High School Third Edition

Hole's Essentials of Human Anatomy and Physiology

Student Edition Sample Chapter
For Review Purposes Only

McGraw Hill

Charles J. Welsh | Cynthia Prentice-Craver

High School Third Edition

Hole's Essentials of Human Anatomy and Physiology

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About the Authors

CHARLES WELSH began his anatomy and physiology teaching career upon graduating with a B.S. in Biology from the University of Pittsburgh in 1989. He entered graduate school in 1992 and continued teaching night classes. He accepted his first full-time teaching position at Clarion University of Pennsylvania in 1996. In 1997, he completed his Ph.D. in Comparative Anatomy, Evolutionary Biology, and Ornithology. Teaching primarily in nursing and other allied health programs, he now brings his 30 years of classroom experience to the third high school edition of *Hole's Essentials of Human Anatomy and Physiology*. Since 2009, he has been teaching at Duquesne University in Pittsburgh, Pennsylvania. During this time, he has received several teaching awards, as well as the Mentor of the Year Award for training graduate students to teach anatomy and physiology. Chuck and his wife, Lori, have three children and four grandchildren. They live in the historic town of Harmony, thirty miles north of Pittsburgh, with their youngest son. Chuck is currently restoring a 1977 GMC truck.

CYNTHIA PRENTICE-CRAVER is a co-author of *Hole's Essentials of Human Anatomy and Physiology*, 3e. She has been teaching human anatomy and physiology for over thirty years at Chemeketa Community College and is a member of the Human Anatomy and Physiology Society (HAPS) and the Textbook & Academic Authors Association (TAA). Cynthia's teaching experience both in grades 6–12 and in college, her passion for curriculum development, and her appetite for learning, fuel her desire to write. Her M.S. in Curriculum and Instruction, B.S. in Exercise Science, and extended graduate coursework in biological sciences have been instrumental in achieving effective results in the courses she teaches. Cynthia co-authored the Martin *Laboratory Manual for Human Anatomy & Physiology*, 4e and 5e, *Hole's Essentials of Human Anatomy & Physiology*, 15e, and *Hole's Human Anatomy & Physiology*, 16e and 2024 Release. Beyond her professional pursuits, Cynthia's passions include reading and listening to books, attending exercise classes, taking long outdoor walks, attending concerts, traveling, and spending time with her family and friends.

(t)Leeanna Smith, (b)Cindy Prentice-Craver

Additional Contributors

Digital Authors

LESLIE DAY earned her B.S. in Exercise Physiology from UMass Lowell, an M.S. in Applied Anatomy & Physiology from Boston University, and a Ph.D. in Biology from Northeastern University. She currently works as an Associate Clinical Professor and Associate Chair in the Department of Physical Therapy, Movement and Rehabilitation Sciences at Northeastern University with her main teaching role in upper-level Gross Anatomy and Neuroanatomy courses but still loves teaching her introductory anatomy course. She has received five teaching awards at the universities, including the coveted University Excellence in Teaching Award. Her current research focuses on the effectiveness of different teaching pedagogies, including the flipped-classroom and various technology. She brings her love for anatomy and quest for trying new technology into the classroom to make for a dynamic evidence-based teaching style that is friendly to all students.

JULIE PILCHER began teaching during her graduate training in Biomedical Sciences at Wright State University, Dayton, Ohio. She found, to her surprise, that working as a teaching assistant held her interest more than her research. Upon completion of her Ph.D. in 1986, she embarked on her teaching career, working for many years as an adjunct in a variety of schools as she raised her four children. In 1998, she began full-time at the University of Southern Indiana, Evansville. Her work with McGraw Hill began several years ago, doing reviews of textbook chapters and lab manuals. When the opportunity arose to become more involved in the authoring of digital content for McGraw Hill, she could not pass it up. Based on her own experience, students are using more and more online resources, and she is pleased to be part of that aspect of A&P education.

High School Contributors

ELIZABETH CO grew up in Vermont and received a BA in Biology from Mount Holyoke College and a PhD in Biomedical Sciences from the University of California, San Francisco. She has been teaching Anatomy, Physiology, Biology and Infectious Disease for the last ten years in California and, more recently, at Boston University in Massachusetts. Liz loves to watch students master and engage with the material through its application to real life. In her classrooms, Liz writes case studies for her students to work through in order to strengthen their critical thinking skills. Liz is also active in the field of pedagogical research.

ERIN HUIZINGA has spent more than 20 years as an educator who has developed rigorous, relevant curricular experiences for high school students. Erin has designed specialized programs that allow students to develop as scientists with an emphasis on real-world applications. Erin has been involved with health science career academies since 2005, teaching anatomy and physiology as part of an integrated curriculum focused on medical and health sciences. Through these highly collaborative and innovative programs, she has been able to implement research-based strategies that directly relate to improving student achievement.

Preface

To the Student

Welcome! As you read this (with your eyes) and understand it (with your brain), perhaps turning to the next page (with muscle actions of your fingers, hand, forearm, and arm), you are using the human body to do so. Indeed, some of you may be using your fingers, hand, forearm, and arm to read through the eBook on your computer, tablet, or smartphone. Whether you use traditional or new technology, the third edition of Hole's Essentials of Human Anatomy and Physiology offers an intriguing and readable introduction to how the human body accomplishes these tasks. The functioning of the body is not simple, and at times understanding it may not seem easy, but learning how the body works is always fascinating and can be both useful and fun!

Some of you are on a path toward a career in healthcare, athletics, science, or education. Or maybe you're just curious about how the human body works, and maybe that interest stems from personal experience, or that of a family member or friend. Explore career prospects and real-life scenarios with Career Connections and Case Studies in every chapter. This book has been written to help you succeed in your coursework and to help prepare you to make that journey to further educational experiences and a successful and rewarding career.

To the Teacher

Written for ease of readability and organized for classroom use, *Hole's Essentials of Human Anatomy and Physiology* serves the student as well as the educator to support instruction in an electives science course or as part of a career and technical education pathway. This edition continues the Learn, Practice, Assess approach that has substantially contributed to instructional efficiency and student success. The features and interactives offered as additional resources are built on the strong foundation grounded in the Learn, Practice, Assess system.

Each lesson opens with Learning Outcomes and a connection to Science and Engineering Practices, providing students many opportunities to practice throughout. Chapters close with Summaries and Assessments closely tied to the Learning Outcomes. Students can use these features not only to focus their study efforts, but also to take on an active role in monitoring their progress toward mastering the material. Both the Student Edition and Teacher Manual offer Key Terms support, including word origins and practice, to help students decode scientific terminology. In addition, thanks to the expertise of Leslie Day and Julie Pilcher, the digital course enhances the printed content and the Learn, Practice, Assess approach. We are proud to have developed and to offer the latest and most efficient technologies to support the teaching and learning experience.

-Chuck Welsh and Cynthia Prentice-Craver

New Authorship

With this new edition of *Hole's Essentials of Human Anatomy and Physiology*, Cynthia Prentice-Craver joins Charles Welsh as co-author of this revised text. The new edition provides a cohesive narrative with an accessible voice. With decades of combined experience in anatomy and physiology classrooms our author team brings a fresh perspective to this well-respected text.

The Next Generation of A&P

As we prepared for this new edition, we surveyed high school anatomy and physiology teachers to help us strengthen an already robust program and meet the ever-evolving needs in today's classrooms. The new authorship team has updated and revised the student edition, teacher manual, laboratory manual, digital resources and added fresh, new features to help students not just learn about, but experience the fascinating world of anatomy and physiology.

- Each chapter contains updated **Career Connections** that help students explore a variety of vocations as they consider their college and career pathways.
- **Data Analysis** activities include new sources from the most up-to-date scientific research.
- **Chapter Summaries** and **Assessments** provide opportunities to revisit and reinforce key concepts.
- **Explore, Explain, and Extend the Phenomena** provides a cohesive narrative between **Unit and Chapter Projects** and **Case Studies**, fostering concept connections and critical thinking.
- An updated **Teacher Manual** provides additional activities, pacing, vocabulary support, and answers to all student edition questions.
- A new **Laboratory Manual** offers labs of varying lengths to accommodate any instructional schedule, while alternative materials lists ensure those activities can be performed in any high school classroom.

Dynamic Digital Resources

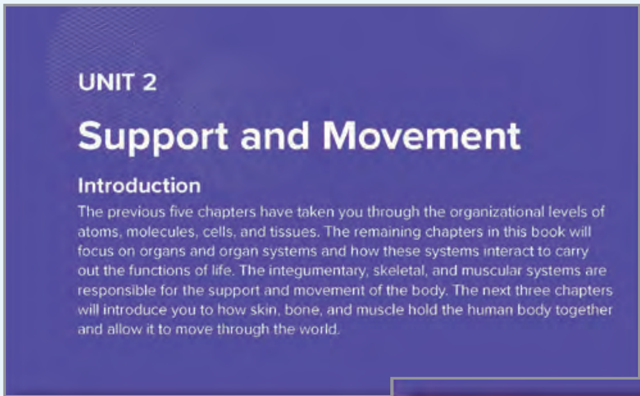
- A variety of **assessments** and **labeling activities** work in conjunction with a **powerful gradebook** to monitor student progress and inform in-class instruction.
- **PowerPoints** and **image banks** help teachers build dynamic presentations.
- An array of **Virtual Labs** delivers realistic, simulated laboratory experiences.
- **Focus Activities** include vocabulary and labeling exercises that check student mastery of difficult structures, vocabulary, and concepts.
- **Animations** offer multi-modal learning opportunities that support students with a variety of learning style as they explore key physiological processes.
- Online **Chapter** and **Unit Projects** enable students to employ science and engineering practices, connecting their learning to practical applications.
- **Kahoot!** gamifies the learning experience to help students review in a fun, engaging way.
- **eFlashcards** support acquisition and retention of key terms.
- ***Actively Learn*** delivers hundreds of curated articles that make connections to current events.
- ***Anatomy & Physiology REVEALED®*, (APR),** the ultimate dissection experience enriches lectures and labs with 3-D interactive models, engaging animations, and real-life images.

Learn, Practice, Assess

Hole's Essentials of Human Anatomy and Physiology, Third Edition, features a proven integrated learning system: **Learn, Practice, Assess**. This solid pedagogical foundation sets students up for success by creating a familiar pattern of instruction, application, and mastery throughout each unit and chapter.

A Systemic Approach

Each of the six **Unit Openers** include features and learning aids that draw students in and provide context for the topics of study that will be addressed in the subsequent chapters.

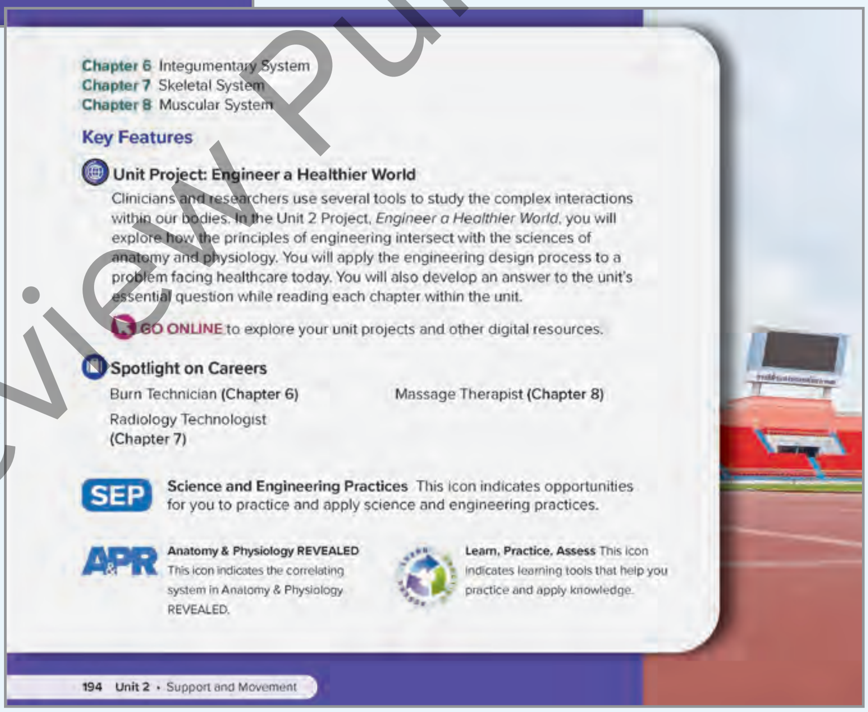

UNIT 2

Support and Movement

Introduction

The previous five chapters have taken you through the organizational levels of atoms, molecules, cells, and tissues. The remaining chapters in this book will focus on organs and organ systems and how these systems interact to carry out the functions of life. The integumentary, skeletal, and muscular systems are responsible for the support and movement of the body. The next three chapters will introduce you to how skin, bone, and muscle hold the human body together and allow it to move through the world.

Introductions provide a throughline that connects subjects and concepts covered in the unit presenting a big picture view of the body's functions and its complexities that go beyond the workings of the isolated systems.


Chapter 6 Integumentary System
Chapter 7 Skeletal System
Chapter 8 Muscular System

Key Features

Unit Project: Engineer a Healthier World

Clinicians and researchers use several tools to study the complex interactions within our bodies. In the Unit 2 Project, *Engineer a Healthier World*, you will explore how the principles of engineering intersect with the sciences of anatomy and physiology. You will apply the engineering design process to a problem facing healthcare today. You will also develop an answer to the unit's essential question while reading each chapter within the unit.

GO ONLINE to explore your unit projects and other digital resources.

Spotlight on Careers

Burn Technician (Chapter 6) Massage Therapist (Chapter 8)

Radiology Technologist (Chapter 7)

SEP Science and Engineering Practices This icon indicates opportunities for you to practice and apply science and engineering practices.

APR Anatomy & Physiology REVEALED This icon indicates the correlating system in Anatomy & Physiology REVEALED.

Learn, Practice, Assess This icon indicates learning tools that help you practice and apply knowledge.

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Unit Projects provide real-world applications of scientific concepts focusing on the essential question.

Spotlight on Careers identifies careers related to the topics in the unit bringing relevancy to the learning.

SEP, APR, and **Learn, Practice, Assess** icons provide visual cues for enrichment opportunities. Students can apply learning, explore additional activities, and reinforce their understanding.

Essential Question: How does a prosthetic limb provide support and movement for the body?

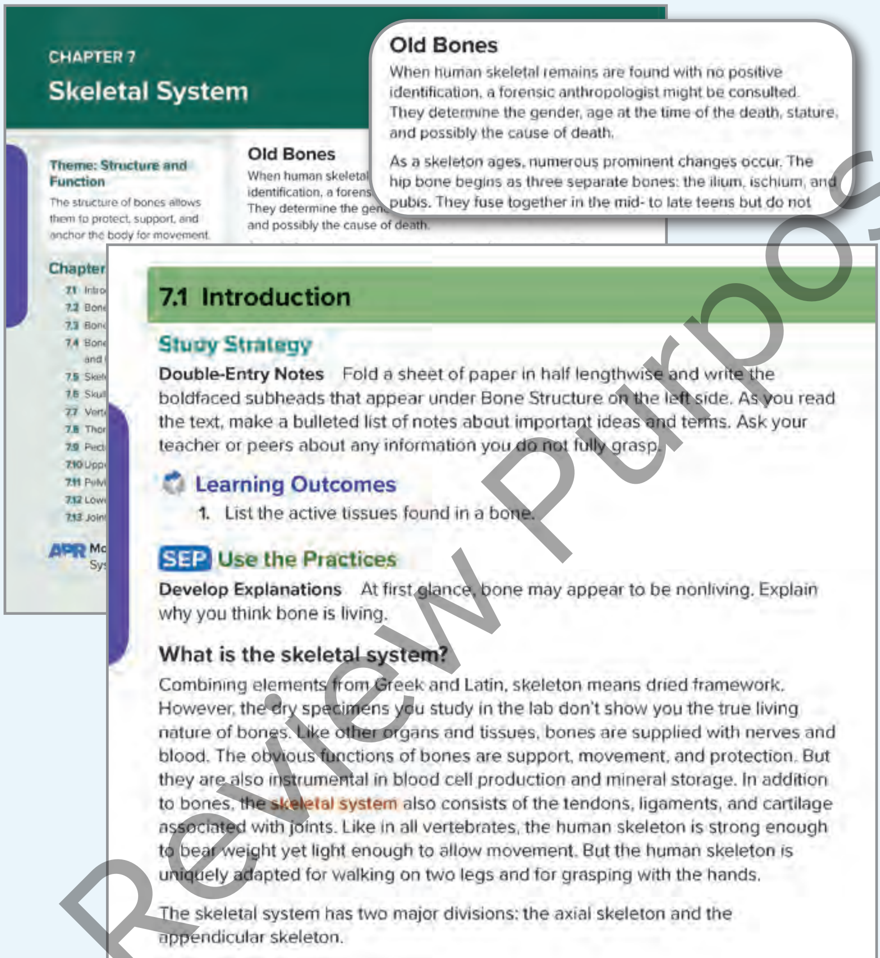
Essential Questions contextualize the unit content and ask students to practice inquiry throughout the learning process. The end-of-unit question assesses their understanding.

Learn, Practice, Assess

Making Critical Connections

Each **Chapter Opener** provides a cohesive learning narrative beginning with the overall theme and list of lessons, before setting the stage with an introduction to the chapter concept. **Lessons** break the content up into more digestible portions, providing opportunities for reflection and practice.

Each chapter starts with Learning Outcomes and a connection to Science and Engineering Practices, while also providing additional vocabulary support and reinforcement of key concepts through practice. Throughout the learning experience, and as a capstone to lessons and chapters, there are many opportunities for key term acquisition and mastery of lesson content through practice and reinforcement.



CHAPTER 7

Skeletal System

Theme: Structure and Function

The structure of bones allows them to protect, support, and anchor the body for movement.

Old Bones

When human skeletal remains are found with no positive identification, a forensic anthropologist might be consulted. They determine the gender, age at the time of the death, stature, and possibly the cause of death.

As a skeleton ages, numerous prominent changes occur. The hip bone begins as three separate bones: the ilium, ischium, and pubis. They fuse together in the mid- to late teens but do not

7.1 Introduction

Study Strategy

Double-Entry Notes Fold a sheet of paper in half lengthwise and write the boldfaced subheads that appear under Bone Structure on the left side. As you read the text, make a bulleted list of notes about important ideas and terms. Ask your teacher or peers about any information you do not fully grasp.

Learning Outcomes

1. List the active tissues found in a bone.

SEP Use the Practices

Develop Explanations At first glance, bone may appear to be nonliving. Explain why you think bone is living.

What is the skeletal system?

Combining elements from Greek and Latin, skeleton means dried framework. However, the dry specimens you study in the lab don't show you the true living nature of bones. Like other organs and tissues, bones are supplied with nerves and blood. The obvious functions of bones are support, movement, and protection. But they are also instrumental in blood cell production and mineral storage. In addition to bones, the skeletal system also consists of the tendons, ligaments, and cartilage associated with joints. Like in all vertebrates, the human skeleton is strong enough to bear weight yet light enough to allow movement. But the human skeleton is uniquely adapted for walking on two legs and for grasping with the hands.

The skeletal system has two major divisions: the axial skeleton and the appendicular skeleton.

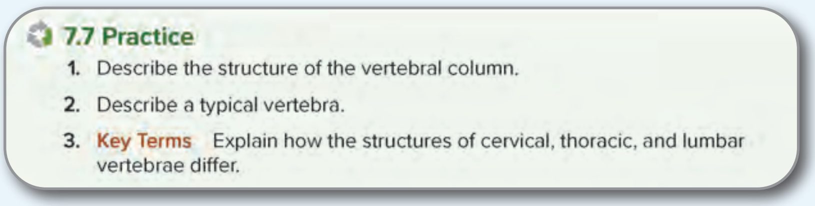
Each chapter begins with an **opening vignette**, drawing connections between the central chapter concept and the real world.

Study Strategies strengthen students' listening, speaking, and collaboration skills while aiding mastery of the vocabulary and language demands of the anatomy and physiology course. Activities are leveled to support English language acquisition.

Use the Science and Engineering Practices is presented up front, asking students to apply the SEPs to learning concepts, encouraging critical thinking and active learning.

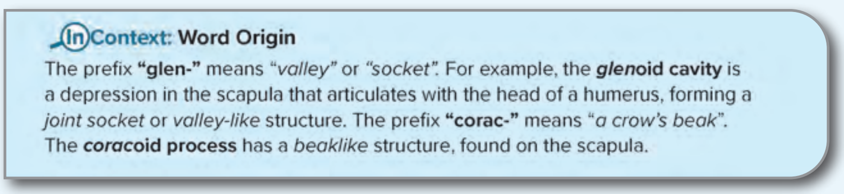
Introductions present an engaging narrative to pique students' interest while building a solid foundation for learning about the systems that will be explored in the subsequent lessons.

Practice questions offer opportunities to reinforce learning as part of the **Learn, Practice, Assess** framework.



7.7 Practice

1. Describe the structure of the vertebral column.
2. Describe a typical vertebra.
3. Key Terms Explain how the structures of cervical, thoracic, and lumbar vertebrae differ.



In Context: Word Origin

The prefix **"glen-"** means *"valley"* or *"socket"*. For example, the ***glenoid* cavity** is a depression in the scapula that articulates with the head of a humerus, forming a *joint socket* or *valley-like* structure. The prefix **"corac-"** means *"a crow's beak"*. The ***coracoid* process** has a *beaklike* structure, found on the scapula.

In Context features focus on word origins and other **vocabulary** support to help students acquire and master key scientific terms.

Learn, Practice, Assess

A Visual Journey through the Human Body

Key Figures illustrate concepts, processes, and systems to help students visualize them in action, step-by-step, providing an engaging touchpoint and helping them grasp complex anatomical structures and physiological processes.

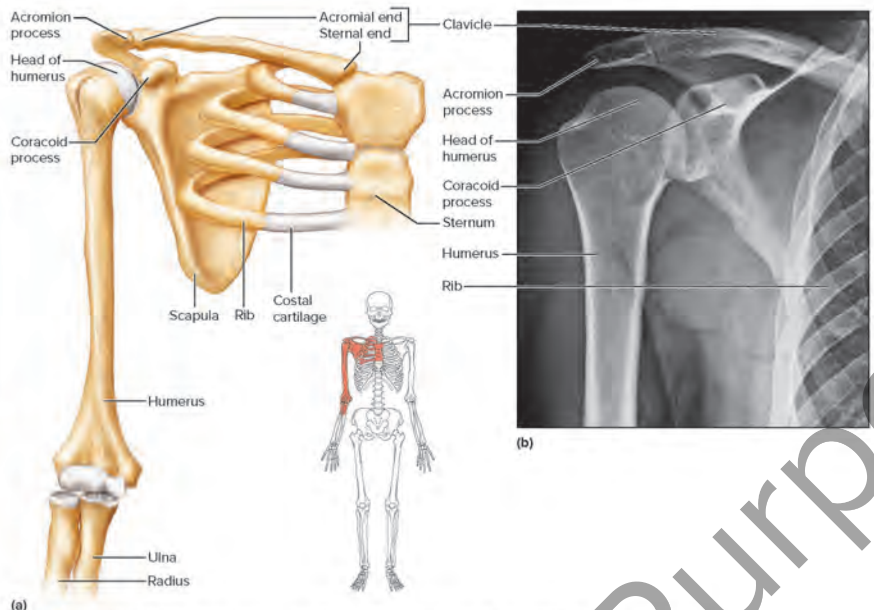
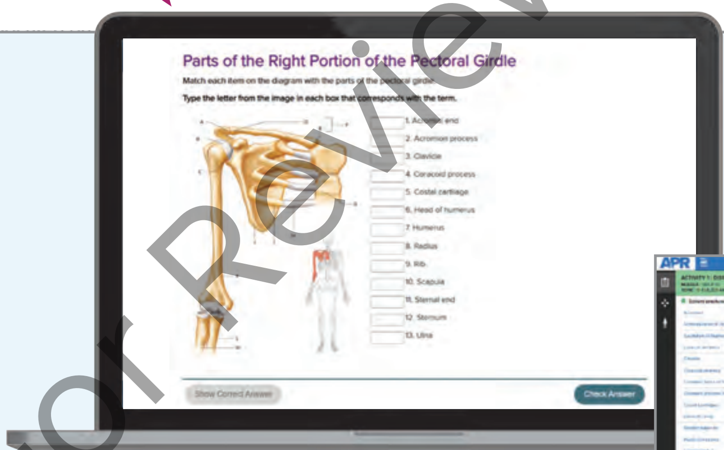


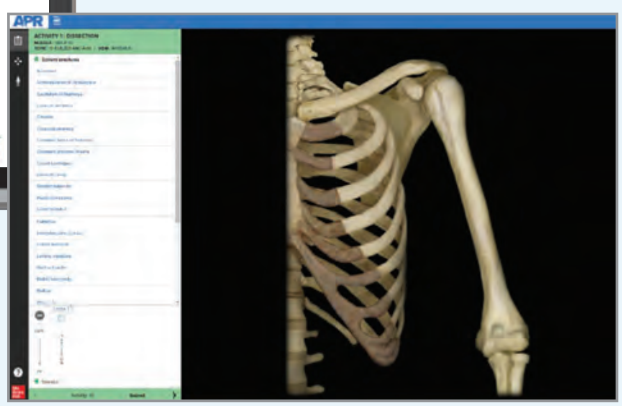
Figure 7.21 Right portion of the pectoral girdle. **(a)** The pectoral girdle, to which the upper limbs are attached, consists of a clavicle and a scapula on each side. **(b)** A radiograph of the right shoulder region, anterior view, showing the right pectoral girdle and proximal end of the right humerus.

GO ONLINE to check your understanding of the parts of the pectoral girdle by completing the Focus Activity.

Figure Captions are included to clarify complex concepts and provide descriptions sequentially.



Many **Key Figures** within the chapter have a corresponding labeling *Focus Activity* found in the digital resources. These activities provide an opportunity to check for understanding or reinforce the learning.



Learn, Practice, Assess

Real World and Career Connections

The special features located throughout the text are categorized into multiple strands: **Healthy Habits**; **Diagnosing Disease and Disorders**; **Technology and Treatments**; and **Medical Mysteries**. These features examine current, real-world topics and issues such as cancer, steroid use, or eating disorders in more depth. Some are used as the jumping off point for the **Engineer a Healthier World** projects introduced at the beginning of each unit.

Each chapter highlights a career path related to anatomy and physiology that builds student's awareness of the vast array of professional occupations in healthcare and sparks an interest in further exploration. Each vocation involves different education requirements; overlaps with other science, technology, and humanities fields; and allows students to envision how they can translate classroom learning into future educational and career paths.

Healthy Habits

The Dangers of Undereating and Overeating

Anorexia nervosa is a complex psychological disorder in which a person significantly restricts food. People with anorexia perceive themselves as overweight and eat barely enough to survive, losing as much as 25 percent of their body weight. Anorexia leads to low blood pressure, slowed or irregular heartbeat, constipation, and constantly … becomes brittle, the skin dri… pale, fine body hair called la… seen only on a fetus) grows … body heat. A person with an… hospitalized. Intravenous fe… to prevent sudden death fro… to electrolyte imbalance. So… anorexia may die from the d… psychotherapy and nutrition…

Medical Mysteries

Exome Sequencing: The Case of Dissolving Intestines

By the time he was 4 years old, the boy had already had 100 surgeries, including removal of his colon. His gastrointestinal (digestive) tract had become riddled with holes, starting at age two with an abscess in his rectum. Feces leaked from his intestines. He was fed by tube and weighed less than 20 pounds. Doctors thought he was suffering from inflamma… disease, but his symptoms see… severe.

Researchers at the medical cen… boy was being treated had rec… perform one of the very first ex… experiments, planned for 2014… the part of the genome that en… is only 1.5 percent of the genom… to affect health. When the boy'… what was causing his terrible s… moved up to 2009, to help the…

Technology and Treatments

Gene Therapy: CRISPR

Nicole was born with sickle cell disease, an inherited disorder involving a gene variant in the oxygen-carrying protein hemoglobin within red blood cells. This variant is a single-base substitution in the β-globin gene on chromosome 11 that results in sickle (S) hemoglobin.

In Nicole's case she has two abnormal genes, one from each parent, a condition called sickle cell anemia. Normally, red blood cells are flexible, disc-shaped cells that can easily move through blood vessels. However, this genetic variant causes the red blood cells to become narrow, sickle shaped in certain conditions. This reduces flexibility making it harder for the cells to move, possibly blocking blood flow and causing organ damage. It is painfule and increases the risk of stroke, infections, and other serious conditions. For Nicole and approximately 20 million people worldwide there is a promising gene therapy involving gene-

A scientist views the results of genetic testing on a patient.

Healthy Habits highlight behaviors, hygiene, and habits and their potential for impacting the body.

Medical Mysteries investigate curious cases of diseases from symptom to resolution, often highlighting patients and doctors who helped bring the mystery to light.

Technology and Treatments delves into the development of technological innovations and the intersection with disease and disorder treatment.

Concept Connections

1. Explain the basics of how CRISPR technology works to treat sickle cell anemia.
2. How might the life of a person who has sickle cell anemia change after receiving gene therapy from CRISPR?

Concept Connections assesses student understanding of the feature topic and how it relates to the overall content of the chapter.

Career Connection

Radiology Technologist

A fifty-two-year-old woman steps into a clinic to have her bone mineral density measured. She is younger than most of the others there. Her gynecologist had advised her to have a baseline test to assess the health of her skeleton because her parents had osteoporosis.

A radiology technologist conducts the test. She explains the procedure to the patient and then positions her on her back on a padded table. The scanner passes painlessly over the patient's hip and lower spine, emitting low-dose X-rays that form images of the bones. Spaces on the scan indicate osteopenia, a low bone mineral density that may indicate osteoporosis in the future.

Radiology technologists administer medical imaging tests, such as ultrasound, magnetic resonance imaging (MRI), mammography, and X-ray cross-sections of computerized tomography (CT). Radiology technologists protect patients from radiation with drapes. Positioning patients and operating scanning devices produces images from which a radiologist can diagnose an illness or injury.

A registered radiology technologist completes two years of training at a hospital or a two-year or four-year college or university program and must pass a national certification exam.

Consider This What would you expect to be included in your training to become a radiology technologist?

From Endoscopy Technicians and Radiologists to Forensic Scientists and Medical Transcriptionists, **Career Connections** explore how anatomy and physiology manifests in the world of work, and the possible careers students might investigate in the future.

Consider This questions allow students to think critically about what they would do in a given clinical situation, immersing them in real-world scenarios.

Learn, **Practice,** Assess

Engage with Scientific Phenomena

Explore, Explain, and Extend the Phenomena features allow students to practice Claim, Evidence, and Reasoning skills as they connect real-world examples to the concepts presented throughout the chapter.

CER Make Your Claim: What are the characteristics of bones that make them valuable to forensic anthropology?

Explore the Phenomenon: Forensic Anthropology

Forensic anthropologists help identify the age, gender, stature, and cause of death for an unidentified skeleton. During your school's career fair, a forensic anthropologist brings actual bone specimens and a presentation with them. They pick up a hip bone and say, "Did you know that when you are born this bone is actually three separate bones: the ilium, ischium, and pubis? And in most of you, they are just now beginning to fuse together." Then, while holding a femur they explain further saying, "The ends of the long bones fuse to the shaft at various ages. For the femur, this is between 14 and 21 years, and for the clavicle it occurs between 20 and 30 years of age. Why do you think the skeleton starts off with more separate bones and fuses them throughout your lifespan? Are there any advantages to either unfused or fused bones?"

CER Claim, Evidence, Reasoning

Make Your Claim: Use your CER chart to make a claim about the characteristics of bones that make them valuable to forensic anthropology. Explain your reasoning.

Collect Evidence: Use the information in this chapter to collect evidence to support your claim. Record your evidence as you move through the chapter.

Explain Your Reasoning: You will revisit your claim and explain your reasoning at the end of this chapter.

GO ONLINE to access your CER chart, APR dissections, chapter project, and practice for key terms and concepts.

Explore the Phenomena provides a real-world scenario illustrating the chapter focus accompanied by a related question and prepares students to use the CER framework to examine it throughout the chapter.

