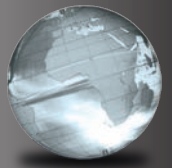


MAIN VERSION

GLOBAL
EDITION



Human Anatomy & Physiology Laboratory Manual

TWELFTH EDITION

Elaine N. Marieb
Lori A. Smith



Anatomy and Physiology

Laboratory Safety Guidelines*

1. Upon entering the laboratory, locate exits, fire extinguisher, fire blanket, chemical shower, eyewash station, first aid kit, containers for broken glass, and materials for cleaning up spills.
2. Do not eat, drink, smoke, handle contact lenses, store food, or apply cosmetics or lip balm in the laboratory. Restrain long hair, loose clothing, and dangling jewelry.
3. Students who are pregnant, are taking immunosuppressive drugs, or have any other medical conditions (e.g., diabetes, immunological defect) that might necessitate special precautions in the laboratory must inform the instructor immediately.
4. Wearing contact lenses in the laboratory is inadvisable because they do not provide eye protection and may trap material on the surface of the eye. Soft contact lenses may absorb volatile chemicals. If possible, wear regular eyeglasses instead.
5. Use safety glasses in all experiments involving liquids, aerosols, vapors, and gases.
6. Decontaminate work surfaces at the beginning and end of every lab period, using a commercially prepared disinfectant or 10% bleach solution. After labs involving dissection of preserved material, use hot soapy water or disinfectant.
7. Keep all liquids away from the edge of the lab bench to avoid spills. Clean up spills of viable materials using disinfectant or 10% bleach solution.
8. Properly label glassware and slides.
9. Use mechanical pipetting devices; mouth pipetting is prohibited.
10. Wear disposable gloves when handling blood and other body fluids, mucous membranes, and nonintact skin, and when touching items or surfaces soiled with blood or other body fluids. Change gloves between procedures. Wash hands immediately after removing gloves. (**Note:** Cover open cuts or scrapes with a sterile bandage before donning gloves.)
11. Place glassware and plasticware contaminated by blood and other body fluids in a disposable autoclave bag for decontamination by autoclaving, or place them directly into a 10% bleach solution before reuse or disposal. Place disposable materials such as gloves, mouthpieces, swabs, and toothpicks that have come into contact with body fluids into a disposable autoclave bag, and decontaminate before disposal.
12. To help prevent contamination by needlestick injuries, use only disposable needles and lancets. Do not bend the needles and lancets. Needles and lancets should be placed promptly in a labeled, puncture-resistant, leakproof container and decontaminated, preferably by autoclaving.
13. Do not leave heat sources unattended.
14. Report all spills or accidents, no matter how minor, to the instructor.
15. Never work alone in the laboratory.
16. Remove protective clothing before leaving the laboratory.

*Adapted from:

Biosafety in Microbiological and Biomedical Laboratories (BMBL), Fifth Edition. 2007. U.S. Government Printing Office. Washington, D.C. www.cdc.gov/od/OHS/biosfty/bmb15/bmb15toc.htm

Centers for Disease Control. 1996. "Universal Precautions for Prevention of Transmission of HIV and Other Bloodborne Infections." Washington, D.C. www.cdc.gov/ncidod/dhqp/bp_universal_precautions.html

Johnson, Ted, and Christine Case. 2010. *Laboratory Experiments in Microbiology*, Ninth Edition. San Francisco: Pearson Benjamin Cummings.

School Chemistry Laboratory Safety Guide. 2006. U.S. Consumer Product Safety Commission. Bethesda, MD. www.cpsc.gov/CPSPUB/PUBS/NIOSH2007107.pdf

Your time is valuable. Make the most of your time *inside and outside* the lab.

To help you manage your time inside and outside the A&P lab classroom, this best-selling manual works hand-in-hand with **Mastering A&P**, the leading online homework and learning program for A&P. This edition features dozens of new, full-color figures and photos, revamped Clinical Application questions, an expanded set of pre-lab videos, dissection videos, and more.

9 The Axial Skeleton

EXERCISE

Learning Outcomes

- ▶ Name the three parts of the axial skeleton.
- ▶ Identify the bones of the axial skeleton, either by examining disarticulated bones or by pointing them out on an articulated skeleton or skull, and name the important bone markings on each.
- ▶ Name and describe the different types of vertebrae.
- ▶ Discuss the importance of intervertebral discs and spinal curvatures.
- ▶ Identify three abnormal spinal curvatures.
- ▶ List the components of the thoracic cage.
- ▶ Identify the bones of the fetal skull by examining an articulated skull or image.
- ▶ Define *fontanelle*, and discuss the function and fate of fontanelles.
- ▶ Discuss important differences between the fetal and adult skulls.

Pre-Lab Quiz

Instructors may assign these and other Pre-Lab Quiz questions using **Mastering A&P™**

- The axial skeleton can be divided into the skull, the vertebral column, and the:
a. thoracic cage c. hip bones
b. femur d. humerus
- The _____ bone allows the passage of the optic and trigeminal nerves.
a. occipital b. temporal c. sphenoid
- The _____ vertebrae contribute to the formation of the pelvis.
a. lumbar b. sacral c. coccygeal
- The _____, commonly referred to as the breastbone, is a flat bone formed by the fusion of three bones: the manubrium, the body, and the xiphoid process.
a. coccyx b. sacrum c. sternum
- The sagittal suture:
a. is between the two parietal bones
b. is between the frontal and temporal bones
c. is between the parietal and temporal bones
d. is between the occipital and parietal bones

Go to Mastering A&P™ > Study Area to improve your performance in A&P Lab.



> Lab Tools > Bone & Dissection Videos

Instructors may assign new Building Vocabulary coaching activities, Pre-Lab Quiz questions, Art Labeling activities, related bone videos and coaching activities, Practice Anatomy Lab Practical questions (PAL), and more using the **Mastering A&P™** Item Library.

Materials

- ▶ Intact skull and Beauchene skull
- ▶ X-ray images of individuals with scoliosis, lordosis, and kyphosis (if available)
- ▶ Articulated skeleton, articulated vertebral column, removable intervertebral discs
- ▶ Isolated cervical, thoracic, and lumbar vertebrae, sacrum, and coccyx
- ▶ Isolated fetal skull

The **axial skeleton** (the green portion of Figure 8.1 on p. 122) can be divided into three parts: the skull, the vertebral column, and the thoracic cage. This division of the skeleton forms the longitudinal axis of the body and protects the brain, spinal cord, heart, and lungs.

133

NEW! Mastering A&P study tools are highlighted on the first page of each lab exercise, along with a photo preview of a related pre-lab video, image from Practice Anatomy Lab 3.1 (PAL), or animation.

NEW! Mastering A&P assignments, including NEW Building Vocabulary Coaching Activities, are signaled at appropriate points throughout the manual to help you connect the exercises to relevant assignments that can be auto-graded in Mastering A&P.

Be Prepared: Learning in A&P Lab is an Active Process.

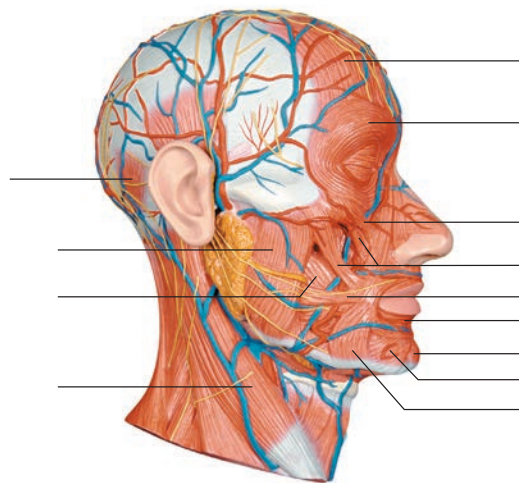
Before going into the lab, read the **background information** for the exercise, connect your reading to the figures and photos, complete the **pre-lab quiz**, and preview the questions in the tear-out **Exercise Review Sheet**. After lab, review your lab notes to remember important concepts. To improve your performance on lab practical exams, log into **Mastering A&P**, where you can watch related videos, practice with customized flashcards, and more.

NEW! Dozens of full-color figures and photos have been added to the Exercise Review Sheets, replacing black-and-white line drawings. Selected labeling questions are available as **new Art-Labeling assignments in Mastering A&P**.

See p. 242

Muscles of the Head and Neck

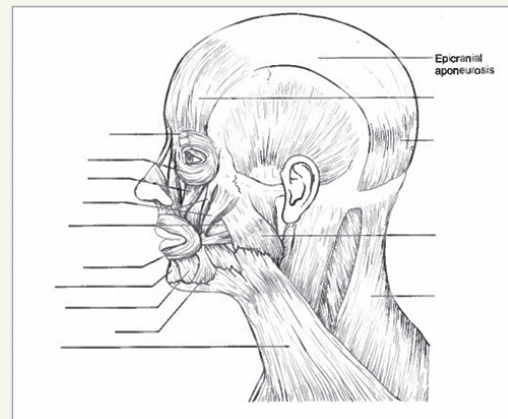
3. Using choices from the key at the right, correctly identify muscles provided with leader lines on the illustration.



Key:

- a. buccinator
- b. depressor anguli oris
- c. depressor labii inferioris
- d. frontal belly of the epicraniius
- e. levator labii inferioris
- f. masseter
- g. mentalis
- h. occipital belly of the epicraniius
- i. orbicularis oculi
- j. orbicularis oris
- k. risorius
- l. sternocleidomastoid
- m. zygomaticus minor and major

Compare to Previous Edition



NEW! Clinical Application Questions have been added to the Exercise Review Sheets to help you connect lab concepts with real-world clinical scenarios.

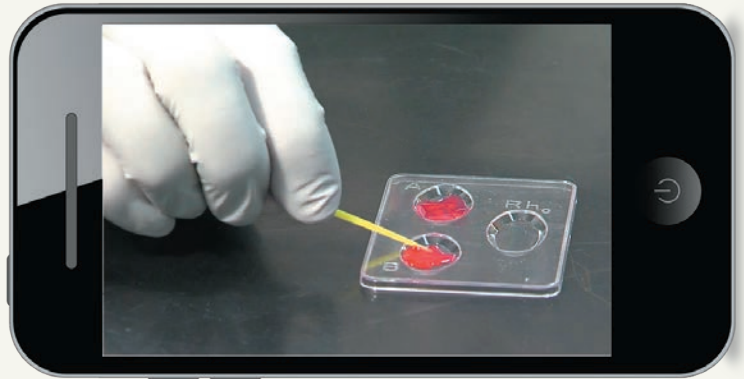
27.  As we age, we often become shorter. Explain why this might occur.

See p. 159

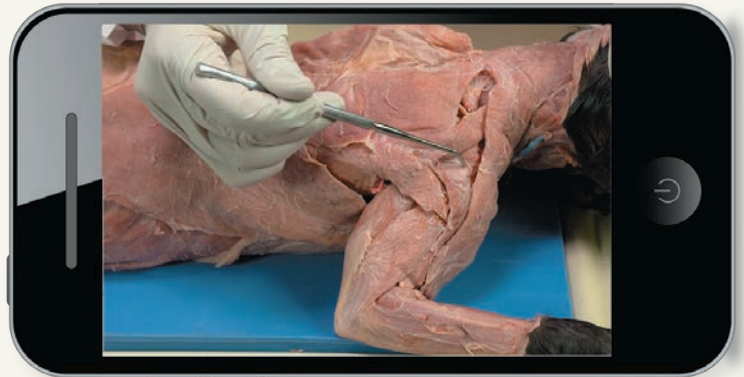
NEW! Building Vocabulary Coaching Activities are a fun way to learn word roots and A&P terminology while building and practicing important language skills.

Get 24/7 videos, coaching, and practice with **Mastering A&P.**

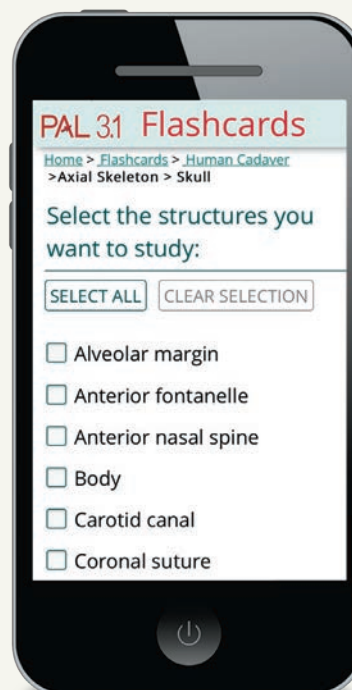
EXPANDED! 8 new Pre-Lab Video Coaching Activities in Mastering A&P (for a total of 18) focus on key concepts in the lab activity and walk you through important procedures. New pre-lab video topics include Preparing and Observing a Wet Mount, Examining a Long Bone, Initiating Pupillary Reflexes, Palpating Superficial Pulse Points, Auscultating Heart Sounds, and more.



NEW! Cat and Fetal Pig Dissection Video Coaching Activities help you prepare for dissection by previewing key anatomical structures. Each video includes one to two comparisons to human structures.



NEW! Customizable Practice Anatomy Lab (PAL) Flashcards allow you to create a personalized, mobile-friendly deck of flashcards and quizzes using images from PAL 3.1. You can generate flashcards using only the structures that your instructor has emphasized in lecture or lab.



IMPROVED! The Pearson eText mobile app allows you to access the complete lab manual online or offline, along with all of the videos described above.

Additional Support for Students & Instructors

Mastering A&P offers thousands of tutorials, activities, and questions that can be assigned for homework and practice. Highlights of popular assignment options include the following:

PhysioEx™ 10.0 is an easy-to-use lab simulation program that consists of 12 exercises containing 63 physiology lab activities that can be used to supplement or substitute for wet labs.

IMPROVED! Practice Anatomy Lab 3.1 is now accessible on all mobile devices to give students 24/7 access to the most widely used lab specimens, including human cadaver, anatomical models, histology slides, cat, and fetal pig.

Dynamic Study Modules are manageable, mobile-friendly sets of questions with extensive feedback for students to test, learn, and retest until they master basic concepts.

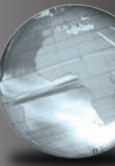
- **NEW!** Instructors can select or deselect specific questions to customize assignments.
- **EXPANDED!** The Lab Manual Mastering A&P course now offers over 3,000 Dynamic Study Module questions, shared with Marieb/Hoehn's *Human Anatomy & Physiology, 12th Edition, Global Edition*.

The **Mastering A&P Instructor Resources Area** includes the following downloadable tools:

- **Customizable PowerPoint® lecture outlines** include customizable images and provide a springboard for lab prep.
 - **All of the figures, photos, and tables from the manual** are available in JPEG and PowerPoint® formats, in labeled and unlabeled versions, and with customizable labels and leader lines.
 - **Test bank** provides thousands of customizable questions across Bloom's taxonomy levels and includes all lab practical and quiz questions from Practice Anatomy Lab 3.1. Each question is tagged to chapter learning outcomes that can also be tracked within Mastering A&P assessments. Available in Microsoft® Word and TestGen® formats.
 - **Animations and videos** bring A&P concepts to life and include pre-lab videos, bone videos, and dissection videos.
 - **A comprehensive Instructor's Guide**, co-authored by Elaine Marieb and Lori Smith, includes prep instructions for each exercise, along with answer keys for all of the Exercise Review Sheets.
-

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Human Anatomy & Physiology Laboratory Manual

TWELFTH EDITION

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About the Authors



Elaine N. Marieb

After receiving her Ph.D. in zoology from the University of Massachusetts at Amherst, Elaine N. Marieb joined the faculty of the Biological Science Division of Holyoke Community College. While teaching at Holyoke Community College, where many of her students were pursuing nursing degrees, she developed a desire to better understand the relationship between the scientific study of the human body and the clinical aspects of the nursing practice. To that end, while continuing to teach full time, Dr. Marieb pursued her nursing education, which culminated in a Master of Science degree with a clinical specialization in gerontology from the University of Massachusetts. It was this experience that informed the development of the unique perspective and accessibility for which her publications are known.

Dr. Marieb gave generously to provide opportunities for students to further their education. She funded the E. N. Marieb Science Research Awards at Mount Holyoke College, which promotes research by undergraduate science majors, and underwrote renovation of the biology labs in Clapp Laboratory at that college. Dr. Marieb also contributed to the University of Massachusetts at Amherst, where she provided funding for reconstruction and instrumentation of a cutting-edge cytology research laboratory. Recognizing the severe national shortage of nursing faculty, she underwrote the Nursing Scholars of the Future Grant Program at the university.

In 2012 and 2017, Dr. Marieb gave generous philanthropic support to Florida Gulf Coast University as a long-term investment in education, research, and training for healthcare and human services professionals in the local community. In honor of her contributions, the university is now home to the Elaine Nicpon Marieb College of Health and Human Services.



Lori A. Smith

Lori A. Smith received her Ph.D. in biochemistry from the University of California at Davis. Before discovering her passion for teaching, she worked as a research scientist and project leader in the medical diagnostics industry. In 1999, she joined the faculty at American River College in the Biology Department, where she teaches anatomy and physiology and microbiology to students preparing for nursing or other allied health careers. Since 2005, she has coauthored Pearson's PhysioEx™: Laboratory Simulations in Physiology and has continued to coauthor several Pearson lab manuals. Dr. Smith has been named Instructor of the Year by the American River College Associated Student Body, and she is a member of the Human Anatomy and Physiology Society (HAPS) and California Academy of Sciences. When not teaching or writing, she enjoys spending time with her family: hiking, cycling, and kayaking.

Preface to the Instructor

The philosophy behind the revision of this manual mirrors that of all earlier editions. It reflects a still developing sensibility for the way teachers teach and students learn, informed by years of teaching the subject and by collecting suggestions from other instructors as well as from students enrolled in multifaceted healthcare programs. *Human Anatomy & Physiology Laboratory Manual* was originally developed to facilitate and enrich the laboratory experience for both teachers and students. This edition retains those same goals.

This manual, intended for students in introductory human anatomy and physiology courses, presents a wide range of laboratory experiences for students concentrating in nursing, physical therapy, pharmacology, respiratory therapy, and exercise science, as well as biology and premedical programs. The manual's coverage is intentionally broad, allowing it to serve both one- and two-semester courses, and it is also available in versions that contain detailed guidelines for dissecting a cat or fetal pig laboratory specimen.

Basic Approach and Features

The generous variety of experiments in this manual provides flexibility that enables instructors to gear their laboratory approach to specific academic programs or to their own teaching preferences. The manual remains independent of any textbook, so it contains the background discussions and terminology necessary to perform all experiments. Such a self-contained learning aid eliminates the need for students to bring a textbook into the laboratory.

Each of the 46 exercises leads students toward a coherent understanding of the structure and function of the human body. The manual begins with anatomical terminology and an orientation to the body, which together provide the necessary tools for studying the various body systems. The exercises that follow reflect the dual focus of the manual—both anatomical and physiological aspects receive considerable attention. As the various organ systems of the body are introduced, the initial exercises focus on organization, from the cellular to the organ system level. As indicated by the table of contents, the anatomical exercises are usually followed by physiological experiments that familiarize students with various aspects of body functioning and promote the critical understanding that function follows structure. The numerous physiological experiments for each organ system range from simple experiments that can be performed without specialized tools to more complex experiments using laboratory equipment, computers, and instrumentation techniques.

Features



The dissection scissors icon appears at the beginning of activities that entail the dissection of isolated animal organs. In addition to the figures, isolated animal organs, such as the sheep heart and pig kidney, are employed to study anatomy because of their exceptional similarity to human organs.



