Concept Connection on learning bony features into the introduction
- Moved Learning Strategy on identifying individual bones to earlier in the chapter
- Revised all tables for accuracy and brevity
- New Figure 9.1 Right Pectoral Girdle
- Revised Figure 9.3 The Right Scapula
- Revised Exercise 9.1B The Scapula due to redundancy
- Refined Clinical View on Clavicular Fracture
- Revised Exercise 9.2A The Humerus
- Revised Figure 9.4 The Humerus
- Revised Figure 9.5 The Radius
- Revised Exercise 9.2D The Carpals to be more interactive
- Refined Learning Strategy on learning carpal bone names
- New Exercise 9.2F on Articulated Bones in the Upper Extremity
- Revised Figure 9.9 The Elbow
- New Figure 9.10 X-Ray of the Wrist
- Revised Figure 9.12 The Right Ox Coxae
- Revised Exercise 9.4B Male and Female Pelves
- Refined Clinical View on Pregnancy and Childbirth
- Revised Figure 9.14 The Proximal and Distal Femur
- Revised Figure 9.15 The Right Femur
- Revised Figure 9.16 The Tibia
- Revised Exercise 9.5D The Tarsals to be more interactive
- New Exercise 9.5F Articulations in the Lower Extremity
- New Figure 9.20 Pelvis X-Ray, Anterior View
- New Figure 9.21 X-ray of the Knee, Medial View
- Refined Concept Connection on red bone marrow
- Revised Post-Laboratory Worksheet to include some new questions and decrease length

Chapter 10

- Revised Introduction to cite the relevance of chapter content to real-life scenarios
- Replaced the term *synovial cavity* with *joint (articular) cavity* to align with the textbook
- Reorganized Table 10.4 Components of Synovial Joints
- Revised Figure 10.3 Diagram of a Representative Synovial Joint
- Revised Table 10.5 Classification of Synovial Joints
- Revised Figure 10.4 Classification of Synovial Joints
- Revised Table 10.6 Movements of Synovial Joints to convert a reference table to an exercise activity
- Revised Figure 10.6 A Representative Synovial Joint: The Right Knee Joint
- Revised Concept Connection on movement of synovial joints to better relate to chapter content
- Revised Clinical View: Low Back Pain for brevity

Chapter 11

- Revised Introduction to better present an overview of chapter content
- Revised the terms for skeletal muscle fiber types to align with the textbook
- Revised Table 11.4 Fascial Compartments of the Limbs and Their General Muscle Actions to convert a reference table to an exercise activity
- Revised Concept Connection on the three types of muscle tissue for brevity
- Simplified Figure 11.7 The Neuromuscular Junction
- Moved Figure 11.8 Cardiac Muscle Tissue within Exercise 11.7 Cardiac Muscle Tissue for chapter consistency
- Moved Figure 11.9 Smooth Muscle Tissue within Exercise 11.8 Smooth Muscle Tissue for chapter consistency
- Revised Table 11.6 Properties of Skeletal Muscle Fiber Types
- Revised Figure 11.10 Recruitment of Motor Units

Chapter 12

- Revised all tables for accuracy and brevity
- Revised Figure 12.1 Muscles of Facial Expression
- New Table 12.6 Muscles that Move the Head and Neck
- Deleted Clinical View on Stroke due to relevance to chapter content
- Simplified Table 12.7 Muscles of the Vertebral Column
- New Clinical View on Strains, Sprains, and Spasms
- Incorporated Concept Connection on pulmonary ventilation into the text
- New Table 12.10 Structures Related to Abdominal Musculature
- Revised Post-Laboratory Worksheet to include a labeling figure and some new questions

Chapter 13

- Revised all tables for accuracy and brevity
- Added new figure to Clinical View on Winged Scapula
- Reorganized Table 13.6 Posterior (Extensor) Compartment of the Forearm
- Revised Figure 13.6 Posterior (Extensor) Compartment of the Forearm
- Reorganized Table 13.8 Muscles of the Gluteal Region
- Reorganized Exercise 13.5 Muscles That Act About the Hip Joint/Thigh for clarity
- Revised Figure 13.8 Actions of Gluteal Muscles During Locomotion
- New Table 13.10 Medial Compartment of the Thigh
- Reorganized Table 13.13 Posterior Compartment of the Leg
- Revised Figure 13.15 Lateral View of the Leg
- Revised Post-Laboratory Worksheet to include labeling figures and some new questions

Chapter 14

- Revised Introduction to discuss the two major branches of the nervous system
- New Figure 14.1 Organization of the Nervous System
- Revised Concept Connection on the excitability and conductivity of nervous tissue
- New Figure 14.2 Gray Matter of the Spinal Cord
- Revised Physiology introductory text: Resting Membrane Potential to describe this potential and what contributes to the generation of the potential
- Revised Learning Strategy on potential and kinetic energy and resting membrane potential

Chapter 15

- New Concept Connection on neuron control of skeletal muscle
- New Table 15.1 Brain Structures Visible from the Superior View
- New Table 15.2 Brain Structures Visible from the Lateral View
- New Table 15.3 Brain Structures Visible from the Inferior View
- New Table 15.4 Brain Structures Visible from the Midsagittal View
- New Table 15.5 General Meningeal Layers
- New Table 15.6 Associated Meningeal Structures
- Revised Figure 15.6 Meningeal Structures
- New Table 15.7 Secondary Brain Vesicles and Associated Structures of the Brain

Chapter 16

- Revised text in The Spinal Cord section for clarity and breadth
- Added new content to Table 16.1 Gross Anatomy of the Spinal Cord
- Revised Figure 16.1 Regional Gross Anatomy of the Spinal Cord
- Revised Exercise 16.3 The Brachial Plexus for clarity
- Revised Table 16.2 Organization of the Brachial Plexus for brevity
- Revised Figure 16.4 for accuracy
- New Clinical View on Additional Nerves of the Brachial Plexus and Spinal Cord Injury
- Revised Table 16.5 for brevity
- Revised Exercise 16.4 The Lumbar and Sacral Plexus
- Refined Learning Strategy on pudendal nerve
- Revised Exercise 16.5 Histological Cross Sections of the Spinal Cord to make more interactive
- Refined Concept Connection on reflexes
- Revised Exercise 16.7 Patellar Reflex
- Revised Post-Laboratory Worksheet to include some new questions

Chapter 17

- Revised Introduction to better explain an overview of chapter content
- Revised the terms for cranial nerves to align with the textbook
- New Figure 17.1 Lower Motor Neurons of the Autonomic Nervous System
- Revised Figure 17.2 Comparison of the Parasympathetic and Sympathetic Divisions of the ANS
- Reorganized Table 17.1 Comparison of Parasympathetic and Sympathetic Divisions to emphasize structure and function
- New Table 17.2 Parasympathetic Division Outflow for content coverage and activity
- Incorporated Learning Strategy on parasympathetic innervation of visceral organs into Exercise 17.1 Parasympathetic Division
- Revised Learning Strategy on parasympathetic innervation of visceral organs to sympathetic innervation of the adrenal gland
- New Table 17.3 Sympathetic Division Pathways for content coverage and activity
- Revised Clinical View on Pheochromocytoma for brevity
- Revised Post-Laboratory Worksheet to include new application questions

Chapter 18

- Revised Figure 18.1 Skin
- Revised Table 18.2 External and Accessory Structures of the Eye
- Revised Table 18.3 Internal Structures of the Eye
- Revised Table 18.4 Extrinsic Eye Muscles
- Revised Figure 18.8 Classroom Model of the Ear
- Revised Table 18.5 Structures of the External, Middle, and Inner Ear
- Revised Table 18.6 Sensory Receptors in Thick Skin
- Revised Table 18.8 Olfactory Epithelium
- Revised Table 18.9 The Retina
- Revised Figure 18.17 The Cochlea
- Revised Table 18.10 The Cochlea
- New Table 18.11 The Spiral Organ
- New Clinical View: Tinnitus

Chapter 19

- Revised Table 19.1 The Hormone-Secreting Cells of the Pituitary Gland
- New Concept Connection on growth hormone effects on skeletal tissue
- Revised Figure 19.8 Endocrine Portion of the Pancreas
- Revised Concept Connection on hormones and transport proteins

Chapter 20

- Revised Introduction for relevance of chapter content and brevity
- Revised Table 20.1 The Four Greek Humors
- Revised Caution to include the hazards of Wright's stain
- Combined and reorganized Table 20.2 Characteristics of the Formed Elements of Blood and Table 20.3 Leukocyte Characteristics
- Removed Exercise 20.3 Identification of Formed Elements of the Blood on Classroom Models or Charts to avoid duplicated content
- Revised Table 20.3 Normal Ranges for Laboratory Blood Tests

- Revised Concept Connection for relevance of chapter content

Chapter 21

- Added new questions to Pre-Laboratory Worksheet to cover entire chapter
- New content on the layers of the heart wall in Exercise 21.2 Gross Anatomy of the Human Heart
- Revised Exercise 21.4 Superficial Structures of the Sheep Heart to make more interactive
- Moved Exercise 21.9 Auscultation of Heart Sounds earlier in chapter for better flow of content
- New Learning Strategy on auscultation of the heart
- Revised Figure 21.20 Normal Components of an ECG for accuracy
- Revised Clinical View on ECG to be more interactive
- Revised Post-Laboratory Worksheet to include a labeling figure and some new questions

Chapter 22

- Revised opening Gross Anatomy text
- New Exercise 22.2 Great Vessels of the Heart
- New Figure 22.2 Great Vessels of the Heart
- Revised Figure 22.7 Circulation to the Thoracic and Abdominal Walls
- Revised Exercise 22.6 Circulation to the Abdominal Cavity to be more interactive
- Revised Figure 22.12 Circulation from the Abdominal Aorta to the Sigmoid Colon and Back to the Right Atrium of the Heart.
- New Concept Connection on blood vessel wall
- Revised Figure 22.21 Elastic Artery
- Revamped Exercise 22.15 Capillaries to be more interactive and concise
- Revised Concept Connection on blood flow
- New Figure 22.27 Blood Pressure Measurement
- Revised figures in Post-Laboratory Worksheet for accuracy