Explain the Phenomena asks students to use evidence they have collected to support or revise the claim they made at the beginning of the chapter.

Explain the Phenomenon: Forensic Anthropology

Recall the phenomenon at the beginning of this chapter. You read about forensic anthropology. Throughout the chapter, you read about the structure and function of the skeletal system. Now it is time to revisit your claim, summarize your evidence, and analyze what you have learned.

CER Claim, Evidence, Reasoning

Revisit Your Claim: Review your CER chart where you recorded your claim about bones and forensic anthropology.

Summarize Your Evidence: Summarize the evidence you gathered from your investigations, and research and finalize your summary table.

Explain Your Reasoning: Does your evidence support your claim? Explain why your evidence supports your claim, and if it does not, revise your claim.

CER Explain Your Reasoning: What are the characteristics of bones that make them valuable to forensic anthropology?

Extend the Phenomena challenges students to broaden their understanding of the chapter's concepts by applying them to new, real-world situations. By exploring different contexts and considering the implications, students develop a deeper appreciation for the relevance of anatomy and physiology in their everyday lives.

Extend the Phenomenon: Chapter Project

When Bones Break Down: An Inquiry into Bone Diseases

As you learned in this chapter, the skeletal system provides many different functions for the human body including critical structure and blood-cell formation. When something goes wrong with the skeletal system, development, growth, and/or repair mechanisms may be affected.

While this chapter mentioned a few bone diseases, such as osteopenia and osteoporosis, which are two of the most common, many more bone diseases exist. Bone diseases are often painful and debilitating disorders. Some bone diseases affect only the movement of joints. Some bone diseases interfere with the ossification process, and others affect the formation of blood cells.

You will:

- Be assigned, or choose, a bone disease to research.
- Take thorough notes on how and why the bone disease forms, how it is diagnosed, and how it is treated.
- Make a short presentation about the disease.
- Present your findings to your class.

Learn, Practice, **Assess**

Achieving and Assessing Mastery

Chapter level summaries provide an opportunity for students to refresh and reinforce their learning. In-text and online assessments provide a comprehensive and multifaceted approach to evaluating student learning. The range of assessment formats allows for a thorough evaluation of student understanding, catering to different learning styles and providing opportunities for both formative and summative assessment.

Chapter 7 Summary

GO ONLINE for a list of key terms and a summary of the Chapter 7 concepts.

7.1 Introduction

The skeletal system is made up of individual organs, bones, tendons, ligaments, and cartilage. Bones contain active tissues.

Revisit the Learning Outcomes

1. List the active tissues found in a bone.

7.2 Bone Structure

Bones can be long, short, flat, or irregular. Long bones are comprised of the diaphysis, epiphyses, periosteum, compact bone, and spongy bone.

Revisit the Learning Outcomes

1. Locate and identify the macroscopic and microscopic structure of a long bone, and describe the functions of these parts.

The **Chapter Summary** provides a concise overview of the key concepts, serving as a valuable tool for review and reinforcement. An expanded online summary provides a more detailed view and includes additional explanations and examples.

Chapter 7 Assessment

Chapter Review Questions

Multiple Choice

1. __________ heals rapidly as a result of blood (nutrient supply) having easy access to and between osteocytes through the cellular processes passing through very small tubes in the extracellular matrix called canaliculi.
   a. Spongy bone
   b. Trabeculae
   c. Medullary cavities
   d. Compact bone
2. All the following directly influence bone development, growth, and repair except __________

6. A patient has dealt with years of back pain caused by degenerative disc disease. After trying other routes of treatment, a doctor decides to treat the patient through spinal fusion surgery, fusing together the three vertebrae closest to the sacrum. Which vertebrae are being fused?
   a. C5, C6, and C7
   b. S1, S2, and S3
   c. L3, L4, and L5
   d. T10, T11, and T12
7. Which structure of the thoracic cage functions in compressing the heart during ideal

The **Chapter Assessment** includes multiple choice and short-answer questions that that are presented at the appropriate level for the high school student.

Critical Thinking and Clinical Connection

1. How does the structure of a bone make it strong yet lightweight?
2. **Clinical Connection** How would you explain to an athlete why damaged joint ligaments and cartilages are so slow to heal following an injury?
3. **Writing Connection** Vitamin D is converted to the hormone calcitriol by three body organs: the skin, liver, and kidneys. Calcitriol enhances the absorption of calcium in the small intestine and acts to prevent the elimination of calcium in urine. Which hormone does calcitriol work with to raise blood calcium? Explain.

The **Critical Thinking and Clinical Applications** asks students to apply writing and higher order thinking skills to answer questions with everyday implications. These exercises go beyond rote memorization and encourage students to analyze, evaluate, and synthesize information, applying their knowledge to real-world scenarios.

Data Analysis activities allow students to analyze and interpret real-world scientific concepts through a data lens, requiring them to interpret information, draw conclusions, and extend their learning.

Data Analysis: Exercise and Bone Health

Bone density is an important measure of bone health. Bone density decreases as humans age, increasing the risk of fractures. Getting enough calcium and vitamin D helps prevent loss of bone density. So does performing weight bearing exercises. Scientists collected data on 25 healthy men between the ages of 23 to 32 years old and divided them into three groups: runners, runners who perform resistance training, and a control group that exercised less than 1 hour per week. Examples of resistance training include lifting weights or using bands that increase resistance when stretched. The scientists measured the bone density of several bones in the bodies of the participants, including in the lumbar spine, and the three places in the femur.

Data and Observations

Figure A shows the results of the study. The bones tested are on the x-axis and bone density in g/cm^3 is on the y-axis.

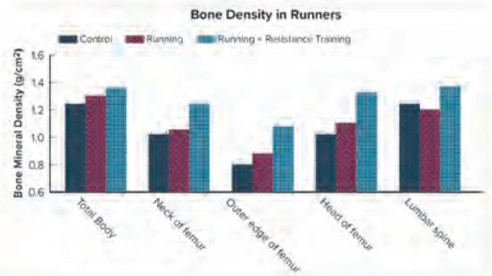


Figure A: Bone mineral density in runners.

Data obtained from: Duplanty, A. A., Levitt, D.E., Hill D.W., McFarlin B.K., DiMarco, N.M., & Vingren, J.L. 2018. Resistance training is associated with higher bone mineral density among young adult male distance runners independent of physiological factors. Journal of Strength and Conditioning Research, 32(6).

Best in Class Digital Resources

Hole's Essentials of Human Anatomy and Physiology, Third Edition is enriched with multimedia content including videos, animations, and simulations that enhance the teaching and learning experience both inside and outside the classroom.

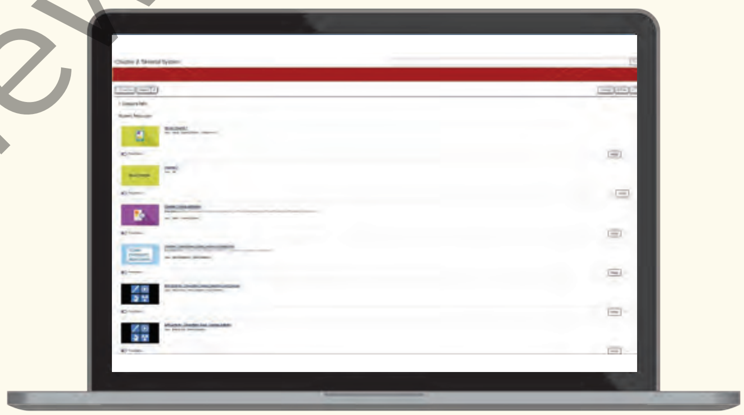
Authored by the world's leading subject matter experts and organized by unit and chapter level, the resources seamlessly integrate with the textbook and provide students with multiple opportunities to contextualize and apply their understanding. Teachers can save time, customize lessons, monitor student progress, and make data-driven decisions in the classroom with flexible, easy-to-navigate instructional tools.

Student Resources

Resources are organized at the unit and chapter level. The chapter landing page gives students access to:

- Interactive eBook and Adaptive SmartBook® assignments
- Animations and interactivities
- Chapter and Unit projects
- Expanded chapter summaries
- Self-guided APR modules
- Guided and inquiry labs, and interactive Virtual Labs
- Actively Learn articles and Kahoot! chapter games

The **chapter landing page** links students to resources that support success. The calendar links directly to all posted assignments to help students stay organized and keep due dates in view.

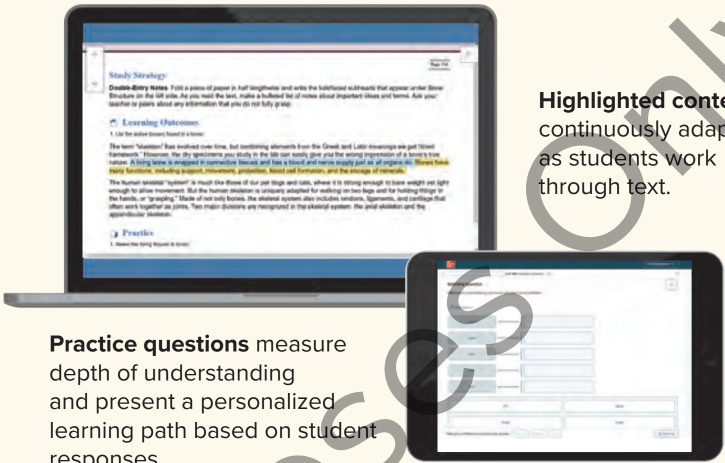


Mobile Ready Access to course content on-the-go is easier and more effective than ever before with the McGraw Hill K-12 Portal App.

Adaptive Instruction

SmartBook® is the assignable, mobile-compatible, adaptive study tool. The interactive features engage students and personalize the learning experience with self-guided tools that:

- Assess a student's proficiency and knowledge,
- track which topics have been mastered,
- identify areas that need more study,
- deliver meaningful practice with guidance and instant feedback,
- recharge the learning with access to previously completed assignments and personalized recommendations,
- allow teachers to assign material at the topic and subtopic level.



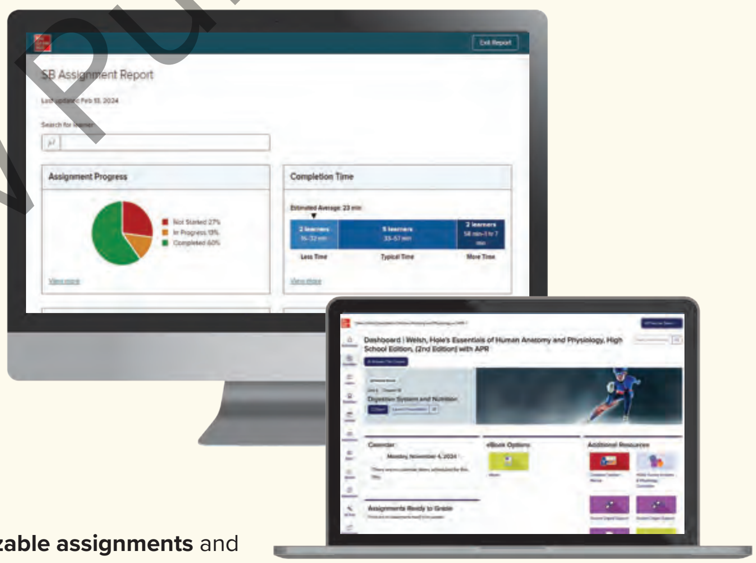
Highlighted content continuously adapts as students work through text.

Practice questions measure depth of understanding and present a personalized learning path based on student responses.

Teacher Resources

Teachers have access to the interactive eBook, adaptive SmartBook®, plus a wealth of customizable chapter resources and powerful gradebook tools. Resources include:

- an online version of the print teacher manual with chapter outlines, teaching suggestions, reading strategies, and pacing guides,
- editable test banks,
- actionable reporting features that track student progress with data-driven insights to guide in-class instruction
- customizable PowerPoint presentations
- labeled diagrams, visual aids, animations, and additional ideas for lecture environment.



Customizable assignments and **quiz banks** are automatically graded and populate easy-to-read reports that provide actionable insights.

Harness technology, unlock success with the digital resources for *Hole's Essentials of Human Anatomy and Physiology*

Visit mheonline.com/honorselectives

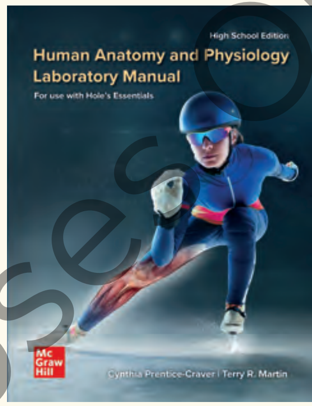
Supplementary Resources

Hole's Essentials of Human Anatomy and Physiology, Third High School Edition is supported by a variety of robust resources that help students not only grow in their understanding of anatomy and physiology, but also in their understanding of the relationship between the course material and the science and engineering practices.

Human Anatomy and Physiology Laboratory Manual

The Human Anatomy and Physiology Laboratory Manual to accompany *Hole's Essentials* by Cynthia Prentice-Craver and Terry R. Martin is a robust, hands-on lab manual ideal for the high school classroom. The lab manual provides:

- Dozens of exercises of varying lengths to accommodate any instructional schedule.
- Alternative material lists in print and online to ensure the exercises can be performed in any classroom.



Hole's Essentials of Human Anatomy and Physiology Teacher Manual

The Teacher Manual, available in print and online, will help teachers create and deliver an anatomy and physiology course that engages students in the content and supports success in content application and mastery. The manual provides:

- Robust Key Terms support, including word origins and practice, to facilitate acquisition and mastery of advanced vocabulary.
- A chapter-level theme activity.
- Pacing for each chapter, including guidance on the most effective timing for labs and activities.
- Differentiated instruction support to accommodate a variety of learning styles and needs.
- Answers to all student edition questions.

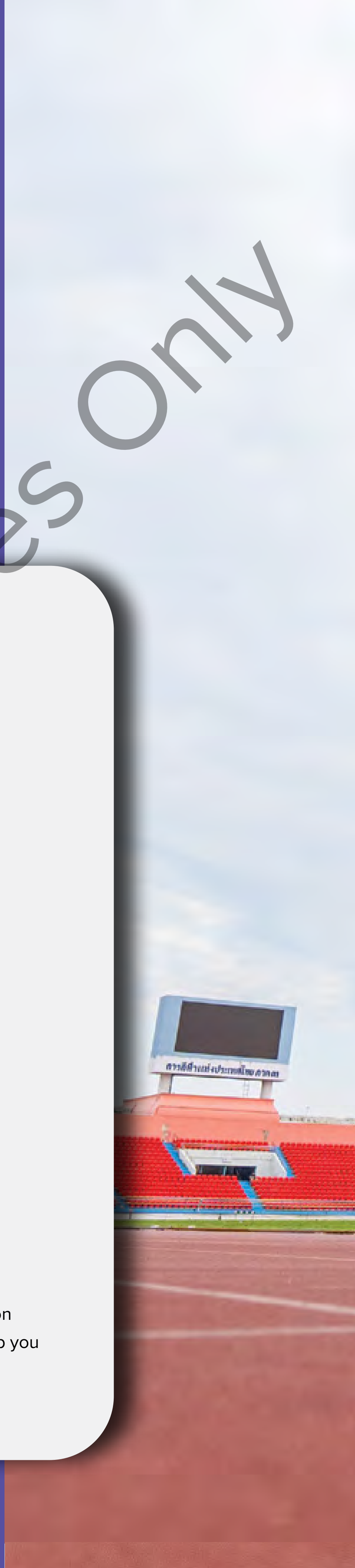
(t, c) Artur Didyk/Getty Images; (b)McGraw Hill

Anatomy & Physiology Revealed 4.0 (APR)

The ultimate online interactive cadaver dissection experience. This state-of-the-art program uses cadaver photos combined with a layering technique that allows the student to peel away layers of the human body to reveal structures beneath the surface. APR covers important topics from chemistry to organ systems, with animations, audio pronunciations, and comprehensive quizzing along the way.

UNIT 2

Support and Movement



Introduction

The previous five chapters have taken you through the organizational levels of atoms, molecules, cells, and tissues. The remaining chapters in this book will focus on organs and organ systems and how these systems interact to carry out the functions of life. The integumentary, skeletal, and muscular systems are responsible for the support and movement of the body. The next three chapters will introduce you to how skin, bone, and muscle hold the human body together and allow it to move through the world.

Key Features

Unit Project: Engineer a Healthier World

Clinicians and researchers use several tools to study the complex interactions within our bodies. In the Unit 2 Project, *Engineer a Healthier World*, you will explore how the principles of engineering intersect with the sciences of anatomy and physiology. You will apply the engineering design process to a problem facing healthcare today. You will also develop an answer to the unit's essential question while reading each chapter within the unit.

GO ONLINE to explore your unit projects and other digital resources.

Spotlight on Careers

Burn Technician **(Chapter 6)**

Radiology Technologist **(Chapter 7)**

Massage Therapist **(Chapter 8)**

SEP **Science and Engineering Practices** This icon indicates opportunities for you to practice and apply science and engineering practices.

A&PR **Anatomy & Physiology REVEALED** This icon indicates the correlating system in Anatomy & Physiology REVEALED.

Learn, Practice, Assess This icon indicates learning tools that help you practice and apply knowledge.

Essential Question: How does a prosthetic limb provide support and movement for the body?

CHAPTER 7

Skeletal System

Theme: Structure and Function

The structure of bones allows them to protect, support, and anchor the body for movement.

Chapter Contents

APR **Module 5:** Skeletal System

Old Bones

When human skeletal remains are found with no positive identification, a forensic anthropologist might be consulted. They determine the gender, age at the time of the death, stature, and possibly the cause of death.

As a skeleton ages, numerous prominent changes occur. The hip bone begins as three separate bones: the ilium, ischium, and pubis. They fuse together in the mid- to late teens but do not completely ossify until the early 20s. The ends of the long bones also fuse to the shaft at various ages. The femur fuses between 14 and 21 years, and the clavicle fuses between 20 and 30 years of age. The sutures in the skull close and often disappear. This begins in a person's late 20s and might continue into their 50s. Vertebrae in the lower back will begin to show signs of wear and osteoarthritis in a person's 60s, but it can begin in their 30s. Teeth can also provide clues about age. If the secondary molars have not yet erupted, the remains are of a preadolescent. Severe wear on the teeth is often associated with a middle-aged or older individual.

The region of the hip bones is the most reliable for determining gender. In general, these bones are tall and narrow in males and short and broad in females. In addition, some of the landmarks on the hips differ. The skull also holds some clues. A female chin is often oval in shape, whereas males tend to have a more squared-off chin and jaw. The area on the occipital bone where the neck muscles attach is more pronounced in males, and the parietal bones in females exhibit a certain swelling.

If bones were broken earlier in life, signs of healing will be evident. If a broken bone is part of the trauma that caused death, signs of healing will be absent.

Stature and size can also be estimated. Height can be calculated based on the length of bones such as the femur and humerus. Markings and ridges on bones can indicate the size of the large muscles of the arms and legs.

Analysis of the facial bones can often yield an approximation of what the person looked like. This includes facial features such as the length and width of the nose and the distance between the eyes. After a full examination, with all factors considered, a fairly accurate assessment of who the skeleton was in life is possible.

Adam Gault/OJO Images/Getty Images

CER Make Your Claim: What are the characteristics of bones that make them valuable to forensic anthropology?

Explore the Phenomenon: Forensic Anthropology

Forensic anthropologists help identify the age, gender, stature, and cause of death for an unidentified skeleton. During your school's career fair, a forensic anthropologist brings actual bone specimens and a presentation with them. They pick up a hip bone and say, "Did you know that when you are born this bone is actually three separate bones: the ilium, ischium, and pubis? And in most of you, they are just now beginning to fuse together." Then, while holding a femur they explain further saying, "The ends of the long bones fuse to the shaft at various ages. For the femur, this is between 14 and 21 years, and for the clavicle it occurs between 20 and 30 years of age. Why do you think the skeleton starts off with more separate bones and fuses them throughout your lifespan? Are there any advantages to either unfused or fused bones?"

CER Claim, Evidence, Reasoning

Make Your Claim: Use your CER chart to make a claim about the characteristics of bones that make them valuable to forensic anthropology. Explain your reasoning.

Collect Evidence: Use the information in this chapter to collect evidence to support your claim. Record your evidence as you move through the chapter.

Explain Your Reasoning: You will revisit your claim and explain your reasoning at the end of this chapter.

GO ONLINE to access your CER chart, APR dissections, chapter project, and practice for key terms and concepts.

7.1 Introduction

Study Strategy

Double-Entry Notes Fold a sheet of paper in half lengthwise and write the boldfaced subheads that appear under Bone Structure on the left side. As you read the text, make a bulleted list of notes about important ideas and terms. Ask your teacher or peers about any information you do not fully grasp.

Learning Outcomes

1. List the active tissues found in a bone.

SEP Use the Practices

Develop Explanations At first glance, bone may appear to be nonliving. Explain why you think bone is living.

What is the skeletal system?

Combining elements from Greek and Latin, skeleton means dried framework. However, the dry specimens you study in the lab don't show you the true living nature of bones. Like other organs and tissues, bones are supplied with nerves and blood. The obvious functions of bones are support, movement, and protection. But they are also instrumental in blood cell production and mineral storage. In addition to bones, the **skeletal system** also consists of the tendons, ligaments, and cartilage associated with joints. Like in all vertebrates, the human skeleton is strong enough to bear weight yet light enough to allow movement. But the human skeleton is uniquely adapted for walking on two legs and for grasping with the hands.

The skeletal system has two major divisions: the axial skeleton and the appendicular skeleton.

7.1 Practice

1. Name the living tissues in bone.

7.2 Bone Structure

Learning Outcomes

1. Locate and identify the macroscopic and microscopic structure of a long bone, and describe the functions of these parts.

SEP Use the Practices

Using Models Draw a diagram of a long bone that illustrates the bone's anatomy. As you read, identify and locate the spongy and compact tissue, epiphysis, diaphysis, medullary cavity, periosteum, bone marrow, and endosteum.

How are bones classified?

The adult human skeleton has 206 bones that vary greatly in size, shape, and function (refer to Table 7.1). However, these bones are all similar in their basic structure and how they develop. Bones may be classified according to their shapes—long, short, flat, or irregular.

- **Long bones** have long longitudinal axes and expanded ends. Examples of long bones are the forearm and thigh bones.
- **Short bones** have roughly equal lengths and widths. The bones of the wrists and ankles are this type. A special type of short bone is a sesamoid bone or round bone. This type of bone is typically small and nodular and develops within a tendon or adjacent to a joint. The kneecap, or patella, is a sesamoid bone.
- **Flat bones** are platelike structures with broad surfaces, such as the ribs, the scapulae, and some skull bones.
- **Irregular bones** have a variety of shapes, and most are connected to several other bones. Irregular bones include many facial bones and the vertebrae that compose the backbone

Structure of a Long Bone

The femur, a bone in the thigh, is the classic example of the structure of a long bone (refer to Fig. 7.1). At each end of a long bone is an expanded portion called an **epiphysis**, (eh-PIF-ih-sis), which articulates (forms a joint) with another bone. The epiphysis nearest to the attachment to the trunk of the body is called the proximal epiphysis. The epiphysis farthest from the trunk of the body is called the distal epiphysis. The outer surface of the articulating portion of the epiphysis is coated with a layer of hyaline cartilage called **articular cartilage**. The shaft of the bone between the epiphyses is called the **diaphysis** (dye-AF-ih-sis). Between the epiphysis and diaphysis, is the **epiphyseal plate**, also called the growth plate. This is a region of cartilage where a bone grows in length. When a bone is no longer growing, the site of the former growth plate is called the epiphyseal line.

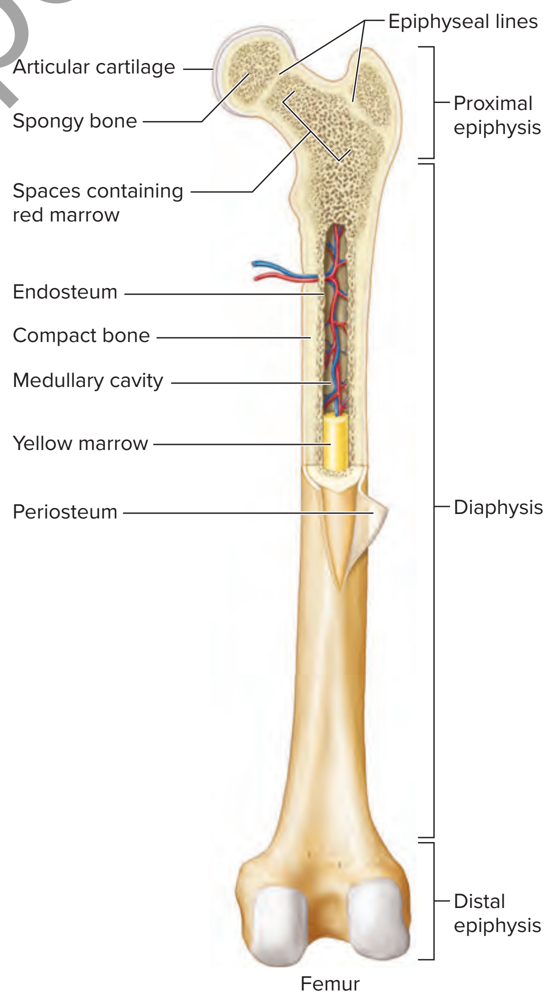


Figure 7.1 The structure of a long bone. This is a femur, the long bone in the thigh.

A tough covering of dense connective tissue called the **periosteum** completely encloses the long bone, except for the articular cartilage on the bone's ends. The periosteum is firmly attached to the bone, and periosteal fibers are continuous with the connecting ligaments and tendons. The periosteum helps form and repair bone tissue.

A bone's shape makes possible the bone's functions. For example, bony projections called processes provide sites where ligaments and tendons attach; grooves and openings form passageways for blood vessels and nerves; and a depression of one bone may articulate with a process of another.

The wall of the diaphysis is mainly composed of tightly packed tissue called **compact bone**, also called cortical bone. Compact bone has a continuous extracellular matrix with no gaps.

Career Connection

Radiology Technologist

A fifty-two-year-old woman steps into a clinic to have her bone mineral density measured. She is younger than most of the others there. Her gynecologist had advised her to have a baseline test to assess the health of her skeleton because her parents had osteoporosis.

A radiology technologist conducts the test. She explains the procedure to the patient and then positions her on her back on a padded table. The scanner passes painlessly over the patient's hip and lower spine, emitting low-dose X-rays that form images of the bones. Spaces on the scan indicate osteopenia, a low bone mineral density that may indicate osteoporosis in the future.

Radiology technologists administer medical imaging tests, such as ultrasound, magnetic resonance imaging (MRI), mammography, and X-ray cross-sections of computerized tomography (CT). Radiology technologists protect patients from radiation with drapes. Positioning patients and operating scanning devices produces images from which a radiologist can diagnose an illness or injury.

A registered radiology technologist completes two years of training at a hospital or a two-year or four-year college or university program and must pass a national certification exam.

Consider This What would you expect to be included in your training to become a radiology technologist?

The epiphyses, in contrast, are composed largely of **spongy bone**, also called cancellous bone, with thin layers of compact bone on their surfaces. Spongy bone consists of numerous branching bony plates called **trabeculae** (trah-BEK-you-lee). Irregular connecting spaces between these plates help reduce the long bone's weight (refer to Fig. 7.2). The bony plates are most highly developed in the regions of the epiphyses that are subjected to compressive forces. Both compact bone and spongy bone are strong and resist bending.

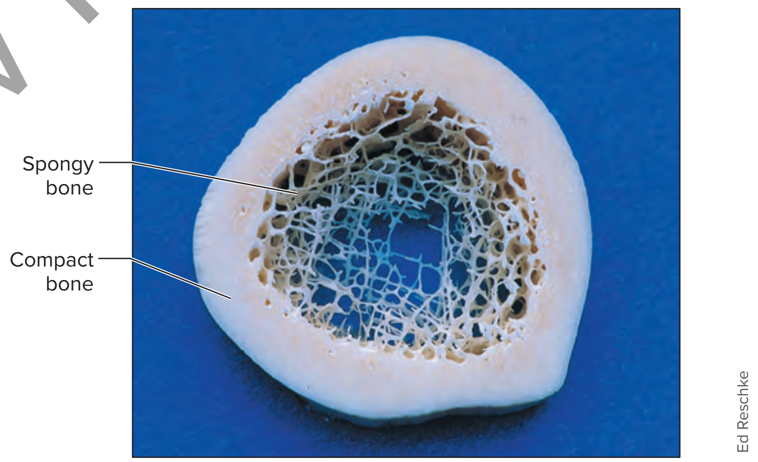


Figure 7.2 This cross section of a long bone reveals a layer of spongy bone beneath a layer of compact bone.

Compact bone in the diaphysis of a long bone forms a tube with a hollow chamber called the **medullary cavity** that is continuous with the spaces of the spongy bone. A thin layer of cells called the **endosteum** lines the

Phenomenon Connection

CER Collect Evidence Where do you find some of these different types of bones? Do they have different functions? Use examples of each type in your answer.

medullary cavity as well as the spaces within spongy bone. A specialized type of soft connective tissue called **marrow** fills them.

Microscopic Structure

Recall from chapter 5 (refer to section 5.3, Connective Tissue) that bone cells called osteocytes occupy very small, bony chambers called **lacunae** (lah-KOO-nee). The lacunae are within the bony matrix of the **lamellae** (lah-MEL-lee), which form concentric circles around central canals. Osteocytes exchange substances with nearby cells by means of cellular processes passing through **canaliculi** (refer to Fig. 7.3 and Fig. 5.20). The extracellular matrix (ECM) of bone tissue is largely collagen and inorganic salts (calcium phosphate). Collagen gives bone its strength and resilience, and inorganic salts make the bone hard and resistant to crushing.

In a compact bone, the osteocytes and layers of ECM concentrically clustered around a central canal form a cylinder-shaped unit called an osteon (Haversian system). Many osteons together form the substance of compact bone.

Each central canal contains blood vessels and nerve fibers surrounded by loose connective tissue. Blood in these vessels nourishes bone cells associated with the central canal.

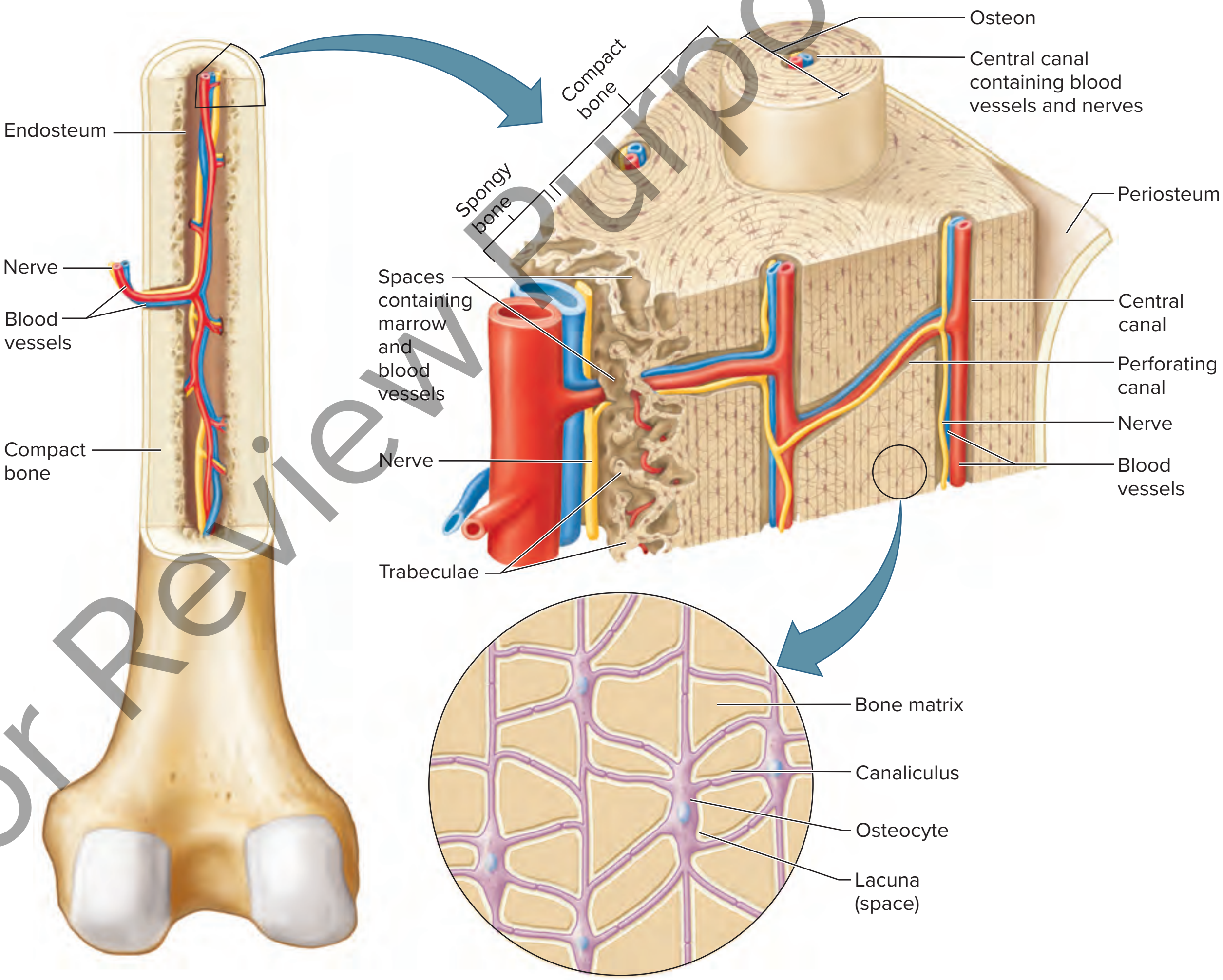


Figure 7.3 Compact bone is composed of osteons cemented together by bone matrix. Osteocytes communicate through tunnel-like extensions called canaliculi. Note: drawing is not to scale.