Homeostasis is continually emphasized as a requirement for optimal health. Pathological conditions

are viewed as a loss of homeostasis; these discussions can be recognized by the homeostatic imbalance logo within the descriptive material of each exercise. This holistic approach encourages an integrated understanding of the human body. The homeostatic imbalance icon directs the student's attention to conditions representing a loss of homeostasis.



A safety icon notifies students that specific safety precautions must be observed when using certain equipment or conducting particular lab procedures. For example, when working with ether, students are to use a hood; and when handling body fluids such as blood, urine, or saliva, students are to wear gloves. All exercises involving body fluids (blood, urine, saliva) incorporate current Centers for Disease Control and Prevention (CDC) guidelines for handling human body fluids. Because it is important that nursing students in particular learn how to safely handle bloodstained articles, the manual has retained the option to use human blood in the laboratory. However, the decision to allow testing of human (student) blood or to use animal blood in the laboratory is left to the discretion of the instructor in accordance with institutional guidelines. The CDC guidelines for handling body fluids are reinforced by the laboratory safety procedures described on the inside front cover of this text, in Exercise 29: Blood, and in the *Instructor's Guide*. You can photocopy the inside front cover and post it in the lab to help students become well versed in laboratory safety.



Group Challenge activities are designed to enhance collaborative group learning and to challenge students to think critically, identify relationships between anatomical structures and physiological functions, and achieve a deeper understanding of anatomy and physiology concepts.



The BIOPAC® icon in a relevant exercise materials list signals the use of the BIOPAC® Student Lab System and alerts you to the equipment needed. BIOPAC® is used in Exercises 14, 18, 20, 21, 31, 33, 34, and 37. The instructions in the lab manual are for use with the BIOPAC® MP36/35 and MP45 data acquisition unit. Note that some exercises are not compatible with the MP45 data acquisition unit. For those exercises, the MP45 will not be listed in the Materials section. In this edition, the lab manual instructions are for use with BSL software 4.0.1 and above for Windows 10/8.x/7 or Mac OS X10.9–10.12. Refer to the Materials section in each exercise for the applicable software version. The Instructor Resources area of Mastering A&P provides the following additional support for alternative data acquisitions systems, including exercises that can be distributed to students:

- *BIOPAC® Instructions for the MP36 (or MP35/30) data acquisition unit* using BSL software versions earlier than 4.0.1 (for Windows and Mac) for Exercises 14, 18, 20, 21, 31, and 34
- *Powerlab® Instructions* for Exercises 14, 21, 31, 33, 34, and 37
- *iWorx® Instructions* for Exercises 14, 18, 21, 31, 33, 34, and 37
- *Intelitool® Instructions* for Exercises 14i, 21i, 31i, and 37i

- **Exercise Review Sheets** follow each laboratory exercise and provide space for recording and interpreting experimental results and require students to label diagrams and answer matching and short-answer questions. Selected questions can be assigned and automatically graded in Mastering A&P.
- **PhysioEx™ 10.0 Exercises**, located in the back of the lab manual and accessible through a subscription to Mastering A&P, are easy-to-use computer simulations that supplement or take the place of traditional wet labs safely and cost-effectively. These 12 exercises contain a total of 63 physiology laboratory activities that allow learners to change variables and test out various hypotheses for the experiments. PhysioEx™ allows students to repeat labs as often as they like, perform experiments without harming live animals, and conduct experiments that are difficult to perform because of time, cost, or safety concerns.

Updated Content in This Edition of the Lab Manual

Throughout the manual, the narrative text has been streamlined and updated to make the language more understandable and to better meet the needs of today's students. Additional highlights include the following:

- **Dozens of new full-color figures and photos** replace black-and-white line drawings in the Exercise Review Sheets. Selected labeling questions in the manual can be assigned in Mastering A&P.
- **New Clinical Application questions** have been added to the Exercise Review Sheets and challenge students to apply lab concepts and critical-thinking skills to real-world clinical scenarios.
- **Updated BIOPAC® procedures** are included in the manual for eight lab exercises for the BIOPAC® 4.0 software upgrade. Procedures for Intelitool®, PowerLab®, and iWorx® remain available in the Instructor Resources area of Mastering A&P.
- **New Mastering A&P visual previews** appear on the first page of each lab exercise, highlighting a recommended pre-lab video, a related image from Practice Anatomy Lab 3.1 (PAL 3.1), or a helpful animation.
- **New Mastering A&P assignment recommendations** are signaled at appropriate points throughout the manual to help instructors assign related auto-graded activities and assessments.
- **Extensive updates and improvements** have been made to each of the 46 laboratory exercises in the manual to increase clarity and reduce ambiguity for students. Art within the exercises, the narrative, as well as the questions and figures within the Review Sheets have been updated. For a complete list of content updates, please refer to the *Instructor's Guide for Human Anatomy & Physiology Laboratory Manual 13/e* (in the Instructor Resources area of Mastering A&P).

Highlights of Updated Content in Mastering A&P

Mastering A&P, the leading online homework, tutorial, and assessment system is designed to engage students and improve results by helping them stay on track in the course and quickly

master challenging anatomy and physiology concepts. Mastering A&P assignments support interactive features in the lab manual, including pre-lab video coaching activities; bone, muscle, and dissection videos; Dynamic Study Modules; *Get Ready for A&P*; plus a variety of Art Labeling questions, Clinical Application questions, and more. Highlights for this edition include the following:

- **8 new Pre-Lab Video Coaching Activities in Mastering A&P** (for a total of 18) focus on key concepts in the lab activity and walk students through important procedures. New pre-lab video titles include Preparing and Observing a Wet Mount, Examining a Long Bone, Initiating Pupillary Reflexes, Palpating Superficial Pulse Points, Auscultating Heart Sounds, and more.
- **New Cat and Fetal Pig Dissection Video Coaching Activities** help students prepare for dissection by previewing key anatomical structures. Each video includes one to two comparisons to human structures.
- **IMPROVED! Practice Anatomy Lab™ (PAL™ 3.1) is now fully accessible on all mobile devices**, including smartphones, tablets, and laptops. PAL is an indispensable virtual anatomy study and practice tool that gives students 24/7 access to the most widely used lab specimens, including human cadaver; anatomical models from leading manufacturers such as 3B Scientific, SOMSO, Denoyer-Geppert, Frey Scientific/Nystrom, Altay Scientific, and Ward's; histology; cat; and fetal pig. PAL 3.1 is easy to use and includes built-in audio pronunciations, rotatable bones, and simulated fill-in-the-blank lab practical exams.
- **New Customizable Practice Anatomy Lab (PAL) Flashcards** enable students to create a personalized, mobile-friendly deck of flashcards and quizzes using images from PAL 3.1. Students can generate flashcards using only the structures that their instructor emphasizes in lecture or lab.
- **New Building Vocabulary Coaching Activities** are a fun way for students to learn word roots and A&P terminology while building and practicing important language skills.
- **Expanded Dynamic Study Modules** help students study effectively on their own by continuously assessing their activity and performance in real time. Students complete a set of questions and indicate their level of confidence in their answer. Questions repeat until the student can answer them all correctly and confidently. These are available as graded assignments prior to class and are accessible on smartphones, tablets, and computers.
 - The Lab Manual Mastering A&P course now offers over 3000 Dynamic Study Module questions, shared with Marieb/Hoehn's *Human Anatomy & Physiology*, 12th Edition, Global Edition.
 - Instructors can now remove questions from Dynamic Study Modules to better fit their course.
- **Expanded Drag-and-Drop Art Labeling Questions** allow students to assess their knowledge of terms and structures in the lab manual. Selected Exercise Review Sheet labeling activities in the manual are now assignable.

Acknowledgments

Continued thanks to our colleagues and friends at Pearson who collaborated with us on this edition, especially Editor-in-Chief Serina Beauparlant, Acquisitions Editor Lauren Harp, Editorial Assistant Dapinder Dosanjh, and Rich Content Media Producers Kimberly Twardochleb and Lauren Chen. We also thank the Pearson Sales and Marketing team for their work in supporting instructors and students, especially Senior A&P Specialist Derek Perrigo and Director of Product Marketing Allison Rona.

Special thanks go out to Amanda Kaufmann for her leadership and expertise in producing the 18 pre-lab videos that support this edition, and to Mike Mullins of BIOPAC®, who helped us update the instructions for consistency with the upgraded software.

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Elaine N. Marieb & Lori A. Smith

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Credits C-1

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1 EXERCISE

The Language of Anatomy

Learning Outcomes

- ▶ Describe the anatomical position, and explain its importance.
- ▶ Use proper anatomical terminology to describe body regions, orientation and direction, and body planes.
- ▶ Name the body cavities, and indicate the important organs in each.
- ▶ Name and describe the serous membranes of the ventral body cavities.
- ▶ Identify the abdominopelvic quadrants and regions on a torso model or image.

Pre-Lab Quiz



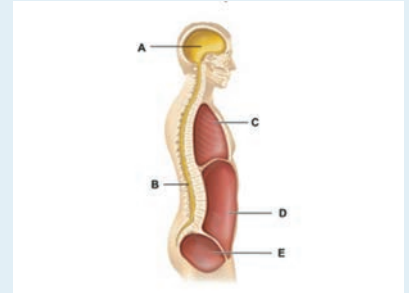
Instructors may assign these and other Pre-Lab Quiz questions using **Mastering A&P™**

1. Circle True or False. In anatomical position, the fists are clenched.
2. Circle the correct underlined term. With regard to surface anatomy, abdominal / axial refers to the structures along the center line of the body.
3. The term *superficial* refers to a structure that is:
 - a. attached near the trunk of the body
 - b. toward or at the body surface
 - c. toward the head
 - d. toward the midline
4. The _____ plane runs longitudinally and divides the body into right and left sides.
 - a. frontal
 - b. sagittal
 - c. transverse
 - d. ventral
5. Circle the correct underlined terms. The ventral body cavity is made up of three / four smaller cavities. Each of these cavities is lined by a thin, fluid-secreting membrane called a serous / visceral membrane.

A student new to any science is often overwhelmed at first by the terminology used in that subject. The study of anatomy is no exception. But without specialized terminology, confusion is inevitable. For example, what do *over*, *on top of*, *above*, and *behind* mean in reference to the human body? Anatomists have an accepted set of reference terms that are universally understood. These allow body structures to be located and identified precisely with a minimum of words.

This exercise presents some of the most important anatomical terminology used to describe the body and introduces you to basic concepts of **gross anatomy**, the study of body structures visible to the naked eye.

Go to **Mastering A&P™** > Study Area to improve your performance in A&P Lab.



Instructors may assign new Building Vocabulary coaching activities, Pre-Lab Quiz questions, Art Labeling activities, and more using the **Mastering A&P™** Item Library.

Materials

- ▶ Human torso model (dissectible)
- ▶ Human skeleton
- ▶ Demonstration: sectioned and labeled kidneys (three separate kidneys uncut or cut so that [a] entire, [b] transverse sectional, and [c] longitudinal sectional views are visible)
- ▶ Gelatin-spaghetti molds
- ▶ Scalpel

Anatomical Position

When anatomists or doctors refer to specific areas of the human body, the picture they keep in mind is a universally accepted standard position called the **anatomical position**. In the anatomical position, the human body is erect, with the feet only slightly apart, head and toes pointed forward, and arms hanging at the sides with palms facing forward (Figure 1.1a). It is also

important to remember that “left” and “right” refer to the sides of the individual, not the observer.

Assume the anatomical position. The hands are held unnaturally forward rather than hanging with palms toward the thighs.

Check the box when you have completed this task.

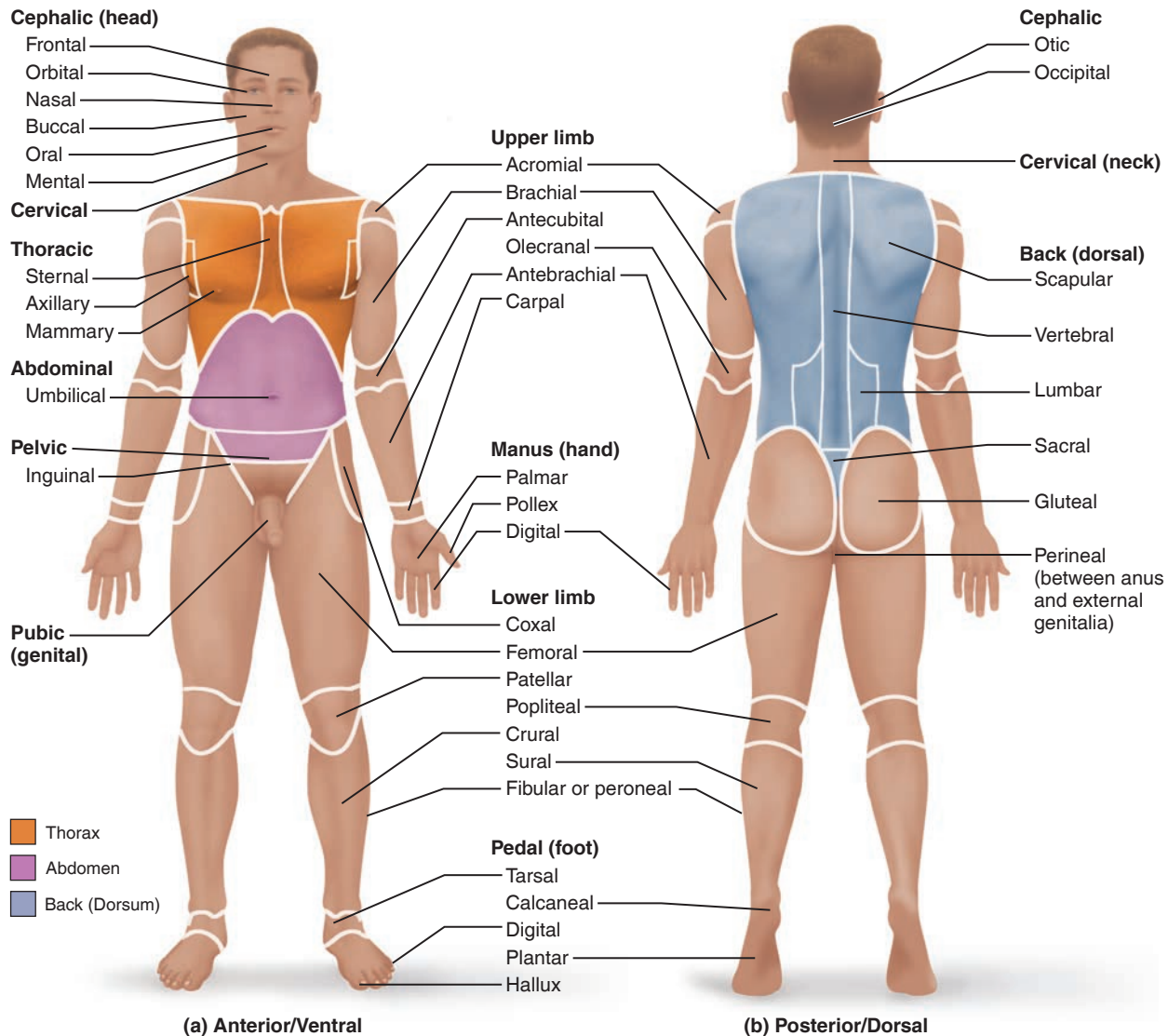


Figure 1.1 Anatomical position and regional terms. Heels are raised to illustrate the plantar surface of the foot, which is actually on the inferior surface of the body.



Instructors may assign this figure as an Art Labeling Activity using **Mastering A&P™**

Regional Anatomy

The body is divided into two main regions, the axial and appendicular regions. The **axial region** includes the head, neck, and trunk; it runs along the vertical axis of the body. The **appendicular region** includes the limbs, which are also

called the appendages or extremities. The body is also divided up into smaller regions within those two main divisions. **Table 1.1** summarizes the body regions that are illustrated in Figure 1.1.

Table 1.1 Regions of the Human Body (Figure 1.1)

Region	Description	Region	Description
Abdominal	Located below the ribs and above the hips	Nasal	Nose
Acromial	Point of the shoulder	Occipital	Back of the head
Antebrachial	Forearm	Olecranal	Back of the elbow
Antecubital	Anterior surface of the elbow	Oral	Mouth
Axillary	Armpit	Orbital	Bony eye socket
Brachial	Arm (upper portion of the upper limb)	Otic	Ear
Buccal	Cheek	Palmar	Palm of the hand
Calcaneal	Heel of the foot	Patellar	Kneecap
Carpal	Wrist	Pedal	Foot
Cephalic	Head	Pelvic	Pelvis
Cervical	Neck	Perineal	Between the anus and the external genitalia
Coxal	Hip	Plantar	Sole of the foot
Crural	Leg	Pollex	Thumb
Digital	Fingers or toes	Popliteal	Back of the knee
Femoral	Thigh	Pubic	Genital
Fibular (peroneal)	Side of the leg	Sacral	Posterior region between the hip bones
Frontal	Forehead	Scapular	Shoulder blade
Gluteal	Buttocks	Sternal	Breastbone
Hallux	Great toe	Sural	Calf
Inguinal	Groin	Tarsal	Ankle
Lumbar	Lower back	Thoracic	Chest
Mammary	Breast	Umbilical	Navel
Manus	Hand	Vertebral	Spine
Mental	Chin		

Activity 1

Locating Body Regions

Locate the anterior and posterior body regions on yourself, your lab partner, and a human torso model.

Directional Terms

Study the terms below, referring to **Figure 1.2** for a visual aid. Notice that certain terms have different meanings, depending on whether they refer to a four-legged animal (quadruped) or to a human (biped).

Superior/inferior (*above/below*): These terms refer to placement of a structure along the long axis of the body. The nose, for example, is superior to the mouth, and the abdomen is inferior to the chest.

Anterior/posterior (*front/back*): In humans, the most anterior structures are those that are most forward—the face, chest, and

abdomen. Posterior structures are those toward the backside of the body. For instance, the spine is posterior to the heart.

Medial/lateral (*toward the midline/away from the midline or median plane*): The sternum (breastbone) is medial to the ribs; the ear is lateral to the nose.

The terms of position just described assume the person is in the anatomical position. The next four term pairs are more absolute. They apply in any body position, and they consistently have the same meaning in all vertebrate animals.

Cephalad (cranial)/caudal (*toward the head/toward the tail*): In humans, these terms are used interchangeably with *superior* and *inferior*, but in four-legged animals they are synonymous with *anterior* and *posterior*, respectively.

Ventral/dorsal (*belly side/backside*): These terms are used chiefly in discussing the comparative anatomy of animals, assuming the animal is standing. In humans, the terms *ventral* and *dorsal* are used interchangeably with the terms *anterior* and *posterior*, but in four-legged animals, *ventral* and *dorsal* are synonymous with *inferior* and *superior*, respectively.

Proximal/distal (*nearer the trunk or attached end/farther from the trunk or point of attachment*): These terms are used primarily to locate various areas of the body limbs. For example, the fingers are distal to the elbow; the knee is proximal to the toes. However, these terms may also be used to indicate regions (closer to or farther from the head) of internal tubular organs.

Superficial (external)/deep (internal) (*toward or at the body surface/away from the body surface*): For example, the skin is superficial to the skeletal muscles, and the lungs are deep to the rib cage.