Chapter 23

- Revised Introduction to more clearly explain the major roles of the lymphatic system
- Revised Histology introductory text: Lymphatic Vessels to more clearly describe the histology of lymphatic vessels
- New Figure 23.6 Lymphatic Nodule
- Revised Clinical View: Appendicitis
- Revised Exercise 23.6 The Thymus to more clearly describe the role of selection during T-cell development
- Revised Table 23.6 Cells of the Immune System

Chapter 24

- New opening text in Gross Anatomy describing the respiratory system
- New Figure 24.1 Parts of Respiratory System
- Revised Figure 24.5 The Pleural Cavities for clarity
- Revised Figure 24.6 The Right Lung
- Revised Figure 24.7 The Left Lung
- Revised Figure 24.10 Histology of the Trachea
- Refined Learning Strategy on the trachea for brevity
- Revised Exercise 24.9 The Lungs to be more interactive
- New Table 24.7 Microscopic Structures Within the Alveoli

Chapter 25

- Revised Introduction to more clearly explain the major roles of the urinary system and the functional components that carry out these roles
- Revised Figure 25.1 Coronal Section Through the Right Kidney
- Revised Figure 25.2 Blood Supply to the Kidney
- Revised Figure 25.3 Model of the Kidney Demonstrating the Blood Supply to the Kidney
- Revised Exercise 25.3 Urine-Draining Structures Within the Kidney to allow students to trace the flow of filtrate
- Revised Table 25.1 Histological Features of the Kidney
- Revised Learning Strategy on glomerular filtration rate
- Revised Concept Connection on glomerular filtration

Chapter 26

- Revised Introduction to more clearly explain how modifications of the GI tract impact function
- Revised Figure 26.2 Oral Cavity
- Reorganized Table 26.2 Gross Anatomic Features of the Liver, Gallbladder, Pancreas, and their Associated Ducts
- Revised Histology introductory text: The Stomach
- Revised Exercise 26.8 Histology of the Stomach
- Revised Figure 26.12 Gastric Pits and Gastric Glands
- Revised Figure 26.13 The Small Intestine

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- Revised Table 27.4 Developmental Stages of Ovarian Follicles
- Revised Table 27.8 Phases of the Menstrual Cycle
- New Concept Connection on smooth muscle in the reproductive system
- New Clinical View: Testicular Cancer and Testicular Self Exam
- Revised Figure 27.17 Oogenesis

Chapter 28

- Revised Figure 28.5 Muscles of the Head, Neck, and Thorax (Anterior View)
- Revised Figure 28.6 Muscles of the Thorax and Abdomen
- Revised Figure 28.8 Superficial Back Muscles
- Revised Figure 28.21 The Thoracic Cavity
- Revised Figure 28.22 The Respiratory System
- Revised Figure 28.24 The Abdominal Cavity

Chapter 29

- Revised Figure 29.4 The Pig Skeleton
- Revised Exercise 29.13 The Heart, Lungs, and Mediastinum

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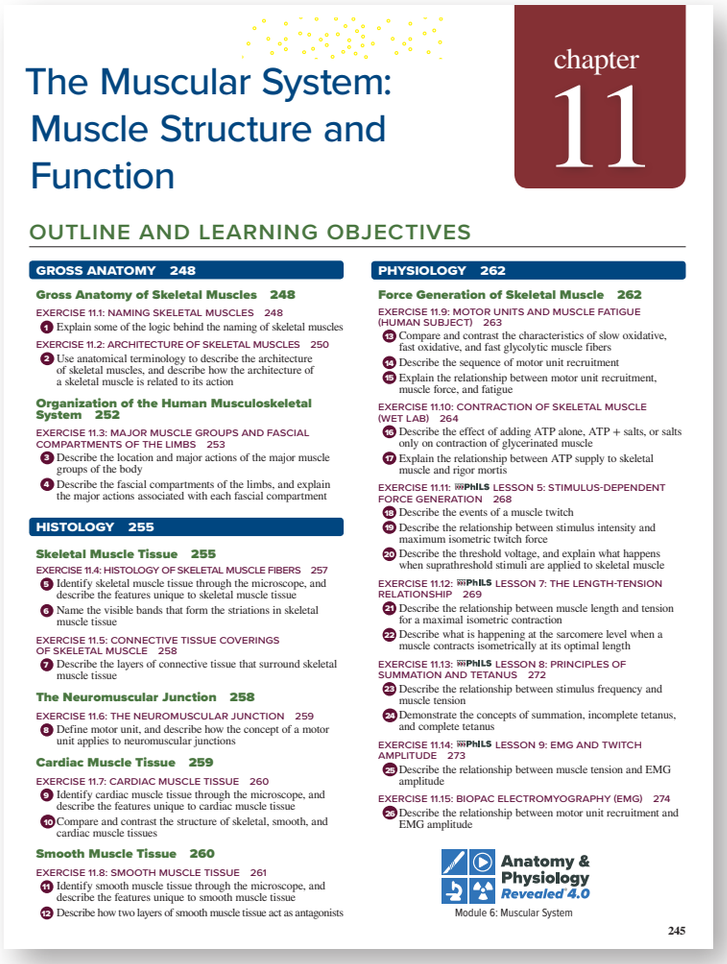
Features

The Ross/Day/Comber/Eckel: *Anatomy & Physiology Laboratory Manual* works well as a complement to the McKinley/O'Loughlin/Bidle: *Anatomy & Physiology: An Integrative Approach* textbook, or to accompany any other anatomy and physiology text. Each chapter opener includes an **outline** that lists a set of **learning objectives** for the chapter.

- A chapter **Introduction** opens with a real-life scenario that emphasizes the section of the body covered in the chapter, to connect the anatomy of our bodies with the physiology that helps us to perform day-to-day activities.

- The laboratory manual exhibits the highest-quality **photographs and illustrations** of any laboratory manual on the market.



chapter 11

The Muscular System: Muscle Structure and Function

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Gross Anatomy of Skeletal Muscles 248

EXERCISE 11.1: NAMING SKELETAL MUSCLES 248
1. Explain some of the logic behind the naming of skeletal muscles

EXERCISE 11.2: ARCHITECTURE OF SKELETAL MUSCLES 250
2. Use anatomical terminology to describe the architecture of skeletal muscles, and describe how the architecture of a skeletal muscle is related to its action

Organization of the Human Musculoskeletal System 252

EXERCISE 11.3: MAJOR MUSCLE GROUPS AND FASCIAL COMPARTMENTS OF THE LIMBS 253
3. Describe the location and major actions of the major muscle groups of the body
4. Describe the fascial compartments of the limbs, and explain the major actions associated with each fascial compartment

HISTOLOGY 255

Skeletal Muscle Tissue 255

EXERCISE 11.4: HISTOLOGY OF SKELETAL MUSCLE FIBERS 257
5. Identify skeletal muscle tissue through the microscope, and describe the features unique to skeletal muscle tissue
6. Name the visible bands that form the striations in skeletal muscle tissue

EXERCISE 11.5: CONNECTIVE TISSUE COVERINGS OF SKELETAL MUSCLE 258
7. Describe the layers of connective tissue that surround skeletal muscle tissue

The Neuromuscular Junction 258

EXERCISE 11.6: THE NEUROMUSCULAR JUNCTION 259
8. Define motor unit, and describe how the concept of a motor unit applies to neuromuscular junctions

Cardiac Muscle Tissue 259

EXERCISE 11.7: CARDIAC MUSCLE TISSUE 260
9. Identify cardiac muscle tissue through the microscope, and describe the features unique to cardiac muscle tissue
10. Compare and contrast the structure of skeletal, smooth, and cardiac muscle tissues

Smooth Muscle Tissue 260

EXERCISE 11.8: SMOOTH MUSCLE TISSUE 261
11. Identify smooth muscle tissue through the microscope, and describe the features unique to smooth muscle tissue
12. Describe how two layers of smooth muscle tissue act as antagonists

PHYSIOLOGY 262

Force Generation of Skeletal Muscle 262

EXERCISE 11.9: MOTOR UNITS AND MUSCLE FATIGUE (HUMAN SUBJECT) 263
13. Compare and contrast the characteristics of slow oxidative, fast oxidative, and fast glycolytic muscle fibers
14. Describe the sequence of motor unit recruitment
15. Explain the relationship between motor unit recruitment, muscle force, and fatigue

EXERCISE 11.10: CONTRACTION OF SKELETAL MUSCLE (WET LAB) 264
16. Describe the effect of adding ATP alone, ATP + salts, or salts only on contraction of glycerinated muscle
17. Explain the relationship between ATP supply to skeletal muscle and rigor mortis

EXERCISE 11.11: PhILS LESSON 5: STIMULUS-DEPENDENT FORCE GENERATION 268
18. Describe the events of a muscle twitch
19. Describe the relationship between stimulus intensity and maximum isometric twitch force
20. Describe the threshold voltage, and explain what happens when suprathreshold stimuli are applied to skeletal muscle

EXERCISE 11.12: PhILS LESSON 7: THE LENGTH-TENSION RELATIONSHIP 269
21. Describe the relationship between muscle length and tension for a maximal isometric contraction
22. Describe what is happening at the sarcomere level when a muscle contracts isometrically at its optimal length

EXERCISE 11.13: PhILS LESSON 8: PRINCIPLES OF SUMMATION AND TETANUS 272
23. Describe the relationship between stimulus frequency and muscle tension
24. Demonstrate the concepts of summation, incomplete tetanus, and complete tetanus

EXERCISE 11.14: PhILS LESSON 9: EMG AND TWITCH AMPLITUDE 273
25. Describe the relationship between muscle tension and EMG amplitude

EXERCISE 11.15: BIOPAC ELECTROMYOGRAPHY (EMG) 274
26. Describe the relationship between motor unit recruitment and EMG amplitude