GO ONLINE to check your understanding of the major parts of a compact bone by completing the Focus Activity.

Central canals extend longitudinally through bone tissue, and transverse perforating canals connect them. Perforating canals contain larger blood vessels and nerves by which the smaller blood vessels and nerves in central canals communicate with the surface of the bone and the medullary cavity (refer to Fig. 7.3).

Spongy bone is also composed of osteocytes and ECM, but the bone cells do not accumulate around central canals. Instead, the cells lie in the trabeculae. They obtain nutrients from substances diffusing into canaliculi that lead to the surface of these thin, bony plates.

7.2 Practice

1. Explain how bones are classified by shape.
2. List five major parts of a long bone.
3. **Key Terms** Explain how compact and spongy bone differ in structure.
4. Describe the microscopic structure of compact bone.

7.3 Bone Function

Learning Outcomes

1. Discuss the major functions of bones.

SEP Use the Practices

Conducting Investigations Write down what you know about how hormones regulate bone calcium deposition. Then, design an experiment to study this concept.

What are the functions of bones?

Bones shape, support, and protect body structures. Bones also aid body movements, house tissue that produces blood cells, and store inorganic salts. Bones give shape to structures such as the head, face, thorax, and limbs. They are also strong enough to lend support and protection. For example, the bones of the lower limbs, pelvis, and backbone support the body's weight. The bones of the skull protect the eyes, ears, and brain. Bones of the rib cage and shoulder girdle protect the heart and lungs, whereas the bones of the pelvic girdle protect the lower abdominal and internal reproductive organs. Bones are not only strong, but they are also light enough to work with muscles to move the limbs and other body parts.

Blood Cell Formation

The process of blood cell formation, called **hematopoiesis** (hee-MAH-toh-poy-EE-sis), begins in the yolk sac, which lies outside the human embryo (refer to section

InContext: Word Origin

The prefix "**poie**-" means to "*make*" or "*produce*". For example, **hemato*poie*sis is a** process that *produces* blood cells.

20.3, Pregnancy and the Prenatal Period). Later in a person's development, the liver and spleen manufacture blood cells, and still later, blood cells form in bone marrow.

Marrow is a soft, netlike mass of connective tissue within the medullary cavities of long bones, in the irregular spaces of spongy bones, and in the larger central canals of compact bone tissues. Marrow is of two kinds: red and yellow. **Red marrow** functions in the formation of red blood cells, white blood cells, and blood platelets. The color comes from the oxygen-carrying pigment **hemoglobin** in the red blood cells.

In an infant, red marrow occupies the cavities of most bones. As a person ages, **yellow marrow**, which stores fat, replaces much of the red marrow. Yellow marrow is not active in blood cell production. In an adult, red marrow is primarily found in the spongy bone of the skull, ribs, breastbone (sternum), collarbones (clavicles), backbones (vertebrae), and hip bones. If the supply of blood cells is deficient, some yellow marrow may become red marrow, which then reverts to yellow marrow when the deficiency is corrected. Chapter 12 (refer to section 12.2, Formed Elements) describes blood cell formation in more detail.

Storage of Inorganic Salts

Vital metabolic processes require calcium. The ECM of bone tissue is rich in calcium salts, mostly in the form of calcium phosphate. When the blood is low in calcium, parathyroid hormones stimulate osteoclasts to break down bone tissue, which releases calcium salts from the ECM into the blood. Calcitonin, a hormone the thyroid gland releases when blood calcium levels are high, inhibits osteoclast activity. The effect of calcitonin on osteoblasts is unclear (refer to Fig. 7.4). Chapter 11 (refer to sections 11.5, Thyroid Gland, and 11.6, Parathyroid Glands) describes the details of this homeostatic mechanism. The maintenance of sufficient blood calcium levels is important in muscle contraction, nerve cell function, blood clotting, and other physiological processes.

In addition to storing calcium and phosphorus, bone tissue contains smaller amounts of magnesium, sodium, potassium, and carbonate ions. Bones also accumulate certain harmful metallic elements such as lead, radium, or strontium. These elements are not normally present in the body but are sometimes accidentally ingested.

7.3 Practice

1. Name the major functions of bones.
2. Key Terms Distinguish between the functions of red marrow and yellow marrow.
3. List the substances normally stored in bone tissue.
4. Explore the Figure What three components of a homeostatic mechanism are shown in Figure 7.4?

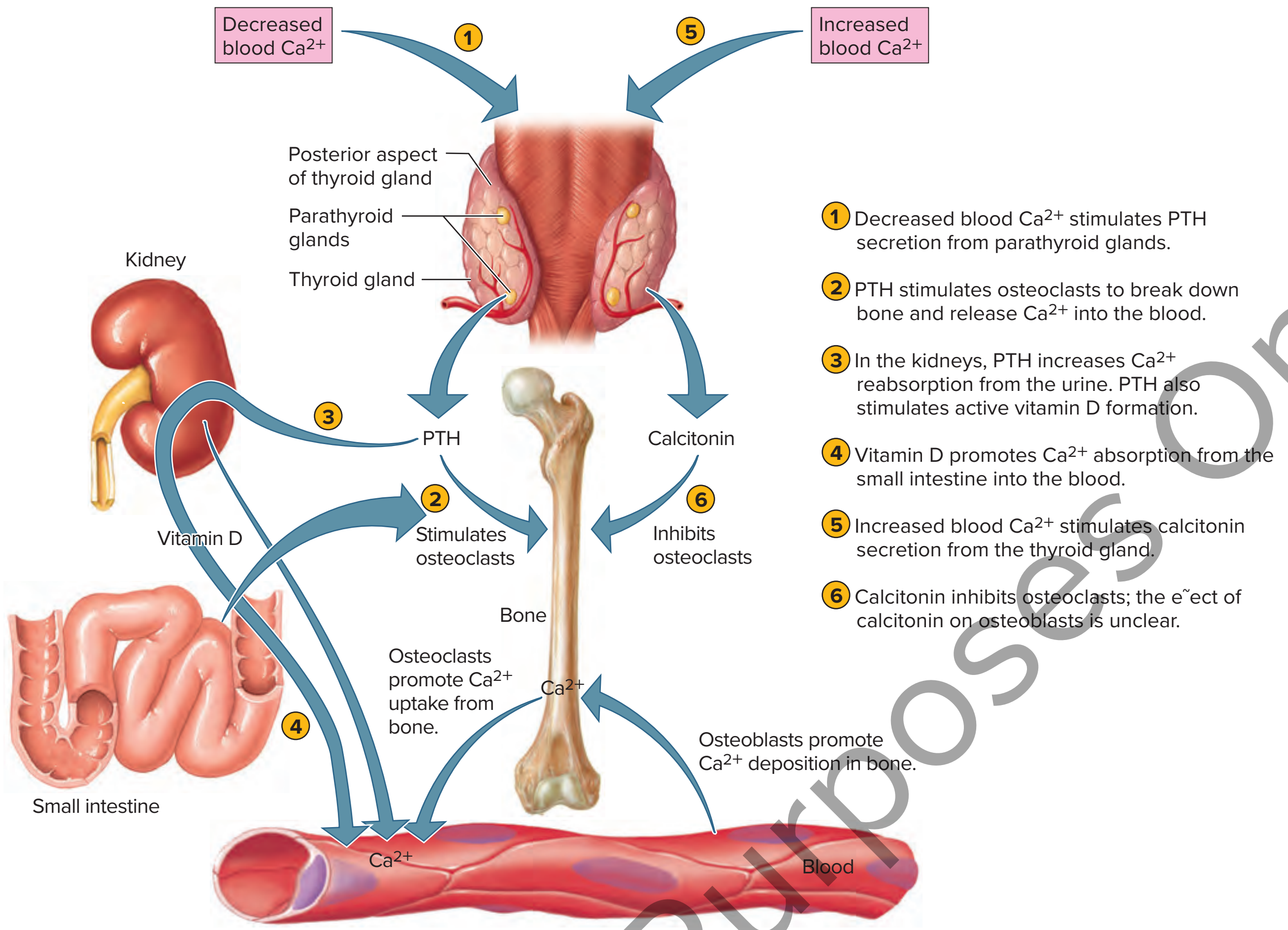


Figure 7.4 Hormonal regulation of bone calcium deposition and resorption. (Note: Drawings are not to scale.)

7.4 Bone Development, Growth, and Repair

Learning Outcomes

1. Distinguish between intramembranous and endochondral bones.
2. Explain the roles of osteoblasts, osteocytes, and osteoclasts in bone growth, development, and repair.

SEP Use the Practices

Arguing from Evidence Osteocytes and osteoblasts are incapable of dividing. Using what you already know, explain how you think bones grow despite the fact that these cells don't divide.

How do bones form?

Parts of the skeletal system begin to form during the first few weeks of prenatal development, and bony structures continue to develop and grow into adulthood. Bones form by replacing existing connective tissues in either of two ways: (1) intramembranous bones originate between sheetlike layers of connective tissues; or (2) endochondral bones begin as masses of hyaline cartilage that bone tissue later replaces (refer to Fig. 7.5). The formation of bone is called ossification.

Intramembranous Bones

The flat bones of the skull are **intramembranous bones**. They develop in the fetus from membranelike layers of unspecialized, connective tissues at the sites of the future bones. Dense networks of blood vessels are contained within these connective tissues. Some of the partially differentiated progenitor cells enlarge and further differentiate into bone-forming cells called **osteoblasts**. The osteoblasts deposit bony matrix around themselves, forming spongy bone tissue in all directions within the layers of connective tissues. When an ECM completely surrounds osteoblasts, they are called **osteocytes**. Eventually, cells of the membranous tissues that persist outside the developing bone give rise to the periosteum. Osteoblasts on the inside of the periosteum form a layer of compact bone over the surface of the newly formed spongy bone.

Figure 7.5 Intramembranous bones in the fetus form by replacing unspecialized connective tissue. Endochondral bones form from hyaline cartilage models that are gradually replaced with the harder tissue of bone. Note the stained, developing bones of this 14-week-old fetus.

Endochondral Bones

Most of the bones of the skeleton are **endochondral bones**. They develop in the fetus from masses of hyaline cartilage shaped like future bony structures. These cartilaginous models grow rapidly for a time and then begin to change extensively.

In a long bone, changes begin in the center of the diaphysis, where the cartilage slowly breaks down and disappears (refer to Fig. 7.6a,b). At about the same time, a periosteum forms from connective tissue that encircles the developing diaphysis. Blood vessels and osteoblasts from the periosteum invade the disintegrating cartilage, and spongy bone forms in its place. This region of bone formation is called the primary ossification center, and bone tissue develops from it toward the ends of the cartilaginous structure (refer to Fig. 7.6c). Meanwhile, osteoblasts from the periosteum deposit a thin layer of compact bone around the primary ossification center.

The epiphyses of the developing bone remain cartilaginous and continue to grow. Later, secondary ossification centers appear in the epiphyses, and spongy bone forms in all directions from them (refer to Fig. 7.6d). As spongy bone is deposited in the diaphysis and in the epiphysis, a band of cartilage called the epiphyseal plate remains between these two ossification centers (refer to Fig. 7.6e).

InContext: Word Origin

The prefix **"intra-"** means "*inside*". For example, the ***intra*membranous** bone forms within, or *inside* sheetlike masses of connective tissue. The suffix **"-blast"** means "*bud*". The **osteo*blast*,** for example, is a cell that will form or *bud* new bone cells to make new bone tissue.

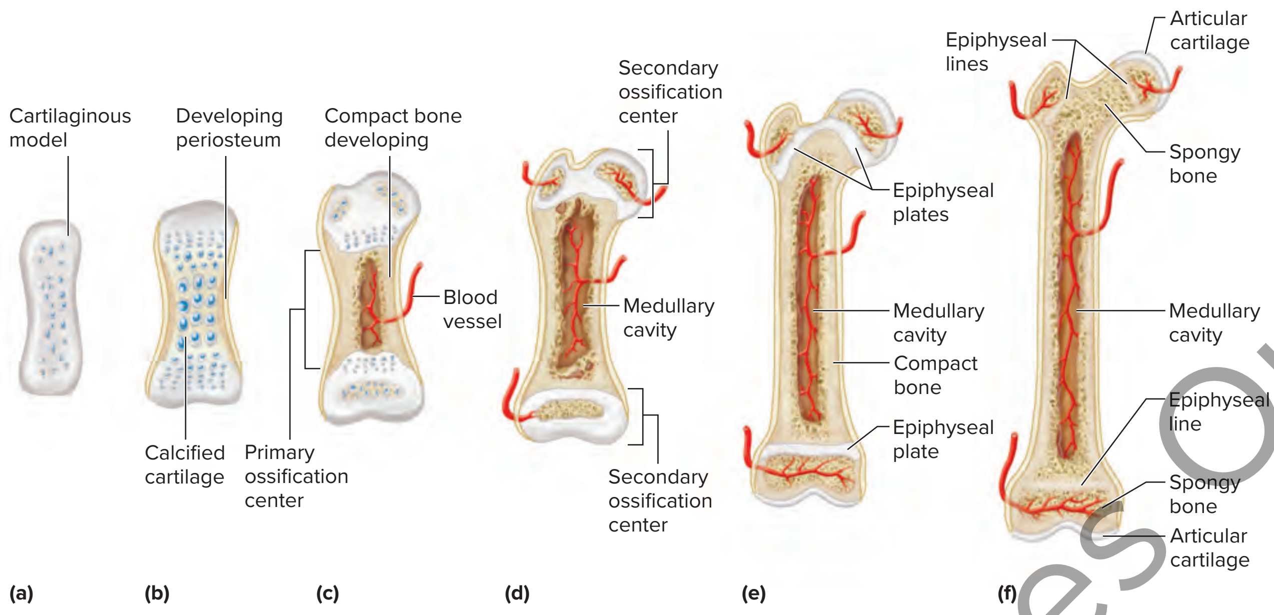


Figure 7.6 Major stages (**a–d** fetal, **e** child) in the development of an endochondral bone. In an **(f)** adult, when bone growth ceases, an epiphyseal line is what remains of the epiphyseal plate. (Note: Relative bone sizes are not to scale.)

The cartilaginous tissue of the epiphyseal plate includes layers of young cells that are undergoing mitosis and producing new cells. These cells enlarge, and an extracellular matrix forms around them. This causes the cartilaginous plate to thicken, lengthening the bone. At the same time, calcium salts accumulate in the ECM adjacent to the oldest cartilaginous cells. As the ECM calcifies, the cartilage cells begin to die.

Phenomenon Connection

CER **Collect Evidence** Why do you think the skeleton grows and elongates first as cartilage before becoming bone? Why might it be difficult to grow a bone longer?

In time, bone-resorbing cells called osteoclasts break down the calcified ECM. These large, multinucleated cells originate in bone marrow when certain single-nucleated white blood cells (monocytes) fuse. Osteoclasts secrete an acid that dissolves the inorganic component of the calcified matrix. Their lysosomal enzymes digest the organic components. After osteoclasts remove the ECM, bone-building osteoblasts invade the region. They deposit new bone tissue in place of the calcified cartilage.

A long bone continues to lengthen while the cartilaginous cells of the epiphyseal plates are active (refer to Fig. 7.7). However, once the ossification centers of the diaphysis and epiphyses meet and the epiphyseal plates ossify, lengthening is no longer possible in that end of the bone (refer to Fig. 7.6f).

InContext: Word Origin

In contrast, the suffix **"-clast"** means "*break*". The **osteo*clast*,** for example, is a cell that *breaks* down other bone cells and tissues.

A developing long bone thickens as compact bone is deposited on the outside, just beneath the periosteum. As this compact bone forms on the surface, osteoclasts erode other bone tissue on the inside. The resulting space becomes the medullary cavity of the diaphysis. This later fills with marrow. The bone in the central regions of the epiphyses and diaphysis remains spongy. Hyaline cartilage on the ends of the epiphyses persists throughout life as articular cartilage.

Figure 7.7 Radiograph of the right hand. Epiphyseal plates (arrows) in a child's bones indicate that the bones are still lengthening.

Ed Reschke/Getty Images

Homeostasis of Bone Tissue

After the intramembranous and endochondral bones form, the actions of osteoclasts and osteoblasts continually remodel them. Throughout a person's life, osteoclasts resorb bone matrix, and osteoblasts replace it. Hormones that regulate blood calcium help control these opposing processes of resorption and deposition of matrix (refer to sections 11.5, Thyroid Gland, and 11.6, Parathyroid Glands). As a result, the total mass of bone tissue of an adult skeleton normally remains nearly constant, even though 3 to 5 percent of bone calcium is exchanged each year.

Factors Affecting Bone Development, Growth, and Repair

A number of factors influence bone development, growth, and repair. These include nutrition, hormonal secretions, and physical exercise. For example, vitamin D is necessary for the proper absorption of calcium in the small intestine. In the absence of this vitamin, dietary calcium is poorly absorbed, and the inorganic salt portion of bone matrix will lack calcium. A lack of calcium softens and thereby deforms the bones. The pituitary gland secretes a growth hormone that stimulates the division of the cartilage cells in the epiphyseal plates. Sex hormones stimulate the ossification of the epiphyseal plates. Physical exercise that pulls on muscular attachments to bones stresses the bones, stimulating the bone tissue to thicken and strengthen.

7.4 Practice

1. Describe the development of an intramembranous bone.
2. Explain how an endochondral bone develops.
3. Key Terms Describe how osteoclasts and osteoblasts remodel bone.
4. Explain how nutritional factors, hormones, and physical exercise affect bone development and growth.

7.5 Skeletal Organization

Learning Outcomes

1. Distinguish between the axial and appendicular skeletons, and name the major parts of each.

SEP Use the Practices

Using Mathematics Table 7.1 divides the bones of the body into axial and appendicular skeletons. Predict the percentage of bones in the axial skeleton. Then, calculate the actual percentage using the table.

Table 7.1 Bones of the Adult Skeleton

Axial Skeleton Region	Bone Name (#)	Total Bone #	Appendicular Skeleton Region	Bone Name (#)	Total Bone #
Skull-cranial	Frontal (1) Parietal (2) Occipital (1) Temporal (2) Sphenoid (1) Ethmoid (1)	**8**	**Pectoral girdle**	Scapula (2) Clavicle (2)	**4**
Skull-facial	Maxilla (2) Zygomatic (2) Palatine (2) Inferior nasal concha (2) Mandible (1) Lacrimal (2) Nasal (2) Vomer (1)	**14**	**Upper limb**	Humerus (2) Radius (2) Ulna (2) Carpal (16) Metacarpal (10) Phalanx (28)	**60**
Middle ear bones	Malleus (2) Incus (2) Stapies (2)	**6**	**Pelvic girdle**	Hip bone (2)	**2**
Hyoid	Hyoid bone (1)	**1**	**Lower limbs**	Femur (2) Tibia (2) Fibula (2) Patella (2) Tarsal (14) Metatarsal (10) Phalanx (28)	**60**
Vertebral column	Cervical vertebra (7) Thoracic vertebra (12) Lumbar vertebra (5) Sacrum (1) Coccyx (1)	**26**			
Thoracic cage	Rib (24) Sternum (1)	**25**			
Total		**80**			**126**

How is the human skeleton organized?

For purposes of study, it is convenient to divide the skeleton into two major portions—an axial skeleton and an appendicular skeleton (refer to Fig. 7.8). Table 7.1 lists the bones of the adult skeleton. Table 7.2 lists terms that describe skeletal structures.

Axial Skeleton

The **axial skeleton** consists of the bony and cartilaginous parts that support and protect the organs of the head, neck, and trunk. These parts include:

- The skull is composed of the cranium, or brain case, and the facial bones.
- The hydoid bone is located in the neck between the lower jaw and the larynx. The hyoid bone supports the tongue and is an attachment for certain muscles that help move the tongue during swallowing.
- The vertebral column, or spinal column (backbone), consists of many vertebrae separated by cartilaginous intervertebral discs. Near the distal end of the vertebral column, five vertebrae fuse, forming the sacrum, which is part of the pelvis. The coccyx, a small, rudimentary tailbone composed of four fused vertebrae, is attached to the end of the sacrum.
- The thoracic cage protects the organs of the thoracic cavity and the upper abdominal cavity. The thoracic cage is composed of twelve pairs of ribs, which articulate posteriorly with thoracic vertebrae. The thoracic cage also includes the sternum, or breastbone, to which most of the ribs attach anteriorly.

Appendicular Skeleton

The **appendicular skeleton** consists of the bones of the upper and lower limbs and the anchoring bones of the axial skeleton. The appendicular skeleton includes:

- The prectoral girdle is formed by a scapula, or shoulder blade, and a clavicle, or collarbone, on both sides of the body. The pectoral girdle connects the bones of the upper limbs to the axial skeleton and aids in upper limb movements.
- Each upper limb consists of a humerus, or arm bone, two forearm bones—a radius and an ulna—and a hand. The humerus, radius, and ulna articulate with each other at the elbow joint. At the distal end of the radius and ulna is the hand. There are eight carpals, or wrist bones. The five bones of the palm are called metacarpals, and the 14 bones of the fingers are called phalanges.
- The pelvic girdle is formed by two hip bones attached to the other anteriorly and to the sacrum posteriorly. The hip bones, sacrum, and coccyx form the pelvis.
- Each lower limb consists of a femur, or thigh bone, two leg bones—a large tibia and a slender fibula—and a foot. The femur and tibia articulate with each other at the knee joint, where the patella, also called the kneecap, covers the anterior surface. At the distal ends of the tibia and fibula is the foot. There are seven tarsals, or ankle bones. The five bones of the instep are called metatarsals, and the 14 bones of the toes, like the fingers, are called phalanges.

Table 7.2 Terms Used to Describe Skeletal Structures

Term	Definition	Examples
Condyle	Rounded process that usually articulates with another bone	Occipital condyle of the occipital bone (refer to Fig. 7.12)
Crest	Narrow, ridgelike projection	Iliac crest of the ilium (refer to Fig. 7.27)
Epicondyle	Projection situated above a condyle	Medial epicondyle of the humerus (refer to Fig. 7.23)
Facet	Small, nearly flat surface	Costal facet of the thoracic vertebra (refer to Fig. 7.16)
Fontanel	Soft spot in the skull where membranes cover the space between bones	Anterior fontanel between the frontal and parietal bones (refer to Fig. 7.15)
Foramen	Opening through a bone, usually a passageway for blood vessels, nerves, or ligaments	Foramen magnum of the occipital bone (refer to Fig. 7.12)
Fossa	Relatively deep pit or depression	Olecranon fossa of the humerus (refer to Fig. 7.23)
Fovea	Tiny pit or depression	Fovea capitis of the femur (refer to Fig. 7.29)
Head	Enlargement on the end of a bone	Head of the humerus (refer to Fig. 7.23)
Meatus	Tubelike passageway within a bone	External acoustic meatus of the temporal bone (refer to Fig. 7.11)
Process	Prominent projection on a bone	Mastoid process of the temporal bone (refer to Fig. 7.11)
Sinus	Cavity within a bone	Frontal sinus of the frontal bone (refer to Fig. 7.14)
Spine	Thornlike projection	Spine of the scapula (refer to Fig. 7.22)
Sulcus	Furrow or groove	Intertubercular sulcus of the humerus (refer to Fig. 7.23)
Suture	Interlocking line of union between bones	Lambdoid suture between the occipital and parietal bones (refer to Fig. 7.11)
Trochanter	Relatively large process	Greater trochanter of the femur (refer to Fig. 7.29)
Tubercle	Small, knoblike process	Greater tubercle of the humerus (refer to Fig. 7.23)
Tuberosity	Knoblike process usually larger than a tubercle	Radial tuberosity of the radius (refer to Fig. 7.24)

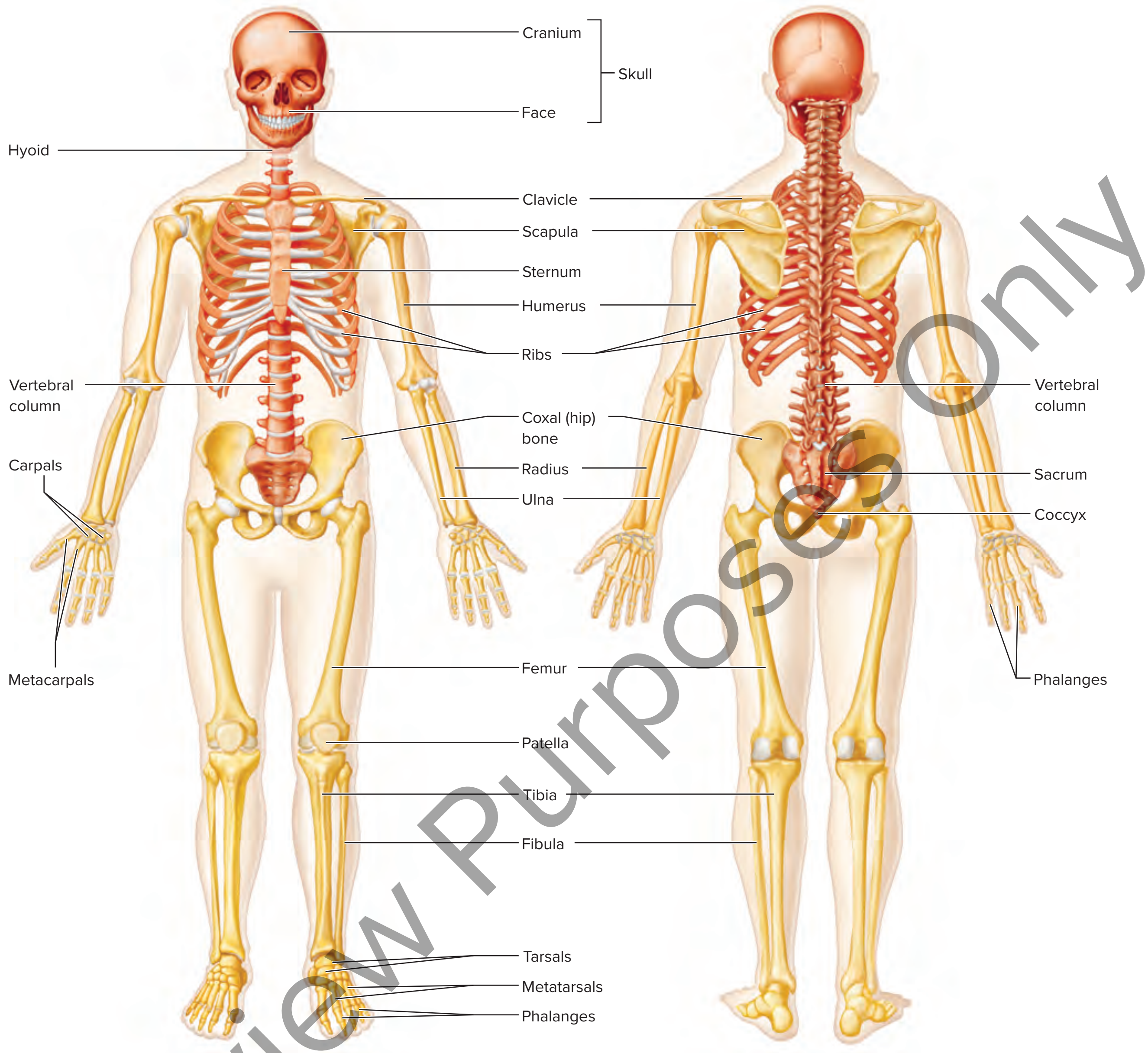


Figure 7.8 Major bones of the skeleton. **(a)** Anterior view. **(b)** Posterior view. The axial portion is shown in orange, and the appendicular portions are shown in yellow.

GO ONLINE to check your understanding of the major bones of the skeleton by completing the Focus Activity.

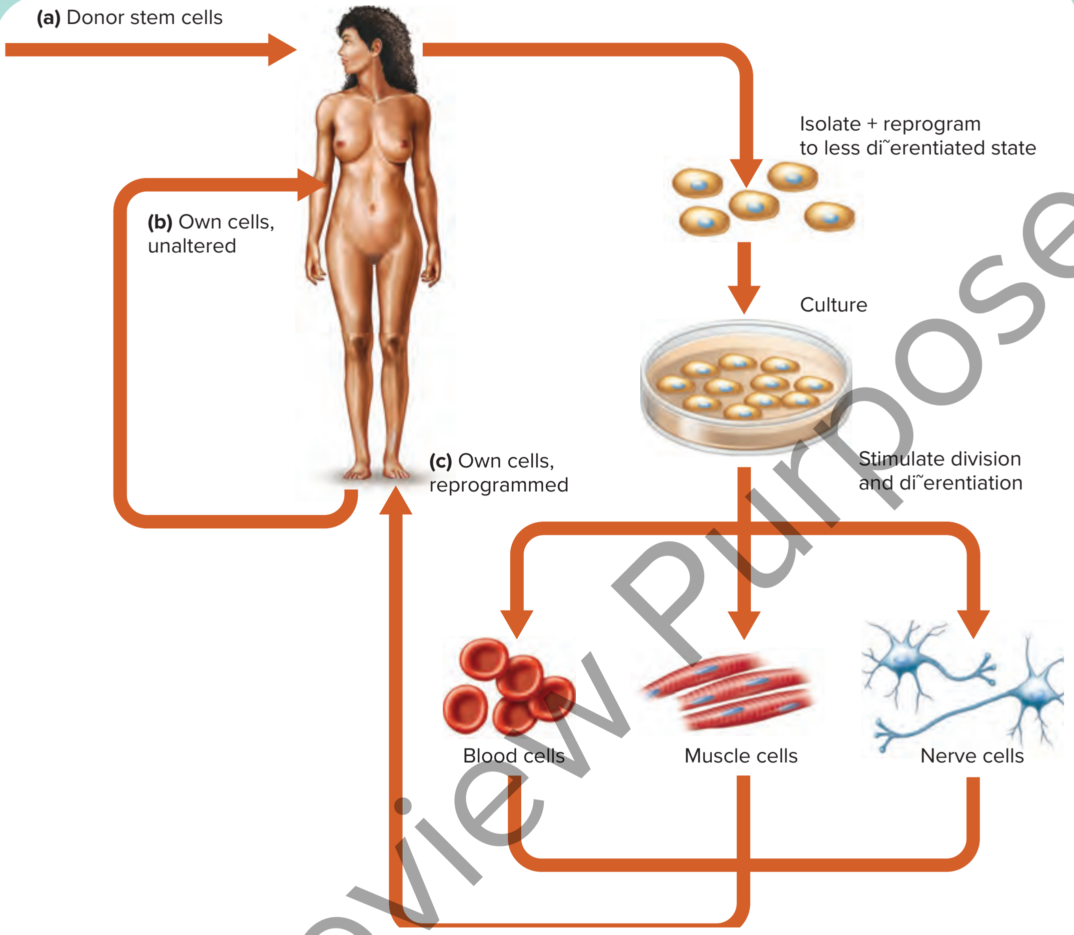
7.5 Practice

1. **Key Terms** Distinguish between the axial and appendicular skeletons.
2. List the bones of the axial skeleton and of the appendicular skeleton.