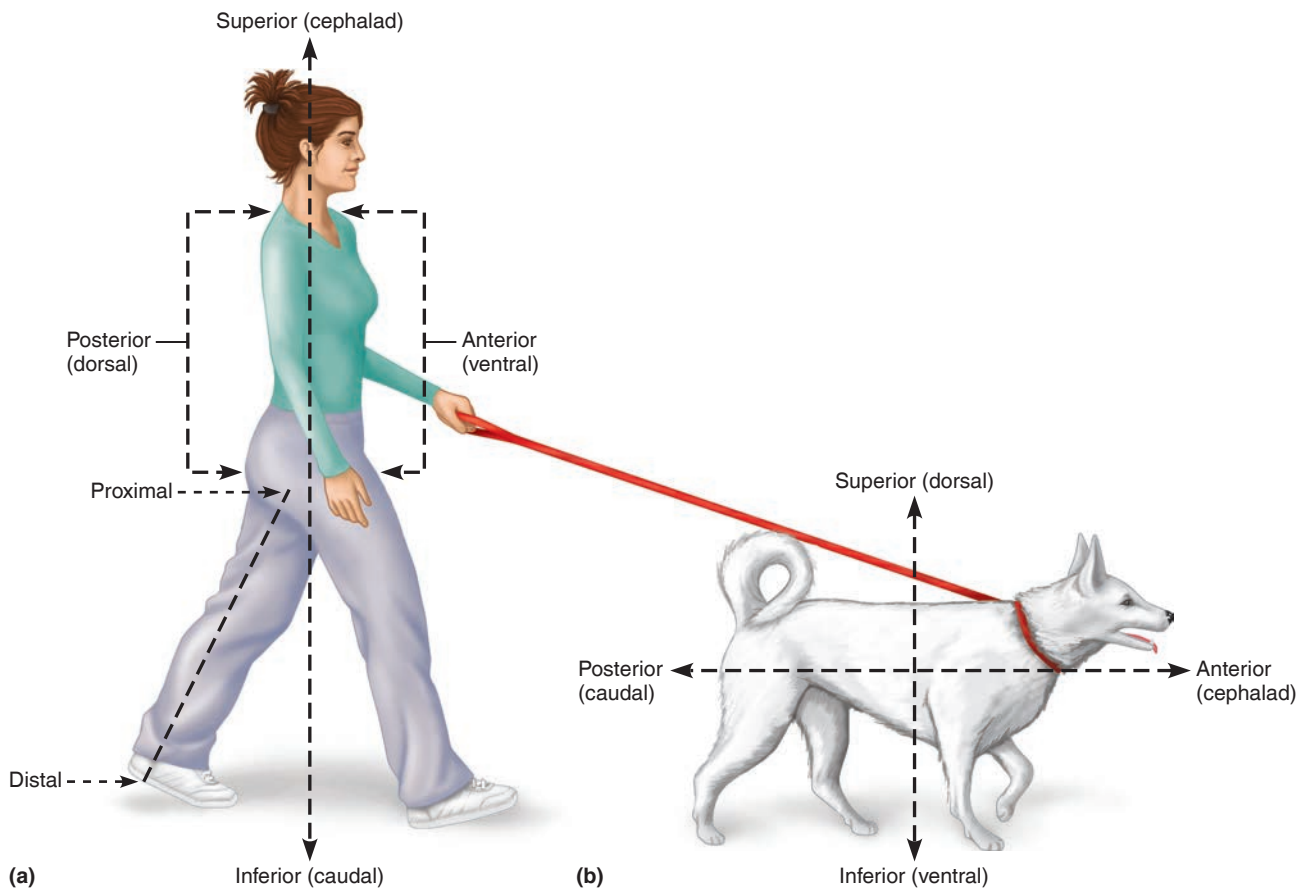


Figure 1.2 Directional terms. **(a)** With reference to a human. **(b)** With reference to a four-legged animal.



Instructors may assign this figure as an Art Labeling Activity using **Mastering A&P™**

Activity 2

Practicing Using Correct Anatomical Terminology

Use a human torso model, a human skeleton, or your own body to practice using the regional and directional terminology.

1. The popliteal region is _____ (anterior or posterior).
2. The acromial region is _____ to the otic region (medial or lateral).

3. The femoral region is _____ to the tarsal region. (proximal or distal)

4. The bones are _____ to the skin. (superficial or deep)

Body Planes and Sections

The body is three-dimensional, and in order to observe its internal structures, it is often necessary to make a **section**, or cut. When the section is made through the body wall or through an organ, it is made along an imaginary surface

or line called a **plane**. A section is named for the plane along which it is cut. Anatomists commonly refer to three planes (**Figure 1.3**), or sections, that lie at right angles to one another.



(a) Median (midsagittal) plane



(b) Frontal (coronal) plane



(c) Transverse plane

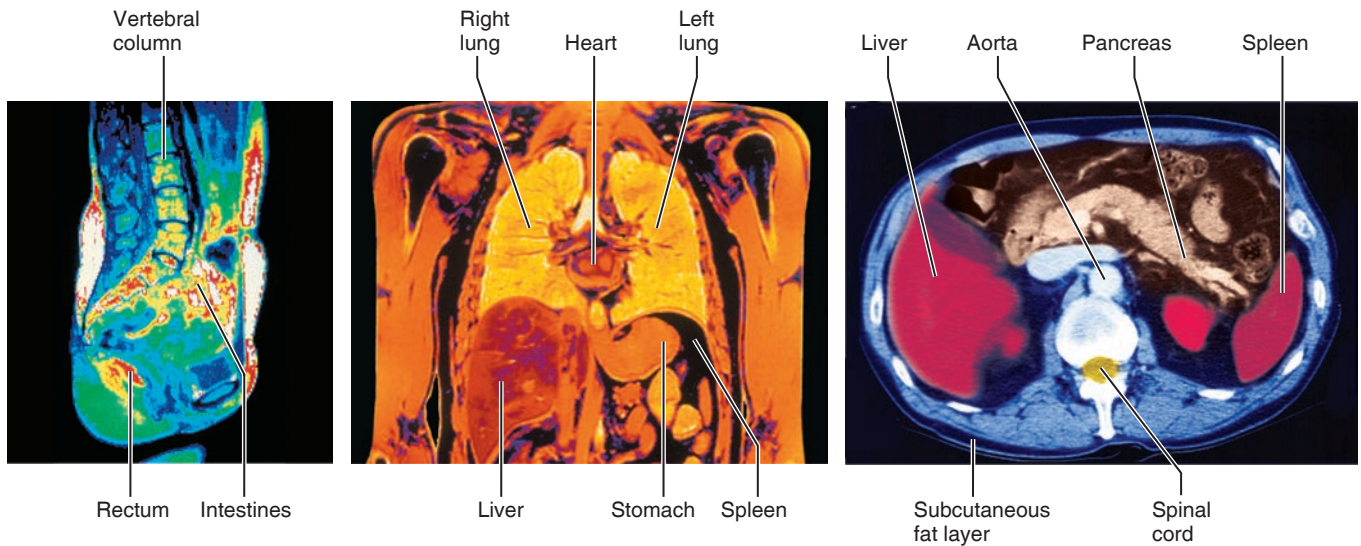



Figure 1.3 Planes of the body with corresponding magnetic resonance imaging (MRI) scans. Note the transverse section is an inferior view.

 Instructors may assign this figure as an Art Labeling Activity using **Mastering A&P™**

Sagittal plane: A sagittal plane runs longitudinally and divides the body into right and left parts. If it divides the body into equal parts, right down the midline of the body, it is called a **median**, or **midsagittal**, **plane**.

Frontal plane: Sometimes called a **coronal plane**, the frontal plane is a longitudinal plane that divides the body (or an organ) into anterior and posterior parts.

Transverse plane: A transverse plane runs horizontally, dividing the body into superior and inferior parts. When organs are sectioned along the transverse plane, the sections are commonly called **cross sections**.

On microscope slides, the abbreviation for a longitudinal section (sagittal or frontal) is l.s. Cross sections are abbreviated x.s. or c.s.

A median or frontal plane section of any nonspherical object, be it a banana or a body organ, provides quite a different view from a cross section (Figure 1.4).

Activity 3

Observing Sectioned Specimens

1. Go to the demonstration area and observe the transversely and longitudinally cut organ specimens (kidneys).
2. After completing instruction 1, obtain a gelatin-spaghetti mold and a scalpel, and take them to your laboratory bench. (Essentially, this is just cooked spaghetti added to warm gelatin, which is then allowed to gel.)
3. Cut through the gelatin-spaghetti mold along any plane, and examine the cut surfaces. You should see spaghetti strands that have been cut transversely (x.s.) and some cut longitudinally (a median section).
4. Draw the appearance of each of these spaghetti sections below, and verify the accuracy of your section identifications with your instructor.

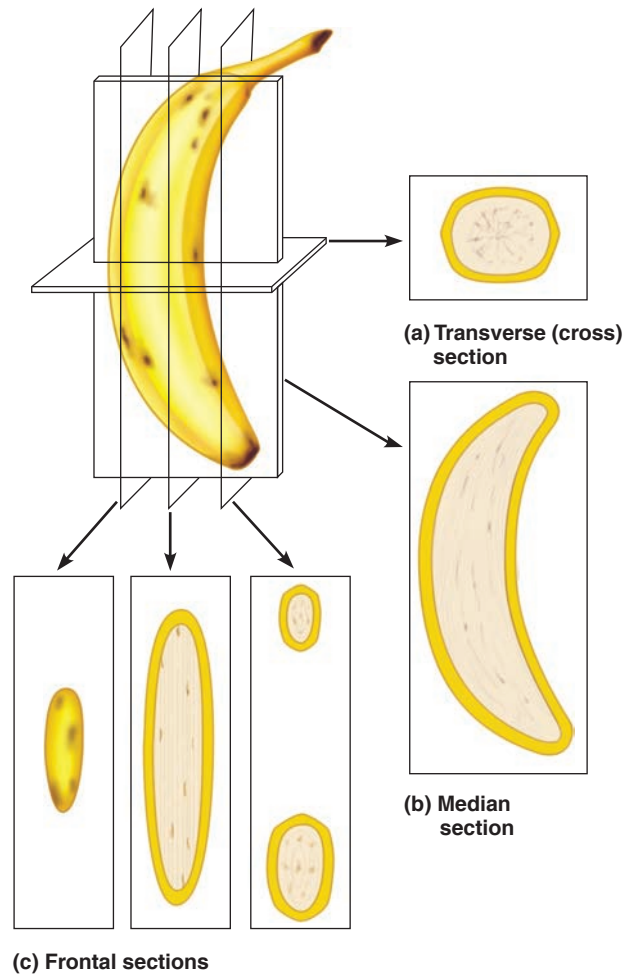
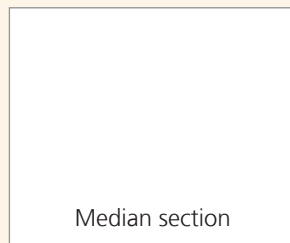
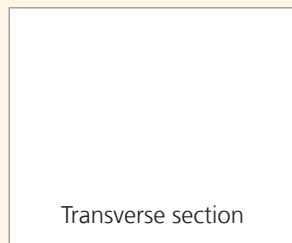


Figure 1.4 Objects can look odd when viewed in section. This banana has been sectioned in three different planes (a–c), and only in one of these planes (b) is it easily recognized as a banana. If one cannot recognize a sectioned organ, it is possible to reconstruct its shape from a series of successive cuts, as from the three serial sections in (c).

Body Cavities

The axial region of the body has two large cavities that provide different degrees of protection to the organs within them (Figure 1.5).

Dorsal Body Cavity

The dorsal body cavity can be subdivided into the **cranial cavity**, which lies within the rigid skull and encases the brain, and the **vertebral** (or **spinal**) **cavity**, which runs through the bony vertebral column to enclose the delicate spinal cord.

Ventral Body Cavity

Like the dorsal cavity, the ventral body cavity is subdivided. The superior **thoracic cavity** is separated from the rest of the ventral cavity by the dome-shaped diaphragm. The heart and lungs, located in the thoracic cavity, are protected by the bony rib cage. The cavity inferior to the diaphragm is referred to

as the **abdominopelvic cavity**. Although there is no further physical separation of the ventral cavity, some describe the abdominopelvic cavity as two areas: a superior **abdominal cavity**, the area that houses the stomach, intestines, liver, and other organs, and an inferior **pelvic cavity**, the region that is partially enclosed by the bony pelvis and contains the reproductive organs, bladder, and rectum.

Serous Membranes of the Ventral Body Cavity

The walls of the ventral body cavity and the outer surfaces of the organs it contains are covered with a very thin, double-layered membrane called the **serosa**, or **serous membrane**. The part of the membrane lining the cavity walls is referred to as the **parietal serosa**, and it is continuous with a similar membrane, the **visceral serosa**, covering the external surface of the organs within the cavity. These membranes produce a thin lubricating fluid that allows the visceral organs to slide over one another or to rub against the body wall with minimal

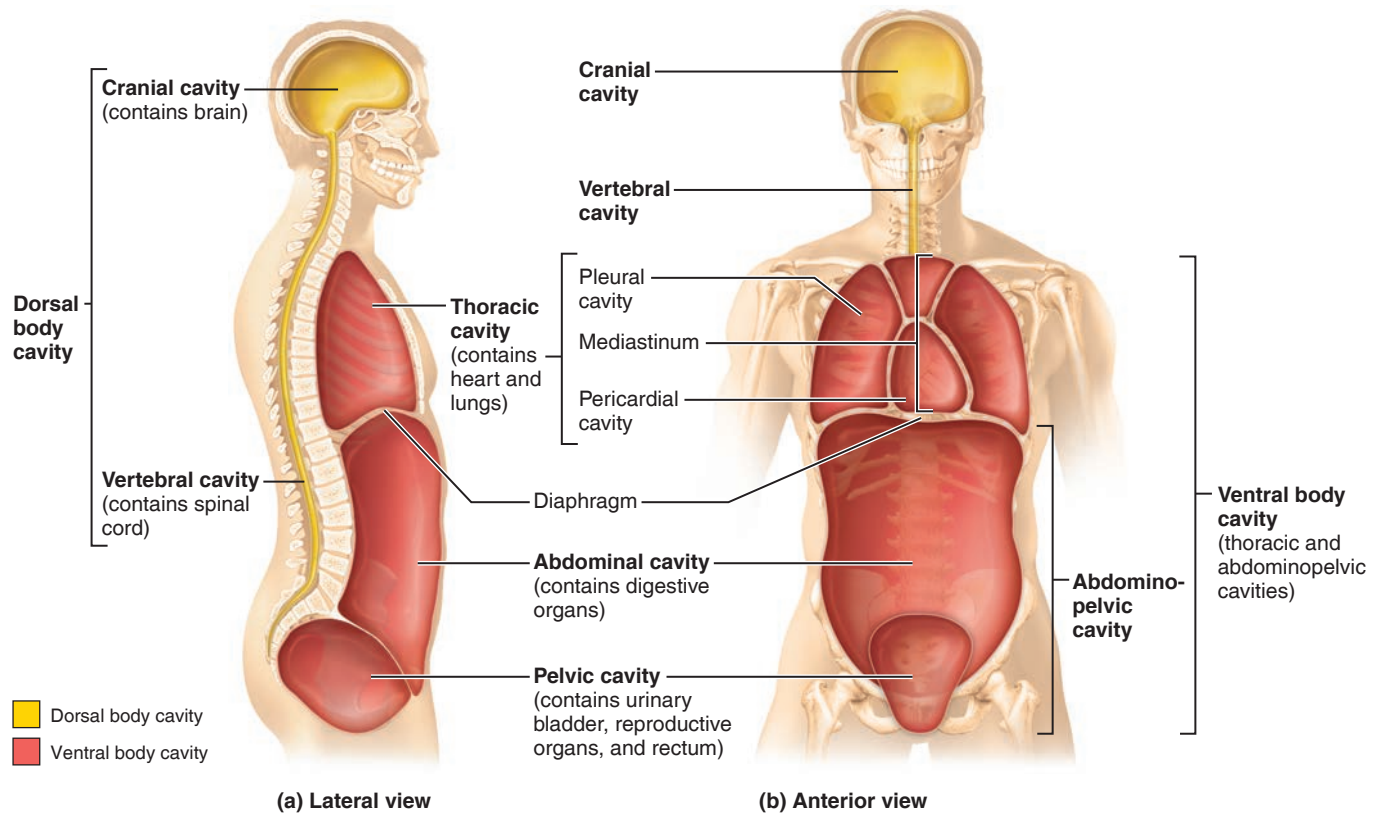
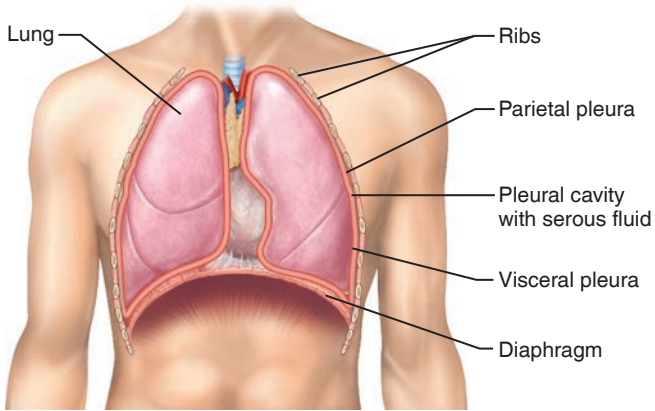


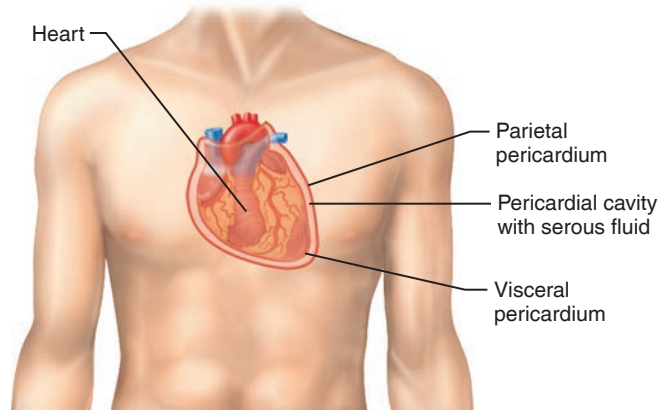
Figure 1.5 Dorsal and ventral body cavities and their subdivisions.



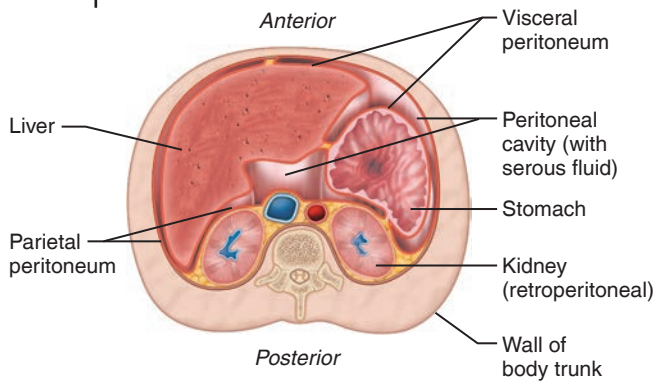
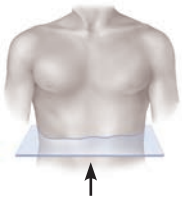
Instructors may assign this figure as an Art Labeling Activity using **Mastering A&P™**



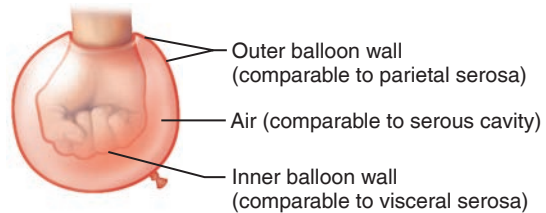
(a) Serosae associated with the lungs: pleura



(b) Serosae associated with the heart: pericardium



(c) Serosae associated with the abdominal viscera: peritoneum



(d) Model of the serous membranes and serous cavity

Figure 1.6 Serous membranes of the ventral body cavities.

friction. Serous membranes also compartmentalize the various organs to prevent infection in one organ from spreading to others.