Anatomy & Physiology Revealed 4.0
Module 6: Muscular System

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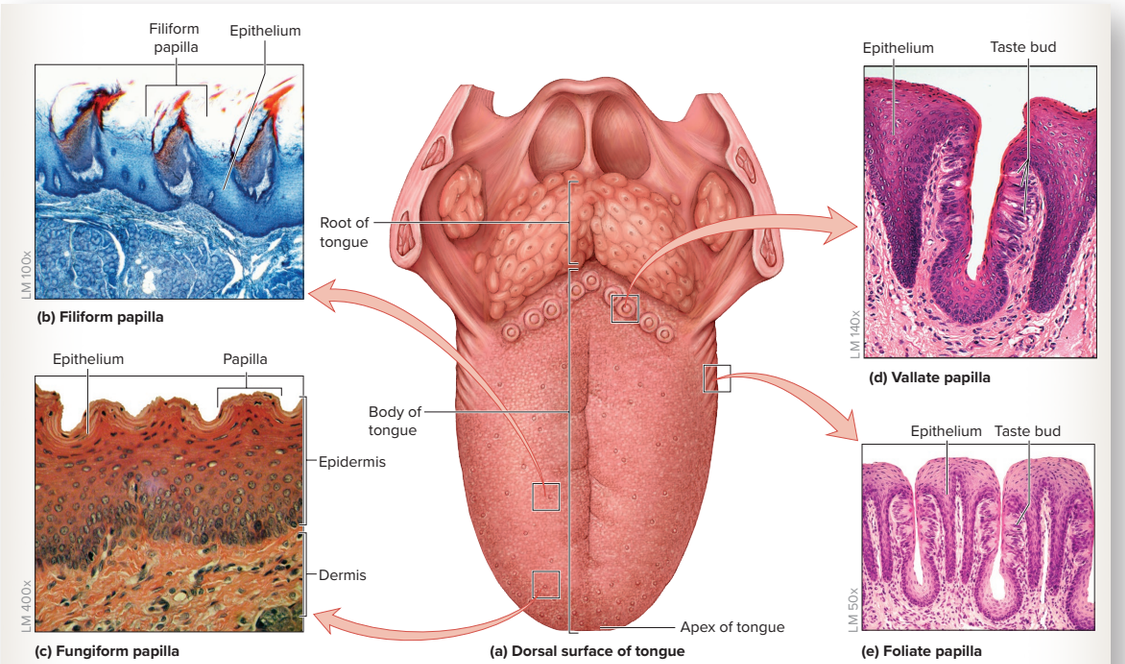


Figure 18.12 **Taste Buds.** Gustation (taste) requires taste buds, which are associated with tongue papillae. (*a*) Dorsal surface of tongue, (*b*) Filiform papilla, (*c*) Fungiform papilla, (*d*) Vallate papilla, (*e*) Foliate papilla.

(*b*) ©CNRI/Science Photo Library/Corbis; (*c*) ©McGraw-Hill Education/Christine Eckel, photographer; (*d*) ©McGraw-Hill Education/Alvin Telser; (*e*) ©Jose Luis Calvo/Shutterstock.com

- The content of the laboratory manual is informed by the textbook, and both the textbook and the laboratory manual share similar pedagogic elements: **Concept Connection**, **Learning Strategy**, and **Clinical View** features from the text are also employed in the laboratory manual.
  - **Integrate: Concept Connection** boxes draw concepts from the classroom into the laboratory for a real-time review of how previously covered concepts relate to body systems.
  - **Integrate: Learning Strategy** boxes offer tried-and-tested learning strategies that consist of everyday analogies, mnemonics, and useful tips to aid understanding and memory.
  - **Integrate: Clinical View** sidebars reinforce facts through a clinical discussion of what happens when the body doesn't perform normally.
- **Pre-Laboratory Worksheets** at the start of each chapter consist of important refresher points to provide students with a "warm-up" before entering the laboratory classroom. Some questions pertain to previous activities that are relevant to upcoming exercises, while others are basic questions that students should be able to answer if they have read the chapter from their lecture text before coming into the laboratory classroom. The goal of completing these worksheets is to have students arrive at the laboratory prepared to deal with the material they will be covering, so valuable laboratory time isn't lost in reviewing necessary information. All Pre-Laboratory Worksheet questions are assignable within Connect.

INTEGRATE

CONCEPT CONNECTION

Two basic cell types make up nervous tissue: neurons and neuroglia. Although these cell types vary in structure, function, and location, they share similarities with one another as well as with most other cell types found throughout the body. Like other cells, neurons are surrounded by a selectively permeable plasma membrane (the neurolemma) that regulates the movement of molecules into

The neuron can be divided into segments based on structural features and function. For example, the *receptive segment* contains the dendrites and the soma of a neuron. The neurolemma of these structures contains many ligand-gated ion channels, which are opened or closed by the binding of neurotransmitters ("ligands") released by the axon terminals of neighboring neurons. Therefore, the structures that make up the receptive segment *receive* the signal. Because these structures do not contain voltage-gated sodium channels, the membrane can only

INTEGRATE

LEARNING STRATEGY

To identify superficial muscles and tendons, place your left palm on the medial epicondyle of your right humerus. In this position, the order of the muscles on your right forearm, from lateral to medial, is:

Index finger—pronator teres (PT)

Middle finger—flexor carpi radialis (FCR)

Ring finger—palmaris longus (PL)

Pinky finger—flexor carpi ulnaris (FCU)

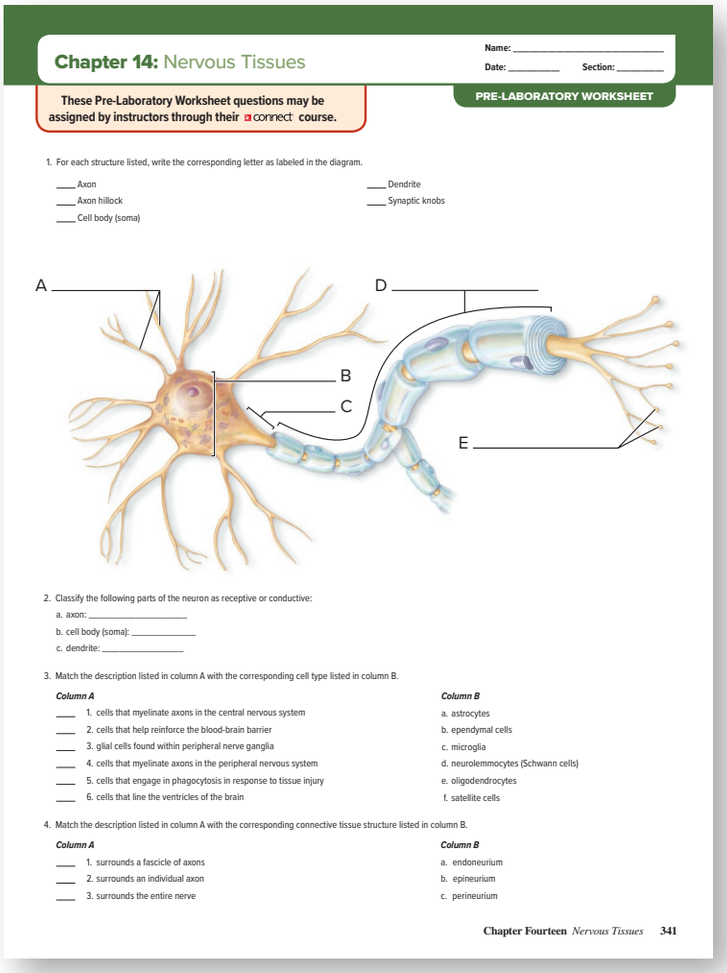
While performing this exercise, flex your wrist and digits to identify the tendons, from lateral to medial, of the flexor carpi radialis, palmaris longus, and flexor carpi ulnaris.

(Left hand covers medial epicondyle)

INTEGRATE

CLINICAL VIEW
Piriformis Syndrome

The piriformis muscle is a "pear-shaped" muscle that lies in close proximity to important structures within the gluteal region, such as the sciatic nerve, and the gluteal arteries and nerves. Piriformis syndrome is a painful condition that results from inflammation or overuse of the piriformis muscle. The incidence of piriformis syndrome is relatively common in athletes such as runners and cyclists, who may develop an imbalance in the strength of the piriformis muscle as compared to the gluteal muscles. As the piriformis muscle becomes inflamed or spasms, it may also compress the underlying sciatic nerve, resulting in sciatica. **Sciatica** is a tingling, painful, or even numbing sensation that travels down the path of the sciatic nerve. Patients complain of shooting pain that runs from the gluteal region down the lateral aspect of the thigh and toward the leg. Often the pain may be exacerbated when the body is held in certain positions, such as prolonged sitting or standing. Many health professionals, including physical therapists and chiropractors, can help treat patients with piriformis syndrome.



Chapter 14: Nervous Tissues

Name: _____
Date: _____ Section: _____

PRE-LABORATORY WORKSHEET

These Pre-Laboratory Worksheet questions may be assigned by instructors through their connect course.

1. For each structure listed, write the corresponding letter as labeled in the diagram.

___ Axon
___ Axon hillock
___ Cell body (soma)
___ Dendrite
___ Synaptic knobs

A
D
B
C
E

2. Classify the following parts of the neuron as receptive or conductive:
   a. axon: _____
   b. cell body (soma): _____
   c. dendrite: _____