Technology and Treatments

Using Stem Cells to Treat Disease

Stem cell technology is part of an emerging field, called regenerative medicine, that harnesses the body's ability to generate new cells to treat certain diseases and injuries. In the human body, lineages of dividing stem cells and progenitor cells produce specialized (differentiated) cell types that assemble and interact to form tissues and organs. Stem and progenitor cells are essential for growth and healing.



Using stem cells to heal. (a) Stem cells from donors (bone marrow or umbilical cord blood) are already in use. (b) A person's cells may be used, unaltered, to replace damaged tissue, such as bone marrow. (c) It is possible to reprogram a person's cells in culture, taking them back to a less specialized state and then nurturing them to differentiate as a needed cell type. The goal is to implant reprogrammed cells back into donors and stimulate the cells to correct the disease.

Stem cells to treat disease come from donors or from the patient. Umbilical cord stem cells saved from newborns provide donor stem cells that are used to treat a variety of blood disorders and certain metabolic conditions. Stem cells have two sources: their natural sites or cultured from reprogrammed differentiated cells.

An example of this is when doctors extract and set aside stem cells from a patient who is about to be exposed to radiation that will destroy their immune system. This is known as an autologous bone marrow transplant. After treatment, the saved stem cells are infused back into the patient to repopulate the bone marrow.

Reprogramming differentiated cells is a promising approach to producing therapeutic stem and progenitor cells. A fibroblast taken from a skin sample, for example, can be given genetic instructions to produce key proteins. These proteins help return the cell to a state that resembles a stem cell from an embryo. Then specific biochemicals are added to guide differentiation. The altered cell divides in culture, specializing and passing on its new characteristics to its daughter cells.

In the future, reprogrammed cells may be used therapeutically, but for now they are a research tool. Rett syndrome, an inherited condition that affects females, illustrates what researchers can learn from experiments using reprogrammed cells. Girls with Rett syndrome move their hands in a characteristic and uncontrollable way. Gradually, the girls lose muscle tone and the ability to speak. Head growth slows, and many girls become disabled by the time they reach their teens. The disease is difficult to study in neuron cells taken from a patient because this cell type does not divide. However, neurons can be continually cultured from reprogrammed cells.

In one case, reprogrammed neurons cultured from skin samples taken from four girls with the syndrome were too small, with too few connections and abnormal signaling. However, drugs that helped mice with a form of Rett syndrome also corrected the defect in the reprogrammed cells from the four girls. The next step is developing a treatment based on what researchers observe in the reprogrammed cells.

Concept Connections

1. Describe how stem cell technology can be used in regenerative medicine.
2. Explain how cells are reprogrammed to perform a different function.

7.6 Skull

Learning Outcomes

1. Locate and identify the bones and the major features of the bones that compose the skull.

SEP Use the Practices

Develop Explanations Research and take some notes about the practice of phrenology. Then, explain if you think this practice could be valid.

Which bones comprise the skull?

A human skull typically consists of twenty-two bones. Except for the lower jaw, the skull bones are firmly interlocked along immovable joints called sutures (refer to Fig. 7.9). Eight of these interlocked bones make up the cranium, and fourteen form the facial skeleton. (Three other bones in each middle ear are discussed in chapter 10, section 10.6, Sense of Hearing.) Reference plates 8, 9, 10, and 11 show the human skull and its parts.

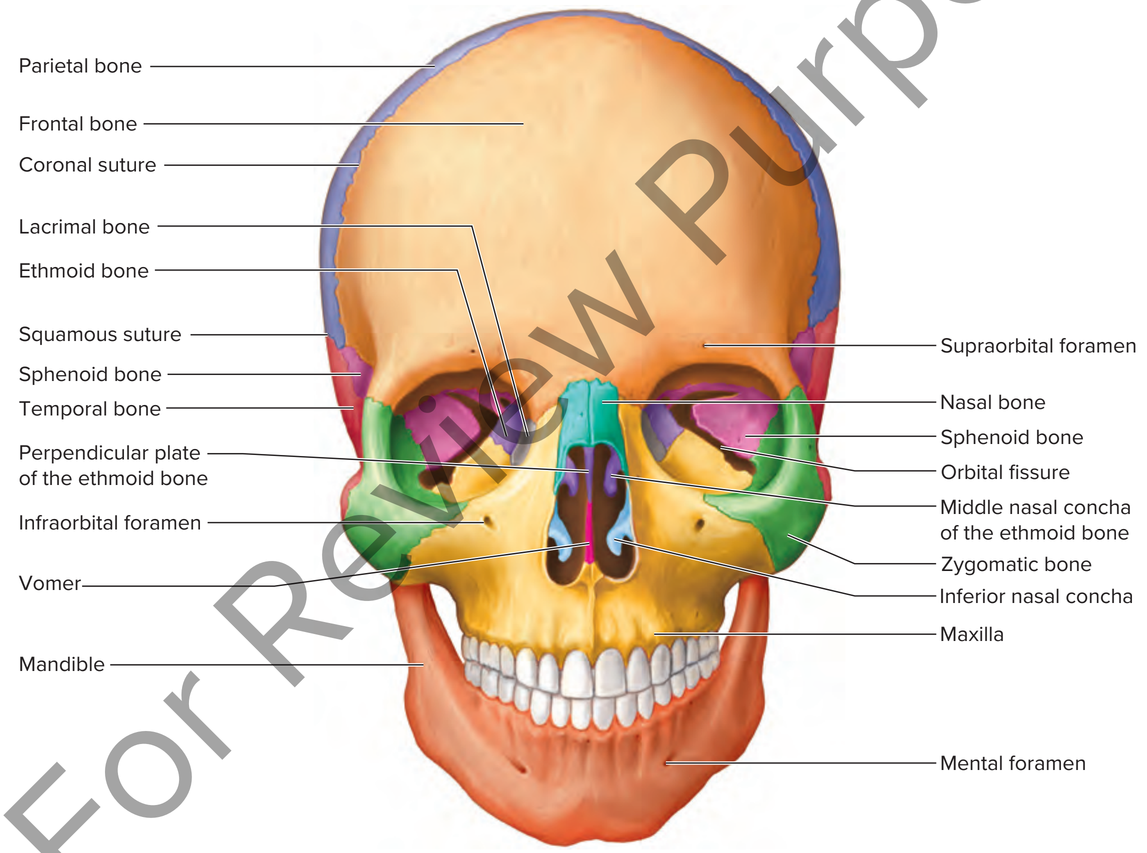


Figure 7.9 Anterior view of the skull.

GO ONLINE to check your understanding of major parts of the anterior view of the skull by completing the Focus Activity.

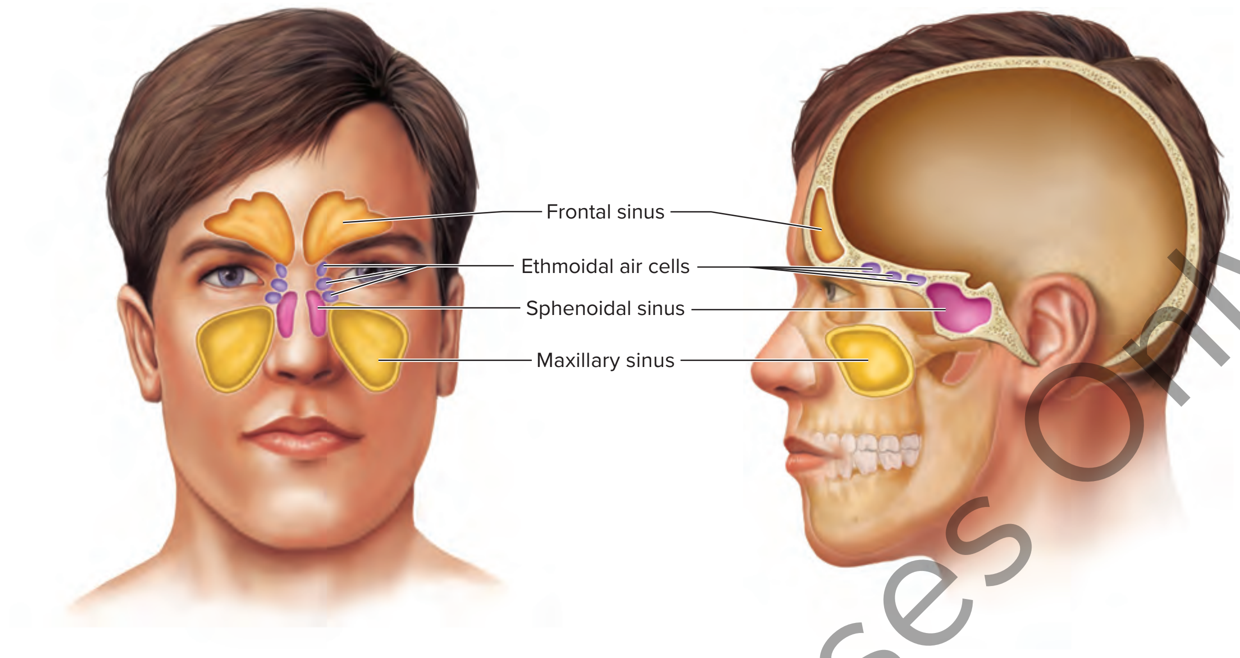


Figure 7.10 Locations of the paranasal sinuses.

GO ONLINE to check your understanding of the parts of the paranasal sinuses by completing the Focus Activity.

Cranium

The **cranium** (KRAY-nee-um) encloses and protects the brain, and its surface provides attachments for muscles that make chewing and head movements possible. Some of the cranial bones contain air-filled cavities called paranasal sinuses that are lined with mucous membranes and are connected by passageways to the nasal cavity (refer to Fig. 7.10). Sinuses reduce the skull's weight and increase the intensity of the voice by serving as resonant sound chambers.

The eight bones of the cranium, shown in Figures 7.9, 7.11, and 7.12, are:

- **Frontal bone** The frontal bone forms the anterior portion of the skull above the eyes. On the upper margin of each orbit (the bony socket of the eye), the frontal bone is marked by a supraorbital foramen (or supraorbital notch in some skulls), through which blood vessels and nerves pass to the tissues of the forehead. Within the frontal bone are two frontal sinuses, one above each eye near the midline (refer to Fig. 7.10).
- **Parietal bones** One parietal bone is located on each side of the skull just behind the frontal bone (refer to Fig. 7.11). Together, the parietal bones form the bulging sides and roof of the cranium. They are joined at the midline along the sagittal suture, and they meet the frontal bone along the coronal suture.
- **Occipital bone** The occipital bone joins the parietal bones along the lambdoid suture (refer to Figs. 7.11 and 7.12). It forms the back of the skull and the base of the cranium. A large opening on its lower surface is the foramen magnum, where nerve fibers from the brain enter the vertebral canal to become part of the spinal cord. Rounded processes called occipital condyles, located on each side of the foramen magnum, articulate with the first vertebra (atlas) of the vertebral column.

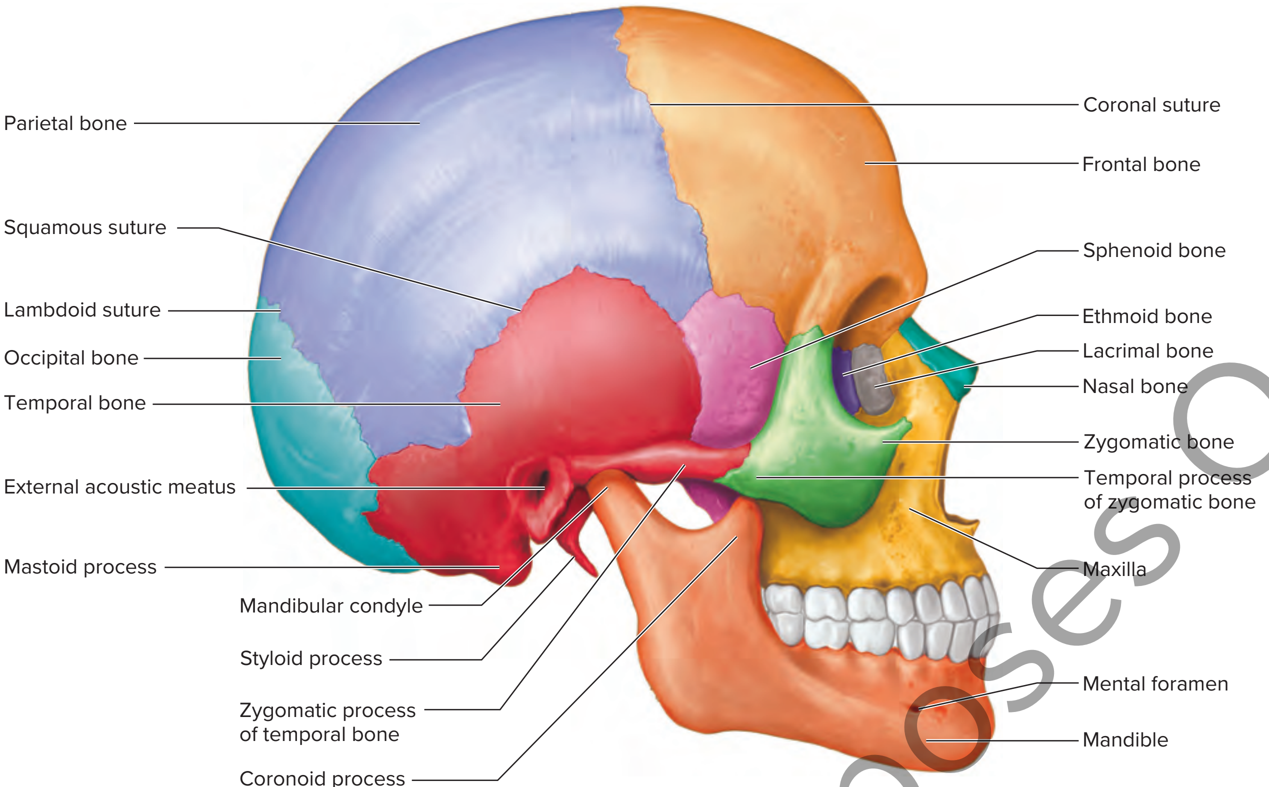


Figure 7.11 Right lateral view of the skull.

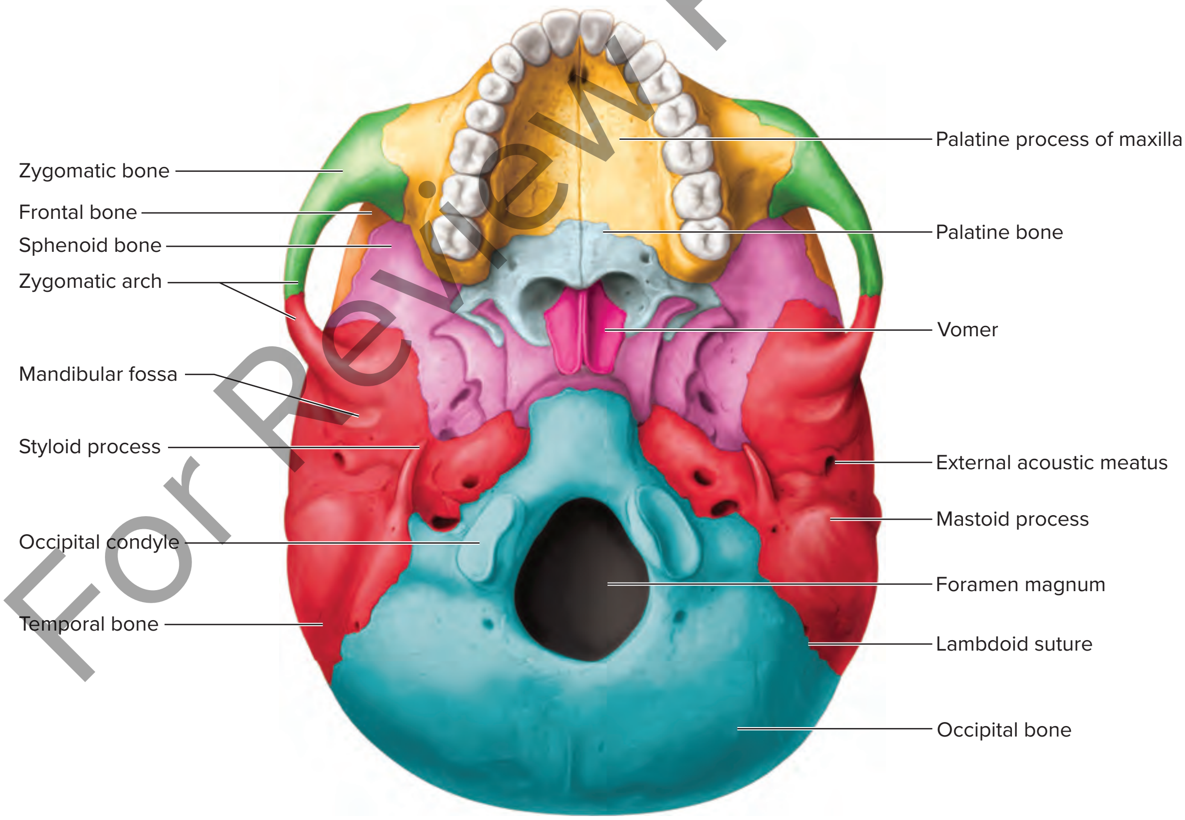


Figure 7.12 Inferior view of the skull.

- **Temporal bones** A temporal bone on each side of the skull joins the parietal bone along a squamous suture (refer to Figs. 7.9 and 7.11). The temporal bones form parts of the sides and the base of the cranium. Located near the inferior margin is an opening, the **external acoustic meatus**, which leads inward to parts of the ear. The temporal bones have depressions called the mandibular fossae that articulate with condyles of the mandible.

Below each external acoustic meatus are two projections—a rounded mastoid process and a long, pointed styloid process. The mastoid process provides an attachment for certain muscles of the neck, whereas the styloid process anchors muscles associated with the tongue and pharynx. A zygomatic process projects anteriorly from the temporal bone, joins the zygomatic bone, and helps form the prominence of the cheek.

- **Sphenoid bone** The sphenoid bone is wedged between several other bones in the anterior portion of the cranium (refer to Figs. 7.11 and 7.12). This bone helps form the base of the cranium, the sides of the skull, and the floors and sides of the orbits. Along the midline within the cranial cavity, a portion of the sphenoid bone indents, forming the saddle-shaped sella turcica. The pituitary gland occupies this depression. The sphenoid bone also contains two sphenoidal sinuses (refer to Fig. 7.10).
- **Ethmoid bone** The ethmoid bone is located in front of the sphenoid bone (refer to Figs. 7.11 and 7.13). It consists of two masses, one on each side of the nasal cavity, which are joined horizontally by thin cribriform plates. These plates form part of the roof of the nasal cavity (refer to Fig. 7.13).

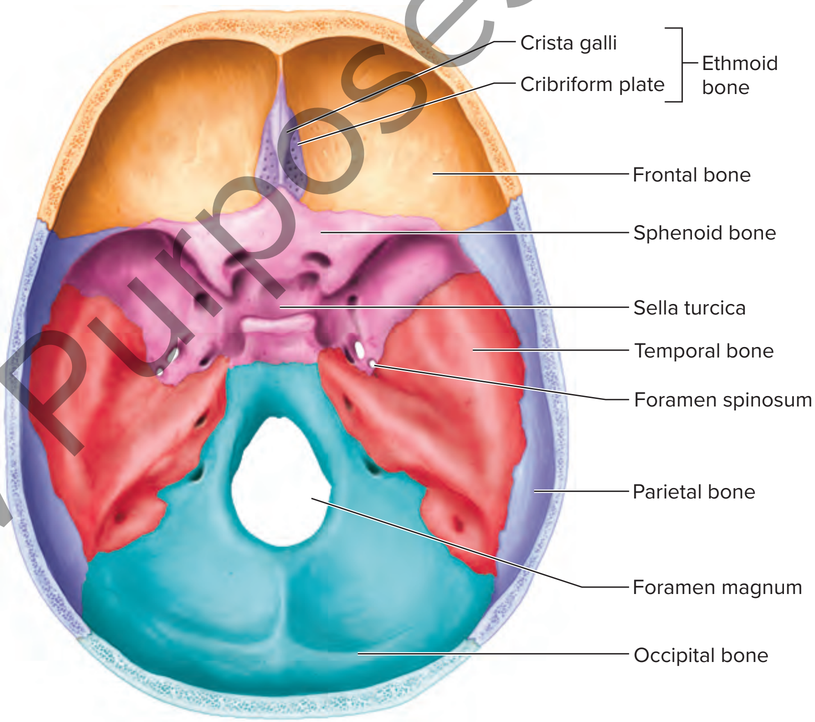


Figure 7.13 Floor of the cranial cavity, viewed from above.

Projecting upward into the cranial cavity between the cribriform plates is a triangular process of the ethmoid bone called the crista galli (crest of the rooster). Membranes that enclose the brain attach to this process (refer to Figs. 7.13 and 7.14).

InContext: Word Origin

The prefix "**meat-**" means "*passage*". For example, the **external acoustic *meatus*** is the canal or *passage* of the temporal bone that leads inward to parts of the ear. The prefix "**condyl-**" means "*knob*". The ***condyl*e,** for example, is a rounded, bony process that resembles a *knob*.

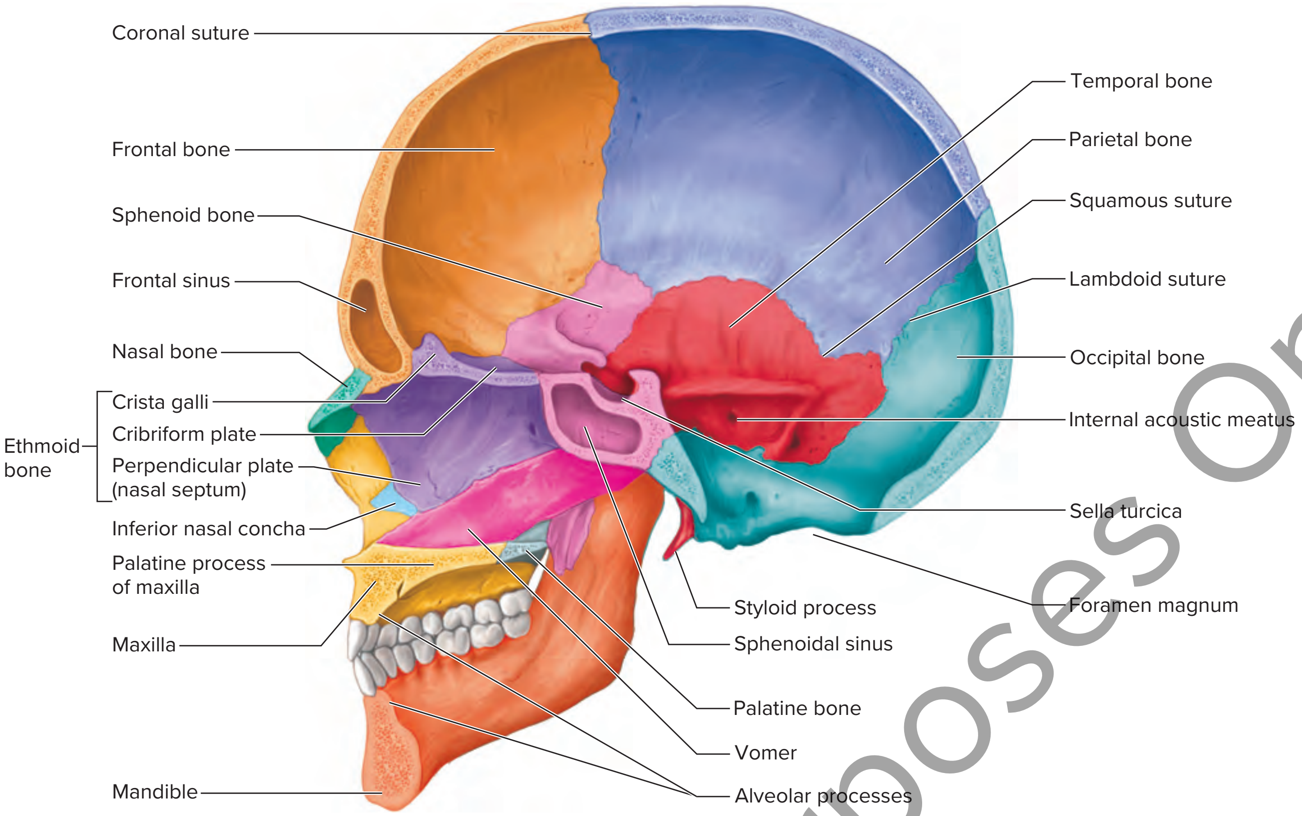


Figure 7.14 Sagittal section of the skull.

Portions of the ethmoid bone also form sections of the cranial floor, the orbital walls, and the nasal cavity walls. A perpendicular plate extends inferiorly between the cribriform plates and forms most of the nasal septum (refer to Fig. 7.14).

Delicate scroll-shaped plates called the superior nasal conchae and the middle nasal conchae project inward from the lateral portions of the ethmoid bone toward the perpendicular plate (refer to Fig. 7.9). The lateral portions of the ethmoid bone contain many small spaces, called ethmoidal air cells, that together form the ethmoidal sinus (refer to Fig. 7.10).

Facial Skeleton

The **facial skeleton** consists of thirteen immovable bones and a movable lower jawbone. These bones form the basic shape of the face and provide attachments for muscles that move the jaw and control facial expressions.

The bones of the facial skeleton are:

- **Maxillae** The maxillae form the upper jaw (refer to Figs. 7.11 and 7.12). Portions of these bones compose the anterior roof of the mouth (hard palate), the floors of the orbits, and the sides and floor of the nasal cavity. The maxillae also contain the sockets of the upper teeth. Inside the maxillae, lateral to the nasal cavity, are maxillary sinuses, the largest of the sinuses (refer to Fig. 7.10). During a human's development, portions of the maxillae called palatine processes grow together and fuse along the midline and form the anterior section of the hard palate. The inferior border of each maxillary bone projects downward, forming an alveolar process (refer to Fig. 7.14). Together, these processes form a horseshoe-shaped alveolar arch (dental arch). Teeth occupy cavities (dental alveoli) in this arch. Dense connective tissue binds teeth to the bony sockets.

- **Palatine bone** The L-shaped palatine bones are located behind the maxillae (refer to Figs. 7.12 and 7.14). The horizontal portions form the posterior section of the hard palate and the floor of the nasal cavity. The perpendicular portions help form parts of the lateral walls of the nasal cavity.
- **Zygomatic bones** The zygomatic bones form the prominences of the cheeks below and to the sides of the eyes (refer to Figs. 7.11 and 7.12). These bones also help form the lateral walls and the floors of the orbits. Each bone has a temporal process, which extends posteriorly, joining the zygomatic process of a temporal bone. Together, a temporal process and a zygomatic process form a zygomatic arch.
- **Lacrimal bones** A lacrimal bone is a thin, scalelike structure located in the medial wall of each orbit between the ethmoid bone and the maxilla (refer to Figs. 7.9 and 7.11).
- **Nasal bones** The nasal bones are long, thin, and nearly rectangular (refer to Figs. 7.9 and 7.11). They lie side by side and are fused at the midline, where they form the bridge of the nose.
- **Vomer** The thin, flat vomer is located along the midline within the nasal cavity (refer to Figs. 7.9 and 7.14). Posteriorly, it joins the perpendicular plate of the ethmoid bone, and together they form the nasal septum.
- **Inferior nasal conchae** The inferior nasal conchae are fragile, scroll-shaped bones attached to the lateral walls of the nasal cavity (refer to Figs. 7.9 and 7.14). Like the superior and middle nasal conchae of the ethmoid bone, the inferior nasal conchae support mucous membranes in the nasal cavity.
- **Mandilbe** The mandible is also called the lower jawbone and is the only movable bone in the skull. It has a horizontal, horseshoe-shaped body with a vertical, flat portion projecting upward at each end (refer to Figs. 7.9 and 7.11). This projection is divided into two processes—a posterior mandibular condyle and an anterior coronoid process. The mandibular condyles articulate with the mandibular fossae of the temporal bones (refer to Fig. 7.12), whereas the coronoid processes provide attachments for the muscles used in chewing. A curved bar of bone on the superior border of the mandible, the alveolar arch, contains the hollow sockets (dental alveoli) that hold the lower teeth.

Infantile Skull

At birth, the human skull is incompletely developed, with fibrous membranes connecting the cranial bones. These membranous areas of incomplete intramembranous ossification are called **fontanels** or, more commonly, soft spots (refer to Fig. 7.15).

They permit some movement between the bones so that the developing skull is partially compressible and can slightly change shape. This malleability enables an infant's skull to more easily pass through the birth canal. Eventually, the fontanels close as the cranial bones grow together.

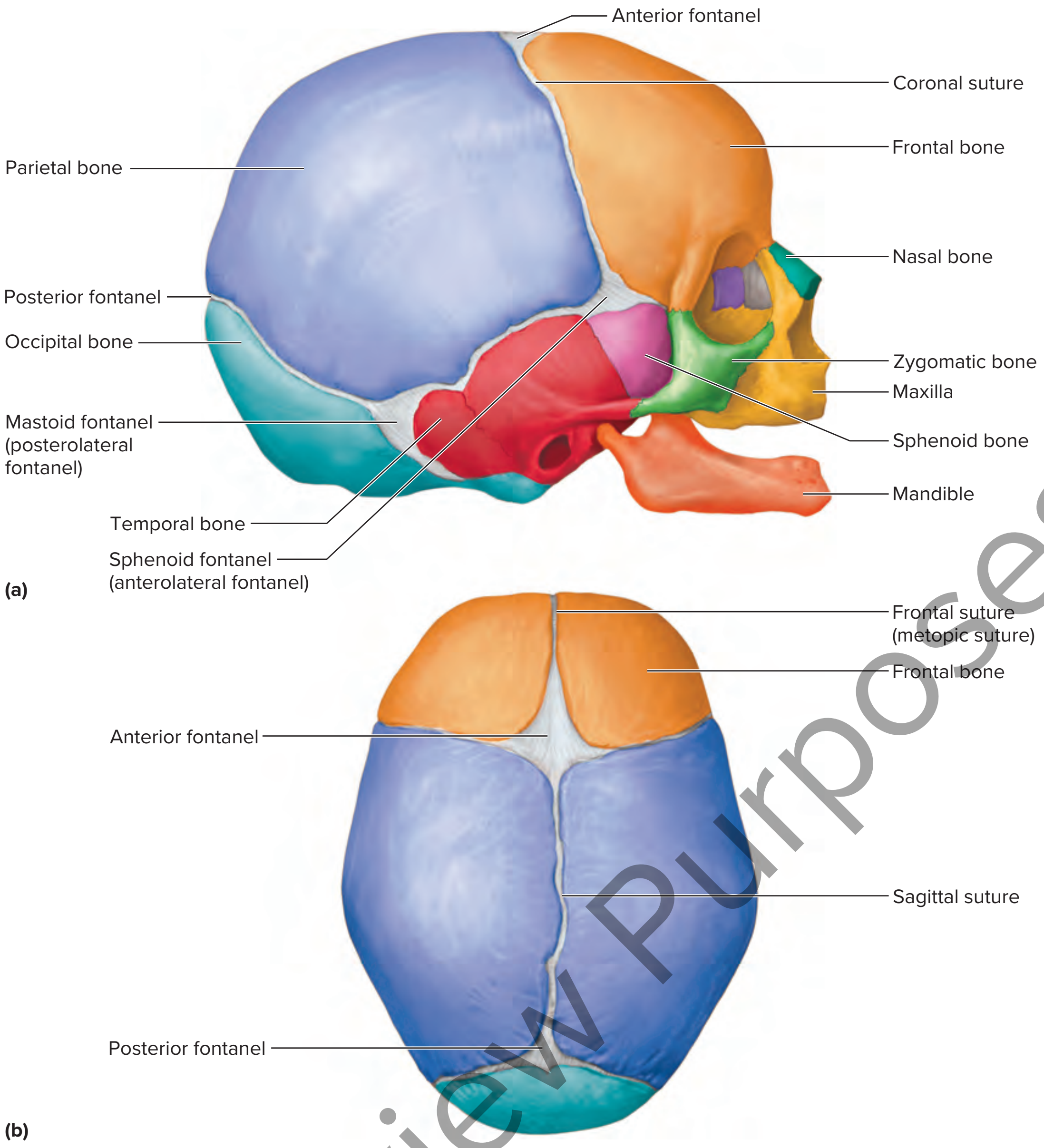


Figure 7.15 Fontanels. **(a)** Right lateral view and **(b)** superior view of the infantile skull.