The specific names of the serous membranes depend on the structures they surround. The serosa lining the abdominal

cavity and covering its organs is the **peritoneum**, the serosa enclosing the lungs is the **pleura**, and the serosa around the heart is the **pericardium** (Figure 1.6). A fist pushed into a limp balloon demonstrates the relationship between the visceral and parietal serosae (Figure 1.6d).

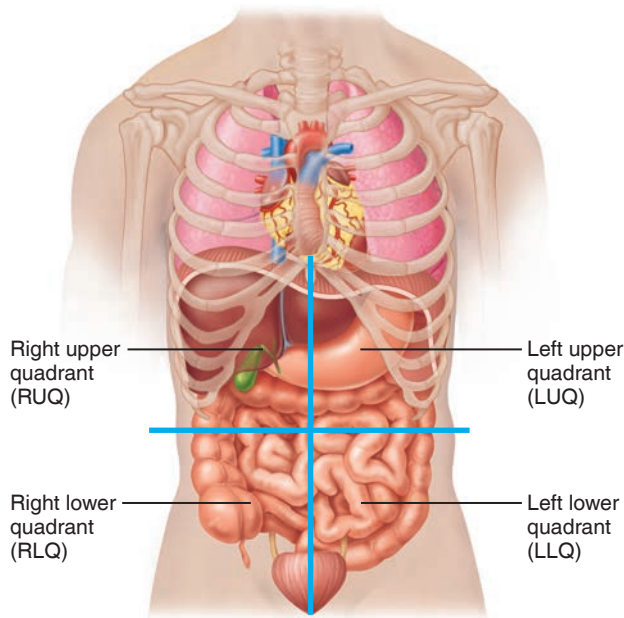


Figure 1.7 Abdominopelvic quadrants. Superficial organs are shown in each quadrant.

Activity 4

Identifying Organs in the Abdominopelvic Cavity

Examine the human torso model to respond to the following questions.

Name two organs found in the left upper quadrant.

_____ and _____

Name two organs found in the right lower quadrant.

_____ and _____

What organ (Figure 1.7) is divided into identical halves by the median plane? _____

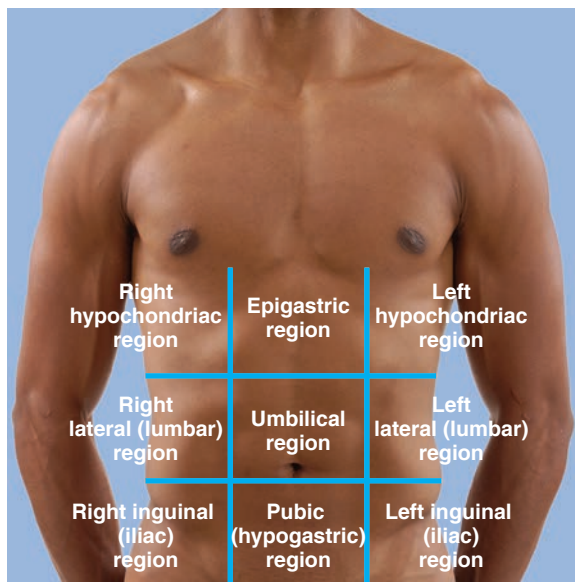
Abdominopelvic Quadrants and Regions

Because the abdominopelvic cavity is quite large and contains many organs, it is helpful to divide it up into smaller areas for discussion or study.

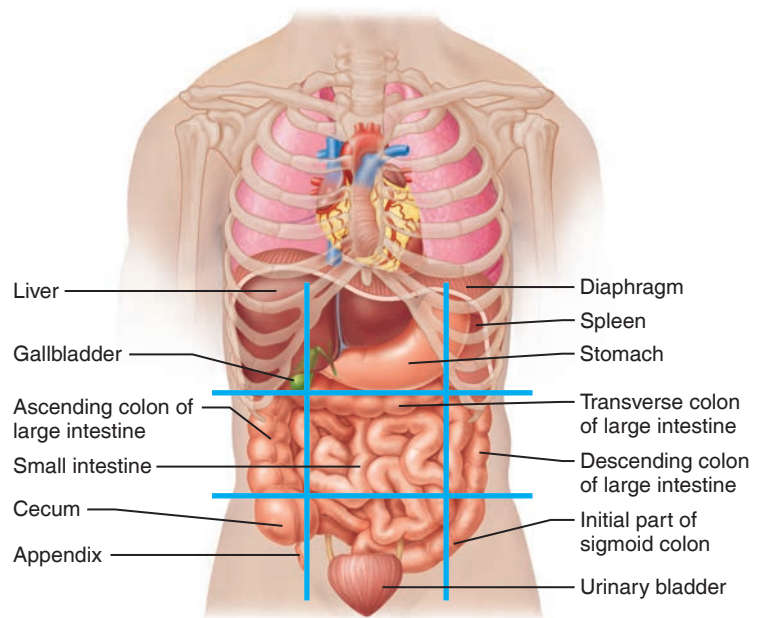
Most physicians and nurses use a scheme that divides the abdominal surface and the abdominopelvic cavity into four approximately equal regions called **quadrants**. These quadrants

are named according to their relative position—that is, *right upper quadrant*, *right lower quadrant*, *left upper quadrant*, and *left lower quadrant* (Figure 1.7). Note that the terms *left* and *right* refer to the left and right side of the body in the figure, not the left and right side of the art on the page.

A different scheme commonly used by anatomists divides the abdominal surface and abdominopelvic cavity into nine separate regions by four planes (Figure 1.8). As you read



(a)



(b)

Figure 1.8 Abdominopelvic regions. Nine regions delineated by four planes. (a) The superior horizontal plane is just inferior to the ribs; the inferior horizontal plane is at the superior aspect of the hip bones. The vertical planes are just medial to the nipples. (b) Superficial organs are shown in each region.

Instructors may assign this figure as an Art Labeling Activity using **Mastering A&P™**

through the descriptions of these nine regions, locate them in Figure 1.8, and note the organs contained in each region.

Umbilical region: The centermost region, which includes the umbilicus (navel)

Epigastric region: Immediately superior to the umbilical region; overlies most of the stomach

Pubic (hypogastric) region: Immediately inferior to the umbilical region; encompasses the pubic area

Inguinal, or iliac, regions: Lateral to the hypogastric region and overlying the superior parts of the hip bones

Lateral (lumbar) regions: Between the ribs and the flaring portions of the hip bones; lateral to the umbilical region

Hypochondriac regions: Flanking the epigastric region laterally and overlying the lower ribs

Activity 5

Locating Abdominopelvic Surface Regions

Locate the regions of the abdominopelvic surface on a human torso model.

Other Body Cavities

Besides the large, closed body cavities, there are several types of smaller body cavities (Figure 1.9). Many of these are in the head, and most open to the body exterior.

Oral cavity: The oral cavity, commonly called the *mouth*, contains the tongue and teeth. It is continuous with the rest of the digestive tube, which opens to the exterior at the anus.

Nasal cavity: Located within and posterior to the nose, the nasal cavity is part of the passages of the respiratory system.

Orbital cavities: The orbital cavities (orbits) in the skull house the eyes and present them in an anterior position.

Middle ear cavities: Each middle ear cavity lies just medial to an eardrum and is carved into the bony skull. These cavities contain tiny bones that transmit sound vibrations to the hearing receptors in the inner ears.

Synovial cavities: Synovial cavities are joint cavities—they are enclosed within fibrous capsules that surround the freely movable joints of the body, such as those between the vertebrae and the knee and hip joints. Like the serous membranes of the ventral body cavity, membranes lining the synovial cavities secrete a lubricating fluid that reduces friction as the enclosed structures move across one another.

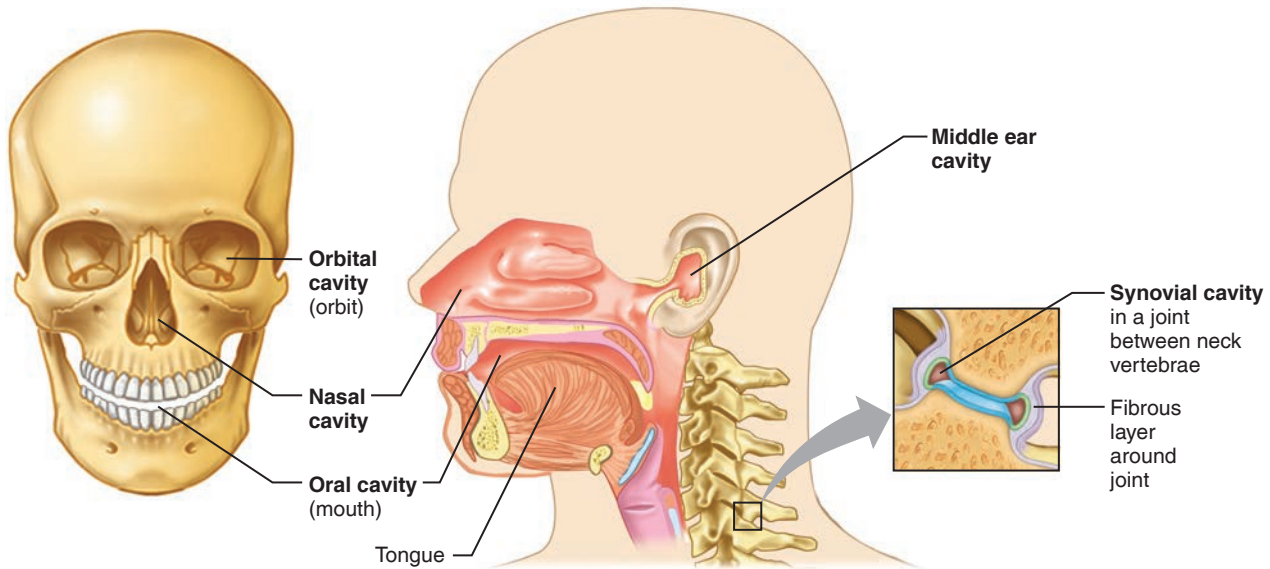


Figure 1.9 Other body cavities. The oral, nasal, orbital, and middle ear cavities are located in the head and open to the body exterior. Synovial cavities are found in joints between bones, such as the vertebrae of the spine, and at the knee, shoulder, and hip.

1 EXERCISE

REVIEW SHEET

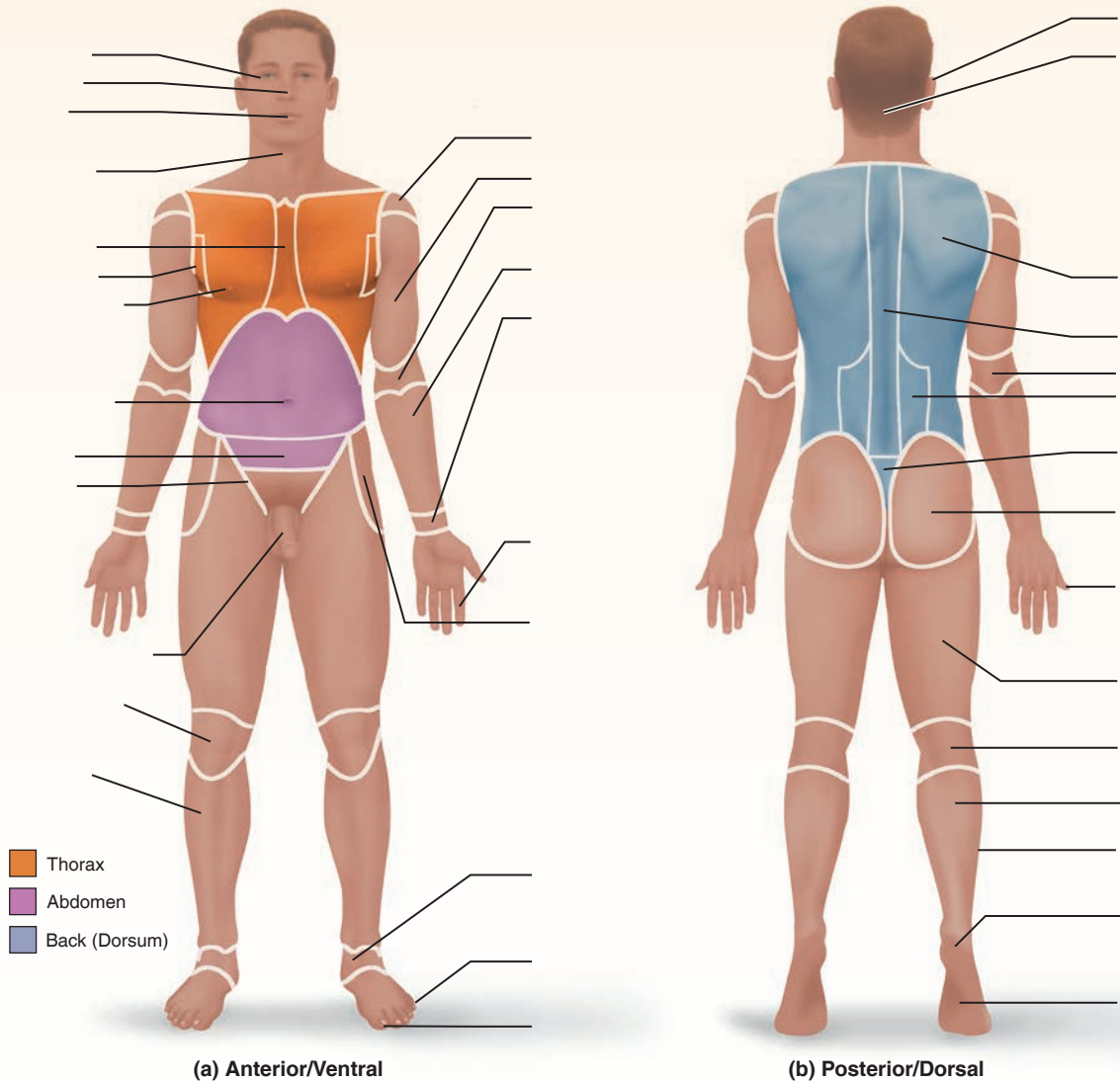
The Language of Anatomy

Name _____ Lab Time/Date _____

Regional Terms

- Describe completely the standard human anatomical position. _____

- Use the regional terms to correctly label the body regions indicated on the figures below.



Directional Terms, Planes, and Sections

3. Define *median*. _____

4. Several incomplete statements appear below. Correctly complete each statement by choosing the appropriate anatomical term from the choices. Use each term only once.

anterior	inferior	posterior	superior
distal	lateral	proximal	transverse
frontal	medial	sagittal	

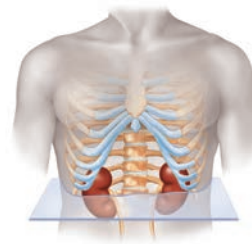
- The thoracic cavity is _____ to the abdominopelvic cavity.
 - The trachea (windpipe) is _____ to the vertebral column.
 - The wrist is _____ to the hand.
 - If an incision cuts the heart into left and right parts, a _____ plane of section was used.
 - The nose is _____ to the cheekbones.
 - The thumb is _____ to the ring finger.
 - The vertebral cavity is _____ to the cranial cavity.
 - The knee is _____ to the thigh.
 - The plane that separates the head from the neck is the _____ plane.
 - The popliteal region is _____ to the patellar region.
 - The plane that separates the anterior body surface from the posterior body surface is the _____ plane.
5. Correctly identify each of the body planes by writing the appropriate term on the answer line below the drawing.



(a) _____








(b) _____



(c) _____

Body Cavities

- Name the muscle that subdivides the ventral body cavity. _____
- What body cavity communicates directly with the thoracic cavity? _____
- For the body cavities listed, name one organ located in each cavity.
 - cranial cavity _____
 - vertebral cavity _____

3. thoracic cavity _____
4. abdominal cavity _____
5. pelvic cavity _____
6. mediastinum _____
9. Name the abdominopelvic region where each of the listed organs is located.
1. spleen _____
2. urinary bladder _____
3. stomach (largest portion) _____
4. cecum _____
10. Define the difference between a parietal and a visceral serous membrane. _____
- _____
11. Which serous membrane(s) is/are found in the thoracic cavity? _____
- _____
12. Explain how serous membranes assist with the function of motile organs. _____
- _____
13. Using the key choices, identify the small body cavities described below.
- Key: a. middle ear cavity e. oral cavity e. synovial cavity
 b. nasal cavity d. orbital cavity
- _____ 1. holds the eyes in an anterior-facing position _____ 4. contains the tongue
- _____ 2. houses three tiny bones involved in hearing _____ 5. surrounds a joint
- _____ 3. contained within the nose
14.  Over what quadrant would hands be placed to palpate the liver? _____
15.  A patient has been diagnosed with appendicitis. Use anatomical terminology to describe the location of the person's pain. Assume that the pain is referred to the surface of the body above the organ. _____
16.  Which body cavity would be opened to perform a hysterectomy? _____
- _____
17.  Which smaller body cavity would be opened to perform a total knee joint replacement? _____
- _____
18.  An abdominal hernia results when weakened muscles allow the protrusion of abdominal structures. In the case of an umbilical hernia, parts of a serous membrane and the small intestine form the bulge. Which serous membrane is involved? _____
- _____

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2 EXERCISE

Organ Systems Overview

Learning Outcomes

- ▶ Name the human organ systems, and indicate the major functions of each.
- ▶ List several major organs of each system, and identify them in a dissected rat, human cadaver or cadaver image, or a dissectible human torso model.
- ▶ Name the correct organ system for each organ when presented with a list of organs.

Pre-Lab Quiz



Instructors may assign these and other Pre-Lab Quiz questions using **Mastering A&P™**

1. Name the structural and functional unit of all living things. _____
2. The small intestine is an example of a(n) _____, because it is composed of two or more tissue types that perform a particular function for the body.
 - a. epithelial tissue
 - b. muscular tissue
 - c. organ
 - d. organ system
3. The _____ system is responsible for ensuring fluid and electrolyte homeostasis within the body.
4. The caecum is a part of the _____ system.
5. The thin muscle that separates the thoracic and abdominal cavities is the _____.

The basic unit of life is the **cell**. Cells fall into four different categories according to their structures and functions. These categories correspond to the four primary tissue types: epithelial, muscular, nervous, and connective. A **tissue** is a group of cells that are similar in structure and function. An **organ** is a structure composed of two or more tissue types that performs a specific function for the body.

An **organ system** is a group of organs that act together to perform a particular body function. For example, the organs of the digestive system work together to break down foods and absorb the end products into the bloodstream in order to provide nutrients and fuel for all the body's cells. In all, there are 11 organ systems, described in **Table 2.1** on p. 34.

Read through this summary of the body's organ systems (Table 2.1) before beginning your rat dissection or examination of the predissected human cadaver. If a human cadaver is not available, Figures 2.3 to 2.6 will serve as a partial replacement.

Go to **Mastering A&P™** > Study Area to improve your performance in A&P Lab.



> **Lab Tools** > **Practice Anatomy Lab**
> **Anatomical Models**



Instructors may assign new Building Vocabulary coaching activities, Pre-Lab Quiz questions, Art Labeling activities, Practice Anatomy Lab Practical questions (PAL), and more using the **Mastering A&P™** Item Library.