3. Match the description listed in column A with the corresponding cell type listed in column B.

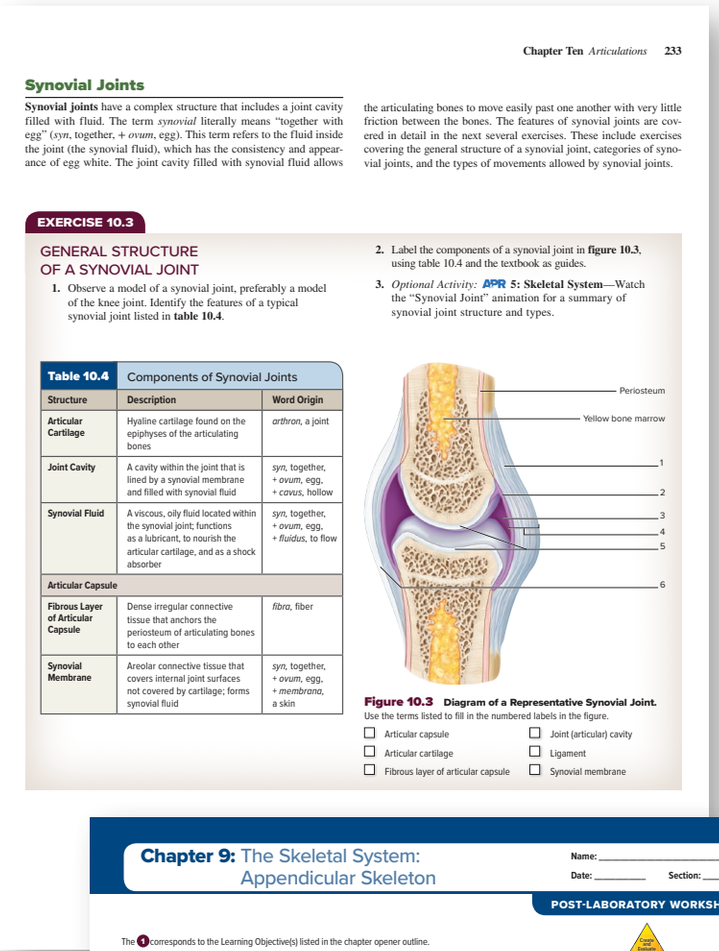
Column A	*Column B*
___ 1. cells that myelinate axons in the central nervous system	a. astrocytes
___ 2. cells that help reinforce the blood-brain barrier	b. ependymal cells
___ 3. glial cells found within peripheral nerve ganglia	c. microglia
___ 4. cells that myelinate axons in the peripheral nervous system	d. neurolemmocytes (Schwann cells)
___ 5. cells that engage in phagocytosis in response to tissue injury	e. oligodendrocytes
___ 6. cells that line the ventricles of the brain	f. satellite cells

4. Match the description listed in column A with the corresponding connective tissue structure listed in column B.

Column A	*Column B*
___ 1. surrounds a fascicle of axons	a. endoneurium
___ 2. surrounds an individual axon	b. epineurium
___ 3. surrounds the entire nerve	c. perineurium

Chapter Fourteen *Nervous Tissues* 341

- In-chapter **activities** offer a mixture of labeling exercises, sketching activities, table completion exercises, data recording and analysis, palpation of surface anatomy, and other sources of learning. In the gross anatomy exercises of this manual, structures such as cranial bones and muscles of the body are *not* always presented as labeled photos, since students already have labeled photos provided in their anatomy and physiology textbook. Instead, images are presented as labeling activities with a checklist of structures. The checklists serve two purposes: (1) they guide students to items they should be able to identify on classroom models, fresh specimens, or cadavers (if the laboratory uses human cadavers), and (2) they double as a list of terms students can use to complete the labeling activities. Answers to the labeling activities are provided in the Appendix. Thus, if a student does not know what a leader line is pointing to, or cannot remember the correct term, the Appendix serves as a resource for locating the correct answer.
- **Anatomy & Physiology REVEALED® 4.0 (APR)** correlations, indicated by the APR logo, direct students to related content in this cutting-edge software.
- Each chapter contains numerous **tables,** which concisely summarize critical information and key structures and serve as important points of reference while in the laboratory classroom. Most tables contain a column that provides word origins for each structure listed within the table. These word origins are intended to give students continual exposure to the origins of the language of anatomy and physiology, which is critical for learning and retention.
- Numerous **Physiology Interactive Lab Simulations© (Ph.I.L.S.) 4.0** exercises throughout the laboratory manual make otherwise difficult and expensive experiments a breeze, and offer additional opportunities to aid student understanding of physiology.
- **BIOPAC©** exercises are included in chapters 11, 15, 17, 21, 22, and 24.
- **Post-Laboratory Worksheets** at the end of each chapter serve as a review of the materials just covered and challenge students to apply knowledge gained in the laboratory. The Post-Laboratory Worksheets contain in-depth critical thinking questions and are perforated so they can be torn out and handed in to the instructor, if so desired. Assessment questions are organized by exercise and are keyed to the Learning Objectives from the chapter opener outline.
  - **Do You Know the Basics?** questions quiz students on the material they have just learned in the chapter, using a variety of question formats including labeling, table completion, matching exercises, and fill-in-the-blank.
  - **Can You Apply What You've Learned?** questions are often clinically oriented and expose health-sciences students to problem solving in clinical contexts.
  - **Can You Synthesize What You've Learned?** questions combine concepts learned in the chapter to ensure student understanding of each chapter's objectives.



Chapter Ten *Articulations* 233

Synovial Joints

Synovial joints have a complex structure that includes a joint cavity filled with fluid. The term *synovial* literally means "together with egg" (*syn*, together, + *ovum*, egg). This term refers to the fluid inside the joint (the synovial fluid), which has the consistency and appearance of egg white. The joint cavity filled with synovial fluid allows the articulating bones to move easily past one another with very little friction between the bones. The features of synovial joints are covered in detail in the next several exercises. These include exercises covering the general structure of a synovial joint, categories of synovial joints, and the types of movements allowed by synovial joints.

EXERCISE 10.3

GENERAL STRUCTURE OF A SYNOVIAL JOINT

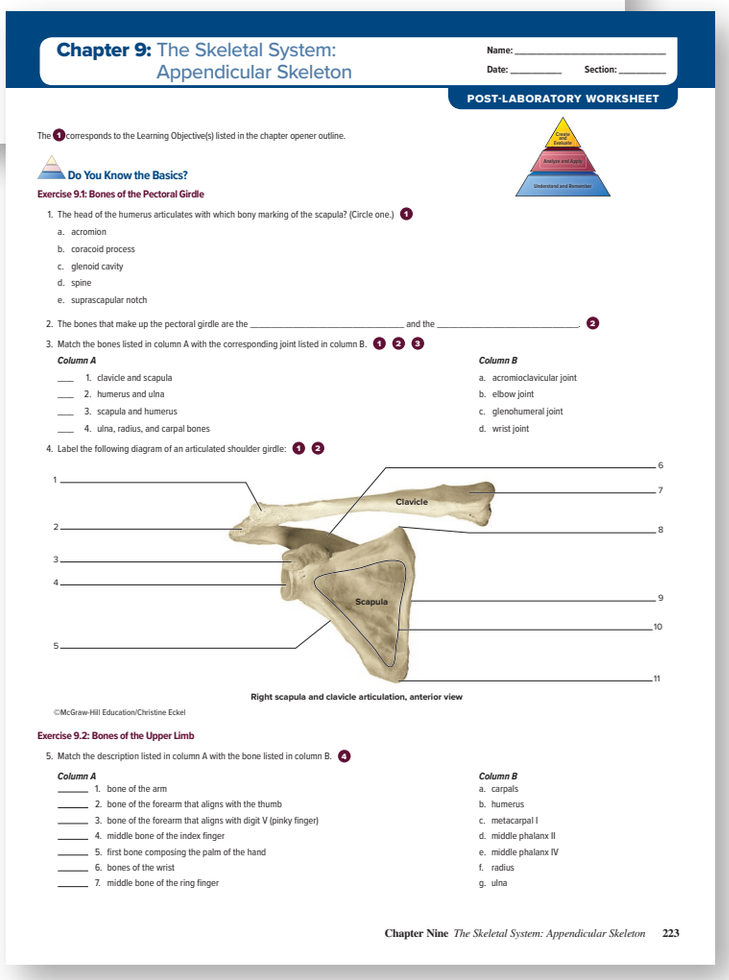
1. Observe a model of a synovial joint, preferably a model of the knee joint. Identify the features of a typical synovial joint listed in **table 10.4**.
2. Label the components of a synovial joint in **figure 10.3**, using table 10.4 and the textbook as guides.
3. *Optional Activity:* **APR 5: Skeletal System**—Watch the "Synovial Joint" animation for a summary of synovial joint structure and types.

Table 10.4 Components of Synovial Joints

Structure	Description	Word Origin
Articular Cartilage	Hyaline cartilage found on the epiphyses of the articulating bones	*arthron*, a joint
Joint Cavity	A cavity within the joint that is lined by a synovial membrane and filled with synovial fluid	*syn*, together, + *ovum*, egg, + *cavus*, hollow
Synovial Fluid	A viscous, oily fluid located within the synovial joint; functions as a lubricant, to nourish the articular cartilage, and as a shock absorber	*syn*, together, + *ovum*, egg, + *fluidus*, to flow
Articular Capsule		
Fibrous Layer of Articular Capsule	Dense irregular connective tissue that anchors the periosteum of articulating bones to each other	*fibra*, fiber
Synovial Membrane	Areolar connective tissue that covers internal joint surfaces not covered by cartilage; forms synovial fluid	*syn*, together, + *ovum*, egg, + *membrana*, a skin

Figure 10.3 Diagram of a Representative Synovial Joint.
Use the terms listed to fill in the numbered labels in the figure.

- ☐ Articular capsule
- ☐ Articular cartilage
- ☐ Fibrous layer of articular capsule
- ☐ Joint (articular) cavity
- ☐ Ligament
- ☐ Synovial membrane



Chapter 9: The Skeletal System: Appendicular Skeleton

Name: _____
Date: _____ Section: _____

POST-LABORATORY WORKSHEET

The 1 corresponds to the Learning Objective(s) listed in the chapter opener outline.

Create / Evaluate / Analyze and Apply / Understand and Remember

Do You Know the Basics?

Exercise 9.1: Bones of the Pectoral Girdle

1. The head of the humerus articulates with which bony marking of the scapula? (Circle one.) 1
   a. acromion
   b. coracoid process
   c. glenoid cavity
   d. spine
   e. suprascapular notch
2. The bones that make up the pectoral girdle are the _____ and the _____. 2
3. Match the bones listed in column A with the corresponding joint listed in column B. 1 2 3

Column A	*Column B*
___ 1. clavicle and scapula	a. acromioclavicular joint
___ 2. humerus and ulna	b. elbow joint
___ 3. scapula and humerus	c. glenohumeral joint
___ 4. ulna, radius, and carpal bones	d. wrist joint

4. Label the following diagram of an articulated shoulder girdle: 1 2

Right scapula and clavicle articulation, anterior view

Exercise 9.2: Bones of the Upper Limb

5. Match the description listed in column A with the bone listed in column B. 4

Column A	*Column B*
_____ 1. bone of the arm	a. carpals
_____ 2. bone of the forearm that aligns with the thumb	b. humerus
_____ 3. bone of the forearm that aligns with digit V (pinky finger)	c. metacarpal I
_____ 4. middle bone of the index finger	d. middle phalanx II
_____ 5. first bone composing the palm of the hand	e. middle phalanx IV
_____ 6. bones of the wrist	f. radius
_____ 7. middle bone of the ring finger	g. ulna

Chapter Nine *The Skeletal System: Appendicular Skeleton* 223

Teaching Supplements

Answers to the Pre-Laboratory and Post-Laboratory Worksheets can be found within the **Instructor's Manual** for this Laboratory Manual within Connect, by accessing the McKinley/O'Loughlin/Bidle: *Anatomy & Physiology,* 4th edition Instructor Resources. **Image files** for use in presentations and teaching materials are also provided for instructor use at this location.