Phenomenon Connection

CER Collect Evidence What changes occur in the skull across a person's lifespan that would be useful in determining the age of a skeleton?

Other characteristics of an infantile skull include a relatively small face with a prominent forehead and large orbits. The jaw and nasal cavity are small, the sinuses are incompletely formed, and the frontal bone is in two parts. The skull bones are thin, but they are also somewhat flexible and thus are less easily fractured than adult skull bones.

7.6 Practice

1. Locate and name each of the bones of the cranium.
2. Locate and name each of the facial bones.
3. Explain how an adult skull differs from that of an infant.

7.7 Vertebral Column

Learning Outcomes

1. Locate and identify the bones and the major features of the bones that compose the vertebral column.

SEP Use the Practices

Asking Questions Develop a question about the vertebral column. Use the information in this section to answer that question.

What bones comprise the vertebral column?

The **vertebral column** extends from the skull to the pelvis and forms the vertical axis of the skeleton. This column is composed of many bony parts called **vertebra**. Vertebra are separated by pads of fibrocartilage called **intervertebral discs** and are connected to one another by ligaments (refer to Fig. 7.16). The vertebral column supports the head and trunk of the body and protects the spinal cord.

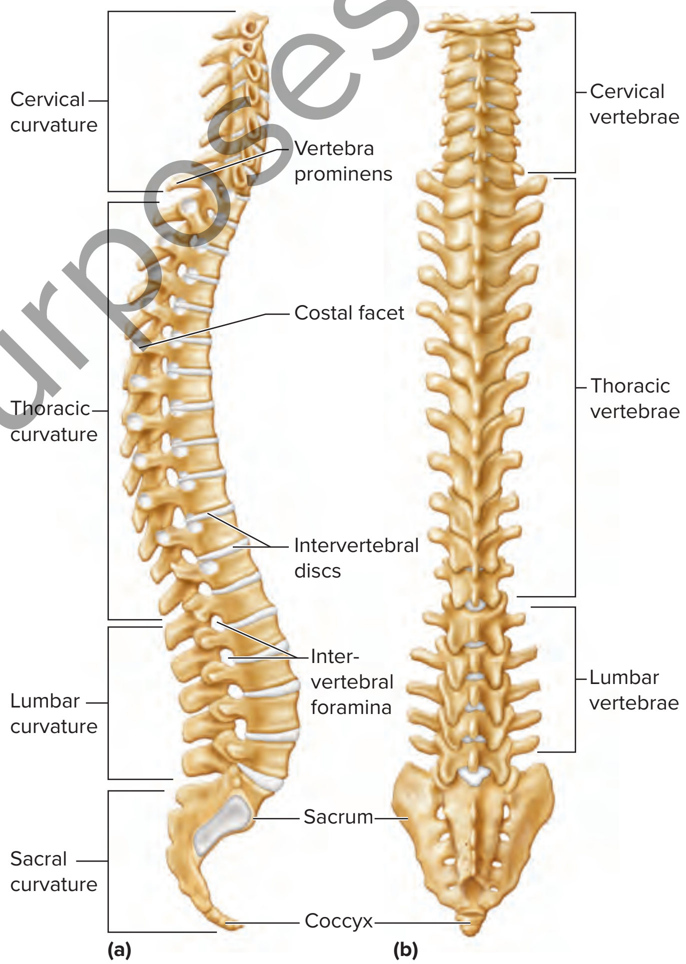


Figure 7.16 The curved vertebral column consists of many vertebrae separated by intervertebral discs. **(a)** Right lateral view. **(b)** Posterior view.

A Typical Vertebra

The vertebrae in different regions of the vertebral column have special characteristics, but they also have features in common. A typical vertebra has a drum-shaped body, which forms the thick, anterior portion of the bone (refer to Fig. 7.17). A longitudinal row of these vertebral bodies supports the weight of the head and trunk.

InContext: Word Origin

Recall that the prefix **"inter-"** means "*between*". For example, the ***inter*vertebral disc** is a structure *between* the vertebrae.

The intervertebral discs, which separate adjacent vertebral bodies, cushion and soften the forces generated by such movements as walking and jumping.

Projecting posteriorly from each vertebral body are two short stalks called pedicles. Two plates called laminae arise from the pedicles. These then fuse in the back to become a spinous process. The pedicles, laminae, and spinous process together complete a bony vertebral arch. This vertebral arch surrounds the vertebral foramen. The vertebral foramina within the bones of the vertebral column form a vertebral canal through which the spinal cord passes.

If the laminae of the vertebrae do not unite during development, the vertebral arch remains incomplete, causing a condition called spina bifida. The contents of the vertebral canal protrude outward. This condition occurs most frequently in the lumbosacral region. Spina bifida is associated with folic acid deficiency in certain individuals who are genetically susceptible to this condition.

Between the pedicles and laminae of a typical vertebra are the transverse processes, which project laterally and posteriorly. Ligaments and muscles are attached to the dorsal spinous process and the transverse processes. Projecting upward and downward from each vertebral arch are superior and inferior articular processes. These processes bear cartilage-covered facets by which each vertebra is joined to the one above and the one below it.

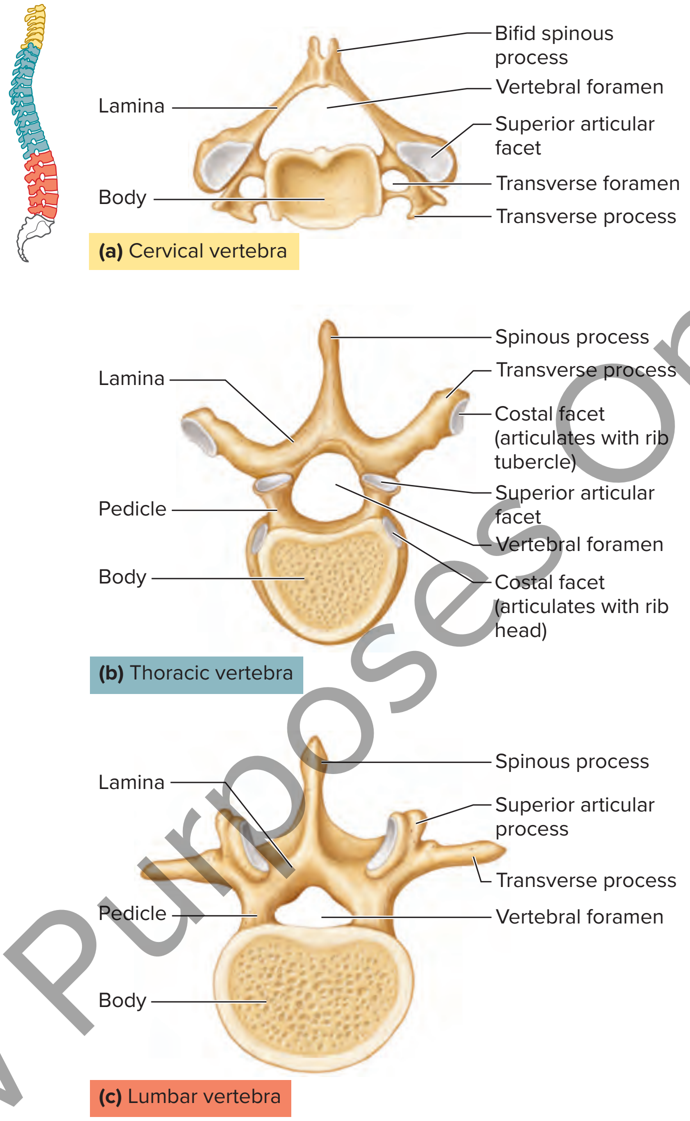


Figure 7.17 Superior view of **(a)** a cervical vertebra, **(b)** a thoracic vertebra, and **(c)** a lumbar vertebra.

On the lower surfaces of the vertebral pedicles are notches that align with adjacent vertebrae to help form openings called intervertebral foramina (refer to Fig. 7.16). These openings provide passageways for spinal nerves.

Cervical Vertebrae

Seven **cervical vertebrae** compose the bony axis of the neck (refer to Fig. 7.16). The transverse processes of only the cervical vertebrae have transverse foramina, which are passageways for blood vessels to and from the brain (refer to Fig. 7.17a). Also, the spinous processes of the second through the sixth cervical vertebrae are uniquely forked. These processes provide attachments for muscles.

The spinous process of the seventh cervical vertebra is called the vertebra prominens. It gets this name because it is more prominent than those of the

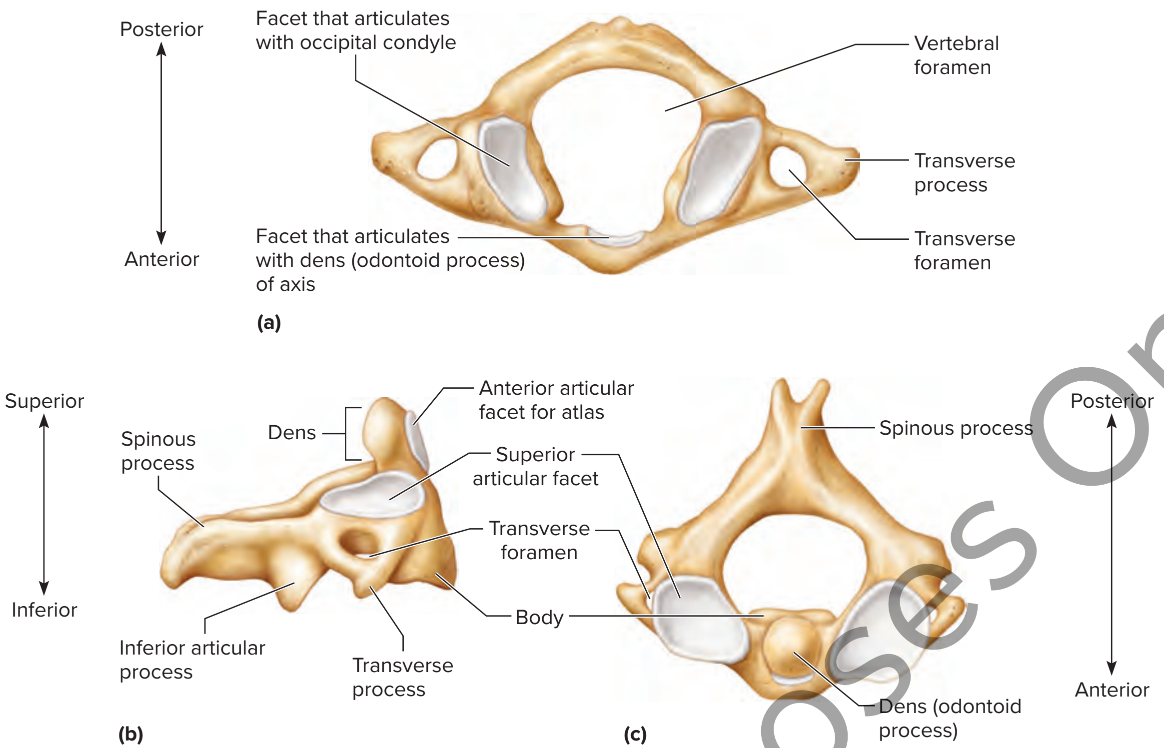


Figure 7.18 Atlas and axis. **(a)** Superior view of the atlas. **(b)** Right lateral view and **(c)** superior view of the axis.

first six cervical vertebrae. The vertebra prominens is easily found at the base of the neck and serves as a landmark for locating other vertebral parts.

Two of the cervical vertebrae are of special interest: the atlas and the axis (refer to Fig. 7.18). The first vertebra, or **atlas**, supports the head. It has practically no body or spinous process and appears as a bony ring with two transverse processes. On its superior surface are two kidney-shaped facets that articulate with the occipital condyles.

The second cervical vertebra, or **axis**, bears a toothlike dens, or odontoid process, on its body. This process projects upward and lies in the ring of the atlas. As the head is turned from side to side, the atlas pivots around the dens.

Thoracic Vertebrae

The twelve **thoracic vertebrae** are larger than the cervical vertebrae (refer to Fig. 7.16). Each thoracic vertebra has a long, pointed spinous process which slopes downward. Thoracic vertebrae except for T10–T12 have two costal facets that articulate with ribs (refer to Fig. 7.17b). Beginning with the third thoracic vertebra and moving inferiorly, the bodies of these bones increase in size. Thus, they are adapted to bear increasing loads of body weight.

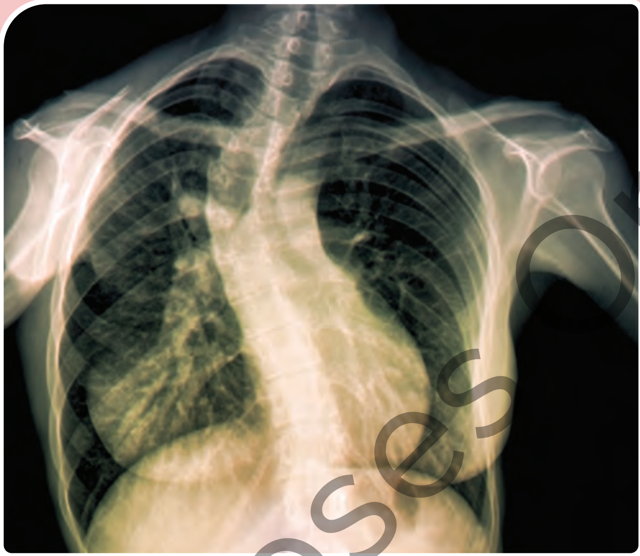
InContext: Word Origin

The prefix **"odont-"** means *"tooth"*. For example, the ***odont*oid process** is a *tooth-like* process of the second cervical vertebra.

Diagnosing Disease and Disorders

Spine Curvature Disorders

Have you ever been told to stand or sit up straight? Odds are you have, but there's a reason for that. Poor posture can affect the curvatures of the vertebral column. However, injury and disease can also cause disorders of the spine. An exaggerated curve in the thoracic spine causes rounded shoulders and a hunchback. This condition, called kyphosis, is seen in teenagers who undertake strenuous athletic activities. Unless corrected before bone growth completes, the condition can permanently deform the vertebral column. The vertebral column may develop an abnormal lateral curvature. This curve places one hip or shoulder lower than the other, which may displace or compress the thoracic and abdominal organs. This condition, called scoliosis, is most common in young females.



An X-ray image of a person with scoliosis.

An accentuated curve in the lumbar spine is called lordosis, or swayback. As a person ages, the intervertebral discs shrink and become more rigid, making compression more likely to fracture the vertebral bodies. Consequently, height may decrease, and the thoracic curvature of the vertebral column may become accentuated (kyphosis), bowing the back.

Concept Connections

1. Identify and describe three types of spinal curvature disorders.
2. Why is it important to address spinal curvature disorders immediately in young children and not wait until they get older?

Lumbar Vertebrae

Five **lumbar vertebrae** are in the small of the back (loin) (refer to Fig. 7.16). These vertebrae are adapted with larger and stronger bodies to support more weight than the vertebrae above them (refer to Fig. 7.17c).

Sacrum

The **sacrum** is a triangular structure, composed of five fused vertebrae, that forms the base of the vertebral column (refer to Fig. 7.19). The spinous processes of these fused bones form a ridge of tubercles. To the sides of the tubercles are rows of openings, the posterior sacral foramina, through which nerves and blood vessels pass.

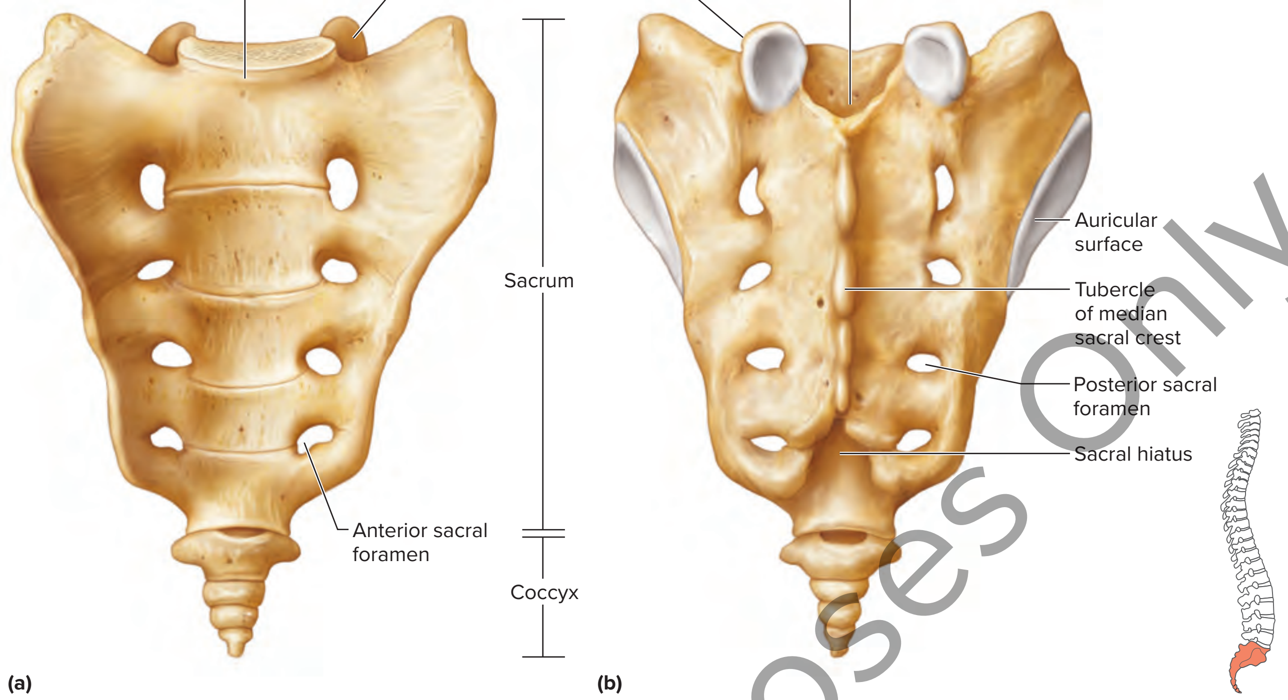


Figure 7.19 Sacrum and coccyx. **(a)** Anterior view and **(b)** posterior view.

The vertebral foramina of the sacral vertebrae form the sacral canal, which continues through the sacrum to an opening of variable size at the tip, called the sacral hiatus. On the ventral surface of the sacrum, four pairs of anterior sacral foramina provide passageways for nerves and blood vessels.

Phenomenon Connection

CER Collect Evidence How might examining the sacrum be important in determining the age of a skeleton?

Coccyx

The coccyx, or tailbone, is the lowest part of the vertebral column and is typically composed of four fused vertebrae (refer to Fig. 7.19). Ligaments attach it to the margins of the sacral hiatus.

7.7 Practice

1. Describe the structure of the vertebral column.
2. Describe a typical vertebra.
3. Key Terms Explain how the structures of cervical, thoracic, and lumbar vertebrae differ.

7.8 Thoracic Cage

Learning Outcomes

1. Locate and identify the bones and the major features of the bones that compose the thoracic cage.

SEP Use the Practices

Conducting Investigations Unlike the cranium, which has fused bones, the thoracic cage has an open structure. Plan an investigation that would demonstrate how the thoracic cage's structure allows for breathing.

What is the thoracic cage?

The **thoracic cage** includes the ribs, the thoracic vertebrae, the sternum, and the costal cartilages that attach the ribs to the sternum (refer to Fig. 7.20). The thoracic cage supports the pectoral girdle and upper limbs, protects the viscera in the thoracic and upper abdominal cavities, and plays a role in breathing.

Ribs

The usual number of **ribs** is twenty-four—one pair attached to each of the twelve thoracic vertebrae. The first seven rib pairs, the true or vertebrosternal ribs, join the sternum directly by their costal cartilages. The remaining five pairs are called false ribs because their cartilages do not reach the sternum directly. Instead, the cartilages

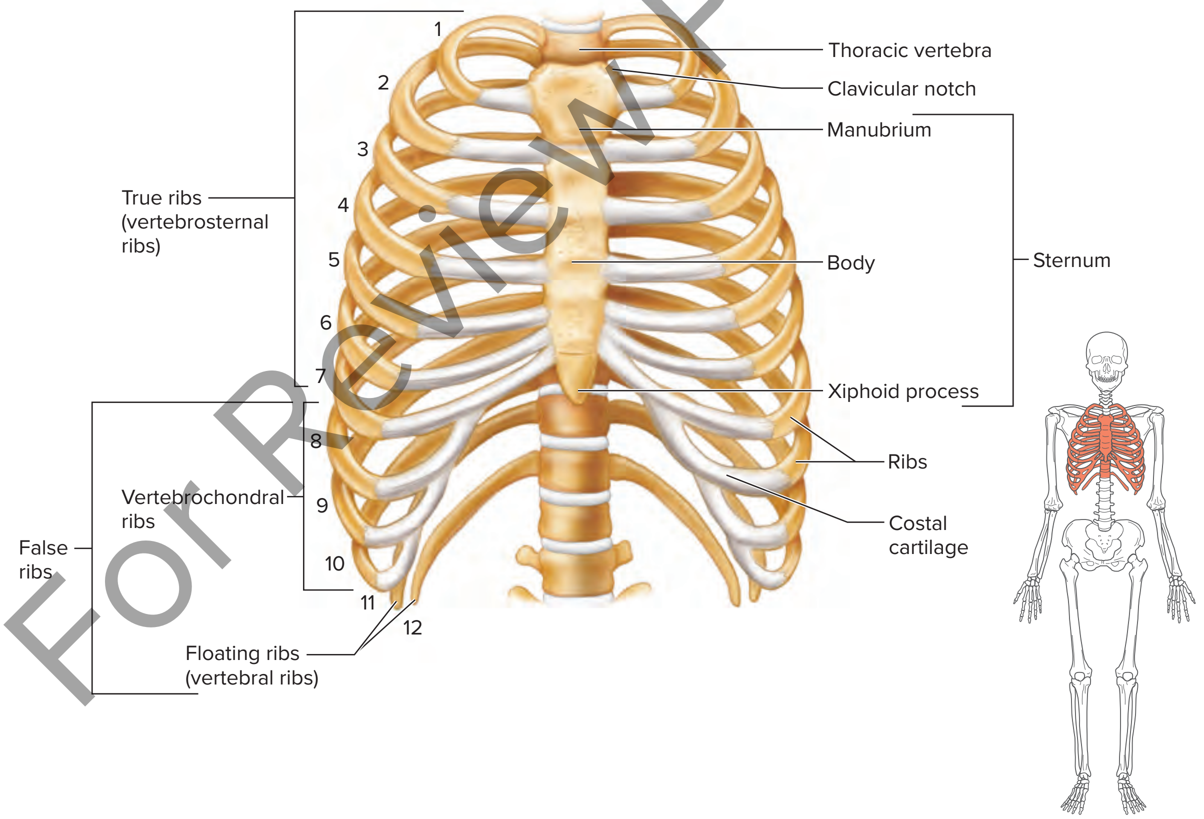


Figure 7.20 The thoracic cage includes the ribs, the thoracic vertebrae, the sternum, and the costal cartilages that attach the ribs to the sternum.

of the upper three false ribs, called vertebrochondral ribs, join the cartilages of the seventh rib. The last two (or sometimes three) rib pairs are called floating or vertebral ribs because they have no cartilaginous attachments to the sternum.

A typical rib has a long, slender shaft, which curves around the chest and slopes downward. On the posterior end is an enlarged head by which the rib articulates with a facet on the body of its own vertebra and with the body of the next higher vertebra. A tubercle, close to the head of the rib, articulates with the transverse process of the vertebra.

Sternum

The **sternum**, or breastbone, is located along the midline in the anterior portion of the thoracic cage (refer to Fig. 7.20). This flat, elongated bone develops in three parts—an upper manubrium, a middle body, and a lower xiphoid process that projects downward. The clavicular notch of the manubrium articulates with the clavicles by facets on its superior border.

7.8 Practice

1. Which bones compose the thoracic cage?
2. What are the differences among true, false, and floating ribs?
3. Name the three parts of the sternum.

7.9 Pectoral Girdle

Learning Outcomes

1. Locate and identify the bones and the major features of the bones that compose the pectoral girdle.

SEP Use the Practices

Using Models The word girdle suggests a ring-shaped structure. Develop a model that predicts how the bones of the pectoral girdle would form a ring-shaped structure to allow various movements to occur.

What is the pectoral girdle?

Each **pectoral girdle**, or shoulder girdle, is composed of two parts—a clavicle and a scapula (refer to Fig. 7.21). Although the word girdle suggests a ring-shaped structure, the pectoral girdle is an incomplete ring. It is open in the back between the scapulae, and the sternum separates its bones in front. The pectoral girdle supports the upper limbs and is an attachment for several muscles that move them.

Clavicle

The **clavicle** is a slender, rodlike bone with an elongated S-shape (refer to Fig. 7.21). Located at the base of the neck, each clavicle runs horizontally between the manubrium and the freely movable scapula, helping hold the shoulders in place. The clavicles also provide attachments for the muscles of the upper limbs, chest, and back.

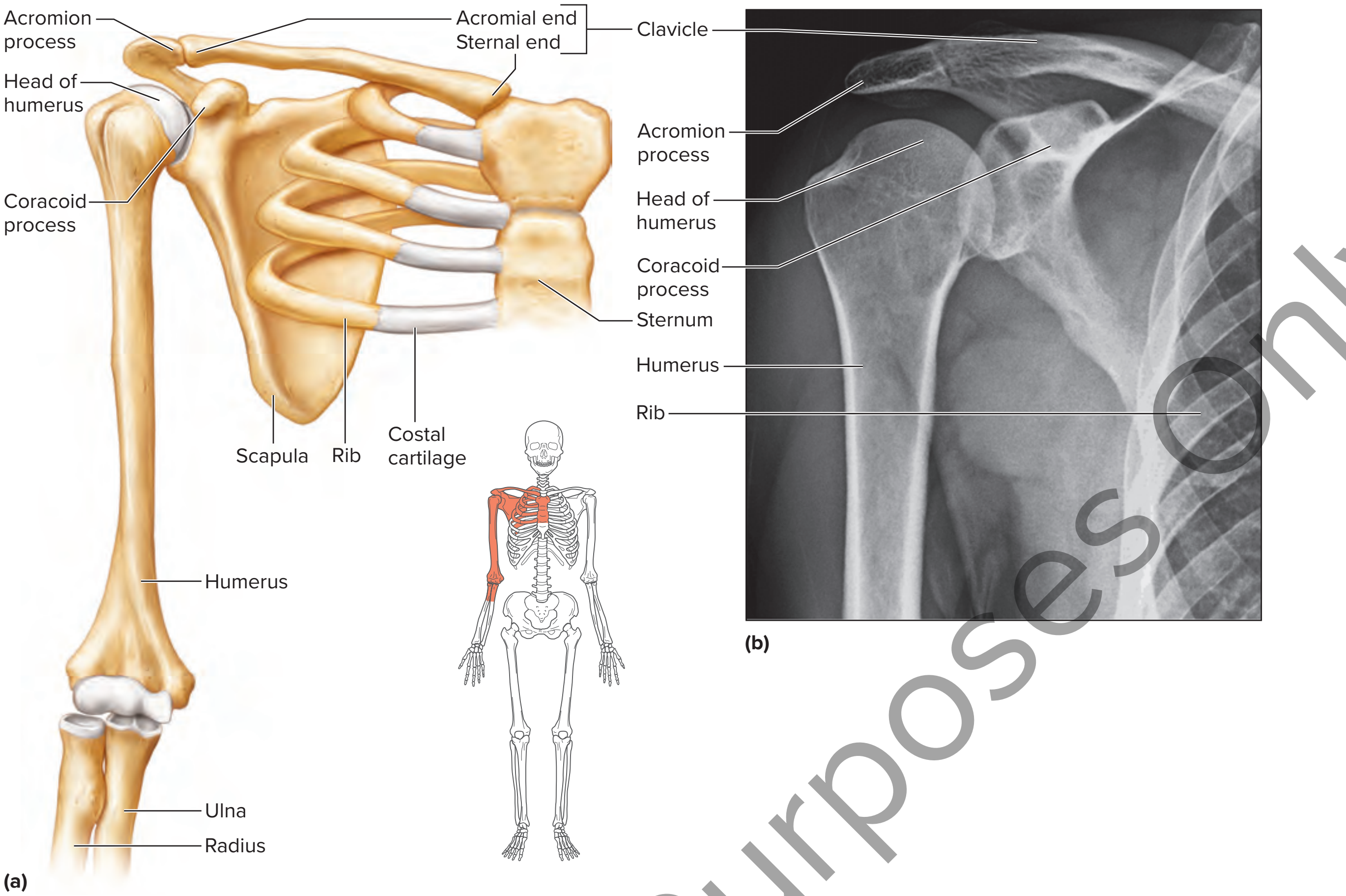


Figure 7.21 Right portion of the pectoral girdle. **(a)** The pectoral girdle, to which the upper limbs are attached, consists of a clavicle and a scapula on each side. **(b)** A radiograph of the right shoulder region, anterior view, showing the right pectoral girdle and proximal end of the right humerus.

GO ONLINE to check your understanding of the parts of the pectoral girdle by completing the Focus Activity.

Scapula

Each **scapula**, or shoulder blade, is a broad, somewhat triangular-shaped bone located on the upper back (refer to Figs. 7.21 and 7.22). A spine divides the posterior surface of each scapula into unequal portions. This spine leads to an acromion process that forms the tip of the shoulder. The acromion process articulates with the clavicle and provides attachments for muscles of the upper limb and chest. A coracoid process curves anteriorly and inferiorly to the clavicle. The coracoid process also provides attachments for upper limb and chest muscles. On the lateral surface of the scapula and between these processes is a depression called the glenoid cavity, or glenoid fossa of the scapula that articulates with the head of the humerus.

In Context: Word Origin

The prefix **"glen-"** means "*valley*" or "*socket*". For example, the ***glen*oid cavity** is a depression in the scapula that articulates with the head of a humerus, forming a *joint socket* or *valley-like* structure. The prefix **"corac-"** means "*a crow's beak*". The ***corac*oid process** has a *beaklike* structure, found on the scapula.