Materials

- ▶ Freshly killed or preserved rat (predissected by instructor as a demonstration or for student dissection [one rat for every two to four students]) or predissected human cadaver
- ▶ Dissection trays
- ▶ Twine or large dissecting pins
- ▶ Scissors
- ▶ Probes
- ▶ Forceps
- ▶ Disposable gloves
- ▶ Human torso model (dissectible)

Table 2.1 Overview of Organ Systems of the Body

Organ system	Major component organs	Function
Integumentary	Skin, hair, and nails; cutaneous sense organs and glands	<ul style="list-style-type: none"> Protects deeper organs from mechanical, chemical, and bacterial injury, and from drying out Excretes salts and urea Aids in regulation of body temperature Produces vitamin D
Skeletal	Bones, cartilages, tendons, ligaments, and joints	<ul style="list-style-type: none"> Body support and protection of internal organs Provides levers for muscular action Cavities provide a site for blood cell formation Bones store minerals
Muscular	Muscles attached to the skeleton	<ul style="list-style-type: none"> Primary function is to contract or shorten; in doing so, skeletal muscles allow locomotion (running, walking, etc.), grasping and manipulation of the environment, and facial expression Generates heat
Nervous	Brain, spinal cord, nerves, and sensory receptors	<ul style="list-style-type: none"> Allows body to detect changes in its internal and external environment and to respond to such information by activating appropriate muscles or glands Helps maintain homeostasis of the body via rapid transmission of electrical signals
Endocrine	Pituitary, thymus, thyroid, parathyroid, adrenal, and pineal glands; ovaries, testes, and pancreas	<ul style="list-style-type: none"> Helps maintain body homeostasis, promotes growth and development; produces chemical messengers called hormones that travel in the blood to exert their effect(s) on various target organs of the body
Cardiovascular	Heart and blood vessels	<ul style="list-style-type: none"> Primarily a transport system that carries blood containing oxygen, carbon dioxide, nutrients, wastes, ions, hormones, and other substances to and from the tissue cells where exchanges are made; blood is propelled through the blood vessels by the pumping action of the heart Antibodies and other protein molecules in the blood protect the body
Lymphatic	Lymphatic vessels, lymph nodes, spleen, and thymus	<ul style="list-style-type: none"> Picks up fluid leaked from the blood vessels and returns it to the blood Cleanses blood of pathogens and other debris Houses lymphocytes that act via the immune response to protect the body from foreign substances
Respiratory	Nasal cavity, pharynx, larynx, trachea, bronchi, and lungs	<ul style="list-style-type: none"> Keeps the blood continuously supplied with oxygen while removing carbon dioxide Contributes to the acid-base balance of the blood
Digestive	Oral cavity, pharynx, esophagus, stomach, small and large intestines, and accessory structures including teeth, salivary glands, liver, and pancreas	<ul style="list-style-type: none"> Breaks down ingested foods to smaller particles, which can be absorbed into the blood for delivery to the body cells Undigested residue removed from the body as feces
Urinary	Kidneys, ureters, bladder, and urethra	<ul style="list-style-type: none"> Rids the body of nitrogen-containing wastes including urea, uric acid, and ammonia, which result from the breakdown of proteins and nucleic acids Maintains water, electrolyte, and acid-base balance of blood
Reproductive	<p>Male: testes, prostate gland, scrotum, penis, and duct system, which carries sperm to the body exterior</p> <p>Female: ovaries, uterine tubes, uterus, mammary glands, and vagina</p>	<ul style="list-style-type: none"> Provides gametes called sperm for perpetuation of the species Provides gametes called eggs; the uterus houses the developing fetus until birth; mammary glands provide nutrition for the infant



DISSECTION AND IDENTIFICATION

The Organ Systems of the Rat

Many of the external and internal structures of the rat are quite similar in structure and function to those of the human. So, a study of the gross anatomy of the rat should help you understand our anatomy. The following instructions include directions for dissecting and observing a rat. In addition, the descriptions of the organs (**Activity 4, Examining the Ventral Body Cavity**, which begins on p. 36) also apply

to superficial observations of a previously dissected human cadaver. The general instructions for observing external structures also apply to human cadaver observations. The photographs in Figures 2.3 to 2.6 will provide visual aids.

Note that four organ systems (integumentary, skeletal, muscular, and nervous) will not be studied at this time, because they require microscopic study or more detailed dissection.

Activity 1

Observing External Structures

1. If your instructor has provided a predissected rat, go to the demonstration area to make your observations. Alternatively, if you and/or members of your group will be dissecting the specimen, obtain a preserved or freshly killed rat, a dissecting tray, dissecting pins or twine, scissors, probe, forceps, and disposable gloves, and bring them to your laboratory bench.

If a predissected human cadaver is available, obtain a probe, forceps, and disposable gloves before going to the demonstration area.



2. Don the gloves before beginning your observations. This precaution is particularly important when handling freshly killed animals, which may harbor pathogens.

3. Observe the major divisions of the body—head, trunk, and extremities. If you are examining a rat, compare these divisions to those of humans.

Activity 2

Examining the Oral Cavity

Examine the structures of the oral cavity. Identify the teeth and tongue. Observe the extent of the hard palate (the portion underlain by bone) and the soft palate (immediately posterior to the hard palate, with no bony support). Notice that the posterior end of the oral cavity leads into the throat, or pharynx, a passageway used by both the digestive and respiratory systems.

Activity 3

Opening the Ventral Body Cavity

1. Pin the animal to the wax of the dissecting tray by placing its dorsal side down and securing its extremities to the wax with large dissecting pins as shown in **Figure 2.1a**.

Text continues on next page →



(a)



(b)



(c)



(d)

Figure 2.1 Rat dissection: Securing for dissection and the initial incision. (a) Securing the rat to the dissecting tray with dissecting pins. (b) Using scissors to make the incision on the median line of the abdominal region. (c) Completed incision from the pelvic region to the lower jaw. (d) Reflection (folding back) of the skin to expose the underlying muscles.

2. Lift the abdominal skin with a forceps, and cut through it with the scissors (Figure 2.1b). Close the scissor blades, and insert them flat under the cut skin. Moving in a cephalad direction, open and close the blades to loosen the skin from the underlying connective tissue and muscle. Now, cut the skin along the body midline, from the pubic region to the lower jaw (Figure 2.1c). Finally, make a lateral cut about halfway down the ventral surface of each limb. Complete the job of freeing the skin with the scissor tips, and pin the flaps to the tray (Figure 2.1d). The underlying tissue that is now exposed is the skeletal musculature of the body wall and limbs. Notice that the muscles are packaged in sheets of pearly white connective tissue (fascia), which protect the muscles and bind them together.

3. Carefully cut through the muscles of the abdominal wall in the pubic region, avoiding the underlying organs. Now, hold and lift the muscle layer with a forceps and cut through the muscle layer from the pubic region to the bottom of the rib cage. Make two lateral cuts at the base of the rib cage (Figure 2.2). A thin membrane attached to the inferior boundary of the rib cage should be obvious; this is the **diaphragm**, which separates the thoracic and abdominal cavities. Cut the diaphragm where it attaches to the ventral ribs to loosen the rib cage. Cut through the rib cage on either side. You can now lift the ribs to view the contents of the thoracic cavity. Cut across the flap, at the level of the neck, and remove the rib cage.



Figure 2.2 Rat dissection. Making lateral cuts at the base of the rib cage.

Activity 4

Examining the Ventral Body Cavity

1. Starting with the most superficial structures and working deeper, examine the structures of the thoracic cavity. Refer to **Figure 2.3** as you work. Choose the appropriate view depending on whether you are examining a rat (a) or a human cadaver (b).

Thymus: An irregular mass of glandular tissue overlying the heart (not illustrated in the human cadaver photograph).

With the probe, push the thymus to the side to view the heart.

Heart: Medial oval structure enclosed within the pericardium (serous membrane).

Lungs: Lateral to the heart on either side.

Now observe the throat region to identify the trachea.

Trachea: Tubelike “windpipe” running medially down the throat; part of the respiratory system.

Follow the trachea into the thoracic cavity; notice where it divides into two branches. These are the bronchi.

Bronchi: Two passageways that plunge laterally into the tissue of the two lungs.

To expose the esophagus, push the trachea to one side.

Esophagus: A food chute; the part of the digestive system that transports food from the pharynx (throat) to the stomach.

Diaphragm: A thin muscle attached to the inferior boundary of the rib cage.

Follow the esophagus through the diaphragm to its junction with the stomach.

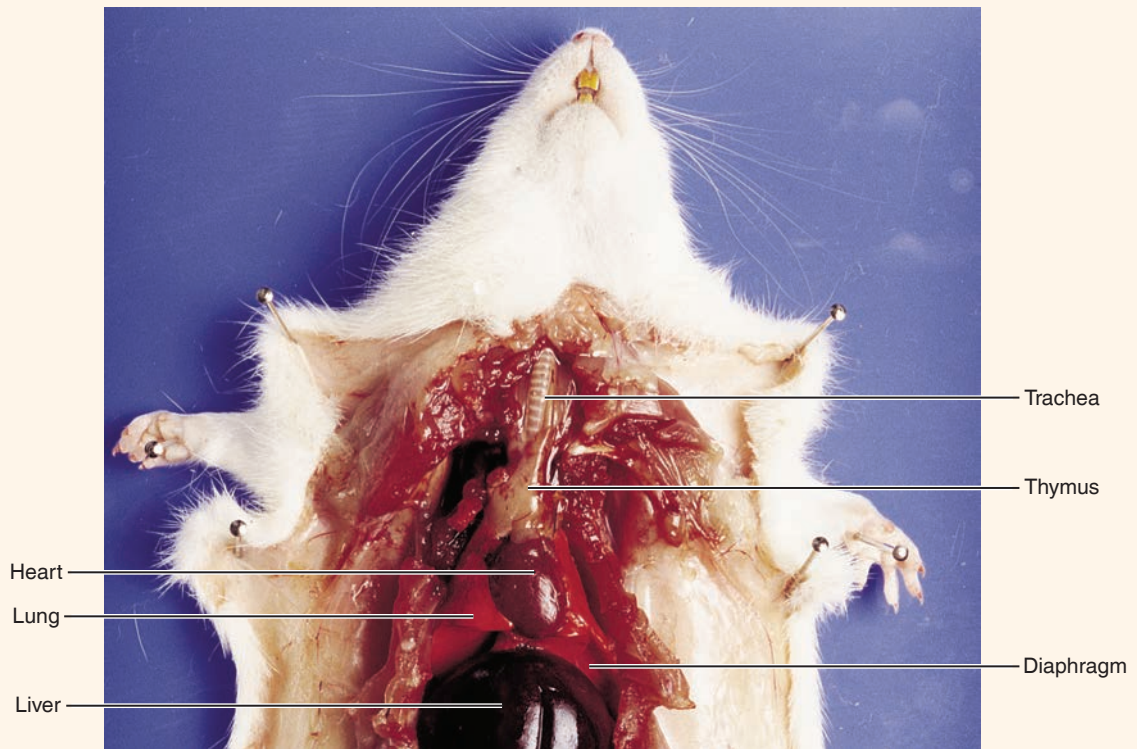
Stomach: A curved organ important in food digestion and temporary food storage.

2. Examine the superficial structures of the abdominopelvic cavity. Lift the **greater omentum**, an extension of the peritoneum (serous membrane) that covers the abdominal viscera. Continuing from the stomach, trace the rest of the digestive tract (**Figure 2.4**, p. 38).

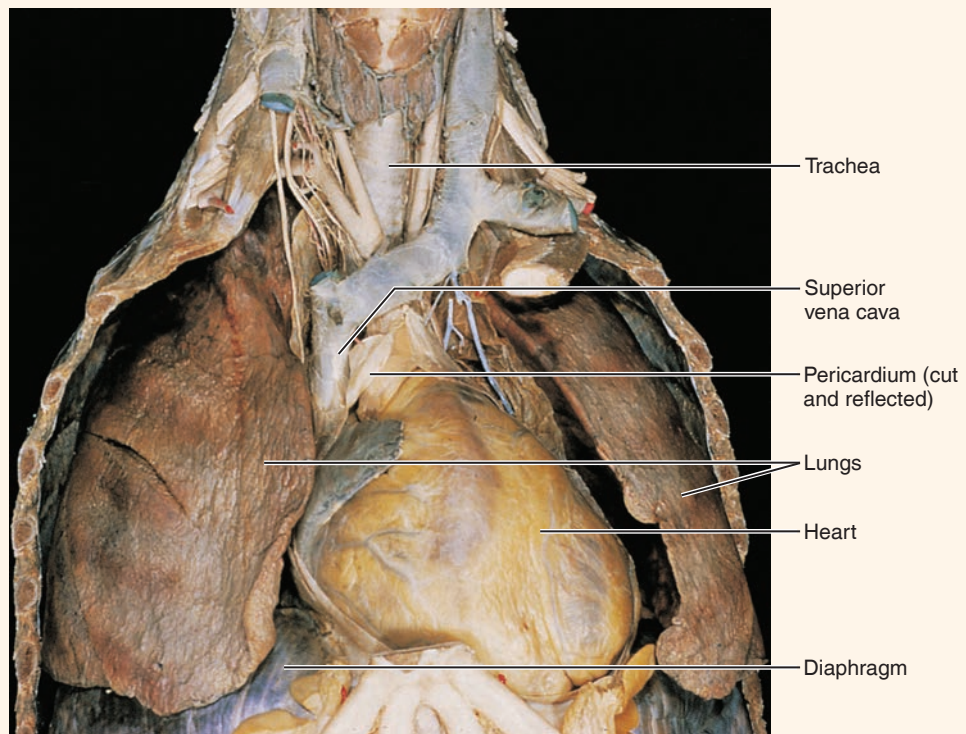
Small intestine: Connected to the stomach and ending just before the saclike cecum.

Large intestine: A large muscular tube connected to the small intestine and ending at the anus.

Text continues on page 38. →




(a)



(b)

Figure 2.3 Superficial organs of the thoracic cavity. (a) Dissected rat. (b) Human cadaver.

 Instructors may assign this figure as an Art Labeling Activity using **Mastering A&P™**

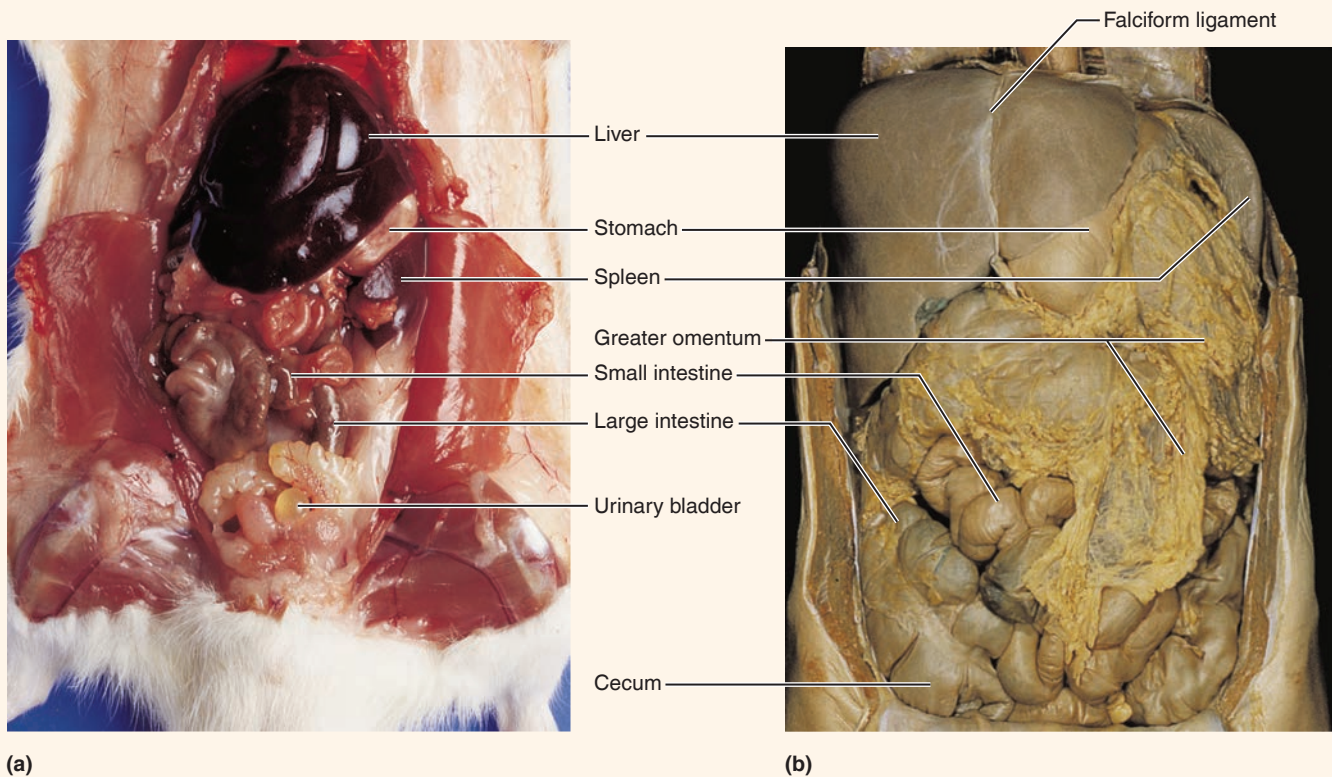


Figure 2.4 Abdominal organs. (a) Dissected rat, superficial view. (b) Human cadaver, superficial view.

Instructors may assign this figure as an Art Labeling Activity using **Mastering A&P™**

Cecum: The initial portion of the large intestine.

Follow the course of the large intestine to the rectum, which is partially covered by the urinary bladder (Figure 2.5).

Rectum: Terminal part of the large intestine; continuous with the anal canal.

Anus: The opening of the digestive tract (through the anal canal) to the exterior.

Now lift the small intestine with the forceps to view the mesentery.

Mesentery: An apronlike serous membrane; suspends many of the digestive organs in the abdominal cavity. Notice that it is heavily invested with blood vessels and, more likely than not, riddled with large fat deposits.

Locate the remaining abdominal structures.

Pancreas: A diffuse gland; rests dorsal to and in the mesentery between the first portion of the small intestine and the stomach. You will need to lift the stomach to view the pancreas.

Spleen: A dark red organ curving around the left lateral side of the stomach; an organ of the lymphatic system, it is often called the red blood cell “graveyard.”

Liver: Large and brownish red; the most superior organ in the abdominal cavity, directly beneath the diaphragm.

3. To locate the deeper structures of the abdominopelvic cavity, move the stomach and the intestines to one side with the probe.

Examine the posterior wall of the abdominal cavity to locate the two kidneys (Figure 2.5).

Kidneys: Bean-shaped organs; retroperitoneal (behind the peritoneum).

Adrenal glands: Large endocrine glands that sit on top of each kidney; considered part of the endocrine system.

Carefully strip away part of the peritoneum with forceps and attempt to follow the course of one of the ureters to the bladder.

Ureter: Tube running from the indented region of a kidney to the urinary bladder.

Urinary bladder: The sac that serves as a reservoir for urine.

4. In the midline of the body cavity lying between the kidneys are the two principal abdominal blood vessels:

Inferior vena cava: The large vein that returns blood to the heart from the lower body regions.

Descending aorta: Deep to the inferior vena cava; the largest artery of the body; carries blood away from the heart.