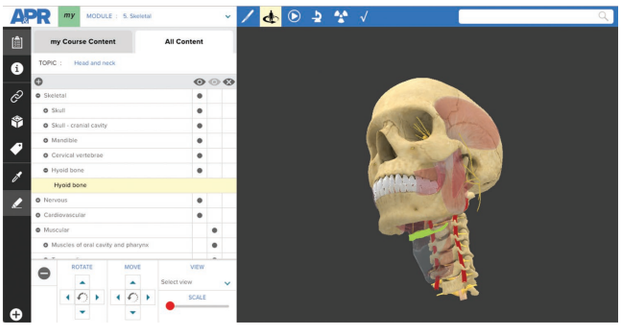
Anatomy & Physiology Revealed® 4.0

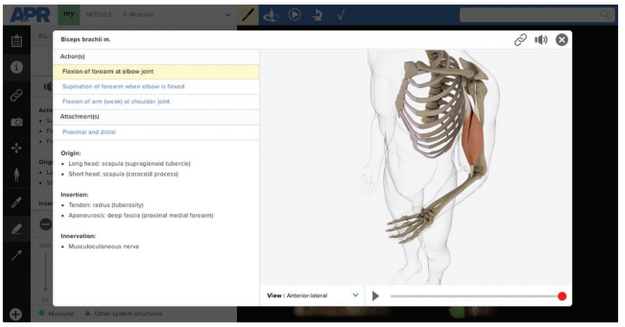
Anatomy & Physiology Revealed® 4.0: An Interactive Cadaver Dissection Experience

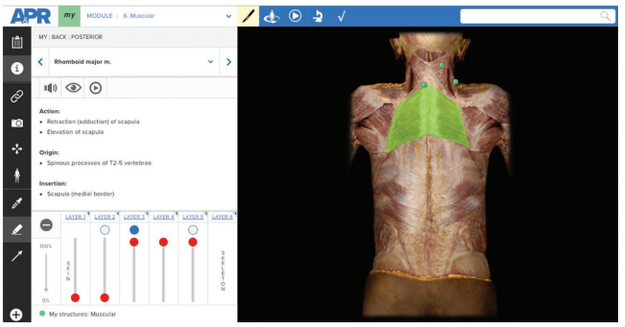
Available in Connect and online at aprevealed.com, Anatomy & Physiology Revealed (APR) is an interactive human cadaver dissection tool built to enhance both lecture and lab. APR contains all the systems covered in A&P and Human Anatomy courses, including Body Orientation, Cells and Chemistry, and Tissues. Detailed cadaver photographs blended with a state-of-the-art layering technique provide a uniquely interactive dissection experience.

With a new streamlined, user- and mobile-friendly interface, increased accessibility, updated animations and 3D interactive models, APR was built to increase the success of your A&P laboratory course.

- Dissection: Peel away layers of the human body to reveal structures. Structures can be pinned and labeled, just as in a real dissection lab. Each labeled structure is accompanied by detailed information, audio pronunciation, and alternate views. Dissection images can be captured and saved. A direct link tool also can be used to bring students to the exact view you specify.
- Animations: Modern, updated animations demonstrate muscle action, show detailed attachments, clarify anatomical relationships, and explain difficult concepts.
- Histology: Labeled light micrographs presented with each body system allow students to study the cellular detail of tissues.
- Imaging: Labeled x-ray, magnetic resonance imaging (MRI), and computed tomography (CT) images familiarize students with the appearance of key anatomical structures as seen through different medical imaging techniques.
- Self-Quizzing: Challenging exercises allow students to test their ability to identify anatomical structures in a timed practical exam format or with traditional multiple choice questions. A results page provides an analysis of test scores and links back to all incorrectly identified structures for review.
- Rotatable 3D Models: Interactive, rotatable 3D models enhance the learning experience and allow students to see the spatial relationship of structures in the human body. Side-by-side corresponding cadaver images provide perspective.
- My Course Content: Instructors may customize APR 4.0 to their course by selecting the specific structures they require in their course. Once the structure list is generated, APR highlights these selected structures for students.







McGraw-Hill Education

McGraw Hill connect® Virtual Labs

Connect Virtual Labs is a fully online lab solution that can be used in conjunction with the lab manual as a preparation, supplement, or make-up lab. These simulations help students learn the practical and conceptual skills needed, then check for understanding and provide feedback. With adaptive pre-lab and post-lab assessment available, instructors can customize each assignment.

PhILS

Physiology Interactive Lab Simulations© 4.0 (Ph.I.L.S.) offers 42 lab simulations that may be used to supplement or substitute for wet labs. Users may adjust variables, view outcomes, make predictions, draw conclusions, and print lab reports. Ph.I.L.S is now more readily available than ever with a new user- and mobile-friendly interface, along with increased accessibility features.

McGraw-Hill empowers students to learn and succeed in the Anatomy and Physiology course.

50% of the country's students are unable to pass the A&P course*

SMARTBOOK®

SmartBook provides personalized learning to individual student needs, continually adapting to pinpoint knowledge gaps and focus learning on concepts requiring additional study. **The result? Students are highly engaged in the content and better prepared for lecture.**

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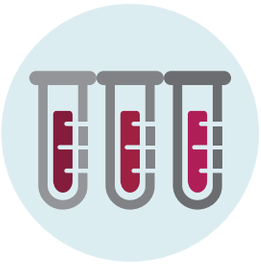
LearnSmart Prep helps students thrive in college-level A&P by helping solidify knowledge in the key areas of cell biology, chemistry, study skills, and math. **The result? Students are better prepared for the A&P course.**



PhILS

Ph.I.L.S. 4.0 (Physiology Interactive Lab Simulations) software is the perfect way to reinforce key physiology concepts with powerful lab experiments. **The result? Students gain critical thinking skills and are better prepared for lab.**

Concept Overview Interactives are ground-breaking interactive animations that encourage students to explore key physiological processes and difficult concepts. **The result? Students are engaged and able to apply what they've learned while tackling difficult A&P concepts.**

PracticeATLAS

Practice Atlas for A&P is an interactive tool that pairs images of common anatomical models with stunning cadaver photography, allowing students to practice naming structures on both models and human bodies, anytime, anywhere. **The result? Students are better prepared, engaged, and move beyond basic memorization.**

*Statistic courtesy of The New England Journal of Higher Education

Virtual Labs

Connect Virtual Labs helps connect the dots between lab and lecture, boosts student confidence and knowledge, and improves student success rates. **The result? Students are engaged, prepared, and utilize critical thinking skills.**

Anatomy & Physiology Revealed® 4.0

Anatomy & Physiology Revealed® (APR) 4.0 is an interactive cadaver dissection tool to enhance lecture and lab that students can use anytime, anywhere. **The result? Students are prepared for lab, engaged in the material, and utilize critical thinking.**

ACKNOWLEDGMENTS

This laboratory manual is the product of the excellent work and dedication of a consummate group of talented professionals who have helped lead us through this publishing process. We are forever indebted to all of you for embarking on this journey with us.

We wish to thank McGraw-Hill for providing us the unique opportunity to share our enthusiasm for teaching anatomy and physiology through the pages of this laboratory manual.

From start to finish, this book has been carried through the able hands of product developers Donna Nemmers and Melisa Seegmiller. Laura Bies, Content Project Manager, kept everyone on track and managed countless details in the production process.

The beautiful design and line art that make this laboratory manual shine are products of a team of hugely talented designers and artists, including David Hash at McGraw-Hill, and the fantastic EPS illustration team. Lori Hancock's direction and guidance were instrumental in bringing out the best of our photography program. Danny Meldung, of Photo Affairs, Inc., researched wonderful photos for this edition.

We thank all of the reviewers of the manual (listed below) for taking the time to review this manual and provide us with their insight and perspective, gained from years of experience in the classroom. We hope we have honored your suggestions for improvement, and we welcome continued feedback. We also thank the many students we have had the pleasure of interacting with over the years, for teaching *us* what works or does not work in the classroom.

The extent of our gratitude is limitless when it comes to the love, understanding, and support that our families, friends, and colleagues gave to us throughout this process. We are truly honored to live our lives in the presence of such wonderful people.

To the users of this laboratory manual: We sincerely hope we have created a learning resource that not only will excite you about the study of anatomy and physiology, but also will actively engage you in the laboratory as you learn about the wonders of the human body. We welcome your thoughts and suggestions for improvements.

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LABORATORY SAFETY GUIDELINES

LABORATORY PRECAUTIONS

1. Never work alone.
2. Do not smoke or bring food, drink, cell phones, or MP3 players into the laboratory. Do not work in the laboratory with an open wound.
3. Tie back long hair and remove loose/dangling jewelry.
4. Wear appropriate clothing: no open-toed shoes, tank tops, bare midriffs, loose clothing, or shorts/short skirts in the laboratory; lab coats are recommended.
5. Treat all chemicals as if they were dangerous.
6. Keep your workspace neat and clean.
7. Wear gloves when handling chemicals, biological materials, or suspicious materials.
8. Do not wear contact lenses in the laboratory. Wear safety goggles when working with chemicals and fluids.
9. Immediately report spills, accidents, or faulty equipment to your instructor.
10. Thoroughly wash your hands and forearms with soap and warm water, and disinfect your laboratory workspace before leaving the laboratory.

LABORATORY GUIDELINES

BIOLOGICAL MATERIALS – When working with bodily fluids (e.g., blood), *use only your own*. Treat human and animal specimens with respect at all times. Dispose of biological waste (e.g., animal tissue, blood-soaked rags) in red or orange "Biohazard" bags.