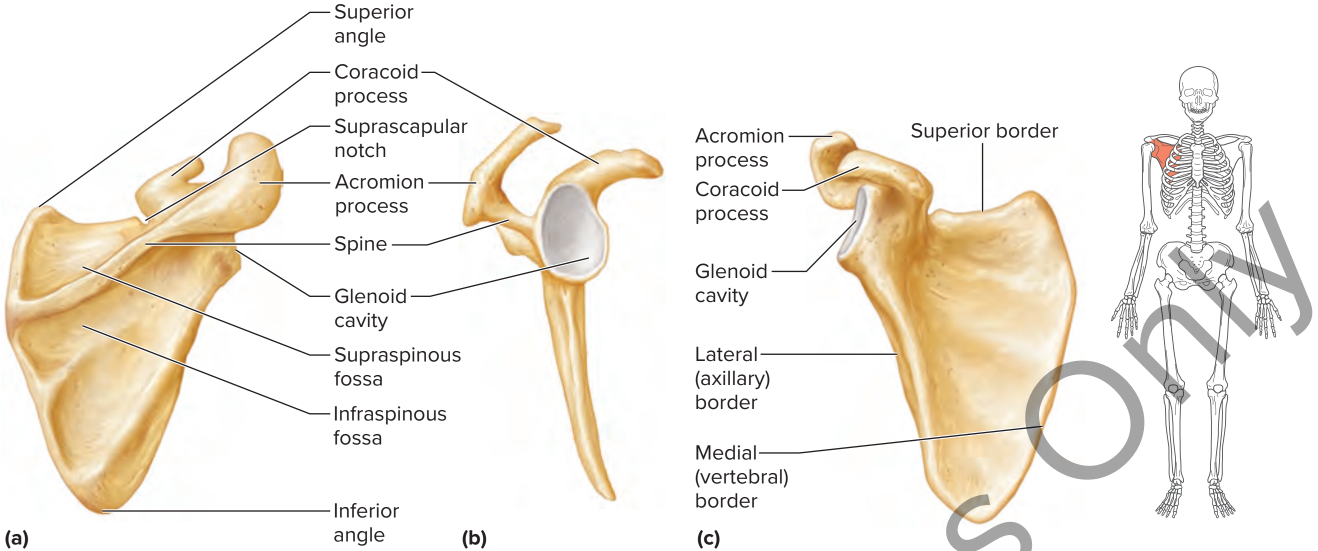


Figure 7.22 Right scapula. **(a)** Posterior surface. **(b)** Lateral view showing the glenoid cavity, which articulates with the head of the humerus. **(c)** Anterior surface.

7.9 Practice

1. **Key Terms** Which bones form the pectoral girdle?
2. What is the function of the pectoral girdle?

7.10 Upper Limb

Learning Outcomes

1. Locate and identify the bones and the major features of the bones that compose the upper limb.

SEP Use the Practices

Develop Explanations Explain how you think the bones of the upper limb allow you to rotate your palm. After you read, add to or adjust your answer.

What bones comprise the upper limb?

The bones of the upper limb form the framework of the arm, forearm, and hand. The upper limb also provides attachments for muscles and interacts with muscles to move limb parts. Upper limb bones include a humerus, a radius, an ulna, carpals, metacarpals, and phalanges (refer to Fig. 7.8).

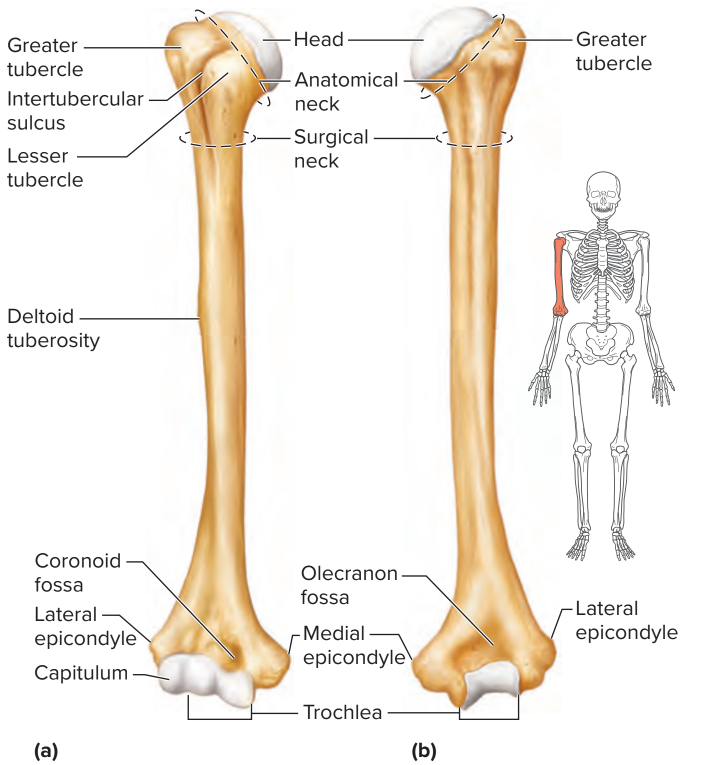


Figure 7.23 Right humerus. **(a)** Anterior surface. **(b)** Posterior surface.

Humerus

The **humerus** is a long bone that extends from the scapula to the elbow (refer to Fig. 7.23). At its upper end is a smooth, rounded head that fits into the glenoid cavity of the scapula. Just below the head are two processes—a greater tubercle on the lateral side and a lesser tubercle on the anterior side. These tubercles provide attachments for muscles that move the upper limb at the shoulder. Between them is a narrow furrow, the intertubercular sulcus or groove.

The narrow depression along the lower margin of the humerus head that separates it from the tubercles is called the anatomical neck. Just below the head and the tubercles is a tapering region called the surgical neck, so named because fractures commonly occur there. Near the middle of the bony shaft on the lateral side is a rough, V-shaped area called the deltoid tuberosity. It provides an attachment for the deltoid muscle that raises the upper limb horizontally to the side.

At the lower end of the humerus are two smooth condyles, a lateral capitulum that articulates with the radius and a medial trochlea that articulates with the ulna. Above the condyles on either side are epicondyles, which provide attachments for muscles and ligaments of the elbow. Between the epicondyles anteriorly is a depression, the coronoid fossa, that receives the coronoid process of the ulna when the elbow bends. Another depression on the posterior surface, the olecranon fossa, receives a different ulnar process, the olecranon process, when the elbow straightens.

Radius

The **radius**, located on the thumb side of the forearm, extends from the elbow to the wrist. The radius crosses over the ulna when the hand is turned so that the palm faces backward (refer to Fig. 7.24). A thick, disclike head at the upper end of the radius articulates with the capitulum of the humerus and the radial notch of the ulna. This arrangement allows the radius to rotate.

On the radial shaft just below the head is a process called the radial tuberosity. It is an attachment for the biceps brachii muscle that bends the upper limb at the elbow. At the distal end of the radius, a lateral styloid process provides attachments for ligaments of the wrist.

Ulna

The **ulna** is medial to the radius. The ulna is longer than the radius and overlaps the end of the humerus posteriorly (refer to Fig. 7.24). At its proximal end, the ulna has a wrenchlike opening, the trochlear notch, that articulates with the trochlea of the humerus. Two processes

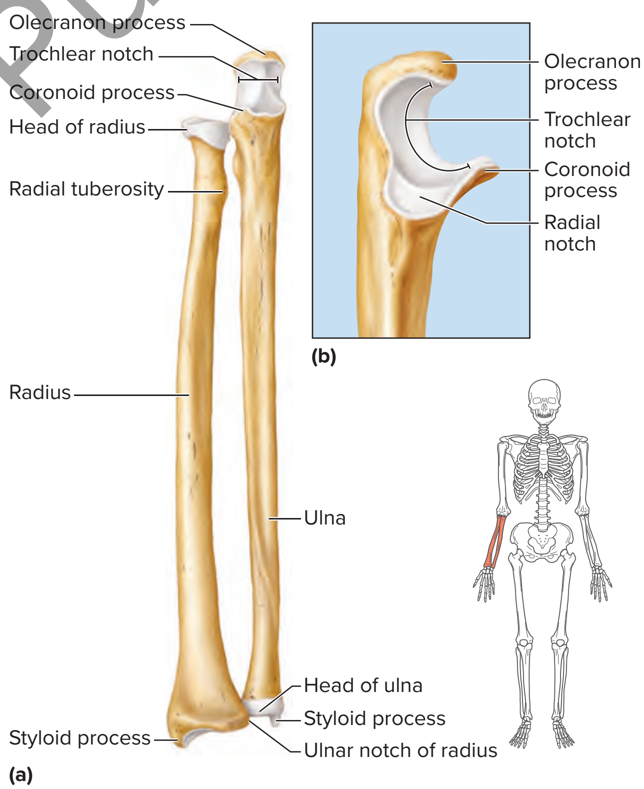


Figure 7.24 Right radius and ulna. **(a)** The head of the radius articulates with the radial notch of the ulna, and the head of the ulna articulates with the ulnar notch of the radius. **(b)** Lateral view of the proximal end of the ulna.

above and below this notch, the olecranon process and the coronoid process, provide attachments for muscles.

At the distal end of the ulna, its knoblike head articulates laterally with the ulnar notch and inferiorly with a disc of fibrocartilage. This disc, in turn, joins the triquetrum, one of the wrist bones. A medial styloid process at the distal end of the ulna provides attachments for wrist ligaments.

Hand

The hand is made up of the wrist, palm, and fingers. The skeleton of the wrist consists of eight small **carpal bones** firmly bound in two rows of four bones each. The resulting compact mass is called a carpus. The carpus articulates with the radius and with the fibrocartilaginous disc on the ulnar side. The carpus's distal surface articulates with the **metacarpal bones**. Figure 7.25 names the individual bones of the carpus.

Five metacarpal bones, one in line with each finger, form the framework of the palm or metacarpus of the hand. These bones are cylindrical, with rounded distal ends that form the knuckles of a clenched fist. They are numbered 1–5, beginning with the metacarpal of the thumb (refer to Fig. 7.25). The metacarpals articulate proximally with the carpals and distally with phalanges.The **phalanges** are the finger bones. Each finger has three phalanges—a proximal, a middle, and a distal phalanx—except the thumb, which has two. It does not have a middle phalanx.

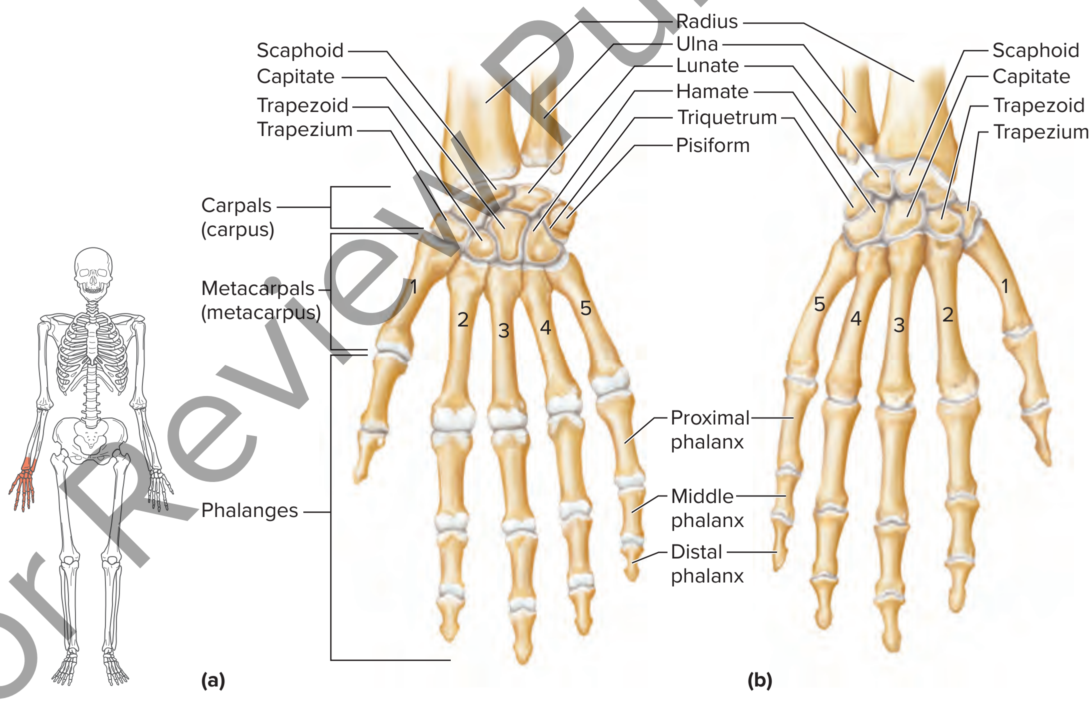


Figure 7.25 Right hand. **(a)** Anterior view. **(b)** Posterior view.

InContext: Word Origin

The prefix "**carp**-" means "*wrist*". The ***carpals***, for example, are the *wrist* bones.

7.10 Practice

1. Locate and name each of the bones of the upper limb.
2. Key Terms Explain how the bones of the upper limb articulate.

7.11 Pelvic Girdle

Learning Outcomes

1. Locate and identify the bones and the major features of the bones that compose the pelvic girdle.

SEP Use the Practices

Using Models In the same way as the pectoral girdle, the pelvic girdle also forms a ring-shaped structure. Develop a model that predicts how the bones of the pelvic girdle would form a ring-shaped structure to allow various movements to occur.

What makes up the pelvic girdle?

The **pelvic girdle** consists of two coxal bones (hip bones, pelvic bones, or innominate bones) that articulate with each other anteriorly and with the sacrum posteriorly. The sacrum, coccyx, and pelvic girdle together form the bowl-shaped pelvis, or pelvic region (refer to Fig. 7.26). The pelvic girdle supports the trunk, provides attachments for the lower limbs, and protects the urinary bladder, the distal end of the large intestine, and the internal reproductive organs.

Each coxal bone develops from three parts—an ilium, an ischium, and a pubis (refer to Fig. 7.27). These parts don't fuse until a person's late teens and don't fully ossify until their early 20s Fusion occurs in the region of a cup-shaped cavity called the acetabulum. This depression, on the lateral surface of the coxal bone, receives the rounded head of the femur, or thigh bone.

The **ilium** (is-KEE-um), which is the largest and uppermost portion of the hip bone, flares outward, forming the prominence of the hip. The margin of this prominence is called the iliac crest.

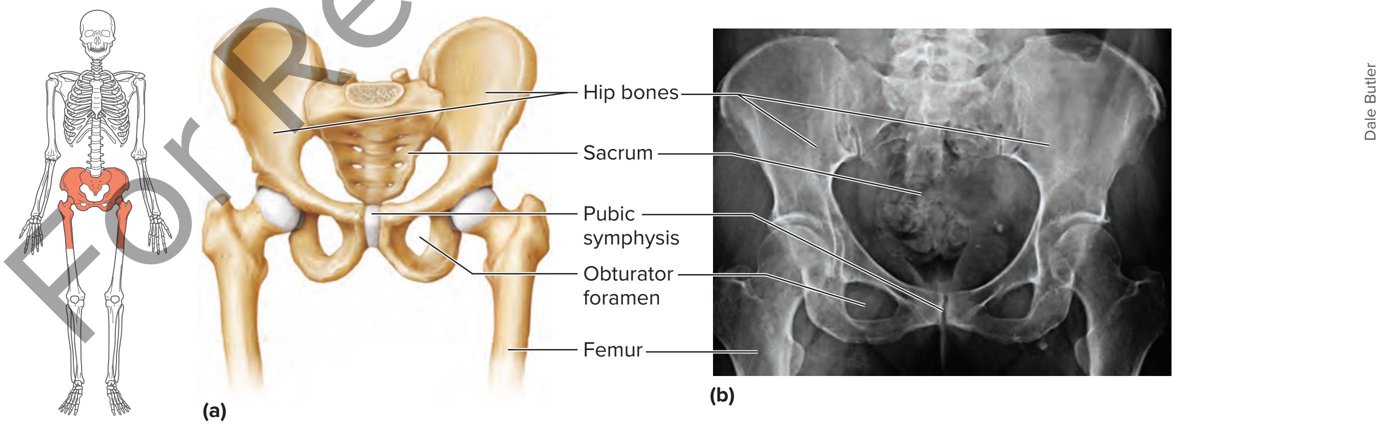


Figure 7.26 Pelvic girdle, anterior view. **(a)** The pelvic girdle is formed by two hip bones. The pelvis includes the pelvic girdle, as well as the sacrum and the coccyx. **(b)** A radiograph of the pelvic girdle showing the sacrum, coccyx, and proximal ends of the femurs.

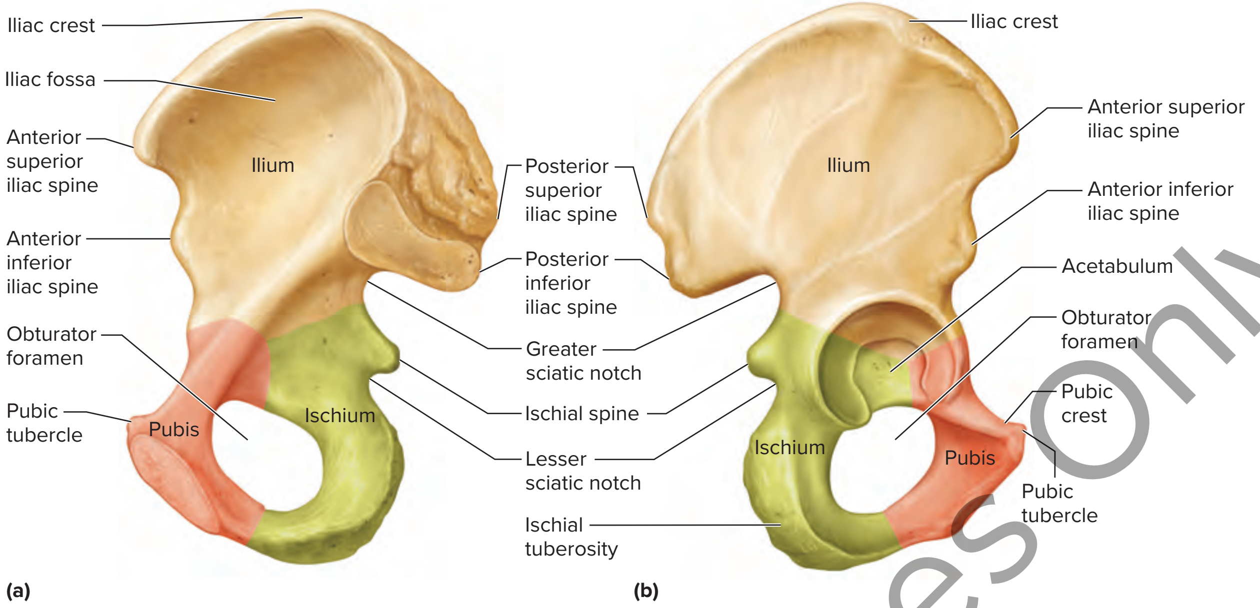


Figure 7.27 Right coxal (hip) bone. **(a)** Medial surface. **(b)** Lateral view.

Posteriorly, the ilium joins the sacrum at the sacroiliac joint. Anteriorly, a projection of the ilium, the anterior superior iliac spine, can be felt lateral to the groin and provides attachments for ligaments and muscles.

The **ischium** (is-KEE-um), which forms the lowest portion of the hip bone, is L-shaped, with its angle, the ischial tuberosity, pointing posteriorly and downward. This tuberosity has a rough surface that provides attachments for ligaments and lower limb muscles. It also supports the weight of the body during sitting. Above the ischial tuberosity, near the junction of the ilium and ischium, is a sharp projection called the ischial spine. The distance between the ischial spines is the shortest diameter of the pelvic outlet.

The **pubis** constitutes the anterior portion of the hip bone. The two pubic bones come together at the midline, forming a joint called the pubic symphysis. The angle these bones form below the symphysis is the pubic arch (refer to Fig. 7.28).

A portion of each pubis passes posteriorly and downward, joining an ischium. Between the bodies of these bones on either side is a large opening, the obturator foramen, which is the largest foramen in the skeleton (refer to Figs. 7.26 and 7.27).

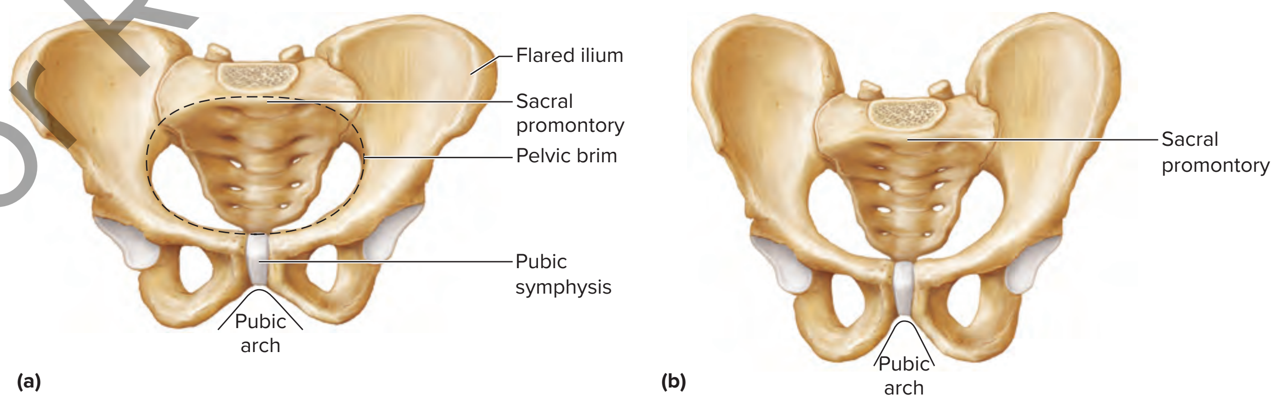


Figure 7.28 The female pelvis is usually wider in all diameters and roomier than that of the male. **(a)** Female pelvis. **(b)** Male pelvis.

Table 7.3 Differences Between the Female and Male Pelvic Regions

Part	Differences
Pelvic girdle	Female hip bones are lighter, thinner, and have less evidence of muscular attachments. The female obturator foramina are triangular, whereas the male's are oval. The female acetabula are smaller, and the pubic arch is wider than corresponding structures of a male.
Pelvic cavity	The female pelvic cavity is wider in all diameters and is shorter, roomier, and less funnel-shaped. The distances between the female ischial spines and ischial tuberosities are greater than in a male.
Sacrum	The female sacrum is wider, and the sacral curvature is bent more sharply posteriorly than in a male.
Coccyx	The female coccyx is more movable than that of a male.

A line drawn along each side of the pelvis from the sacral promontory downward and anteriorly to the upper margin of the pubic symphysis would mark the pelvic brim, or linea terminalis (refer to Fig. 7.28). The pelvic outlet is the inferior opening of the pelvis, bounded by the coccyx, ischial tuberosities, and pubic symphysis. Table 7.3 summarizes some differences in the female and male pelvic regions.

7.11 Practice

1. Locate and name each bone that forms the pelvis.
2. Name the bones that fuse to form a hip bone.
3. **Explore the Figure** Use Figure 7.28 to identify specific differences between the female and male pelvic regions.

7.12 Lower Limb

Learning Outcomes

1. Locate and identify the bones and the major features of the bones that compose the lower limb.

SEP Use the Practices

Communicating Information Design an infographic to convey what you understand about the strength and size of the femur. Add to your infographic as you read.

What bones form the lower limb?

The bones of the lower limb form the framework of each thigh, leg, and foot. They include a femur, a tibia, a fibula, tarsals, metatarsals, and phalanges (refer to Fig. 7.8).

Femur

The **femur**, or thigh bone, is the longest bone in the body and extends from the hip to the knee (refer to Fig. 7.29). A large, rounded head at its proximal end projects medially into the acetabulum of the hip bone. On the head, a pit called the fovea capitis marks the attachment of the ligamentum capitis ligament. Just below the head are a constriction, or neck, and two large processes—a superior, lateral greater trochanter and an inferior, medial lesser trochanter. These processes provide attachments for muscles of the lower limbs and buttocks.

At the distal end of the femur, two rounded processes, the lateral and medial condyles, articulate with the tibia of the leg. The **patella**, or kneecap, also articulates with the femur on its distal anterior surface (refer to Fig. 7.8). The patella is located in a tendon that passes anteriorly over the knee.

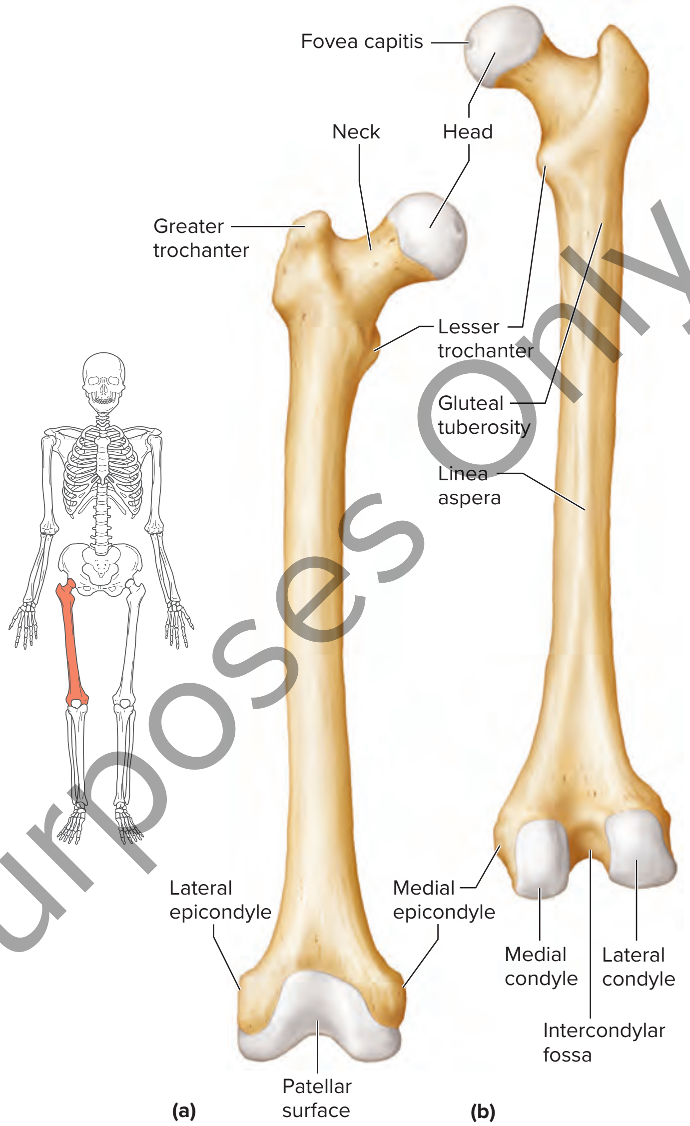


Figure 7.29 Right femur. **(a)** Anterior surface. **(b)** Posterior surface.

Tibia

The **tibia**, or shin bone, is the larger of the two leg bones and is located on the medial side (refer to Fig. 7.30). Its proximal end is expanded into medial and lateral condyles, which have concave surfaces and articulate with the condyles of the femur. Below the condyles on the anterior surface is a process called the tibial tuberosity. It provides an attachment for the patellar ligament, which is a continuation of the patellar tendon.

At its distal end, the tibia expands, forming a prominence on the inner ankle called the medial malleolus, which is an attachment for ligaments. On its lateral side is a depression that articulates with the fibula. The inferior surface of the tibia's distal end articulates with a large bone in the ankle called the talus.

Fibula

The **fibula** is a long, slender bone located on the lateral side of the tibia (refer to Fig. 7.30). The fibula's ends are slightly enlarged into a proximal head and a distal lateral malleolus. The head articulates with the tibia just below the lateral condyle. However, the head does not enter into the knee joint and does not bear any body weight. The lateral malleolus articulates with the ankle and protrudes on the lateral side.

In Context: Word Origin

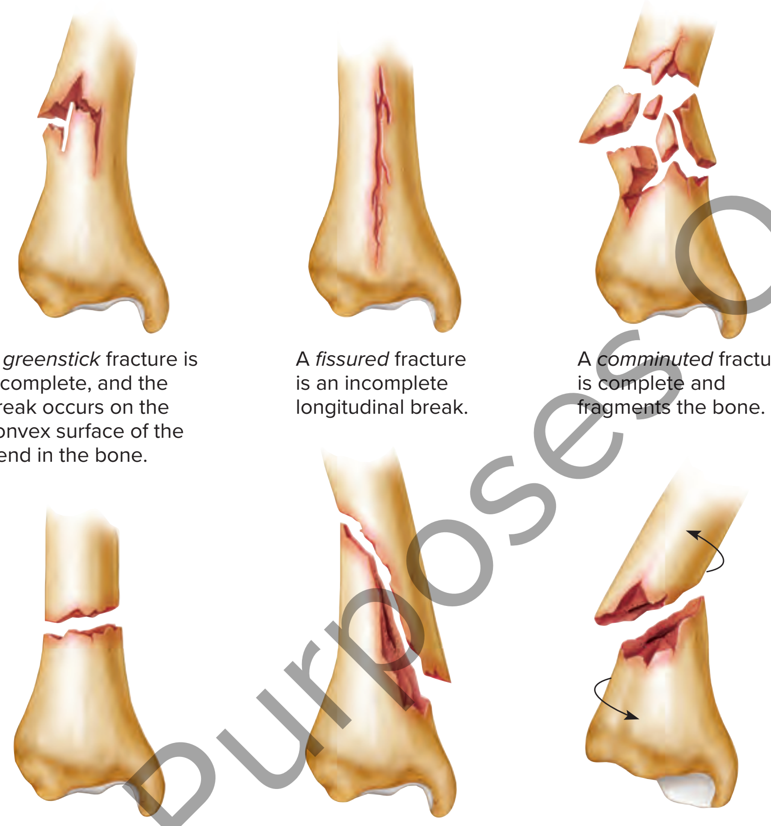
The prefix "**fov**-" means "*pit*". The ***fovea* capitis** is a *pit*-like structure found at the head of a femur.

Diagnosing Disease and Disorders

Bone Fractures

What happens when your bone breaks? A bone break is actually called a fracture. A fracture is classified by its cause as a traumatic, spontaneous, or pathologic fracture, and by the nature of the break as a greenstick, a fissured, a comminuted, a transverse, an oblique, or a spiral fracture. A broken bone exposed to the outside by an opening in the skin is termed a compound (open) fracture.

When a bone breaks, blood vessels in it rupture, and the periosteum is likely to tear. Blood from the broken vessels spreads through the damaged area and soon forms a blood clot, or hematoma. Vessels in surrounding tissues dilate, swelling and inflaming the tissues.



A *greenstick* fracture is incomplete, and the break occurs on the convex surface of the bend in the bone.

A *fissured* fracture is an incomplete longitudinal break.

A *comminuted* fracture is complete and fragments the bone.

A *transverse* fracture is complete, and the break occurs at a right angle to the axis of the bone.

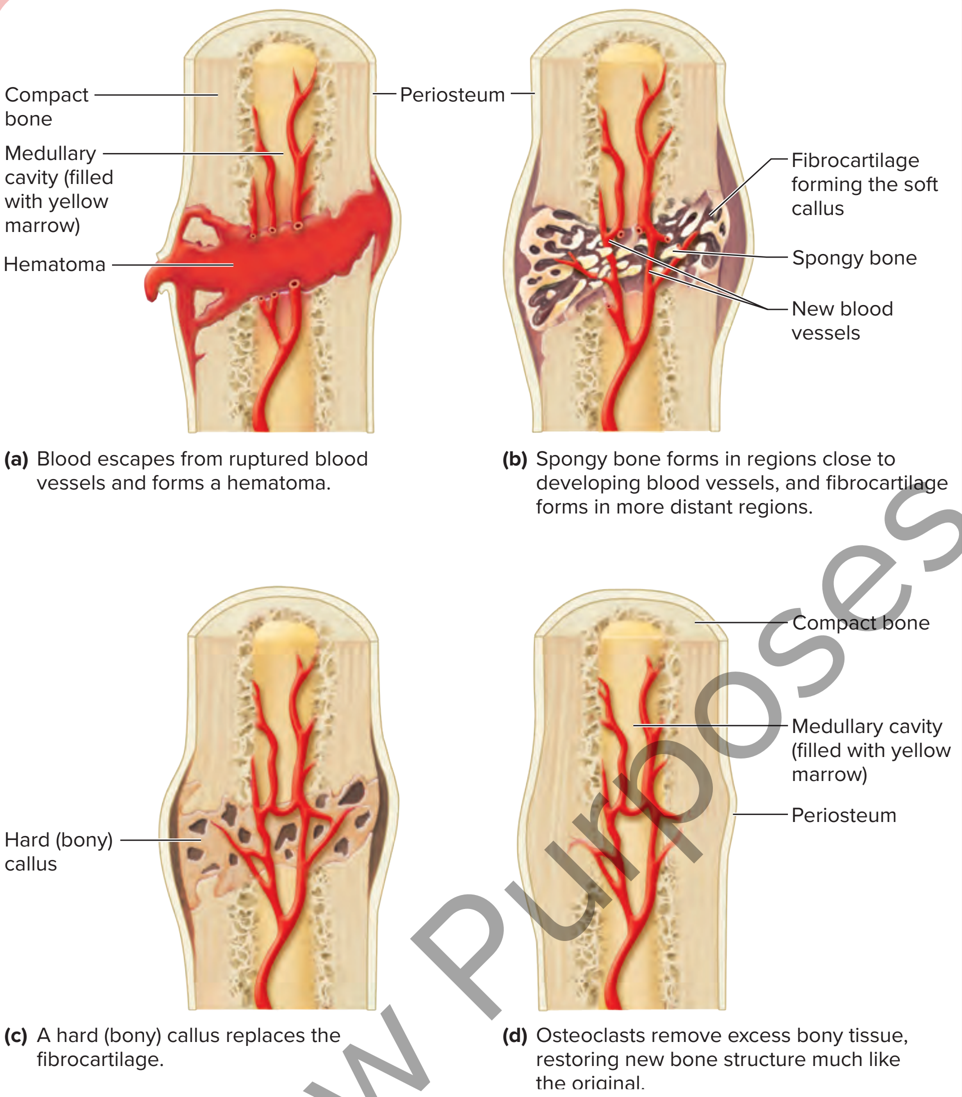
An *oblique* fracture occurs at an angle other than a right angle to the axis of the bone.