5. You will perform only a brief examination of reproductive organs. If you are working with a rat, first determine if the animal is a male or female. Observe the ventral body surface beneath the tail. If a saclike scrotum and an opening for the anus are visible, the animal is a male. If three body openings—urethral, vaginal, and anal—are present, it is a female.

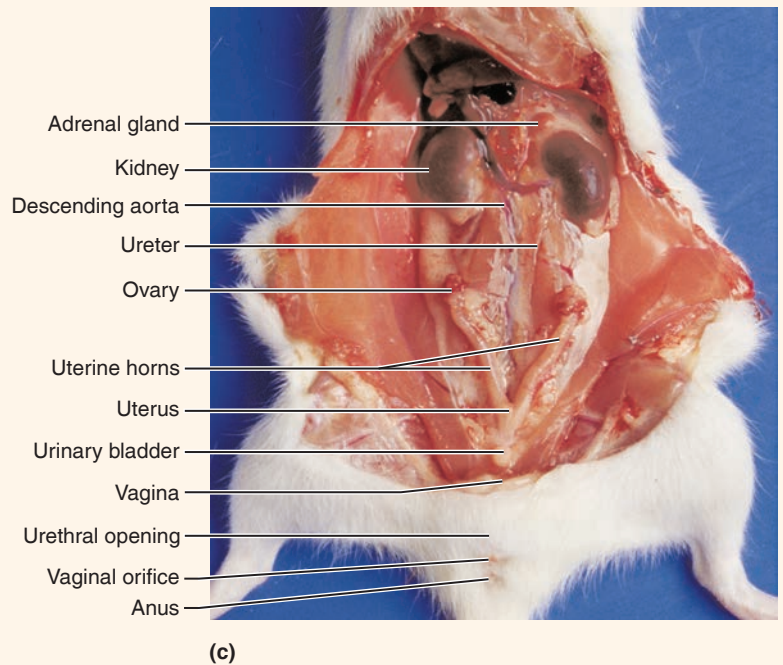
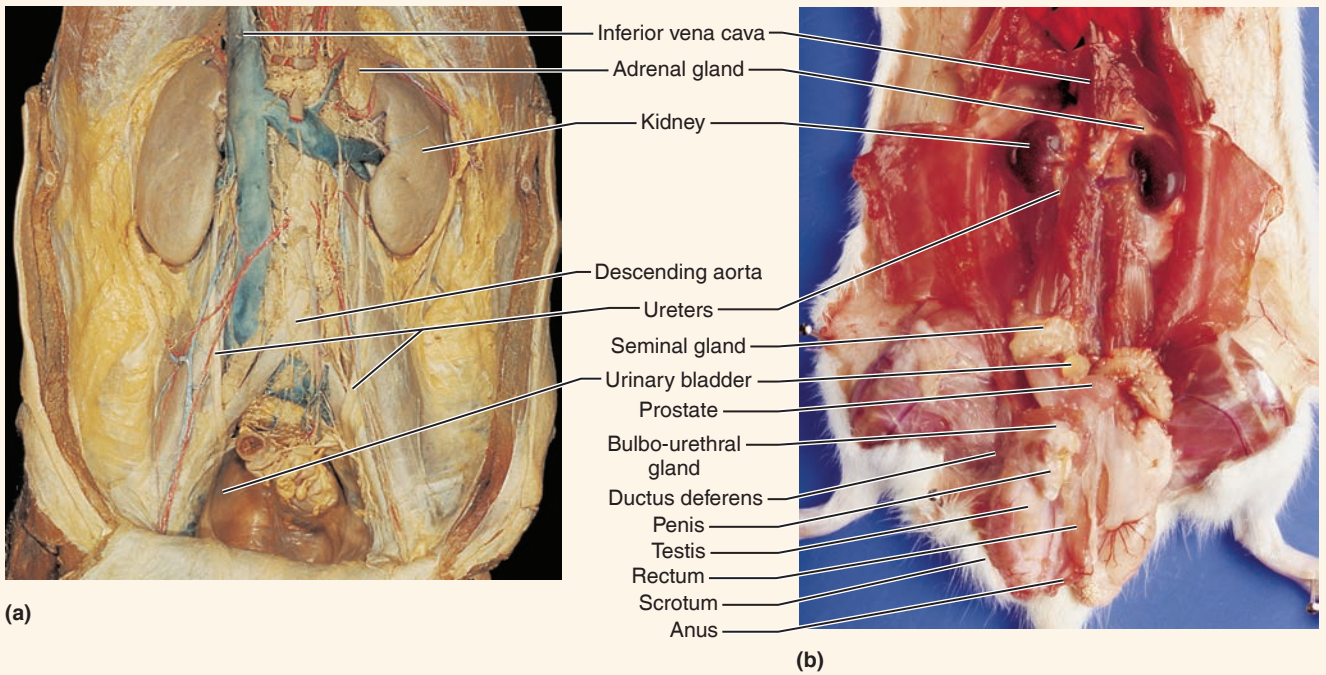


Figure 2.5 Deep structures of the abdominopelvic cavity. (a) Human cadaver. (b) Dissected male rat. (Some reproductive structures also shown.) (c) Dissected female rat. (Some reproductive structures also shown.)

Male Rat

Make a shallow incision into the **scrotum**. Loosen and lift out one oval **testis**. Exert a gentle pull on the testis to identify the slender **ductus deferens**, or **vas deferens**, which carries sperm from the testis superiorly into the abdominal cavity and joins with the urethra. The urethra runs through the penis and carries both urine and sperm out of the body. Identify the **penis**, extending from the bladder to the ventral body wall. Figure 2.5b indicates other glands of the male rat’s reproductive system, but they need not be identified at this time.

Female Rat

Inspect the pelvic cavity to identify the Y-shaped **uterus** lying against the dorsal body wall and superior to the bladder (Figure 2.5c). Follow one of the uterine horns superiorly to identify an **ovary**, a small oval structure at the end of the uterine horn. (The rat uterus is quite different from the uterus of a human female, which is a single-chambered organ about the size and shape of a pear.) The inferior undivided part of the rat uterus is continuous with the **vagina**, which leads to the body exterior. Identify the **vaginal orifice** (external vaginal opening).

Text continues on next page →

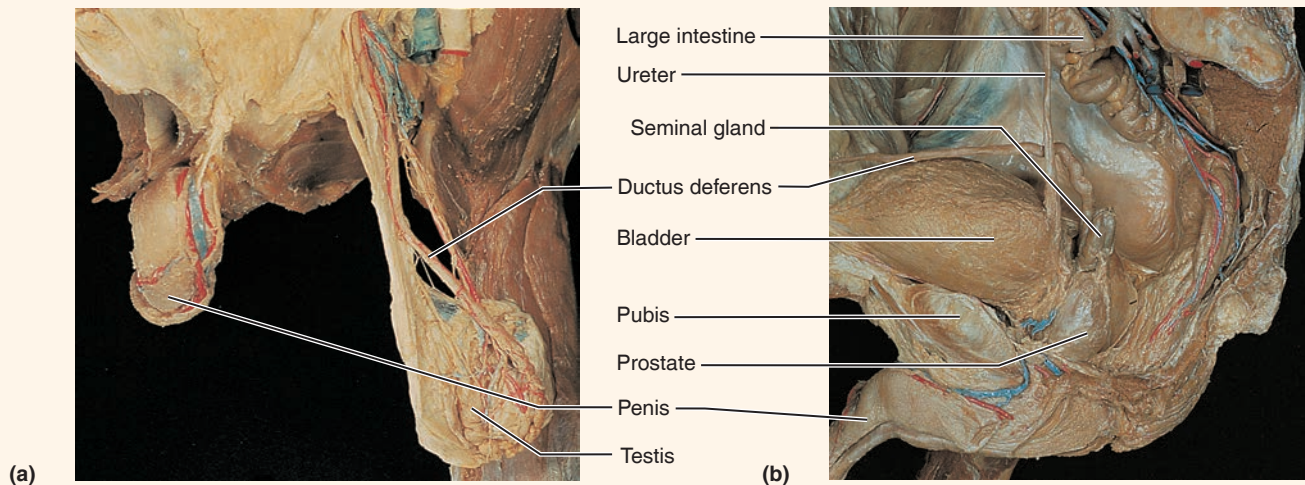


Figure 2.6 Human reproductive organs. (a) Male external genitalia. (b) Sagittal section of the male pelvis. (c) Sagittal section of the female pelvis.

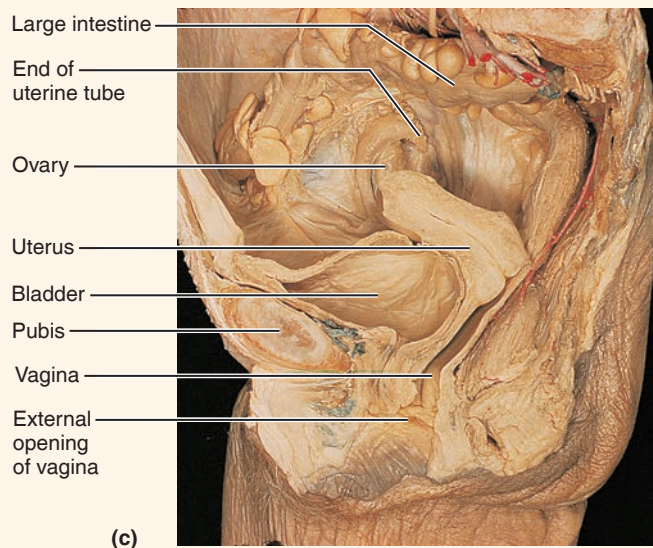
Male Cadaver

Make a shallow incision into the **scrotum** (Figure 2.6a). Loosen and lift out the oval **testis**. Exert a gentle pull on the testis to identify the slender **ductus (vas) deferens**, which carries sperm from the testis superiorly into the abdominopelvic cavity and joins with the urethra (Figure 2.6b). The urethra runs through the penis and carries both urine and sperm out of the body. Identify the **penis**, extending from the bladder to the ventral body wall.

Female Cadaver

Inspect the pelvic cavity to identify the pear-shaped **uterus** lying against the dorsal body wall and superior to the bladder. Follow one of the **uterine tubes** superiorly to identify an **ovary**, a small oval structure at the end of the uterine tube (Figure 2.6c). The inferior part of the uterus is continuous with the **vagina**, which leads to the body exterior. Identify the **vaginal orifice** (external vaginal opening).

6. When you have finished your observations, rewrap or store the dissection animal or cadaver according to your instructor's directions. Wash the dissecting tools and equipment with laboratory detergent. Dispose of the gloves as instructed.



Activity 5

Examining the Human Torso Model

Examine a human torso model to identify the organs listed. Check off the boxes as you locate the organs. Some model organs will have to be removed to see the deeper organs.

- | | | | |
|----------------------------------------|---------------------------------------------|------------------------------------------|------------------------------------------|
| <input type="checkbox"/> Adrenal gland | <input type="checkbox"/> Esophagus | <input type="checkbox"/> Large intestine | <input type="checkbox"/> Spleen |
| <input type="checkbox"/> Aortic arch | <input type="checkbox"/> Heart | <input type="checkbox"/> Liver | <input type="checkbox"/> Stomach |
| <input type="checkbox"/> Brain | <input type="checkbox"/> Inferior vena cava | <input type="checkbox"/> Lungs | <input type="checkbox"/> Thyroid gland |
| <input type="checkbox"/> Diaphragm | <input type="checkbox"/> Kidneys | <input type="checkbox"/> Mesentery | <input type="checkbox"/> Trachea |
| | | <input type="checkbox"/> Pancreas | <input type="checkbox"/> Ureters |
| | | <input type="checkbox"/> Small intestine | <input type="checkbox"/> Urinary bladder |

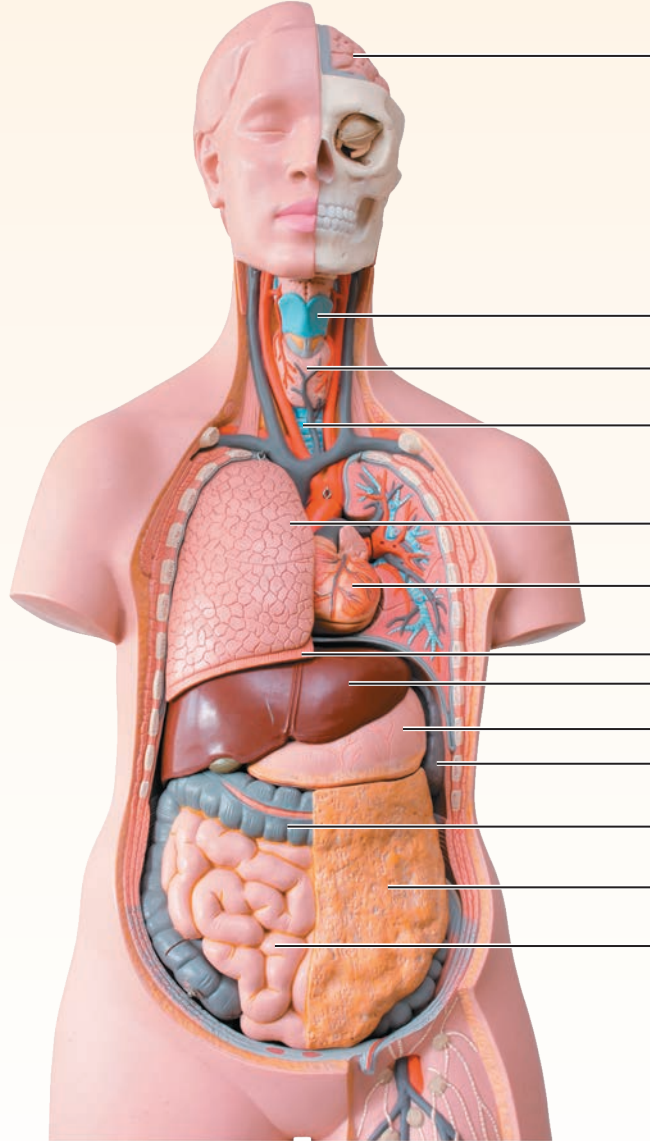
2 EXERCISE

REVIEW SHEET

Organ Systems Overview

Name _____ Lab Time/Date _____

1. Label each of the organs at the end of the supplied leader lines.



2. Name the *organ system* to which each of the following sets of organs or body structures belongs.

- | | |
|--------------------------------------------|----------------------------------------------------|
| _____ 1. thymus, spleen, lymphatic vessels | _____ 5. epidermis, dermis, cutaneous sense organs |
| _____ 2. bones, cartilages, tendons | _____ 6. testis, prostate |
| _____ 3. pancreas, pituitary gland | _____ 7. liver, large intestine, rectum |
| _____ 4. trachea, bronchi, lungs | _____ 8. kidneys, ureter, urethra |


3. Name the cells that are produced by the testes and ovaries. _____


4. List the four primary tissue types. _____


5. Explain why an artery is an organ. _____

6. Where do the digestive and respiratory structures interact? What name is given to this region? _____

7. What organs are responsible for the absorption of nutrients? How are they adapted to this role? _____

8.  During anesthesia, a patient's muscular system is disabled. Why must a doctor carefully monitor a patient's temperature in this case? _____

9.  The mother of a child scheduled to receive a thymectomy (removal of the thymus gland) asks you whether there will be any side effects from the removal of the gland. Which two organ systems would you mention in your explanation? _____

10.  Individuals with asplenia are missing their spleen or have a spleen that doesn't function well. It is recommended that these patients talk to their doctor about vaccines that are indicated for their health condition. Explain how this recommendation correlates to their chronic health condition. _____

3 EXERCISE

The Microscope

Learning Outcomes

- ▶ Identify the parts of the microscope, and list the function of each.
- ▶ Describe and demonstrate the proper techniques for care of the microscope.
- ▶ Demonstrate proper focusing technique.
- ▶ Define *total magnification*, *resolution*, *parfocal*, *field*, *depth of field*, and *working distance*.
- ▶ Measure the field diameter for one objective lens, calculate it for all the other objective lenses, and estimate the size of objects in each field.
- ▶ Discuss the general relationships between magnification, working distance, and field diameter.

Pre-Lab Quiz



Instructors may assign these and other Pre-Lab Quiz questions using **Mastering A&P™**

1. The microscope slide rests on the _____ while being viewed.
 - a. base
 - b. condenser
 - c. iris
 - d. stage
2. What type of preparation is made by suspending a specimen in water under a cover slip?
 - a. Wet mount
 - b. Oil immersion
 - c. Smear
3. If the ocular lens magnifies a specimen 10 \times , and the objective lens used magnifies the specimen 35 \times , what is the total magnification being used to observe the specimen? _____
4. What is adjusted to ensure uniform light distribution over the slide?
 - a. Condenser knob
 - b. Coarse adjustment knob
 - c. Fine adjustment knob
5. Circle True or False. You should always begin observation of specimens with the oil immersion lens.

With the invention of the microscope, biologists gained a valuable tool to observe and study structures, such as cells, that are too small to be seen by the unaided eye. This exercise will familiarize you with the workhorse of microscopes—the compound microscope—and provide you with the necessary instructions for its proper use.

***Note to the Instructor:** The slides and coverslips used for viewing cheek cells are to be soaked for 2 hours (or longer) in 10% bleach solution and then drained. The slides and disposable autoclave bag containing coverslips, lens paper, and used toothpicks are to be autoclaved for 15 min at 121°C and 15 pounds pressure to ensure sterility. After autoclaving, the disposable autoclave bag may be discarded in any disposal facility, and the slides and glassware washed with laboratory detergent and prepared for use. These instructions apply as well to any bloodstained glassware or disposable items used in other experimental procedures.

Go to **Mastering A&P™** > Study Area to improve your performance in A&P Lab.



> Lab Tools > Pre-Lab Videos > Compound Microscope



Instructors may assign new Building Vocabulary coaching activities, Pre-Lab Quiz questions, Art Labeling activities, Pre-Lab Video Coaching Activities for The Compound Microscope, and more using the **Mastering A&P™** Item Library.

Materials*

- ▶ Compound microscope
- ▶ Millimeter ruler
- ▶ Prepared slides of the letter e or newsprint
- ▶ Immersion oil
- ▶ Lens paper
- ▶ Prepared slide of grid ruled in millimeters
- ▶ Prepared slide of three crossed colored threads
- ▶ Clean microscope slide and coverslip
- ▶ Toothpicks (flat-tipped)
- ▶ Physiological saline in a dropper bottle
- ▶ Iodine or dilute methylene blue stain in a dropper bottle
- ▶ Filter paper or paper towels
- ▶ Beaker containing fresh 10% household bleach solution for wet mount disposal
- ▶ Disposable autoclave bag
- ▶ Prepared slide of cheek epithelial cells

Care and Structure of the Compound Microscope

The **compound microscope** is a precision instrument and should always be handled with care. *At all times you must observe the following rules for its transport, cleaning, use, and storage:*

- When transporting the microscope, hold it in an upright position, with one hand on its arm and the other supporting its base. Do not swing the instrument during its transport or jar the instrument when setting it down.
- Use only special grit-free lens paper to clean the lenses. Use a circular motion to wipe the lenses, and clean all lenses before and after use.
- Always begin the focusing process with the scanning objective lens in position, changing to the higher-power lenses as necessary.
- Use the coarse adjustment knob only with the scanning objective lens.
- Always use a coverslip with wet mount preparations.
- Before putting the microscope in the storage cabinet, remove the slide from the stage, rotate the scanning objective lens into position, wrap the cord as directed, and replace the dust cover or return the microscope to the appropriate storage area.
- Never remove any parts from the microscope; inform your instructor of any mechanical problems that arise.