BROKEN GLASS AND "SHARPS" – Dispose of broken glass in "broken glass" containers, and "sharps" (e.g., scalpel blades, needles) in sharps containers (solid plastic containers labeled with the "biohazard" symbol); *never* put broken glass or sharps in regular waste baskets.

CLEANUP PROCEDURES – Spray a disinfectant solution (e.g., a commercial cleaning solution, or a 10% bleach solution) on your workspace and wipe it up with paper towels both before and after using the workspace. Clean all reusable glassware and lab equipment with soap and water, and disinfect by soaking in a 10% bleach solution. Dispose of waste in the proper waste receptacle.

CHEMICALS – Observe the Material Safety Data Sheets (MSDS, located in a red or yellow binder) for proper usage, precaution, and disposal procedures for each chemical you use. **General rule:** If you would not drink it, do not pour it down the drain.

FIRE – Never leave heated materials unattended, and never point a heated test tube or volatile materials in the direction of another person. Identify the locations of fire extinguisher, fire blanket, and emergency exits in the laboratory classroom *on the first day of class*. Follow emergency exit guidelines set by your instructor.

FIRST AID – Locate the first aid materials in your laboratory classroom so you know where they are *before* an emergency arises (e.g., eyewash station, first aid kit, safety shower, laboratory telephone).

FLUID IN EYE – Immediately rinse eyes at the eyewash station.

PERSONAL HEALTH CONCERNS – If you are taking medications, think you may be pregnant, or have other personal concerns about working in the laboratory, inform your instructor on the first day of class.

WHEN IN DOUBT – ALWAYS ASK YOUR LABORATORY INSTRUCTOR.

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chapter 1

The Laboratory Environment

OUTLINE AND LEARNING OBJECTIVES

Anatomy & Physiology Revealed® 4.0

Module 1: Body Orientation

INTRODUCTION

Welcome to the human anatomy and physiology laboratory! You are about to embark on a fascinating journey. The human body is one of the most amazing machines in existence. Provide it with fuel (i.e., food and water), and it can accomplish feats that put most mechanical machines to shame. Are you aware of any other machine that has an engine capable of sustaining it for 100 years without ever stopping? Yet, the human heart—the body's "engine"—can keep the body running for decades upon decades without ceasing. In this course, you will learn the many wonderful ways the body is able to accomplish this. It is well known that this course can be challenging. Students often experience both excitement and anxiety about it. These mixed emotions are normal and to be expected. It is our hope that the exercises in this laboratory manual will make your study both enjoyable and rewarding.

This laboratory manual is designed for an integrated, systems-based course that combines human gross anatomy, histology, and physiology. **Gross anatomy** is the study of structures that can be seen with the naked eye. This includes any structure that can be seen without the use of a microscope. **Histology** is the study of tissues and requires the use of a microscope. **Physiology** is the study of body functions. After completing this course, it is our hope that you will have developed an understanding and appreciation for how gross anatomical structures relate to tissue structures, and how all levels of structure relate to function. That said, in the laboratory itself, you will often be studying the three somewhat separately. That is, laboratory studies in gross anatomy will likely involve observing classroom models, dissecting animal specimens, or making observations of human bones and/or human cadavers; laboratory studies in histology will likely involve observing histology slides with a microscope or using some sort of virtual microscopy system; and laboratory studies in physiology will involve performing wet lab or virtual (computer software–based) experiments. To assist you in these endeavors, the exercises in this manual are divided into three types of activities: gross anatomy, histology, and physiology activities. Where applicable, each chapter will begin with a section on gross anatomy and will end with a section on physiology. Although you will perform the activities somewhat separately, the goal is to integrate what you learn in each exercise and to associate structure with function. "Concept Connection" boxes and questions within exercises in each chapter will assist with this task.

The purpose of this introductory chapter is to familiarize you with the process of science, systems of measurement, common equipment and dissection techniques encountered in the anatomy and physiology laboratory, proper disposal of laboratory waste materials, and common dissection techniques.

List of Reference Tables

INTEGRATE

CLINICAL VIEW

Use of Human Cadavers in the Anatomy and Physiology Laboratory

Where did that body lying on a table in the human anatomy and physiology laboratory come from? Typically, the body was donated by a person who made special arrangements before the time of death to donate his or her body to a body donor program so it could be used for education or research. Individuals who donate their bodies for these purposes made a conscious decision to do so. Such individuals have given us an incredible gift—the opportunity to learn human anatomy and physiology from an actual human body. It is important to remember that what that person has given is, indeed, a gift. The cadaver deserves the utmost respect at all times. Making jokes about any part of the cadaver or intentionally damaging or "poking" at parts of the cadaver is unacceptable behavior.

The idea that one will be learning anatomy and physiology by observing structures on what was, at one time, a living, breathing human being might make a person feel very uncomfortable at first. It is quite normal to have an emotional response to the cadaver upon first inspection. It takes time and experience to become comfortable around the cadaver. Even if you think you will be just fine around the cadaver when you are to observe it for the first time, it is important to be aware of your initial response and of the responses of fellow classmates. If at any time you feel faint or light-headed, sit down immediately. Fainting, though rare, is a possibility, and can lead to injuries if a fainting person falls down unexpectedly. Be aware of fellow students. If they appear to lose color in their faces or start to look sick—they might need your assistance.

Typically the part of the body that evokes the most emotional response is the face, because it is most indicative of the person that the cadaver once was. Because of this, the face of the cadaver should remain covered most of the time. This does not mean you are not allowed to view it. However, when you wish to do so, make sure that other students in the room know that you will be uncovering the face. If you have a particularly strong emotional response to the cadaver, take a break and come back to it later when you are feeling better.

Individuals with a great deal of experience around cadavers had a similar emotional response during their first time as well. In time one learns to disconnect one's emotions from the experience. Certainly at one time the body that is the cadaver in the laboratory was the home of a living human being. However, now it is just a body. Eventually students do become comfortable using the cadaver and find that it is an invaluable learning tool that is far more useful than any model or picture could ever be. There is nothing quite like the real thing to help students truly understand the structure of the human body. Make the most of this unique opportunity—and give thanks to those who selflessly donated their bodies to provide students with the ultimate learning experience in anatomy and physiology.

Students who are curious about the uses of cadavers in science and research are encouraged to check out the following book from the library: Mary Roach, *Stiff: The Curious Lives of Human Cadavers* (New York: W.W. Norton, 2003).

Chapter 1: The Laboratory Environment

Name: _____

Date: _____ Section: _____

These Pre-Laboratory Worksheet questions may be assigned by instructors through their connect course.

PRE-LABORATORY WORKSHEET

1. The study of structures is called _____ (anatomy/physiology), whereas the study of functions is called _____ (anatomy/physiology).

2. Which of the following metric unit(s) is/are used to report mass? (Check all that apply.)

   _____ a. centimeter
   _____ b. decigram
   _____ c. kiloliter
   _____ d. microgram
   _____ e. millimeter

3. Number the following steps involved in the scientific method in the correct order.

   _____ a. conclusions
   _____ b. data analysis
   _____ c. data collection
   _____ d. experiment
   _____ e. hypothesis

4. When presenting data, the _____ (dependent/independent) variable is plotted on the X-axis, whereas the _____ (dependent/independent) variable is plotted on the Y-axis.

5. For each of the following metric prefixes, write the corresponding power of ten in the space provided.

   a. centi-: _____
   b. deci-: _____
   c. kilo-: _____
   d. milli-: _____
   e. micro-: _____

6. Which of the following chemical(s) require(s) the use of personal protective equipment? (Check all that apply.)

   _____ a. ethanol
   _____ b. formalin
   _____ c. methylene blue
   _____ d. phenol
   _____ e. potassium permanganate

7. When removing a scalpel blade, be sure to point the blade _____ (toward/away from) you to avoid injury.

8. Which of the following dissecting tools is the most beneficial for attempting to loosen the hold between a specimen's skin and underlying fascia? (Circle one.)

   a. dissecting probe
   b. finger
   c. scalpel
   d. scissors

INTEGRATE

LEARNING STRATEGY

The volume of material students cover in an anatomy and physiology course is likely to be greater than that of any other college course. This is the reason it is considered by most to be a very challenging course. Learning how to approach a subject with such a vast amount of material can be quite difficult at first and might require a change of study habits. The list below provides several suggestions that you may want to incorporate into your study habits to make you more effective and efficient. Everyone learns in their own way, so all tips may not be suitable for all students.

1. Study a little bit *every day.* "Cramming" simply does not work in a course such as human anatomy and physiology in which there are a large number of terms to learn. Instead, break down the topics that are to be covered into manageable chunks. For example, if a student sits down to study with the goal of learning the details of every bone in the human body, that student may feel so overwhelmed that he or she has no idea where to start. On the other hand, if the student studies with the goal of learning the details of *one* bone at a time (e.g., the humerus), then the task becomes much simpler and the student is more likely to complete it.
2. Only study with a group when you are *reviewing* material that you have already covered on your own. Because all individuals learn differently, group study when first learning material is very inefficient. On the other hand, having someone ask you questions to review what you know is an excellent way to prepare for exams.
3. Use *active* study methods whenever possible. Active methods include writing, speaking, labeling, and the like. *Passive* methods include reading the book, listening to a lecture, and the like. Many students mistakenly believe they have mastered the material once they feel as if they understand what the instructor lectured about or what they read in the book. Do not make this mistake! Force yourself to recall information by writing it down, drawing it, or telling it to a friend or family member (even the family cat or dog will do as an audience). You will quickly find out what you do or don't know.
4. Use spaced repetition. Studies show that reviewing material at regular intervals is an effective way to help solidify the information in your head. As you plan your daily (yes, *daily*) and weekly study schedule, be sure to include time to review material you studied previously. It does not have to be a lot of time, but it is absolutely necessary to keep the material fresh in your head.
5. Learning anything new can sometimes be a struggle. The more you struggle to learn something, the better you actually learn the material. Most of us feel better when we review things we already know well because it gives us confidence. However, this approach may not be effective. Think of it like physical exercise. To gain a benefit, you must apply stress to your body and then allow your body to adapt to that stress. The stress may not feel good while you are exercising—in fact, it may feel difficult! However, with time your body adapts, and the stress/overload becomes easier to deal with. Your brain works much the same way.