A *spiral* fracture is caused by excessive twisting of a bone.

Various types of fractures.

Within days or weeks, developing blood vessels and large numbers of osteoblasts originating in the periosteum invade the hematoma. The osteoblasts rapidly divide in the regions close to the new blood vessels, building spongy bone nearby. Granulation tissue develops, and in regions farther from a blood supply, fibroblasts produce masses of fibrocartilage. Meanwhile, phagocytic cells begin to remove the blood clot and any dead or damaged cells in the affected area. Osteoclasts also appear and resorb bone fragments, aiding in cleaning up the debris.

In time, fibrocartilage fills the gap between the ends of the broken bone. This mass, a cartilaginous soft callus, is later replaced by bone tissue in much the same way that the hyaline cartilage of a developing endochondral bone is replaced. In other words, the cartilaginous callus breaks down, blood vessels and osteoblasts invade the area, and a hard, bony callus fills the space. Typically, more bone is produced at the site of a healing fracture than is necessary to replace the damaged tissues. Osteoclasts remove the excess, and the result is a bone shaped much like the original.



Major steps **(a–d)** in repair of a fracture.

Several techniques are used to help the bone-healing process. The first casts to immobilize fractured bones were introduced in 1876, and soon after, doctors began using screws and plates internally to align healing bone parts. Today, orthopedic surgeons also use rods, wires, and nails. These devices have become lighter and smaller. Many are built of titanium. A device called a hybrid fixator treats a broken leg using metal pins internally to align bone pieces. The pins are anchored to a metal ring device worn outside the leg. Experimental approaches to helping bones heal include cartilage grafts and infusions of stem cells taken from a patient's own bone marrow.

Concept Connections

1. Describe the techniques used to help bone healing.
2. Identity and describe how a fragility fracture is different from a traumatic fracture.

Foot

The foot is made up of the ankle, instep, and toes. The ankle, or tarsus, is composed of seven **tarsal bones** (refer to Figs. 7.31 and 7.32). One of these bones, the **talus**, can move freely where it joins the tibia and fibula. Figure 7.32 names the individual bones of the tarsus.

The largest of the tarsals, the calcaneus, or heel bone, is below the talus, where it projects backward, forming the base of the heel. The calcaneus helps support body weight and provides an attachment for the muscles that move the foot (refer to Fig. 7.31).

The instep, or metatarsus, consists of five elongated metatarsal bones that articulate with the tarsus. They are numbered 1–5, beginning on the medial side (refer to Fig. 7.32). The heads at the distal ends of these bones form the ball of the foot. The tarsals and metatarsals are bound by ligaments in a way that forms the arches of the foot. A longitudinal arch extends from the heel to the toe, and a transverse arch stretches across the foot. These arches provide a stable, springy base for the body. Sometimes, however, the tissues that bind the metatarsals weaken, producing fallen arches, or flat feet.

The proximal **phalanges** of the toes, which are similar to those of the fingers, align and articulate with the metatarsals. Each toe has three phalanges—a proximal, a middle, and a distal phalanx—except the great toe, which has only a proximal and a distal phalanx.

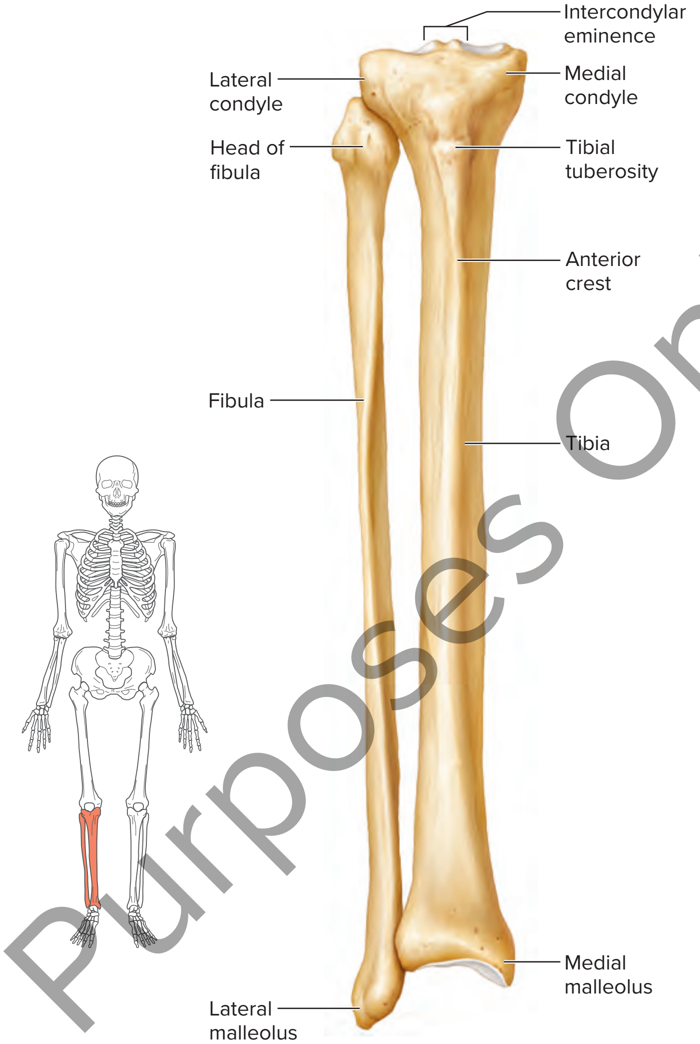


Figure 7.30 Right tibia and fibula, anterior view.

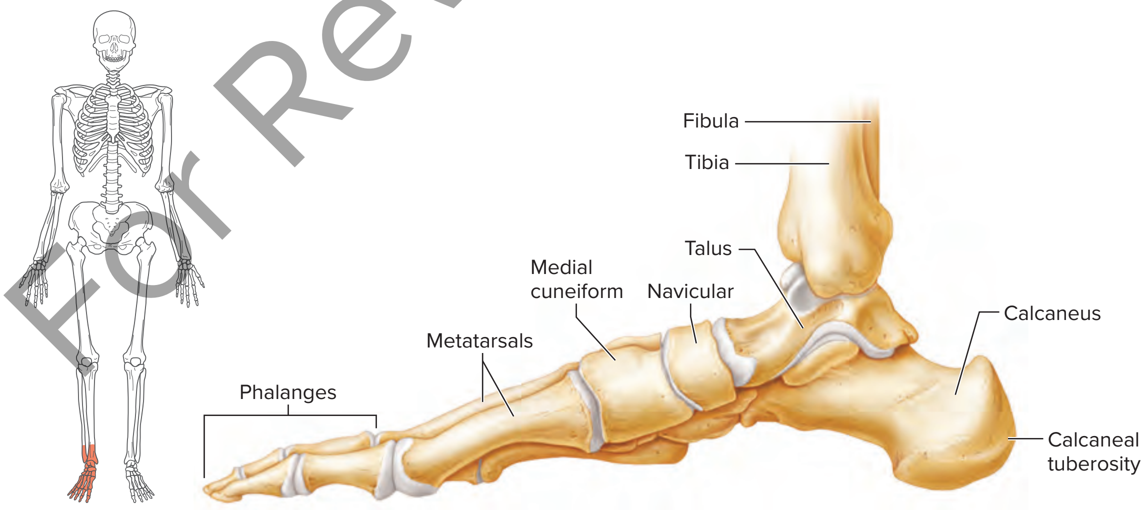


Figure 7.31 Right foot, medial view. The talus moves freely where it articulates with the tibia and fibula.

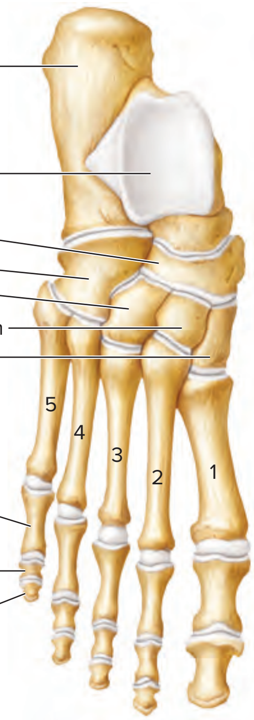


Figure 7.32 Right foot viewed superiorly.

7.12 Practice

1. Locate and name each of the bones of the lower limb.
2. **Key Terms** Explain how the bones of the lower limb articulate.
3. Describe how the foot is adapted to support the body.

7.13 Joints

Learning Outcomes

1. Classify joints according to the type of tissue binding the bones, describe the different joint characteristics, and name an example of each joint type.
2. List six types of synovial joints, and describe the actions of each.
3. Explain how skeletal muscles produce movements at joints, and identify several types of joint movements.

SEP Use the Practices

Communicating Information Construct a chart that explains the joint movements in an everyday activity, such as swinging a baseball bat or playing a video game. Adjust in the chart as you read.

What are different types of joints?

Joints, or articulations, are functional junctions between bones. Joints bind parts of the skeletal system, make bone growth possible, permit parts of the skeleton to change shape during childbirth, and enable the body to move in response to skeletal muscle contractions.

The number of joints changes in the human body from birth until older adulthood. However, typically the average adult has about 230 joints. They can be classified according to the degree of movement they make possible. Joints can be immovable (synarthrotic), slightly movable (amphiarthrotic), or freely movable (diarthrotic). They vary considerably in function and structure. Joints also can be grouped according to the type of tissue (fibrous, cartilaginous, or synovial) that binds the bones at each junction. Currently, this structural classification by tissue type is most commonly used.

Fibrous Joints

Fibrous joints lie between bones that closely contact one another and are held together by a thin layer of dense connective tissue. An example of such a joint is a suture between a pair of flat bones of the skull (refer to Fig. 7.33). Generally, no appreciable movement (synarthrosis) takes place at a fibrous joint. Some fibrous joints, such as the one in the leg between the distal ends of the tibia and fibula, are amphiarthrotic.

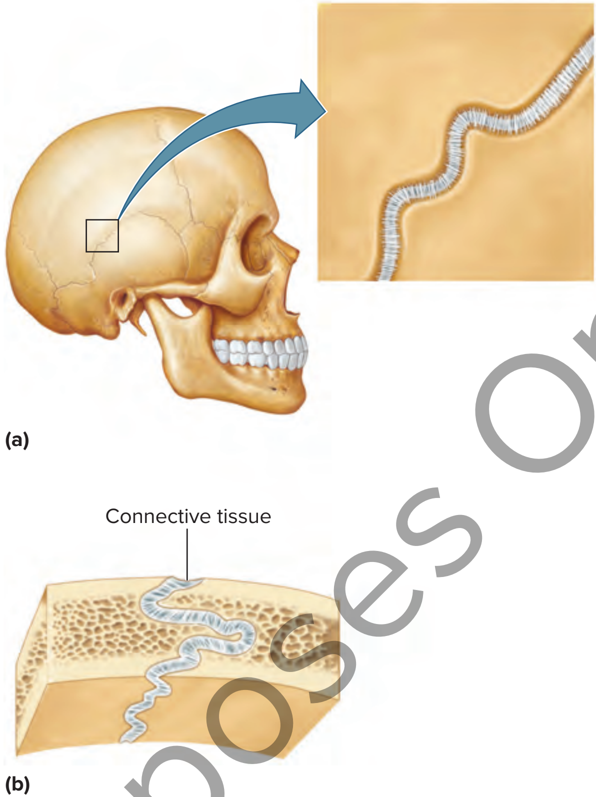


Figure 7.33 Fibrous joints. **(a)** The fibrous joints between the bones of the skull are immovable and are called sutures. **(b)** A thin layer of connective tissue connects the bones at the suture.

Cartilaginous Joints

Hyaline cartilage, or fibrocartilage, connects the bones of **cartilaginous joints**. For example, joints of this type separate the vertebrae of the vertebral column. Each intervertebral disc is composed of a band of fibrocartilage (annulus fibrosus) surrounding a pulpy or gelatinous core (nucleus pulposus). The disc absorbs shocks and helps equalize pressure between vertebrae when the body moves (refer to Fig. 7.16).

Due to the slight flexibility of the discs, cartilaginous joints allow amphiarthrotic movement, such as when the back is bent forward or to the side or is twisted. Other examples of cartilaginous joints include the pubic symphysis and the first rib with the sternum.

Synovial Joints

Most joints in the skeletal system are **synovial joints**, which allow free movement. They are more complex structurally than fibrous or cartilaginous joints.

The articular ends of the bones in a synovial joint are covered with a thin layer of hyaline cartilage. A tubular joint capsule holds the bones of a synovial joint together. Each joint capsule is composed of an outer fibrous layer of dense connective tissue and an inner lining of synovial membrane, which secretes synovial fluid (refer to Fig. 7.34). Ligaments in the fibrous layer prevent the bones from being pulled apart.

Synovial fluid has a consistency similar to uncooked egg white, and it lubricates joints.

Some synovial joints have flattened, shock-absorbing pads of fibrocartilage called **menisci** between the articulating surfaces of the bones (refer to Fig. 7.35). Such joints may also have fluid-filled sacs called **bursae** associated with them. Each bursa is lined with synovial membrane, which may be continuous with the synovial membrane of a nearby joint cavity. Bursae are commonly located between tendons and underlying bony prominences, as in the patella of the knee or the olecranon process of the elbow. They aid the movement of tendons that glide over these bony parts or over other tendons. Figure 7.35 shows and names some of the bursae associated with the knee.

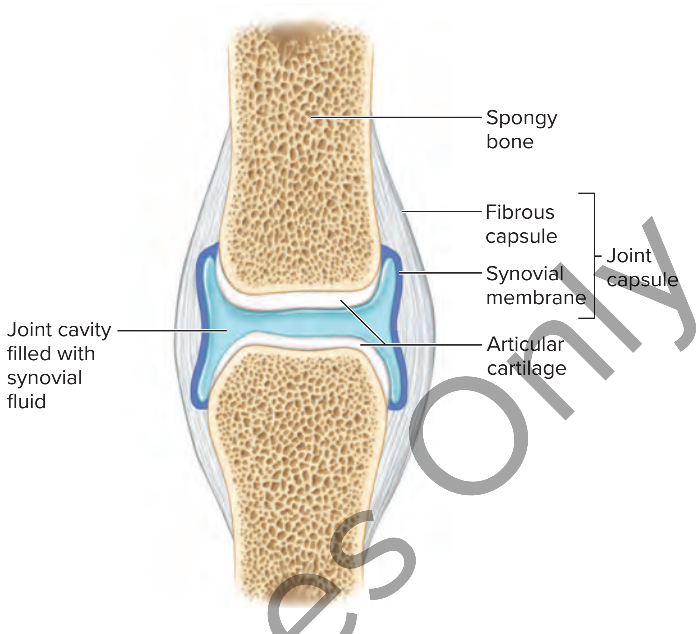


Figure 7.34 The generalized structure of a synovial joint.

GO ONLINE to check your understanding of the structure of synovial joints by completing the Focus Activity.

Based upon the shapes of their parts and the movements they permit, synovial joints are classified as follows:

- A **ball-and-socket joint**, or spheroidal joint, consists of a bone with a globular or slightly egg-shaped head that articulates with the cup-shaped cavity of another bone. A spheroidal joint permits multiaxial movement, the widest range of motion in all planes, including rotational movement around a central axis. The shoulder and hip have joints of this type (refer to Fig. 7.36a).
- In a **condylar joint**, or ellipsoidal joint, the ovoid condyle of one bone fits into the elliptical cavity of another bone, as in the joints between the metacarpals and phalanges (refer to Fig. 7.36b). This type of joint permits biaxial movement, or back-and-forth and side-to-side movement in two planes with no rotation.
- The articulating surfaces of **plane joints**, or gliding joints, are nearly flat or slightly curved. Most of the joints in the wrist and ankle, as well as those between the articular processes of adjacent vertebrae, belong to this group (refer to Fig. 7.36c). Plane joints allow nonaxial movements like sliding and twisting. The sacroiliac joints and the joints formed by ribs 2–7 connecting with the sternum are also plane joints.

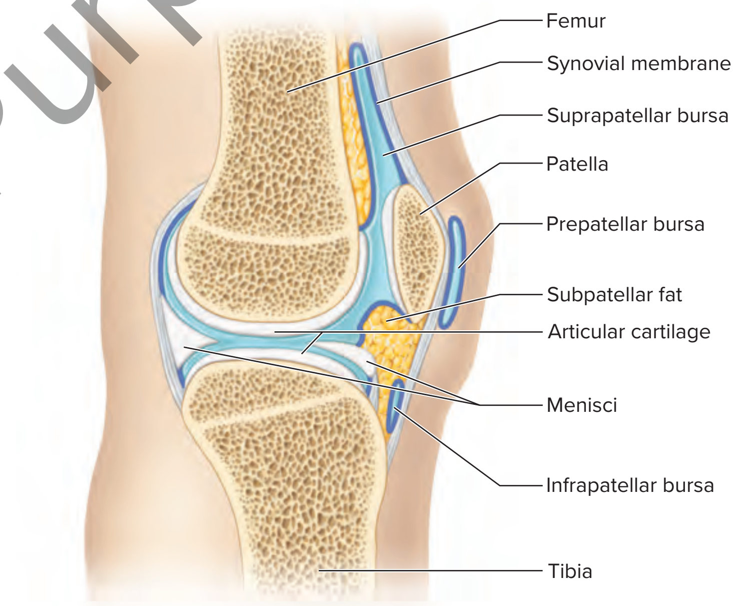


Figure 7.35 Menisci separate the articulating surfaces of the femur and tibia. Several bursae are associated with the knee joint. Synovial spaces in this and other line drawings of joints in this chapter are exaggerated.

GO ONLINE to check your understanding of the structure of synovial joints by completing the Focus Activity.

Medical Mysteries

Lyme Disease

Bony ankylosis. Bony ankylosis of the joints of the fingers in a person with rheumatoid arthritis.

Suze777/iStock/ Getty Images

Joints must support weight and allow a variety of body movements. Joints are also used frequently. Trauma, overuse, infection, a misdirected immune system attack, or degeneration can injure joints. Arthritis is a disease that causes inflamed, swollen, and painful joints. More than 100 different types of arthritis affect millions of people worldwide.

In 1975, in Lyme, Connecticut, an astute woman alerted a prominent rheumatologist to the fact that many of her young neighbors had what appeared to be the very rare juvenile form of rheumatoid arthritis (RA). Rheumatoid arthritis is a painful and debilitating autoimmune disorder. The condition causes the immune system to attack the body's healthy tissues. The synovial membrane of a joint becomes inflamed and thickened, and then the articular cartilage is damaged, and fibrous tissue infiltrates, interfering with joint movements. Over time, the joints may ossify, or fuse, the articulating bones. RA may affect many joints or only a few. It is often accompanied by muscular atrophy, fatigue, and other symptoms. Although RA cannot be cured, it can be treated. Physicians often instruct patients to take over-the-counter medications for inflammation, do physical therapy for joint flexibility, and take disease-modifying antirheumatic drugs to slow the progression of the disease.

Older people have a higher risk of developing rheumatoid arthritis, so it was odd that arthritis was appearing in so many young children in the town of Lyme and in clusters. Researchers found most of these children lived near wooded areas and shared many other symptoms such as rash, fatigue, and flu-like aches and pains. A scientist finally traced the illness to a tick-borne bacterial infection.

Today Lyme disease is a well-known bacterial infection received from a tick bite. Lyme disease can cause intermittent arthritis of several joints, usually weeks after the initial symptoms. Antibiotic treatment that begins as soon as the early symptoms are recognized may prevent them. Scientists now know that other types of bacteria can cause arthritis too.

Another form of arthritis is osteoarthritis (OA). This degenerative disorder may result from aging or a poorly healed injury, or it may be inherited. Articular cartilage softens and disintegrates gradually, which roughens the articular surfaces. Joints become painful, and movement becomes restricted. OA usually affects the most active joints, such as those of the fingers, hips, knees, and the lower vertebral column.

If a person with OA is overweight or obese, the first treatment is usually an exercise and dietary program to lose weight. Nonsteroidal anti-inflammatory drugs

(NSAIDs) such as aspirin and ibuprofen have been used for many years to control OA symptoms. NSAIDs called COX-2 inhibitors relieve inflammation without the gastrointestinal side effects of earlier drugs. However, some of these drugs have been linked to cardiovascular issues, so the FDA advises that COX-2 inhibitors be prescribed only to people who do not have risk factors for cardiovascular disease.

Sprains

Sprains result from overstretching or tearing the connective tissues, including cartilage, ligaments, and tendons, associated with a joint. However, sprains do not dislocate the articular bones. Usually, forceful wrenching or twisting causes a sprained wrist or ankle. For example, inverting an ankle too far can sprain it by stretching the ligaments on its lateral surface. Severe injuries may pull these structures loose from their attachments.

A sprained joint is painful and swollen and restricts movement by swelling. Immediate treatment of a sprain is rest. More serious cases require medical attention. However, immobilization of a joint, even for a brief period, causes bone resorption and weakens ligaments. Consequently, exercise may help strengthen the joint.

Bursitis

Overuse of a joint or stress on a bursa may cause bursitis, an inflammation of a bursa. The bursa between the calcaneus (heel bone) and the Achilles tendon may become inflamed as a result of a sudden increase in physical activity involving the feet. Bursitis is treated with rest. Medical attention may be necessary.

Injuries to the elbow, shoulder, and knee are commonly diagnosed and treated using a procedure called arthroscopy. Arthroscopy enables a surgeon to see the interior of a joint and perform procedures. An arthroscope is a thin, tubular instrument about 25 centimeters long containing optical fibers that transmit an image to a video screen. The surgeon inserts the device through a small incision in the joint capsule, which is much less invasive than conventional surgery. Some runners have undergone uncomplicated arthroscopy and raced several weeks later.

Concept Connections

1. Explain what is occurring in the joints of someone who has Rheumatoid arthritis and how this diagnosis would interrupt their daily life.
2. Why would a diagnosis of Lyme disease be preferable to a diagnosis of Rheumatoid arthritis?

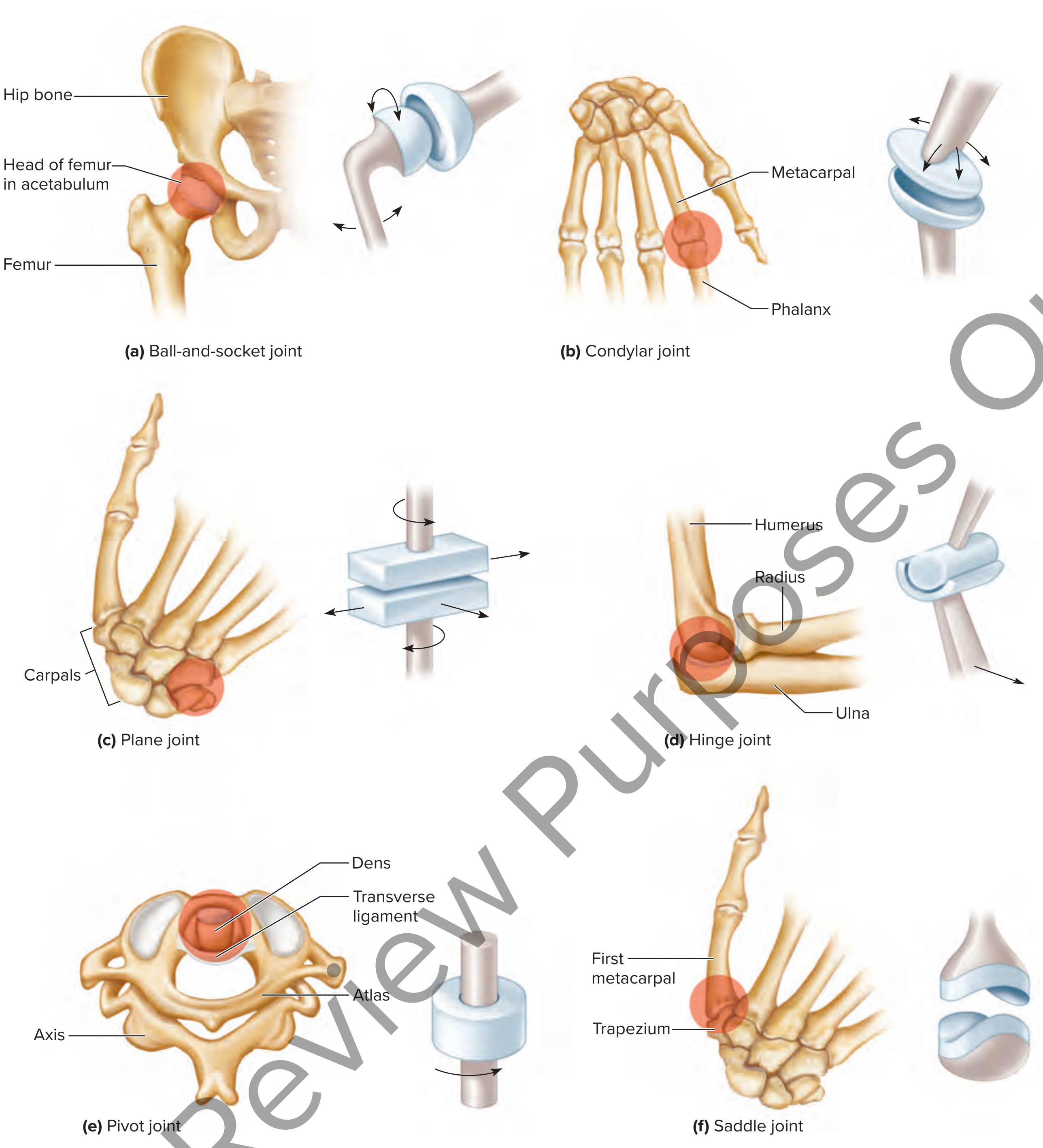


Figure 7.36 Types and examples of synovial (freely movable) joints **(a–f).**

- In a **hinge joint**, the convex surface of one bone fits into the concave surface of another, as in the elbow and the joints between the phalanges (refer to Fig. 7.36d). Such a joint resembles the hinge of a door in that it permits movement in one plane only, appropriately called uniaxial movement.
- In a **pivot joint**, or trochoid joint, the cylindrical surface of one bone rotates within a ring formed of bone and ligament. Movement is limited to the rotation around a central axis (uniaxial movement). The joint between the atlas and the dens of the axis is a pivot joint (refer to Fig. 7.36e).

- A **saddle joint**, or sellar joint, forms between bones whose articulating surfaces have both concave and convex regions. The surface of one bone fits the complementary surface of the other. This physical relationship permits a variety of biaxial movements, mainly in two planes, as in the joint between the carpal (trapezium) and metacarpal of the thumb (refer to Fig. 7.36f).

Table 7.4 summarizes the types of joints.

Table 7.4 Types of Joints

Type of Joint	Description	Possible Movements	Examples
Fibrous	Articulating bones are fastened together by a thin layer of dense connective tissue.	None or slight twisting	Suture between bones of skull, joint between the distal ends of tibia and fibula
Cartilaginous	Articulating bones are connected by hyaline cartilage or fibrocartilage.	Limited movement, as when the back is bent or twisted	Joints between the bodies of vertebrae, pubic symphysis
Synovial	Articulating ends of bones are surrounded by a joint capsule of ligaments and synovial membranes; ends of articulating bones are covered by hyaline cartilage and separated by synovial fluid.	Allow free movement (refer to the Types of Joint Movements)	
Ball-and-socket	Ball-shaped head of one bone articulates with cup-shaped cavity of another.	Movements, including rotation, in all planes	Shoulder, hip
Condylar	Oval-shaped condyle of one bone articulates with elliptical cavity of another.	Variety of movements in two planes, but no rotation	Joints between the metacarpals and phalanges
Plane	Articulating surfaces are nearly flat or slightly curved.	Sliding or twisting	Joints between various bones of wrist and ankle, sacroiliac joints, joints between ribs 2–7 and sternum
Hinge	Convex surface of one bone articulates with concave surface of another.	Flexion and extension	Elbow, joints of phalanges
Pivot	Cylindrical surface of one bone articulates with ring of bone and ligament.	Rotation around a central axis	Joint between the atlas and dens of the axis
Saddle	Articulating surfaces have both concave and convex regions; the surface of one bone fits the complementary surface of another.	Variety of movements, mainly in two planes	Joint between the carpal and metacarpal of thumb

Types of Joint Movements

Skeletal muscle action produces movements at synovial joints. Typically, one end of a muscle is attached to a less movable or relatively fixed part on one side of a joint, and the other end of the muscle is fastened to a more movable part on the other side. When the muscle contracts, its fibers pull its movable end (insertion) toward its fixed end (origin), and a movement occurs at the joint.

Note that in the anatomical position some actions have already occurred, such as supination of the forearm and hand, extension of the elbow, and extension of the knee. The muscle actions described in this section consider the entire range of movement at each joint and do not necessarily presume that the starting point is the anatomical position. The following terms describe movements at joints (refer to Figs. 7.37, 7.38, and 7.39):

- **Flexion** Parts bend at a joint so that the angle between them decreases, and the parts come closer together (bending the knee).
- **Extension** Parts move at a joint so that the angle between them increases, and the parts move farther apart (straightening the knee).
- **Dorsiflexion** Moving the ankle to bring the foot closer to the shin (rocking back on one's heels).
- **Plantar flexion** Moving the ankle to move the foot farther from the shin (walking or standing on one's toes).
- **Hyperextension** Extending the parts at a joint beyond the anatomical position (bending the head back beyond the upright position). This is often used to describe an abnormal extension beyond the normal range of motion that results in injury.

J & J Photography

Figure 7.37 Joint movements illustrating abduction, adduction, lateral flexion, extension, and flexion.