Activity 1

Identifying the Parts of a Microscope

1. Using the proper transport technique, obtain a microscope and bring it to the laboratory bench.

Record the number of your microscope in the **Summary chart** (p. 46).

Compare your microscope with **Figure 3.1**, and identify the microscope parts described in **Table 3.1** on p. 47.

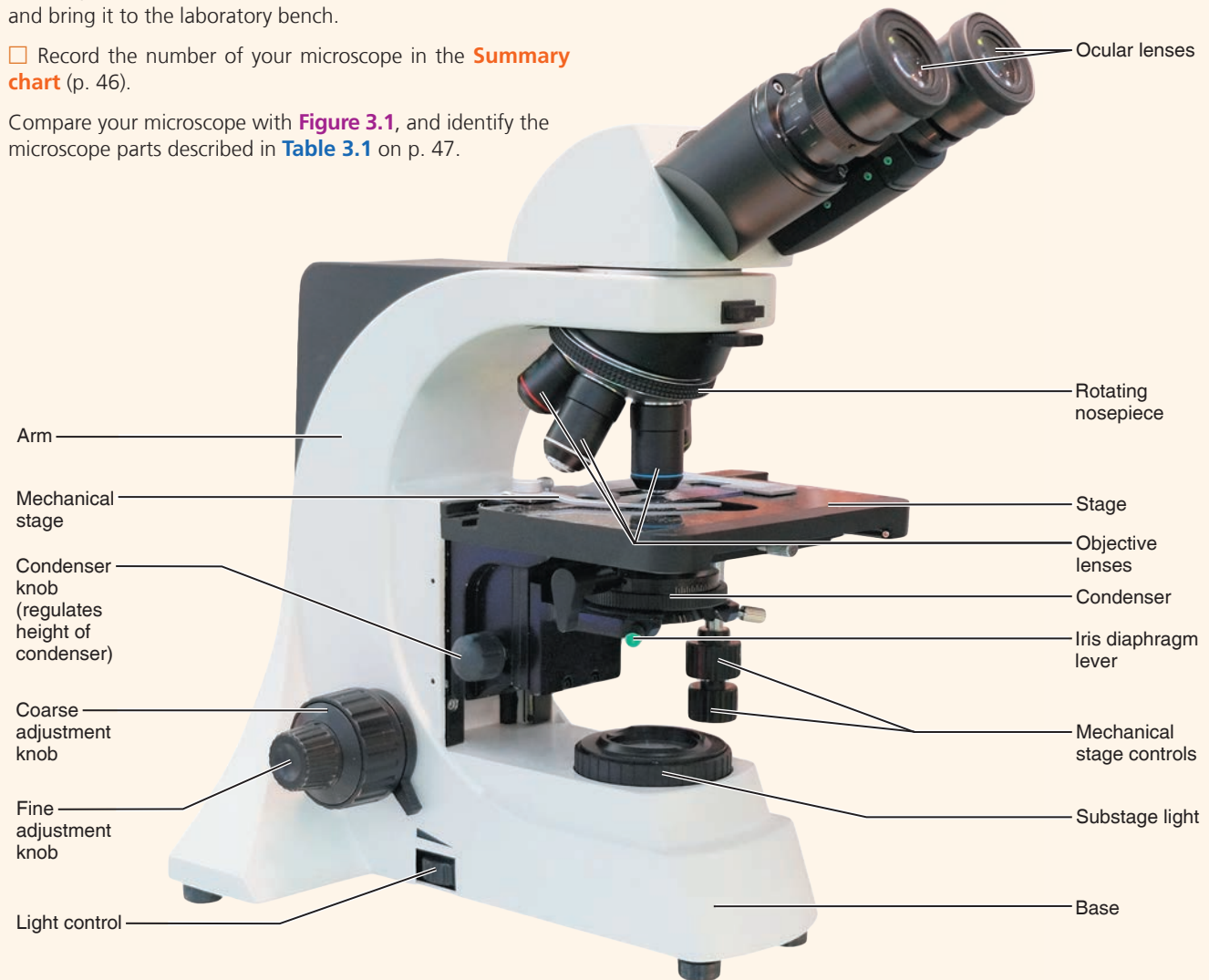


Figure 3.1 Compound microscope and its parts.



Instructors may assign this figure as an Art Labeling Activity using **Mastering A&P™**

2. Examine the objective lenses carefully; note their relative lengths and the numbers inscribed on their sides. On many microscopes, the scanning lens, with a magnification of $4\times$, is the shortest lens. The low-power objective lens typically has a magnification of $10\times$. The high-power objective lens is of intermediate length and has a magnification range from $40\times$ to $50\times$. The oil immersion objective lens is usually the longest

of the objective lenses and has a magnifying power of $100\times$. Some microscopes lack the oil immersion lens.

□ Record the magnification of each objective lens of your microscope in the first row of the Summary chart (p. 46). Also, cross out any column relating to a lens that your microscope does not have.

Magnification and Resolution

The microscope is an instrument of magnification. With the compound microscope, magnification is achieved through the interplay of two lenses—the ocular lens and the objective lens. The objective lens magnifies the specimen to produce a **real image** that is projected to the ocular. This real image is magnified by the ocular lens to produce the **virtual image** that your eye sees (Figure 3.2).

The **total magnification (TM)** of any specimen being viewed is equal to the power of the ocular lens multiplied by the power of the objective lens used. For example, if the ocular lens magnifies $10\times$ and the objective lens being used magnifies $45\times$, the total magnification is $450\times$ (or 10×45).

- Determine the total magnification for each of the objectives on your microscope, and record the figures on the third row of the Summary chart.

The compound light microscope has certain limitations. Although the level of magnification is almost limitless,

the **resolution** (or resolving power), that is, the ability to discriminate two close objects as separate, is not. The human eye can resolve objects about $100\ \mu\text{m}$ apart, but the compound microscope has a resolution of $0.2\ \mu\text{m}$ under ideal conditions. Objects closer than $0.2\ \mu\text{m}$ are seen as a single fused image.

Resolution is determined by the amount and physical properties of the visible light that enters the microscope. In general, the more light delivered to the objective lens, the greater the resolution. The size of the objective lens aperture (opening) decreases with increasing magnification, allowing less light to enter the objective. Thus, you will probably find it necessary to increase the light intensity at the higher magnifications.

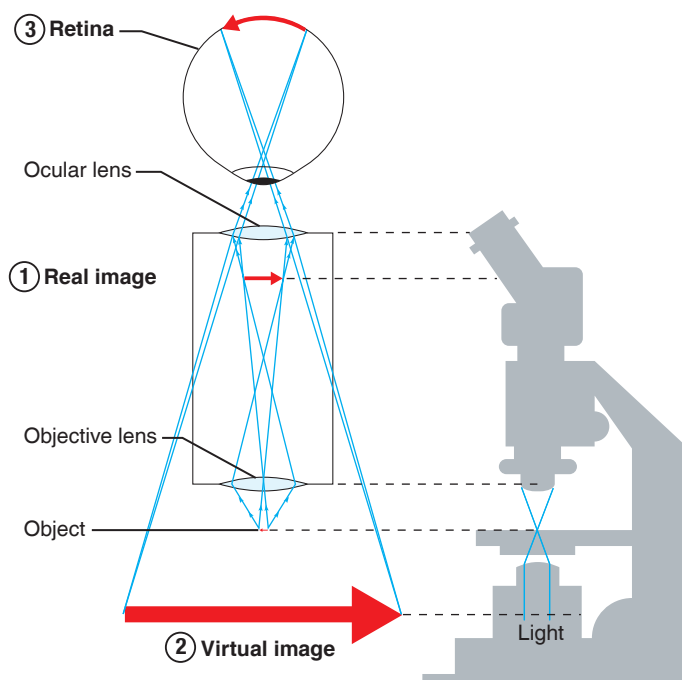


Figure 3.2 Image formation in light microscopy.

Step 1 The objective lens magnifies the object, forming the real image. **Step 2** The ocular lens magnifies the real image, forming the virtual image. **Step 3** The virtual image passes through the lens of the eye and is focused on the retina.

Activity 2



Instructors may assign a related Pre-Lab Video Coaching Activity using **Mastering A&P™**

Viewing Objects Through the Microscope

1. Obtain a millimeter ruler, a prepared slide of the letter e or newsprint, a dropper bottle of immersion oil, and some lens paper. Adjust the condenser to its highest position, and switch on the light source of your microscope.
2. Secure the slide on the stage so that you can read the slide label and the letter e is centered over the light beam passing through the stage. On the mechanical stage of your microscope, open the jaws of its slide holder by using the control lever, typically located at the rear left corner of the mechanical stage. Insert the slide squarely within the confines of the slide holder.
3. With your scanning objective lens in position over the stage, use the coarse adjustment knob to bring the objective lens and stage as close together as possible.
4. Look through the ocular lens and adjust the light for comfort using the iris diaphragm lever. Now use the coarse adjustment knob to focus slowly away from the e until it is as clearly focused as possible. Complete the focusing with the fine adjustment knob.
5. Sketch the letter e in the circle on the Summary chart (p. 46) just as it appears in the **field**—the area you see through the microscope.

How far is the bottom of the objective lens from the surface of the slide? In other words, what is the **working distance**? (See Figure 3.3.) Use a millimeter ruler to measure the working distance.

Record the working distance in the Summary chart.

Text continues on next page. →

How has the apparent orientation of the e changed top to bottom, right to left, and so on?

6. Move the slide slowly away from you on the stage as you view it through the ocular lens. In what direction does the image move?

Move the slide to the left. In what direction does the image move?

7. Today, most good laboratory microscopes are **parfocal**; that is, the slide should be in focus (or nearly so) at the higher magnifications once you have properly focused at the lower magnification. *Without touching the focusing knobs*, increase the magnification by rotating the next higher magnification lens into position over the stage. Make sure it clicks into position. Using the fine adjustment only, sharpen the focus. If you are unable to focus with a new lens, your microscope is not parfocal. Do not try to force the lens into position. Consult your instructor. Note the decrease in working distance. As you can see, focusing with the coarse adjustment knob could drive the objective lens through the slide, breaking the slide and possibly damaging the lens. Sketch the letter e in the Summary chart. What new details become clear?

As best you can, measure the distance between the objective and the slide.

Record the working distance in the Summary chart.

Is the image larger or smaller? _____

Approximately how much of the letter e is visible now?

Is the field diameter larger or smaller? _____

Why is it necessary to center your object (or the portion of the slide you wish to view) before changing to a higher power?

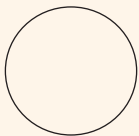
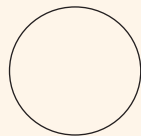
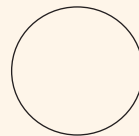
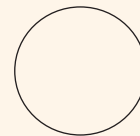
Move the iris diaphragm lever while observing the field. What happens?

Is it better to increase or to decrease the light when changing to a higher magnification?

_____ Why? _____

8. If you have just been using the low-power objective, repeat the steps given in direction 7 using the high-power objective lens. What new details become clear?

Record the working distance in the Summary chart.

Summary Chart for Microscope # _____				
	Scanning	Low power	High power	Oil immersion
Magnification of objective lens	_____ ×	_____ ×	_____ ×	_____ ×
Magnification of ocular lens	10 _____ ×	10 _____ ×	10 _____ ×	10 _____ ×
Total magnification	_____ ×	_____ ×	_____ ×	_____ ×
Working distance	_____ mm	_____ mm	_____ mm	_____ mm
Detail observed letter e				
Field diameter	_____ mm _____ μm	_____ mm _____ μm	_____ mm _____ μm	_____ mm _____ μm

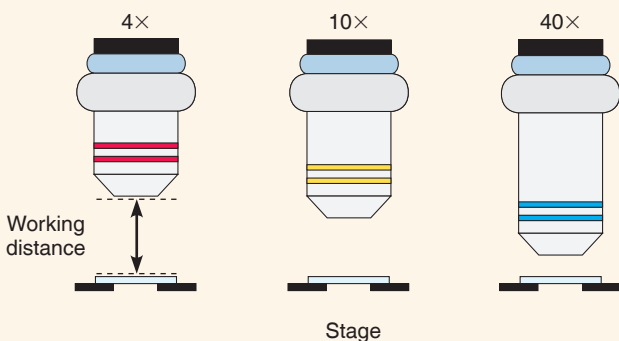


Figure 3.3 Relative working distances of the 4×, 10×, and 40× objectives.

9. Without touching the focusing knob, rotate the high-power lens out of position so that the area of the slide over the opening in the stage is unobstructed. Place a drop of immersion oil over the *e* on the slide and rotate the oil immersion lens into position. Set the condenser at its highest point (closest to the stage), and open the diaphragm fully. Adjust the fine focus and fine-tune the light for the best possible resolution.

Note: If for some reason the specimen does not come into view after adjusting the fine focus, do not go back to the 40× lens to recenter. You do not want oil from the oil immersion lens to cloud the 40× lens. Turn the revolving nosepiece in the other direction to the low-power lens, and recenter and refocus the object. Then move the

immersion lens back into position, again avoiding the 40× lens. Sketch the letter *e* in the Summary chart. What new details become clear?

Is the field diameter again decreased in size? _____

As best you can, estimate the working distance, and record it in the Summary chart. Is the working distance less or greater than it was when the high-power lens was focused?

Compare your observations on the relative working distances of the objective lenses with the illustration in **Figure 3.3**. Explain why it is desirable to begin the focusing process at the lowest power.

10. Rotate the oil immersion lens slightly to the side, and remove the slide. Clean the oil immersion lens carefully with lens paper, and then clean the slide in the same manner with a fresh piece of lens paper.

Table 3.1 Parts of the Microscope

Microscope part	Description and function
Base	The bottom of the microscope. Provides a sturdy flat surface to support and steady the microscope.
Substage light	Located in the base. The light from the lamp passes directly upward through the microscope.
Light control	Located on the base or arm. This dial allows you to adjust the intensity of the light passing through the specimen.
Stage	The platform that the slide rests on while being viewed. The stage has a hole in it to allow light to pass through the stage and through the specimen.
Mechanical stage	Holds the slide in position for viewing and has two adjustable knobs that control the precise movement of the slide.
Condenser	Small nonmagnifying lens located beneath the stage that concentrates the light on the specimen. The condenser may have a knob that raises and lowers the condenser to vary the light delivery. Generally, the best position is close to the inferior surface of the stage.
Iris diaphragm lever	The iris diaphragm is a shutter within the condenser that can be controlled by a lever to adjust the amount of light passing through the condenser. The lever can be moved to close the diaphragm and improve contrast. If your field of view is too dark, you can open the diaphragm to let in more light.
Coarse adjustment knob	This knob allows you to make large adjustments to the height of the stage to initially focus your specimen.
Fine adjustment knob	This knob is used for precise focusing once the initial coarse focusing has been completed.
Head	Attaches to the nosepiece to support the objective lens system. It also provides for attachment of the eyepieces which house the ocular lenses.
Arm	Vertical portion of the microscope that connects the base and the head.
Nosepiece	Rotating mechanism connected to the head. Generally, it carries three or four objective lenses and permits positioning of these lenses over the hole in the stage.
Objective lenses	These lenses are attached to the nosepiece. Usually, a compound microscope has four objective lenses: scanning (4×), low-power (10×), high-power (40×), and oil immersion (100×) lenses. Typical magnifying powers for the objectives are listed in parentheses.
Ocular lens(es)	Binocular microscopes will have two lenses located in the eyepieces at the superior end of the head. Most ocular lenses have a magnification power of 10×. Some microscopes will have a pointer and/or reticle (micrometer), which can be positioned by rotating the ocular lens.

The Microscope Field

The microscope field decreases with increasing magnification. Measuring the diameter of each of the microscope fields will allow you to estimate the size of the objects you view in any field. For example, if you have calculated the field diameter to be 4 mm and the object being observed extends across half this diameter, you can estimate that the length of the object is approximately 2 mm.

Microscopic specimens are usually measured in micrometers and millimeters, both units of the metric system. You can get an idea of the relationship and meaning of these units from **Table 3.2**. A more detailed treatment appears in the appendix.

Table 3.2 Comparison of Metric Units of Length

Metric unit	Abbreviation	Equivalent
Meter	m	(about 39.37 in.)
Centimeter	cm	10^{-2} m
Millimeter	mm	10^{-3} m
Micrometer (or micron)	μm (μ)	10^{-6} m
Nanometer	nm (m μ)	10^{-9} m

(Refer to the Getting Started exercise on Mastering A&P for tips on metric conversions.)

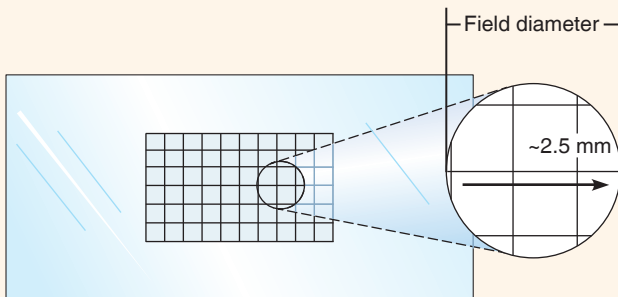
Activity 3



Instructors may assign a related Pre-Lab Video Coaching Activity using **Mastering A&P™**

Estimating the Diameter of the Microscope Field

- Obtain a grid slide, which is a slide prepared with graph paper ruled in millimeters. Each of the squares in the grid is 1 mm on each side. Use your scanning objective lens to bring the grid lines into focus.
- Move the slide so that one grid line touches the edge of the field on one side, and then count the number of squares you can see across the diameter of the field. If you can see only part of a square, as in the accompanying diagram, estimate the part of a millimeter that the partial square represents.



Record this figure in the appropriate space marked "field diameter" on the Summary chart (p. 46). (If you have been using the scanning lens, repeat the procedure with the low-power objective lens.)

Complete the chart by computing the approximate diameter of the high-power and oil immersion fields. The general formula for calculating the unknown field diameter is:

$$\text{Diameter of field } A \times \text{total magnification of field } A = \text{diameter of field } B \times \text{total magnification of field } B$$

where A represents the known or measured field and B represents the unknown field. This can be simplified to

$$\text{Diameter of field } B = \frac{\text{diameter of field } A \times \text{total magnification of field } A}{\text{total magnification of field } B}$$

For example, if the diameter of the low-power field (field A) is 2 mm and the total magnification is $50\times$, you would compute

the diameter of the high-power field (field B) with a total magnification of $100\times$ as follows:

$$\text{Field diameter } B = (2 \text{ mm} \times 50) / 100$$

$$\text{Field diameter } B = 1 \text{ mm}$$

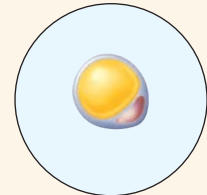
- Estimate the length (longest dimension) of the following drawings of microscopic objects. Base your calculations on the field diameters you have determined for your microscope and the approximate percentage of the diameter that the object occupies. The first one is done for you.

Fat cell seen in $400\times$ (total magnification, TM) field:

$$\text{Field diameter} = 0.4 \text{ mm} = 400 \mu\text{m}$$

Portion of the field diameter occupied by the object = $1/3$

$$\text{Approximate length} = 133 \mu\text{m}$$

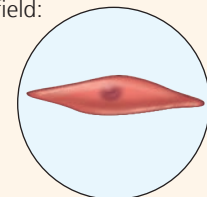


Smooth muscle cell seen in $400\times$ (TM) field:

approximate length:

_____ mm

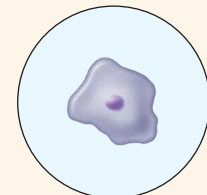
or _____ μm



Cheek cell seen in oil immersion field:

approximate length:

_____ μm



Perceiving Depth

Any microscopic specimen has depth as well as length and width; it is rare indeed to view a tissue slide with just one layer of cells. Normally you can see two or three cell thicknesses. Therefore, it is important to learn how to determine relative

depth with your microscope. In microscope work, the **depth of field** (the thickness of the plane that is clearly in focus) is greater at lower magnifications. As magnification increases, depth of field decreases.