Be patient and persistent. Have confidence in your ability to learn the material. Think of how AMAZING the human body is, and feel fortunate that you have this opportunity to learn about it. You *can* do this!

GROSS ANATOMY

The Scientific Process of Discovery

What is science? **Science** is a way of acquiring knowledge of the natural world through observation and experimentation. A **scientist** is an individual who engages in research using the scientific method to learn facts about the world. The **scientific method** is a systematic approach to inquiry that assumes that the answer to a question can be explained by phenomena that are *observable* and *measurable*. In the anatomy and physiology laboratory, the scientific method will be used to make observations and conclusions about the structure and function of the human body.

The scientific method is a rigorous and systematic approach to inquiry that requires certain steps be taken. However, the steps need not be followed precisely. That is, there is some flexibility in the order in which the steps take place. Very often several steps take place concurrently as the process of discovery evolves. The steps involved in the scientific method follow the general pattern shown below:

Observation → Hypothesis → Experiment → Data Collection → Data Analysis → Conclusions

Observation

The first step of the scientific method is **observation**. When an unknown phenomenon is observed, the observer often makes a tentative explanation as to the cause of that phenomenon. This explanation is called a **hypothesis**. For example, consider the observation that body temperature changes during the day, and an observer of this fact is interested in knowing if body temperature also changes during the course of the night while a person is asleep. An observation has been made (body temperature changes during the day) that was followed up with a question: Does body temperature change during the night? The next step is to formulate a hypothesis.

Hypothesis

The second step of the scientific method is to **formulate a hypothesis**. One of the key features of a good hypothesis is that it must be testable. That is, some aspect of the variable of interest must be measurable. In the current example, body temperature is the variable of interest, and it can be measured using a thermometer. Another feature of a good hypothesis is that it must be specific, yet limited in scope. This is not to say that the explanation for a phenomenon is limited, nor that the questions asked are limited. Instead, it means that the testable hypothesis must be limited to something that is measurable while all other conditions are controlled. An example of a simple, testable hypothesis is the following: Body temperature changes over time during the night. Once the hypothesis has been formulated, the next step is to design an experiment to test the hypothesis.

Experiment

One of the most creative and interesting aspects of the scientific method is to **design an experiment** to test a hypothesis. Designing a good experiment to test a hypothesis is a challenging task. The key feature of good experimental design is to attempt to predict any variables that may have an influence on the variables of interest and

control for them. In the current example, the variables of interest are body temperature and time during the night. To determine if body temperature changes during the night, an experiment must be designed to measure body temperature at given time intervals during the night.

Variables

A **variable** is a characteristic that may or may not influence the outcome of an experiment. In the current experiment, two variables of interest have been identified: body temperature and time. Based on convention, the variables in the experiment must be categorized as independent, dependent, or confounding variables.

The **independent variable** is a variable that is set at the outset of the experiment. It does not change as a result of the experimental procedure. Thus, it is said to be *independent* of the experimental procedure. In this example, time is the independent variable. Note that it is impossible for time to change as a result of any experimental procedure. The **dependent variable** is the unknown variable that is going to be measured and is often expected to change as a result of the experimental procedure. Thus, it is said to be *dependent* on the experimental procedure. In the current example, body temperature is the dependent variable. **Confounding variables** are any variables that may affect the variable of interest (dependent variable). Examples of some confounding variables are the amount and type of clothing the subject is wearing, the type of bedding the subject uses, and how much and what the subject eats or drinks before going to sleep. In setting up an experiment, great efforts are made to control as many confounding variables as possible. Finally, a **control value** with which to compare the measured values of body temperature is required. In this example, a "normal" body temperature of 37 °C is the obvious control value.

Data Collection

Once a controlled experiment has been designed to test the hypothesis, data collection can begin. When a scientist conducts an experiment, he or she begins by performing a statistical test to determine the sample size necessary to get a meaningful result from the experiment. Why? In this example, if body temperature was measured for only one subject, it would be neither reasonable nor appropriate to extrapolate that data to include all individuals, because the person measured may not be typical of most individuals. For experiments conducted in the anatomy and physiology laboratory, the study subjects will likely consist of the students in the class. Thus, the data set will be limited in scope compared to the ideal situation. However, in most cases enough data will have been collected to obtain reasonable results.

Once the sample size has been determined, the next step is to **collect the data**. In this example, body temperature would likely be measured for each of the study subjects at specific time intervals during the night. At the same time, confounding variables would be controlled for by having all study subjects wear the same clothing, use the same bedding, refrain from eating within a certain number of hours before bed, and go to bed at a prescribed time. After data collection comes the fun part: data analysis!

Data Analysis

Once the data have been collected, the experimenter must **analyze the data** in a way that makes sense both to the experimenter(s) and to the rest of the scientific community. There are several ways to present data, and presentation depends somewhat on the variable in question. For any given data set, a mean, median, and standard deviation must be calculated for the value to ensure the value represents the data for the group of study subjects as a whole. The **mean** is the average of all the data points and is calculated by taking the sum of all the data points and dividing by the number of study subjects. The **median** is the middle value of all the data points. The **standard deviation** is a measure of the variability of the individual data points as compared to the mean. When the standard deviation is small, it means that individual data points are all very close to the mean. When the standard deviation is large, it means there is much variability between individual data points and the mean.

For the purposes of the exercises in this manual, standard deviations will not be reported for experimental data because this generally requires using a computer program to perform the calculations. An easier way of determining variability is to calculate and report the *range* of values. The **range** is simply the difference between the highest and lowest values, and it is calculated by subtracting the lowest value from the highest value. If the range is small, it indicates that there is very little variability of individual data points as compared to the mean. If the range is large, it indicates that there was quite a bit of variability of individual data points as compared to the mean. **Table 1.1** shows hypothetical temperature data for five study subjects taken at two different times (12 a.m. and 6 a.m.). The mean, standard deviation, and range of the data are also shown in the table. Notice that even though the standard deviation and range are different for each time, they have the same pattern. That is, for the data taken at 6 a.m., both the standard deviation and the range are higher than for the data taken at 12 a.m. Thus, both of these measures demonstrate there was greater variability in the individual temperature values at 6 a.m. than there was at 12 a.m.

Conclusions

The final step in the scientific method involves **drawing conclusions** based on the results of the experiment. This requires reviewing the hypothesis in light of the data collected. That is, the data will either support or refute the hypothesis. In this example, the hypothesis was that body temperature would change over the course of the night. **Figure 1.1** is a sample graph that is based on data from actual studies that looked at the variation in body temperature of a large number

Table 1.1 Body Temperature Data for Five Study Subjects

Study Subject	Body Temperature at 12 a.m. (°C)	Body Temperature at 6 a.m. (°C)
Subject A	36.2	35.0
Subject B	36.8	34.0
Subject C	37.2	34.3
Subject D	37.0	35.9
Subject E	36.5	36.0
Mean	**36.7**	**35.0**
Standard Deviation	**0.4**	**0.9**
Range	**1.0**	**2.0**

of study subjects during a daily cycle. Thus, it can be used as an estimate of data that might have been obtained had the hypothetical experiment been performed. In this example, the data support the hypothesis that body temperature does change as a result of time of the night. Furthermore, it is possible to be more specific and say *how* body temperature changes during the night. That is, body temperature appears to decrease steadily throughout the night and reaches its lowest point just before waking (5 a.m.).

The scientific method is a continual process. Often a hypothesis and related experiment will result in a few answers, but even more questions. For example, after concluding that body temperature changes during the night, a follow-up question may be asked: *why* does body temperature change during the night? Using the scientific method, the scientific process can continue through to the formulation of a new hypothesis. The new hypothesis will lead to further experimentation, data collection, and data analysis. As the process continues, more and more details concerning the area of interest emerge.

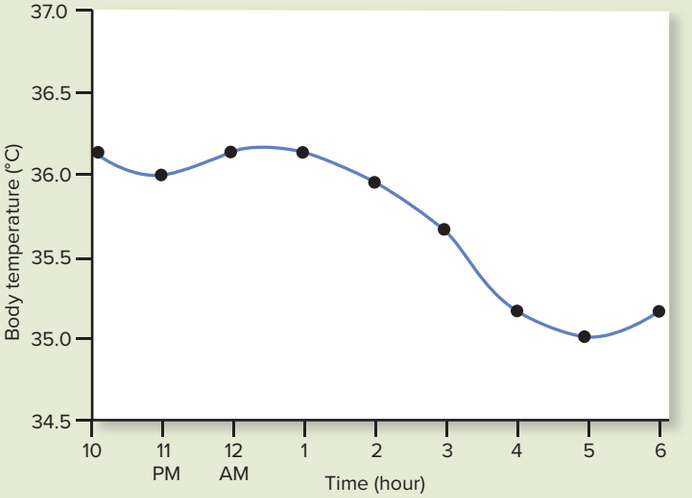


Figure 1.1 Temperature Variance During the Course of the Night. Each data point represents the mean for a number of study subjects.

EXERCISE 1.1

THE SCIENTIFIC METHOD

Let's say that you have observed that heart rate varies with activity level. That is, when an individual exercises, heart rate is higher, and when an individual is at rest, heart rate is lower. Now, let's say that because you have observed that heart rate is lower when an individual is in a "rested" state, you are interested in knowing if meditation, an activity that is designed to put the body in a calm/rested state, causes an individual's heart rate to decrease. You decide to perform a scientific experiment to figure out if this is accurate.

1. State your hypothesis: _____

2. What is the independent variable? _____

3. What is the dependent variable? _____

4. Design an experiment to test your hypothesis. In the explanation of your experimental design, describe what variable(s) you will control and what variable(s) you will measure.

5. Finally, describe any confounding variables that may affect the results of the experiment, and explain how you might control for such variables.

EXERCISE 1.2

PRESENTING DATA

Once experimental data have been collected, they must be presented in a meaningful way so that others who view the data will be able to draw their own conclusions about the data. In the previous description of the scientific method, data were presented using a data table (table 1.1) and a graph (figure 1.1). These are two of the most common modes of data presentation and are the modes most often used to present data for the experiments performed in this manual. When presenting data using a **table**, it is common to include mean, number of study subjects, and standard deviation (or range) for each data point (see table 1.1 for an example). When presenting data using a **graph**, there are conventions to follow. Namely, the *independent* variable is plotted on the X-axis (horizontal) and the *dependent* variable is plotted on the Y-axis (vertical). Graphing data this way allows the individual reading the graph to determine what effect, if any, variable X has on variable Y. For the sample experiment looking at the effect of time of the night on body temperature, the data have been plotted in the graph shown in figure 1.1.