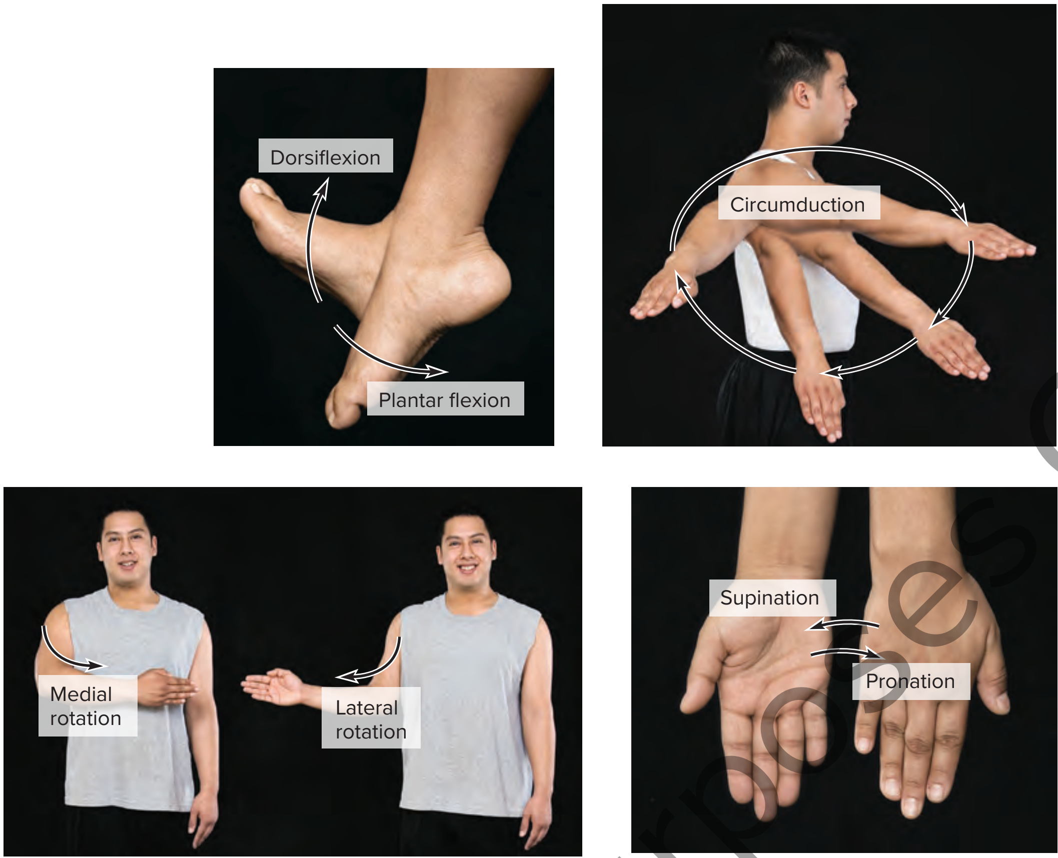


Figure 7.38 Joint movements illustrating dorsiflexion, plantar flexion, circumduction, rotation, supination, and pronation.

- **Abduction** Moving a part away from the midline (lifting the upper limb horizontally to form an angle with the side of the body) or away from the axial line of the limb (spreading the fingers or toes). Abduction of the head and neck and bending of the trunk to the side may be termed lateral flexion.
- **Adduction** Moving a part toward the midline (returning the upper limb from the horizontal position to the side of the body) or toward the axial line of the limb (moving the fingers and toes closer together).
- **Rotation** Moving a part around an axis (twisting the head from side to side). Medial (internal) rotation is the turning of a limb on its longitudinal axis so its anterior surface moves toward the midline, whereas lateral (external) rotation is the turning of a limb on its longitudinal axis in the opposite direction.
- **Circumduction** Moving a part so that its end follows a circular path (moving the finger in a circular motion without moving the hand).
- **Pronation** Rotation of the forearm so the palm is downward or facing posteriorly (in anatomical position). Prone refers to the body's lying face down.
- **Supination** Rotation of the forearm so the palm is upward or facing anteriorly (in anatomical position). Supine refers to the body's lying face up.
- **Eversion** Turning the foot so the plantar surface faces laterally.

J & J Photography

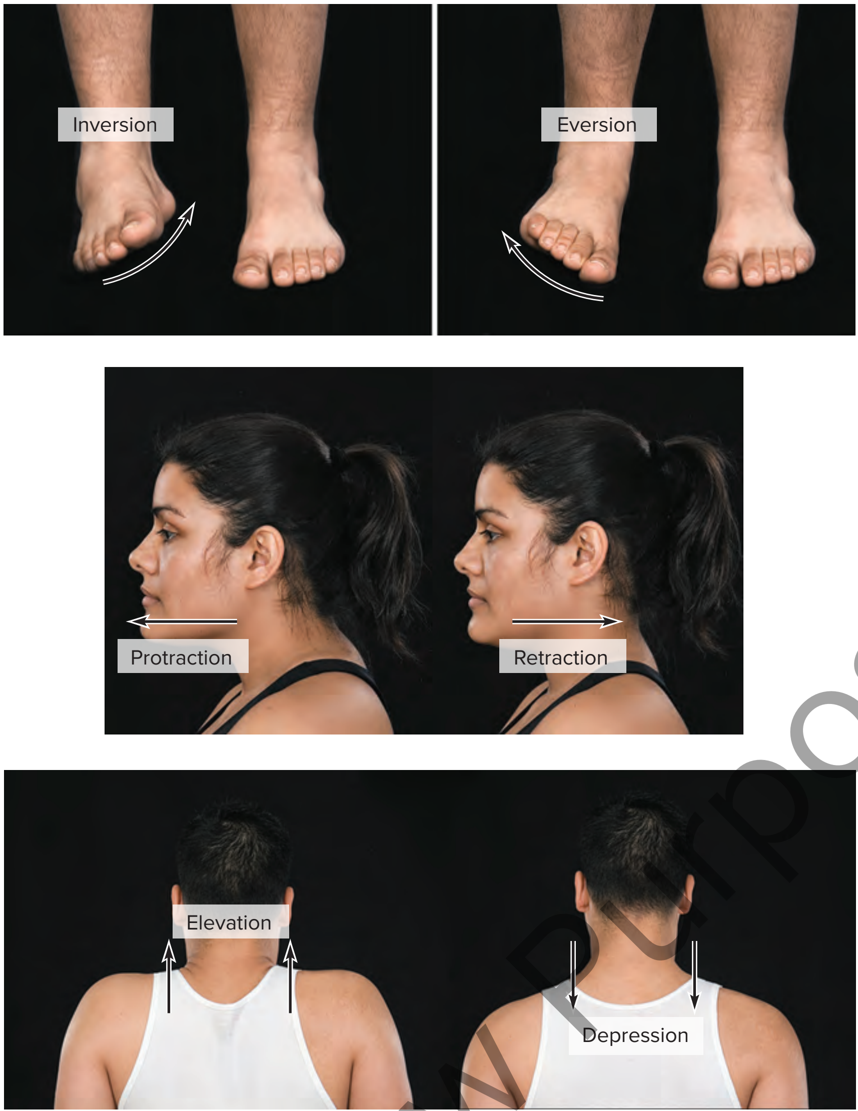


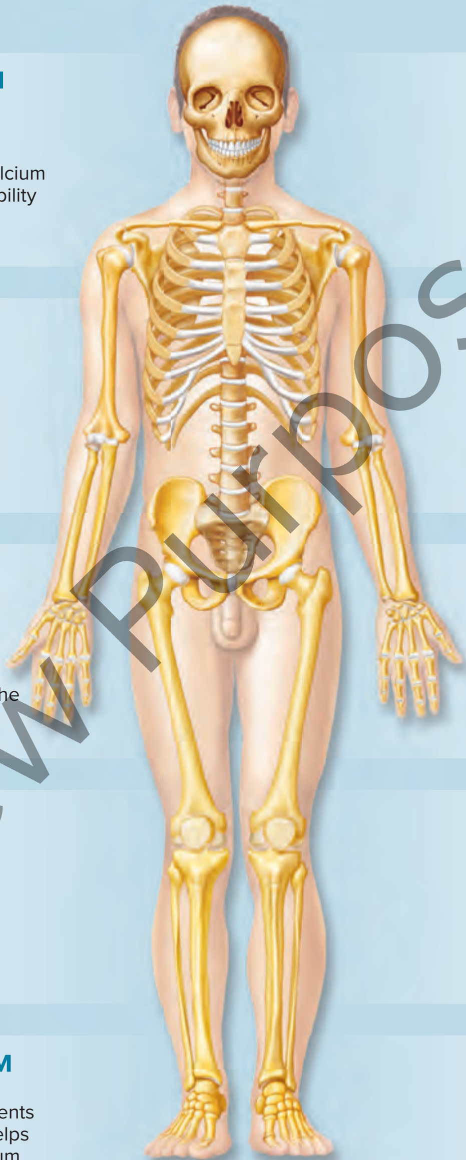
Figure 7.39 Joint movements illustrating inversion, eversion, protraction, retraction, elevation, and depression.

- **Inversion** Turning the foot so the plantar surface faces medially.
- **Retraction** Moving a part backward (pulling the head backward).
- **Protraction** Moving a part forward (thrusting the head forward).
- **Elevation** Raising a part (shrugging the shoulders).
- **Depression** Lowering a part (drooping the shoulders).

7.13 Practice

1. **Key Terms** Describe the characteristics of the three major types of joints.
2. Name six types of synovial joints.
3. What terms describe movements possible at synovial joints?

Skeletal System



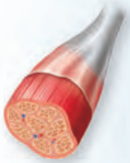
INTEGUMENTARY SYSTEM

Vitamin D, production of which begins in the skin, plays a role in calcium absorption and availability for bone matrix.

LYMPHATIC SYSTEM

Cells of the immune system originate in the bone marrow.

MUSCULAR SYSTEM



Muscles pull on bones to cause movement.

DIGESTIVE SYSTEM

Absorption of dietary calcium provides material for bone matrix.

NERVOUS SYSTEM

Proprioceptors sense the position of body parts. Pain receptors warn of trauma to bone. Bones protect the brain and spinal cord.

RESPIRATORY SYSTEM

Ribs and muscles work together in breathing.

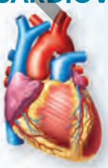
ENDOCRINE SYSTEM

Some hormones act on bone to help regulate blood calcium levels.

URINARY SYSTEM

The kidneys and bones work together to help regulate blood calcium levels.

CARDIOVASCULAR SYSTEM



Blood transports nutrients to bone cells. Bone helps regulate plasma calcium levels, important to heart function.

REPRODUCTIVE SYSTEM

The pelvis helps support the uterus during pregnancy. Bones provide a source of calcium during lactation.

Bones provide support, protection, and movement and also play a role in calcium balance.

Chapter 7 Summary

GO ONLINE for a list of key terms and a summary of the Chapter 7 concepts.

7.1 Introduction

The skeletal system is made up of individual organs, bones, tendons, ligaments, and cartilage. Bones contain active tissues.

Revisit the Learning Outcomes

1. List the active tissues found in a bone.

7.2 Bone Structure

Bones can be long, short, flat, or irregular. Long bones are comprised of the diaphysis, epiphyses, periosteum, compact bone, and spongy bone.

Revisit the Learning Outcomes

1. Locate and identify the macroscopic and microscopic structure of a long bone, and describe the functions of these parts.

7.3 Bone Function

Bones serve the function of providing support and protection as well as interacting with muscles to allow body parts to move. Red marrow in the bones develops red blood cells, white blood cells, and blood platelets, while yellow marrow stores fat.

Revisit the Learning Outcomes

1. Discuss the major functions of bones.

7.4 Bone Development, Growth, and Repair

Sheetlike layers of connective tissue form intramembranous bones. Ossification of hyaline cartilage creates endochondral bones. Osteoclasts and osteoblasts maintain the homeostasis of bones after they develop.

Revisit the Learning Outcomes

1. Distinguish between intramembranous and endochondral bones.
2. Explain the roles of osteoblasts, osteocytes, and osteoclasts in bone growth, development, and repair.

7.5 Skeletal Organization

The skeletal system can be organized into the axial and the appendicular skeleton. The axial skeleton is comprised of the skull, hyoid bone, vertebral column, and thoracic cage. The appendicular skeleton consists of the upper limbs, pelvic girdle, lower limbs, and pectoral girdle.

Revisit the Learning Outcomes

1. Distinguish between the axial and appendicular skeletons, and name the major parts of each.

7.6 Skull

The cranium protects and encases the brain. The ethmoid bone, sphenoid bone, temporal bones, occipital bone, parietal bones, and frontal bone come together to make the cranium. The facial skeleton includes the maxillae, palatine bones, zygomatic bones, lacrimal bones, nasal bones, vomer bone, and mandible.

Revisit the Learning Outcomes

1. Locate and identify the bones and the major features of the bones that compose the skull.

7.7 Vertebral Column

The vertebral column contains the cervical vertebrae, thoracic vertebrae, lumbar vertebrae, sacrum, and coccyx.

Revisit the Learning Outcomes

1. Locate and identify the bones and the major features of the bones that compose the vertebral column.

7.8 Thoracic Cage

The twelve thoracic vertebrae are attached to the twelve pairs of ribs by costal cartilage. The manubrium, body, and xiphoid process make up the sternum.

Revisit the Learning Outcomes

1. Locate and identify the bones and the major features of the bones that compose the thoracic cage.

7.9 Pectoral Girdle

The clavicles and two scapulae are what make up the pectoral girdle. The scapulae hold the shoulders in place and provide attachments for the muscles. The scapulae are bones that articulate with each humerus.

Revisit the Learning Outcomes

1. Locate and identify the bones and the major features of the bones that compose the pectoral girdle.

7.10 Upper Limb

The humerus, radius, and ulna comprise the upper limbs from the scapula to wrist. The hand contains carpal and metacarpal bones as well as fourteen phalanges.

Revisit the Learning Outcomes

1. Locate and identify the bones and the major features of the bones that compose the upper limb.

7.11 Pelvic Girdle

Two hip bones create the pelvic girdle. The ilium, ischium, and pubis come together to create each hip.

Revisit the Learning Outcomes

1. Locate and identify the bones and the major features of the bones that compose the pelvic girdle.

7.12 Lower Limb

The femur, patella, tibia, and fibula comprise the lower limbs from the hip to the top of the ankle. The ankle contains six tarsal bones and the talus as well as the metatarsal bones and fourteen phalanges.

Revisit the Learning Outcomes

1. Locate and identify the bones and the major features of the bones that compose the lower limb.

7.13 Joints

Joints can be classified based on tissue type as well as degree of movement. The body has three types of joints: synovial, fibrous, and cartilaginous. Each joint can move in ways that are specific to its type.

Revisit the Learning Outcomes

1. Classify joints according to the type of tissue binding the bones, describe the different joint characteristics, and name an example of each joint type.
2. List six types of synovial joints, and describe the actions of each.
3. Explain how skeletal muscles produce movements at joints, and identify several types of joint movements

Chapter 7 Assessment

Chapter Review Questions

Multiple Choice

1. ______________ heals rapidly as a result of blood (nutrient supply) having easy access to and between osteocytes through the cellular processes passing through very small tubes in the extracellular matrix called canaliculi.
   a. Spongy bone
   b. Trabeculae
   c. Medullary cavities
   d. Compact bone
2. All the following directly influence bone development, growth, and repair except ______________
   a. deposition by osteoclasts and resorption by osteoblasts.
   b. a diet sufficient in vitamin D and calcium.
   c. the stimulation of processes by growth and sex hormones.
   d. physical stress from exercise.
3. When levels of calcium are too high in the blood, there is a homeostatic response. The thyroid gland releases ______________, and then ______________ deposit calcium in bones.
   a. parathyroid hormone; osteoclasts
   b. calcitonin; osteoblasts
   c. calcitonin; osteoclasts
   d. parathyroid hormone; osteoblasts
4. The fourteen bones in the fingers and fourteen bones in the toes are called ______________
   a. carpals and tarsals, respectively.
   b. metacarpals and metatarsals, respectively.
   c. phalanges.
   d. clavicles.
5. Which features of the skull increase resonance of the voice and decrease the weight of the skull?
   a. occipital bone
   b. coronoid processes
   c. paranasal sinuses
   d. maxillae
6. A patient has dealt with years of back pain caused by degenerative disc disease. After trying other routes of treatment, a doctor decides to treat the patient through spinal fusion surgery, fusing together the three vertebrae closest to the sacrum. Which vertebrae are being fused?
   a. C5, C6, and C7
   b. S1, S2, and S3
   c. L3, L4, and L5
   d. T10, T11, and T12
7. Which structure of the thoracic cage functions in compressing the heart during ideal cardiopulmonary resuscitation (CPR) performed after cardiac arrest?
   a. sternum
   b. ribs
   c. clavicle
   d. scapulae
8. Which lateral structures of the upper limbs provide attachments for the muscles and ligaments of the elbow?
   a. greater tubercles
   b. epicondyles
   c. styloid processes
   d. lesser tubercles
9. Which section of the skeletal system supports the body's trunk and protects the reproductive organs?
   a. pelvic girdle
   b. vertebral column
   c. thoracic cage
   d. hyoid
10. As seen in the vertebral column, cartilaginous joints allow which type of movement?
   a. synarthrotic
   b. amphiarthrotic
   c. diarthrotic
   d. both a and c

Short Answer

1. Sketch a typical long bone, and label its epiphyses, diaphysis, medullary cavity, periosteum, and articular cartilages. On the sketch, designate the locations of compact and spongy bone.
2. Discuss the functions of the parts labeled in the sketch you made for question 1.
3. Distinguish between the microscopic structure of compact bone and spongy bone.
4. Give several examples of how bones support and protect body parts.
5. List and describe other functions of bones.
6. Explain how the development of intramembranous bone differs from that of endochondral bone.
7. _________ are mature bone cells, whereas _________ are bone-forming cells, and _________ are bone-resorbing cells.
8. Explain the function of an epiphyseal plate.
9. Physical exercise pulling on muscular attachments to bones stimulates _________.
10. Bones of the head, neck, and trunk compose the _________ skeleton; bones of the limbs and their attachments compose the _________ skeleton.
11. Name the bones of the cranium and the facial skeleton.
12. Describe a typical vertebra, and distinguish among the cervical, thoracic, and lumbar vertebrae.
13. Name the bones that compose the thoracic cage.
14. The clavicle and scapula form the _________ girdle, whereas the hip bones form the _________ girdle.
15. Name the bones of the upper and lower limbs.
16. Describe and give an example of a fibrous joint, a cartilaginous joint, and a synovial joint.
17. Name an example of each type of synovial joint, and describe the parts of the joint as they relate to the movement(s) allowed by that particular joint.
18. Joint movements occur when a muscle contracts and the muscle fibers pull the muscle's movable end of attachment to the bone, the _________, toward its fixed end, the _________.

Critical Thinking and Clinical Connection

1. How does the structure of a bone make it strong yet lightweight?
2. **Clinical Connection** How would you explain to an athlete why damaged joint ligaments and cartilages are so slow to heal following an injury?
3. **Writing Connection** Vitamin D is converted to the hormone calcitriol by three body organs: the skin, liver, and kidneys. Calcitriol enhances the absorption of calcium in the small intestine and acts to prevent the elimination of calcium in urine. Which hormone does calcitriol work with to raise blood calcium? Explain.
4. When a child's bone is fractured, growth may be stimulated at the epiphyseal plate of that bone. What problems might this extra growth cause in an upper or lower limb before the growth of the other limb compensates for the difference in length?
5. Suppose archaeologists discover human skeletal remains. Examination of the bones suggests that the remains represent four individuals. Two of the skeletons have a broad pubic bone and a pelvis with a wide pubic arch. Within the two groups defined by pelvic differences, smaller skeletons have bones with evidence of epiphyseal plates, but larger bones have only a thin line where the epiphyseal plates should be. Give the age group and sex of the four individuals in the find.

Data Analysis: Exercise and Bone Health

Bone density is an important measure of bone health. Bone density decreases as humans age, increasing the risk of fractures. Getting enough calcium and vitamin D helps prevent loss of bone density. So does performing weight bearing exercises. Scientists collected data on 25 healthy men between the ages of 23 to 32 years old and divided them into three groups: runners, runners who perform resistance training, and a control group that exercised less than 1 hour per week. Examples of resistance training include lifting weights or using bands that increase resistance when stretched. The scientists measured the bone density of several bones in the bodies of the participants, including in the lumbar spine, and the three places in the femur.

Data and Observations

Figure A shows the results of the study. The bones tested are on the x-axis and bone density in g/cm^2 is on the y-axis.

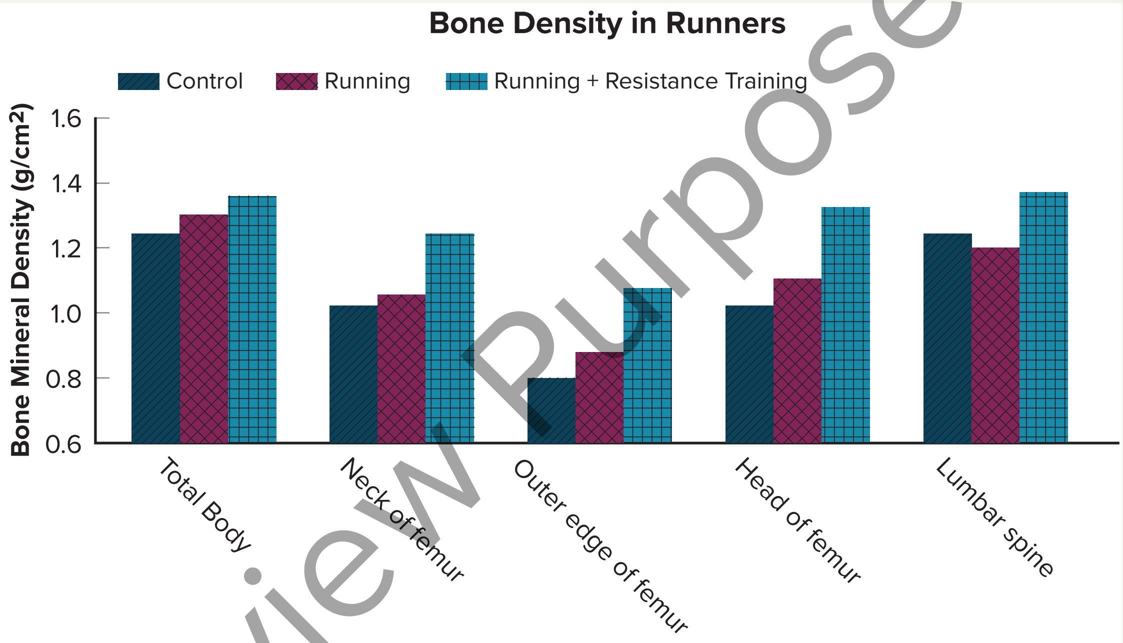


Figure A Bone mineral density in runners.

Data obtained from: Duplanty, A. A., Levitt, D.E., Hill, D.W., McFarlin, B.K., DiMarco, N.M., &Vingren, J.L. 2018. Resistance training is associated with higher bone mineral density among young adult male distance runners independent of physiological factors. Journal of Strength and Conditioning Research, 32(6).

Think Critically

1. Summarize the results of the study. Which group had the highest levels of bone density?
2. Suppose you are a healthcare professional. What would you recommend to patients asking about the best exercises for bone health?
3. The participants in this study were men between the ages of 23 and 32 who ran up to 32 kilometers per week. How does this limit the results of the study?

Chapter 7 Wrap-up

GO ONLINE to access your chapter and unit projects.

Explain the Phenomenon: Forensic Anthropology

Recall the phenomenon at the beginning of this chapter. You read about forensic anthropology. Throughout the chapter, you read about the structure and function of the skeletal system. Now it is time to revisit your claim, summarize your evidence, and analyze what you have learned.

CER Claim, Evidence, Reasoning

Revisit Your Claim: Review your CER chart where you recorded your claim about bones and forensic anthropology.

Summarize Your Evidence: Summarize the evidence you gathered from your investigations, and research and finalize your summary table.

Explain Your Reasoning: Does your evidence support your claim? Explain why your evidence supports your claim, and if it does not, revise your claim.

Adam Gault/OJO Images/Getty Images

CER Explain Your Reasoning: What are the characteristics of bones that make them valuable to forensic anthropology?

Extend the Phenomenon: Chapter Project

When Bones Break Down: An Inquiry into Bone Diseases

As you learned in this chapter, the skeletal system provides many different functions for the human body including critical structure and blood-cell formation. When something goes wrong with the skeletal system, development, growth, and/or repair mechanisms may be affected.

While this chapter mentioned a few bone diseases, such as osteopenia and osteoporosis, which are two of the most common, many more bone diseases exist. Bone diseases are often painful and debilitating disorders. Some bone diseases affect only the movement of joints. Some bone diseases interfere with the ossification process, and others affect the formation of blood cells.

You will:

- Be assigned, or choose, a bone disease to research.
- Take thorough notes on how and why the bone disease forms, how it is diagnosed, and how it is treated.
- Make a short presentation about the disease.
- Present your findings to your class.

Connect to the Unit Project

Essential Question: How does a prosthetic limb provide support and movement for the body?

Recall the unit's essential question. Consider how the prosthetic is modelling the functions of the integumentary system. Think about the connections between the functions of a prosthetic limb and the function of the integumentary system and how might be related. Record your ideas and connections from the chapter in your notebook.

GO ONLINE to access your chapter and unit projects.

Human Skull

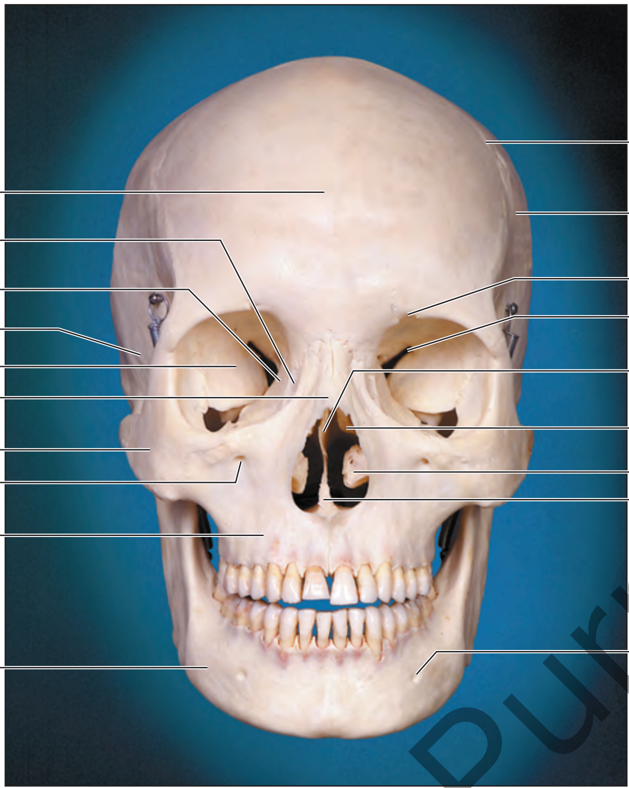


PLATE 8 The skull, anterior view.

PLATE 9 The skull, inferior view.

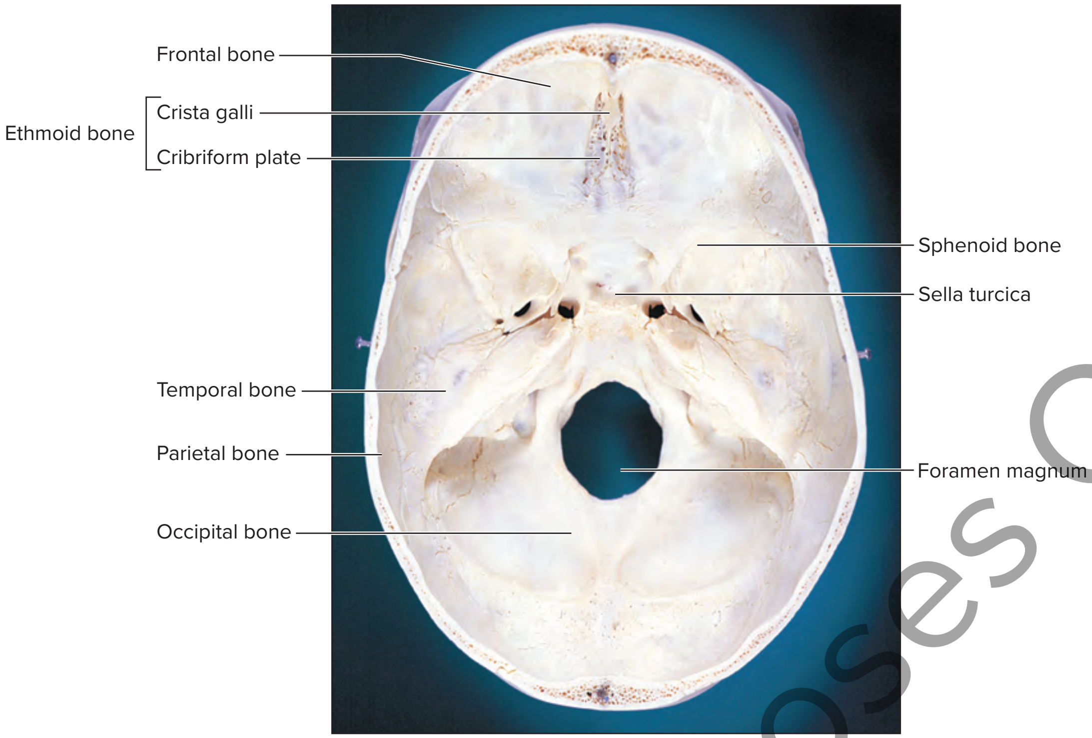


PLATE 10 The skull, floor of the cranial cavity.

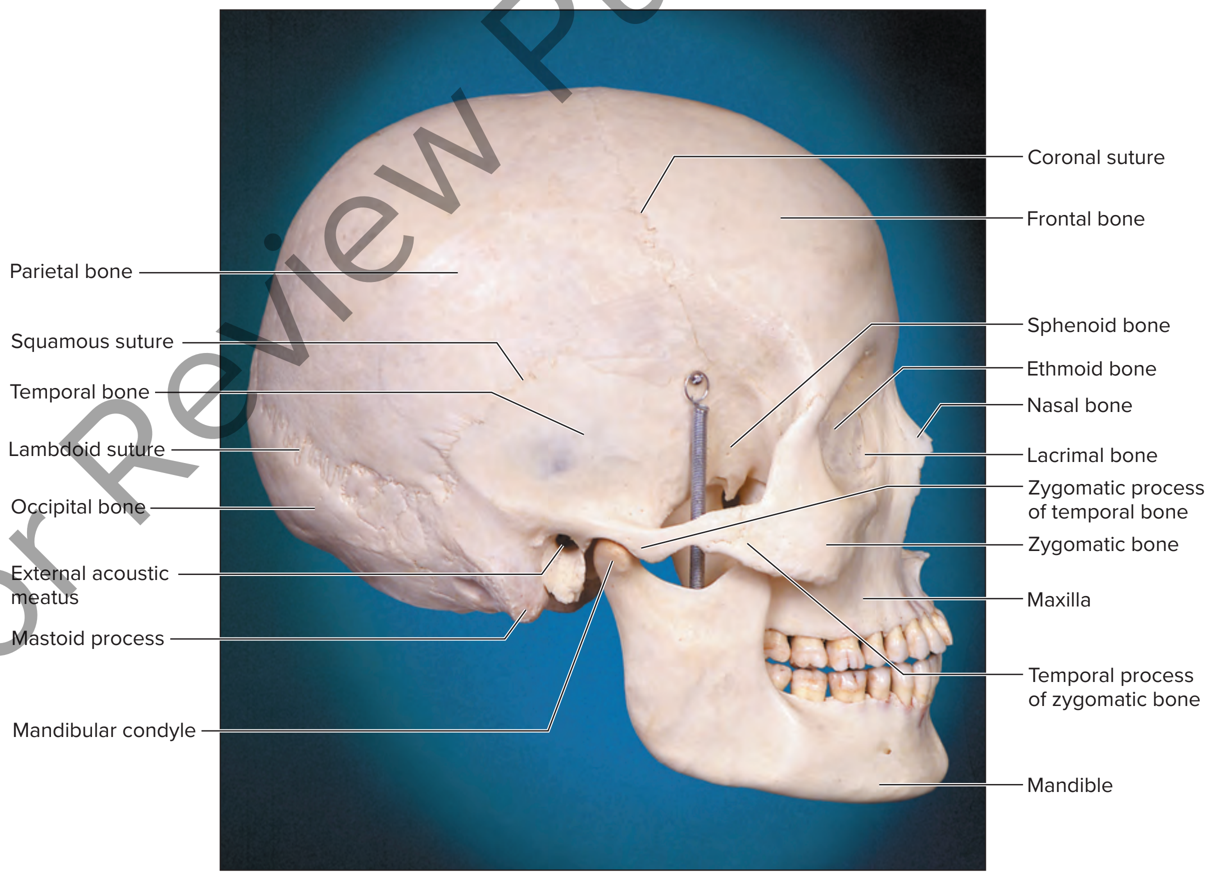


PLATE 11 The skull, right lateral view.