1. Why was time plotted on the X-axis? _____

   _____

2. Why was temperature plotted on the Y-axis? _____

   _____

Other items to note when creating a graph are the following:

1. Each axis must be labeled with the appropriate numbers indicating the value of the measurement. For example, in the graph (figure 1.1), these are the measured values for "hour" and "degrees Celsius."
2. Each axis must have a title and must provide the units that are used. In the graph (figure 1.1), the X-axis is labeled "Time" and the unit is "hour"; the Y-axis is labeled "Body temperature" and the units are "degrees Celsius."

It is very important to always place labels on graphs. A common mistake many students make is to assume that their instructor—or whoever is grading their laboratory report—already knows what is supposed to be graphed, therefore the student does not need to put the units on the graph. Do not make this mistake! Always assume that the person who is going to read a graph has no idea what the graph is trying to present. Failing to put units on a graph results in a graph that means nothing. For example, let's say the label "Time" is on the X-axis, but there are no units provided. The reader of the graph is left to wonder if the intervals indicate time in seconds, minutes, hours, or some other unit. Likewise, failing to indicate the units for "Body temperature" on the Y-axis leaves the reader wondering if the temperature is given in Celsius (°C) or Fahrenheit (°F).

Sample Graphing Exercise

1. **Table 1.2** represents experimental data obtained by rolling a bowling ball on a track and measuring how far the ball rolls over time.

Table 1.2 Distance Traveled by a Bowling Ball

Time	Distance Traveled
(sec)	(meters)
0	0
1	6
2	8
3	9.5
4	10.5
5	11
6	11.5
7	11.75
8	11.8
9	11.9
10	12

Questions:

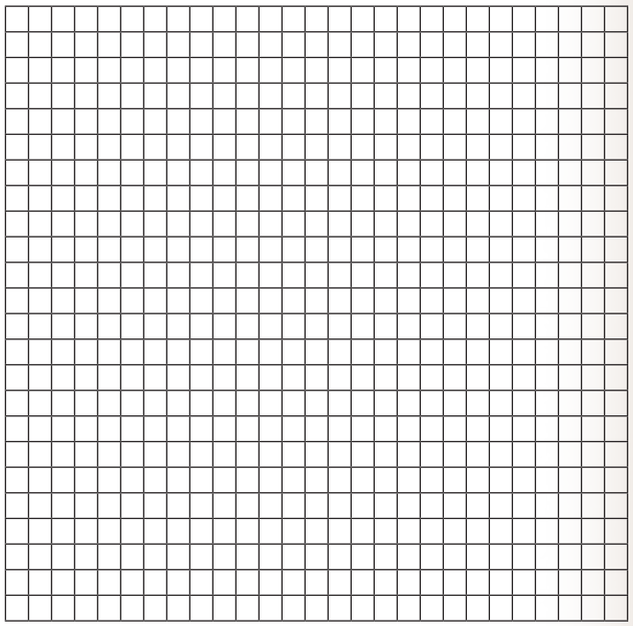
a. What is the independent variable? _____

_____

b. What is the dependent variable? _____

_____

2. Using the data in table 1.2, graph the data on the grid provided. Be sure to label the axes and provide the appropriate units.



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3. Now that the data have been graphed, write a brief paragraph explaining the results in the space provided.

Measurement in Science

Systems of Measurement

If one has ever baked a cake or done another activity that required making measurements, common units of measurement such as cups, gallons, teaspoons, liters, and the like should be familiar. There are two systems of measurement that are most commonly used in the world: English and metric systems. Because of its uniformity and ease of use, the **metric system** is the system most widely used throughout the world. It is also the system of measurement that scientists use when reporting data. Thus, when performing the laboratory activities in this manual, students will be reporting results using metric units.

The metric system is relatively simple to use because all units are given as powers (multiples) of ten. To calculate a power of ten, simply take the superscript (i.e., 10^x, where x is the superscript) and multiply ten by ten that many times. Thus, $10^2 = 10 \times 10 = 100$; $10^3 = 10 \times 10 \times 10 = 1000$. The only unusual numbers are 10^0 and 10^1. When you see these numbers, just remember that ten to the zero power is 1 and ten to the 1st power is ten. In the metric system, specific prefixes denote the power of ten that is used in a measurement. For example, a kilometer is 10^3 meters and thus represents 1000 meters. **Table 1.3** lists common metric prefixes and the power of ten that each represents.

When converting one metric unit to another, move the decimal point to the right or to the left, depending on if the conversion is from a larger unit to a smaller unit (e.g., kilograms to grams) or vice versa (e.g., grams to kilograms). When converting from a larger unit to a smaller unit, move the decimal to the *right* the same number of units as the power of ten. This is the same as *multiplying* the larger measurement by the appropriate factor of ten. For example, to convert kilometers to meters (1 km = 1000 meters), move the decimal point to the right *three* positions because a kilometer is one meter times ten to the *third* power (10^3). Conversely, when converting from a smaller unit to a larger unit, move the decimal to the *left* the same number of units as the power of ten. This is the same as *dividing* the smaller measurement by the appropriate factor of ten. For example, to convert meters to millimeters (1 mm = 1/1000 meter), move the decimal point to the left *three* positions because a millimeter is one meter times ten to the negative *third* power (10^{-3}). Another way to remember this is that a power of ten that is positive moves the decimal to the right (forward) and a power of ten that is negative moves the decimal to the left (backward).

larger unit → smaller unit MULTIPLY by appropriate power of ten

smaller unit → larger unit DIVIDE by appropriate power of ten

Practice:

Convert 457 milligrams to grams

Convert 5698 centimeters to decimeters

Convert 4.3 kilometers to meters

Convert 0.5 liter to milliliters

Table 1.3 Metrics

Metric Prefix	Meaning	Symbol	Amount	Power of Ten	Length Measure	Mass Measure	Volume Measure	Word Origin
kilo	one thousand	k	1000	10^3	kilometer (km)	kilogram (kg)	kiloliter (kL)	*chlioi*, a thousand
No prefix/ base unit	Use the standard unit	–	1	10^0	meter (m)	gram (g)	liter (L)	NA
deci-	one-tenth	d	0.1	10^{-1}	decimeter (dm)	decigram (dg)	deciliter (dL)	*decimus*, tenth
centi-	one-hundredth	c	0.01	10^{-2}	centimeter (cm)	centigram (cg)	centiliter (cL)	*centum*, hundred
milli	one-thousandth	m	0.001	10^{-3}	millimeter (mm)	milligram (mg)	milliliter (mL)	*mille*, thousand
micro-	one-millionth	µg	0.000001	10^{-6}	micrometer (µm)	microgram (µg)	microliter (µL)	*mikros*, small

Metric Conversions

If measurements are made using the English system, the measurements will need to be converted from English units to metric units for laboratory reports. **Table 1.4** lists some common conversions between English and metric measurements. Some of these conversions are conversions that you should be able to make in your head easily. For example, 1 inch = 2.54 centimeters and 1 pound = 0.45 kilogram.

For example, to convert 16 ounces (English measurement) into milliliters (metric measurement), multiply the number of ounces (16) by 30 (see table 1.4) to get milliliters:

$$16 \text{ ounces} \times 30 = 480 \text{ milliliters}$$

Notice that the conversion in table 1.4 tells how to convert ounces to milliliters. What if we want to convert ounces to liters instead? Recall from table 1.3 that one milliliter is one one-thousandth of a liter, and its power of ten is 10^{-3}. Thus, to convert ounces to liters, first convert to milliliters using the multiplier listed in table 1.4, then convert milliliters to liters by moving the decimal point three places to the left: 480.0 milliliters = 0.48 liter.

Temperature Scales

Just as there are two systems of measurement for volume, length, and mass, there are also two systems of measurement for temperature. In the United States most of our temperatures (such as air temperatures reported by weather stations) are reported as degrees Fahrenheit (°F). However, often temperatures will instead be reported as degrees Celsius (°C, also known as centigrade). In science, it is appropriate to report temperature readings (such as body temperature) in degrees Celsius. To make conversions between these two temperature readings, use the following equations:

To convert degrees Celsius to degrees Fahrenheit:

$$°F = ((°C \times 9) / 5) + 32$$

To convert degrees Fahrenheit to degrees Celsius:

$$°C = ((°F - 32) \times 5) / 9$$

Table 1.4 Common English-Metric Conversions

To Convert From:	To:	Multiply:	By:	Conversion
centimeters	inches	centimeters	0.39	1 cm = 0.39 inch
feet	centimeters	feet	30.48	1 foot = 30.48 cm
feet	meters	feet	0.3	1 foot = 0.3 m
fluid ounces	milliliters	fluid ounces	30	1 oz = 30 mL
gallons	liters	gallons	3.78	1 gallon = 3.78 L
grams	ounces	grams	0.035	1 g = 0.035 oz
inches	centimeters	inches	2.54	1 inch = 2.54 cm
kilograms	pounds	kilograms	2.2	1 kg = 2.2 lb
kilometers	miles	kilometers	0.62	1 km = 0.62 mile
liters	quarts	liters	1.06	1 L = 1.06 qt
liters	gallons	liters	0.26	1 L = 0.26 gallon
meters	yards	meters	0.9	1 m = 1.1 yd
meters	feet	meters	3.3	1 m = 3.3 feet
miles	kilometers	miles	1.61	1 mi = 1.61 km
milliliters	fluid ounces	milliliters	0.03	1 mL = 0.03 oz
millimeters	inches	millimeters	0.039	1 mm = 0.039 inch
fluid ounces	grams	fluid ounces	28.3	1 oz = 28.3 g
fluid ounces	milliliters	fluid ounces	29.6	1 oz = 29.6 mL
pounds	grams	pounds	453.6	1 lb = 453.6 g
pounds	kilograms	pounds	0.45	1 lb = 0.45 kg
quarts	liters	quarts	0.95	1 qt = 0.95 L
yards	meters	yards	0.9	1 yd = 0.9 m