Activity 4

Perceiving Depth

1. Obtain a slide with colored crossed threads. Focusing at low magnification, locate the point where the three threads cross each other.
2. Use the iris diaphragm lever to greatly reduce the light, thus increasing the contrast. Focus down with the coarse adjustment until the threads are out of focus, then slowly focus upward again, noting which thread comes into clear focus first. Observe: As you rotate the adjustment knob forward (away from you), does the stage rise or fall? If the stage rises, then the first clearly focused thread is the top one; the last clearly focused thread is the bottom one.

If the stage descends, how is the order affected? _____

Record your observations, relative to which color of thread is uppermost, middle, or lowest:

Top thread _____

Middle thread _____

Bottom thread _____

Viewing Cells Under the Microscope

There are various ways to prepare cells for viewing under a microscope. One method is to mix the cells in physiological saline (called a *wet mount*) and stain them.

If you are not instructed to prepare your own wet mount, obtain a prepared slide of epithelial cells to make the observations in step 10 of Activity 5.


Activity 5




Instructors may assign a related Pre-Lab Video Coaching Activity using **Mastering A&P™**

Preparing and Observing a Wet Mount

1. Obtain the following: a clean microscope slide and coverslip, two flat-tipped toothpicks, a dropper bottle of physiological saline, a dropper bottle of iodine or methylene blue stain, and filter paper (or paper towels). Handle only your own slides throughout the procedure.
2. Place a drop of physiological saline in the center of the slide. Using the flat end of the toothpick, *gently* scrape the inner lining of your cheek. Transfer your cheek scrapings to the slide by agitating the end of the toothpick in the drop of saline (**Figure 3.4a** on p. 50).

 *Immediately* discard the used toothpick in the disposable autoclave bag provided.
3. Add a tiny drop of the iodine or methylene blue stain to the preparation. (These epithelial cells are nearly transparent and

thus difficult to see without the stain, which colors the nuclei of the cells.) Stir again, using a second toothpick.

 *Immediately* discard the used toothpicks in the disposable autoclave bag provided.

4. Hold the coverslip with your fingertips so that its bottom edge touches one side of the drop (Figure 3.4b), then *slowly* lower the coverslip onto the preparation (Figure 3.4c). *Do not just drop the coverslip*, or you will trap large air bubbles under it, which will obscure the cells. *Always use a coverslip with a wet mount* to protect the lens.

5. Examine your preparation carefully. The coverslip should be tight against the slide. If there is excess fluid around its edges, you will need to remove it. Obtain a piece of filter paper, fold it in half, and use the folded edge to absorb the excess fluid.

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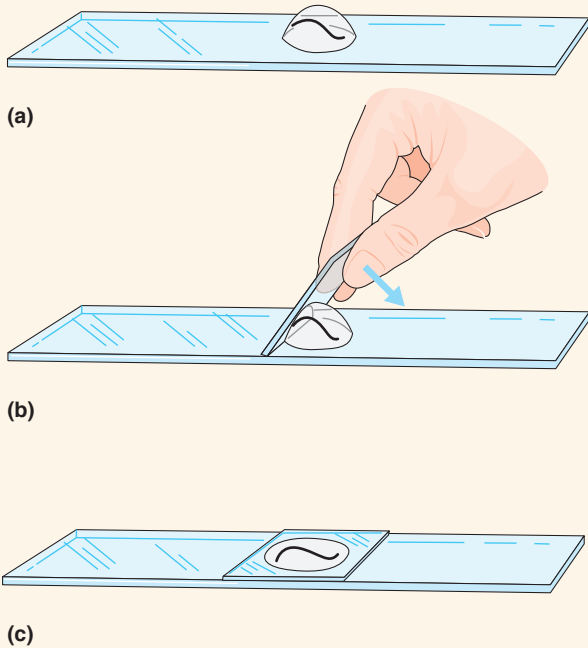


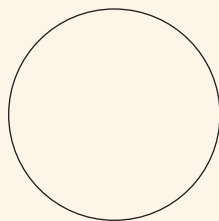
Figure 3.4 Procedure for preparation of a wet mount. (a) Place the object in a drop of water (or saline) on a clean slide; (b) hold a coverslip at a 45° angle with the fingertips; and (c) lower the coverslip slowly.

! Before continuing, discard the filter paper or paper towel in the disposable autoclave bag.

6. Place the slide on the stage, and locate the cells at the lowest power. You will probably want to dim the light to provide more contrast for viewing the lightly stained cells.

7. Cheek epithelial cells are very thin, flat cells. In the cheek, they provide a smooth, tilelike lining (Figure 3.5). Move to high power to examine the cells more closely.

8. Make a sketch of the epithelial cells that you observe.



Use information on your Summary chart (p. 46) to estimate the diameter of cheek epithelial cells. Record the total magnification (TM) used.

_____ μm _____ × (TM)

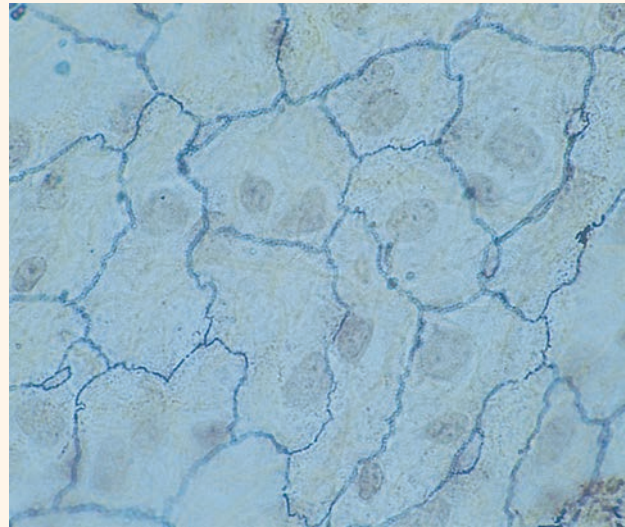


Figure 3.5 Epithelial cells of the cheek cavity (surface view, 600×).

Why do *your* cheek cells look different from those in Figure 3.5? (Hint: What did you have to *do* to your cheek to obtain them?)

! **9.** When you complete your observations of the wet mount, dispose of your wet mount preparation in the beaker of bleach solution, and put the coverslips in an autoclave bag.

10. Obtain a prepared slide of cheek epithelial cells, and view them under the microscope.

Estimate the diameter of one of these cheek epithelial cells using information from the Summary chart (p. 46).

_____ μm _____ × (TM)

Why are these cells more similar to those in Figure 3.5 and easier to measure than those of the wet mount?

11. Before leaving the laboratory, make sure all other materials are properly discarded or returned to the appropriate laboratory station. Clean the microscope lenses, and return the microscope to the storage cabinet.

3 REVIEW SHEET

EXERCISE The Microscope

Instructors may assign a portion of the Review Sheet questions using **Mastering A&P™**

Name _____ Lab Time/Date _____

Care and Structure of the Compound Microscope

1. Label all indicated parts of the microscope.



2. Explain the proper technique for transporting the microscope.

3. Each of the following statements is either true or false. If true, write *T* on the answer blank. If false, correct the statement by writing on the blank the proper word or phrase to replace the one that is underlined.

- _____ 1. The microscope lens may be cleaned with any soft tissue.
- _____ 2. The microscope should be stored with the oil immersion lens in position over the stage.
- _____ 3. When beginning to focus, use the scanning objective lens.
- _____ 4. When focusing on high power, always use the coarse adjustment knob to focus.
- _____ 5. A coverslip should always be used with wet mounts.

4. Match the microscope structures in column B with the statements in column A that identify or describe them.

Column A

- _____ 1. platform on which the slide rests for viewing
- _____ 2. used to adjust the amount of light passing through the specimen
- _____ 3. controls the movement of the slide on the stage
- _____ 4. delivers a concentrated beam of light to the specimen
- _____ 5. used for precise focusing once initial focusing has been done
- _____ 6. carries the objective lenses; rotates so that the different objective lenses can be brought into position over the specimen.

Column B

- a. coarse adjustment knob
- b. condenser
- c. fine adjustment knob
- d. iris diaphragm lever
- e. mechanical stage
- f. nosepiece
- g. objective lenses
- h. ocular lens
- i. stage

5. Define the following terms.

total magnification: _____

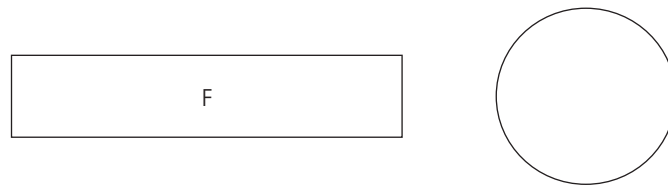
resolution: _____

Viewing Objects Through the Microscope

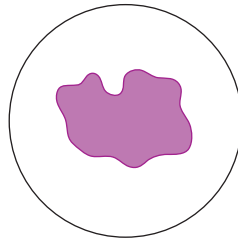
6. Complete, or respond to, the following statements:

- _____ 1. The distance from the bottom of the objective lens to the surface of the slide is called the _____.
- _____ 2. Assume there is an object on the left side of the field that you want to bring to the center (that is, toward the apparent right). In what direction would you move your slide? _____.
- _____ 3. The area of the slide seen when looking through the microscope is the _____.
- _____ 4. If a microscope has a 10× ocular lens and the total magnification is 950×, the objective lens in use at that time is _____ ×.

- _____ 5. Why should the light be dimmed when looking at living (nearly transparent) cells?
- _____ 6. If, after focusing in low power, you need to use only the fine adjustment to focus the specimen at the higher powers, the microscope is said to be _____.
- _____ 7. You are using a 10× ocular and a 15× objective, and the field diameter is 1.5 mm. The approximate field size with a 30× objective is _____ mm.
- _____ 8. If the diameter of the low-power field is 1.5 mm, an object that occupies approximately a third of that field has an estimated diameter of _____ mm.
7. You have been asked to prepare a slide with the letter *F* on it (as shown below). In the circle below, draw the *F* as seen in the low-power field.



8. Estimate the length (longest dimension) of the object in μm :



Total magnification = 100×

Field diameter = 1.6 mm

Length of object = _____ μm

9. You have produced a wet mounted slide, and when viewing the slide, only part of the specimen can be clearly visualized.

Why might this occur? _____

What should you do to ensure this doesn't happen again? _____

10. Do the following factors increase or decrease as one moves to higher magnifications with the microscope?

resolution: _____ amount of light needed: _____

working distance: _____ depth of field: _____

11. When calculating total magnification, why is the power of the objective lens normally multiplied by 10?

12. What are oil immersion lenses? Why are they used?

13. Indicate the probable cause of the following situations during use of a microscope.

a. Only half of the field is illuminated: _____

b. The visible field does not change as the mechanical stage is moved: _____

14.  A histopathologist viewing sample slides is careful to always wear gloves and dispose slides in an autoclave bag after viewing. Explain why this technique is essential to protect the histopathologist.

15.  A diagnostician is preparing a biopsy. Why is iodine or methylene blue used in the practice of microscopy? _____

4 EXERCISE

The Cell: Anatomy and Division

Learning Outcomes

- ▶ Define *cell*, *organelle*, and *inclusion*.
- ▶ Identify on a cell model or diagram the following cellular regions and list the major function of each: nucleus, cytoplasm, and plasma membrane.
- ▶ Identify the cytoplasmic organelles and discuss their structure and function.
- ▶ Compare and contrast specialized cells with the concept of the “generalized cell.”
- ▶ Define *interphase*, *mitosis*, and *cytokinesis*.
- ▶ List the stages of mitosis, and describe the key events of each stage.
- ▶ Identify the mitotic phases on slides or appropriate diagrams.
- ▶ Explain the importance of mitotic cell division, and describe its product.

Pre-Lab Quiz



Instructors may assign these and other Pre-Lab Quiz questions using **Mastering A&P™**

1. When a cell is not dividing, the DNA is loosely spread throughout the nucleus in a threadlike form called:

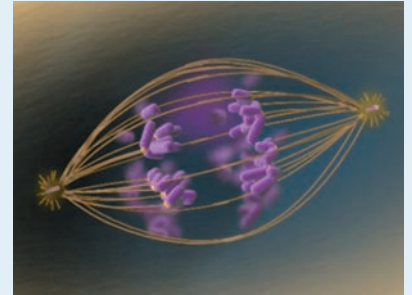
a. chromatin	c. cytosol
b. chromosomes	d. ribosomes
2. The plasma membrane not only provides a protective boundary for the cell but also determines which substances enter or exit the cell. We call this characteristic:

a. diffusion	c. osmosis
b. membrane potential	d. selective permeability
3. Because these organelles are responsible for providing most of the ATP that the cell needs, they are often referred to as the “powerhouses” of the cell. They are the:

a. centrioles	c. mitochondria
b. lysosomes	d. ribosomes
4. Circle True or False. The end product of mitosis is four genetically identical daughter nuclei.
5. DNA replication occurs during:

a. cytokinesis	c. metaphase
b. interphase	d. prophase

Go to **Mastering A&P™** > **Study Area to improve your performance in A&P Lab.**



> **Animations & Videos > A&P Flix > Mitosis**



Instructors may assign new Building Vocabulary coaching activities, Pre-Lab Quiz questions, Art Labeling activities, and more using the **Mastering A&P™** Item Library.

Materials

- ▶ Three-dimensional model of the “composite” animal cell or laboratory chart of cell anatomy
- ▶ Compound microscope
- ▶ Prepared slides of simple squamous epithelium, teased smooth muscle (l.s.), human blood smear, and sperm
- ▶ Animation/video of mitosis
- ▶ Three-dimensional models of mitotic stages
- ▶ Prepared slides of whitefish blastulas
- ▶ Chenille sticks (pipe cleaners), two different colors cut into 3-inch pieces, 8 pieces per group

Note to the Instructor: See directions for handling wet mount preparations and disposable supplies (p. 43, Exercise 3). For suggestions on the animation/video of mitosis, see the Instructor’s Guide.

The **cell** is the structural and functional unit of all living things. The cells of the human body are highly diverse, and their differences in size, shape, and internal composition reflect their specific roles in the body. Still, cells do have many common anatomical features, and all cells must carry out certain functions to sustain life. For example, all cells can

maintain their boundaries, metabolize, digest nutrients and dispose of wastes, grow and reproduce, move, and respond to a stimulus. This exercise begins by describing the structural similarities found in many cells, illustrated by a “composite,” or “generalized,” cell (**Figure 4.1a**), and then considers the function of cell reproduction (cell division).

Anatomy of the Composite Cell

In general, all animal cells have three major regions, or parts, that can readily be identified with a light microscope: the **nucleus**, the **plasma membrane**, and the **cytoplasm**. The nucleus is near the center of the cell. It is surrounded by cytoplasm, which in turn is enclosed by the plasma membrane. **Figure 4.1a** is a diagram representing the fine structure of the composite cell. An electron micrograph (**Figure 4.1b**) reveals the cellular structure, particularly of the nucleus.

Nucleus

The nucleus contains the genetic material, DNA, sections of which are called *genes*. Often described as the control center

of the cell, the nucleus is necessary for cell reproduction. A cell that has lost or ejected its nucleus is programmed to stop dividing.

When the cell is not dividing, the genetic material is loosely dispersed throughout the nucleus in a threadlike form called **chromatin**. When the cell is in the process of dividing to form daughter cells, the chromatin coils and condenses, forming dense, rodlike bodies called **chromosomes**—much in the way a stretched spring becomes shorter and thicker when it is released.

The nucleus also contains one or more small spherical bodies, called **nucleoli**, composed primarily of proteins and ribonucleic acid (RNA). The nucleoli are assembly sites for ribosomes that are particularly abundant in the cytoplasm.

The nucleus is bound by a double-layered porous membrane, the **nuclear envelope**. The nuclear envelope is similar in composition to other cellular membranes, but it is distinguished by its large **nuclear pores**. They are spanned by protein complexes that regulate what passes through, and they permit easy passage of protein and RNA molecules.

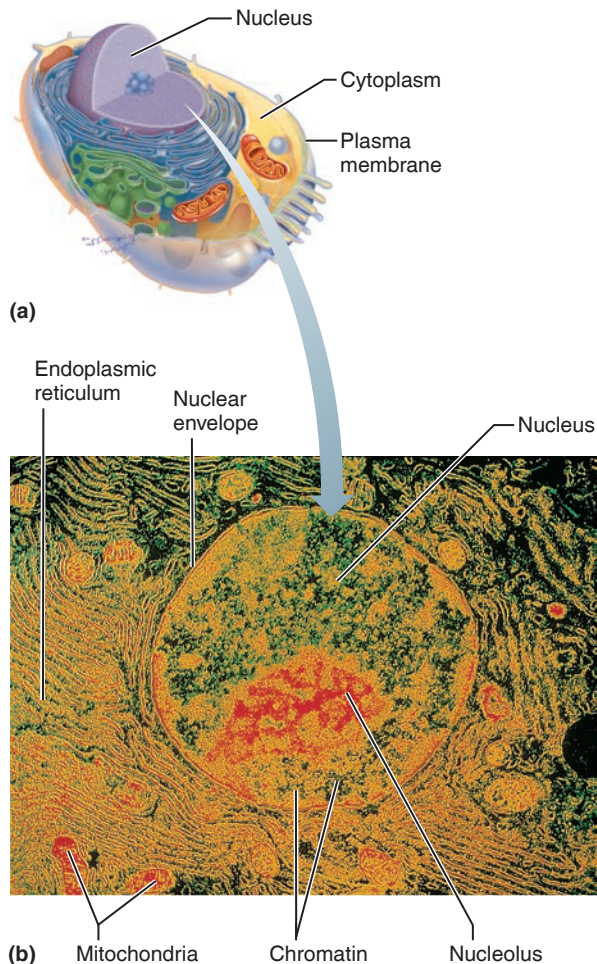


Figure 4.1 Anatomy of the composite animal cell. **(a)** Diagram. **(b)** Transmission electron micrograph (5000 \times).

Activity 1

Identifying Parts of a Cell

Identify the nuclear envelope, chromatin, nucleolus, and the nuclear pores in **Figure 4.1a** and **b** and **Figure 4.3**.

Plasma Membrane

The **plasma membrane** separates cell contents from the surrounding environment, providing a protective barrier. Its main structural building blocks are phospholipids (fats) and globular protein molecules. Some of the externally facing proteins and lipids have sugar (carbohydrate) side chains attached to them that are important in cellular interactions (**Figure 4.2**). As described by the fluid mosaic model, the membrane is a bilayer of phospholipid molecules in which the protein molecules float. Occasional cholesterol molecules dispersed in the bilayer help stabilize it.

Because of its molecular composition, the plasma membrane is selective about what passes through it. It allows nutrients to enter the cell but keeps out undesirable substances. By the same token, valuable cell proteins and other substances are kept within the cell, and excreta, or wastes, pass to the exterior. This property is known as **selective permeability**.

Additionally, the plasma membrane maintains a resting potential that is essential to normal functioning of excitable cells, such as neurons and muscle cells, and plays a vital role

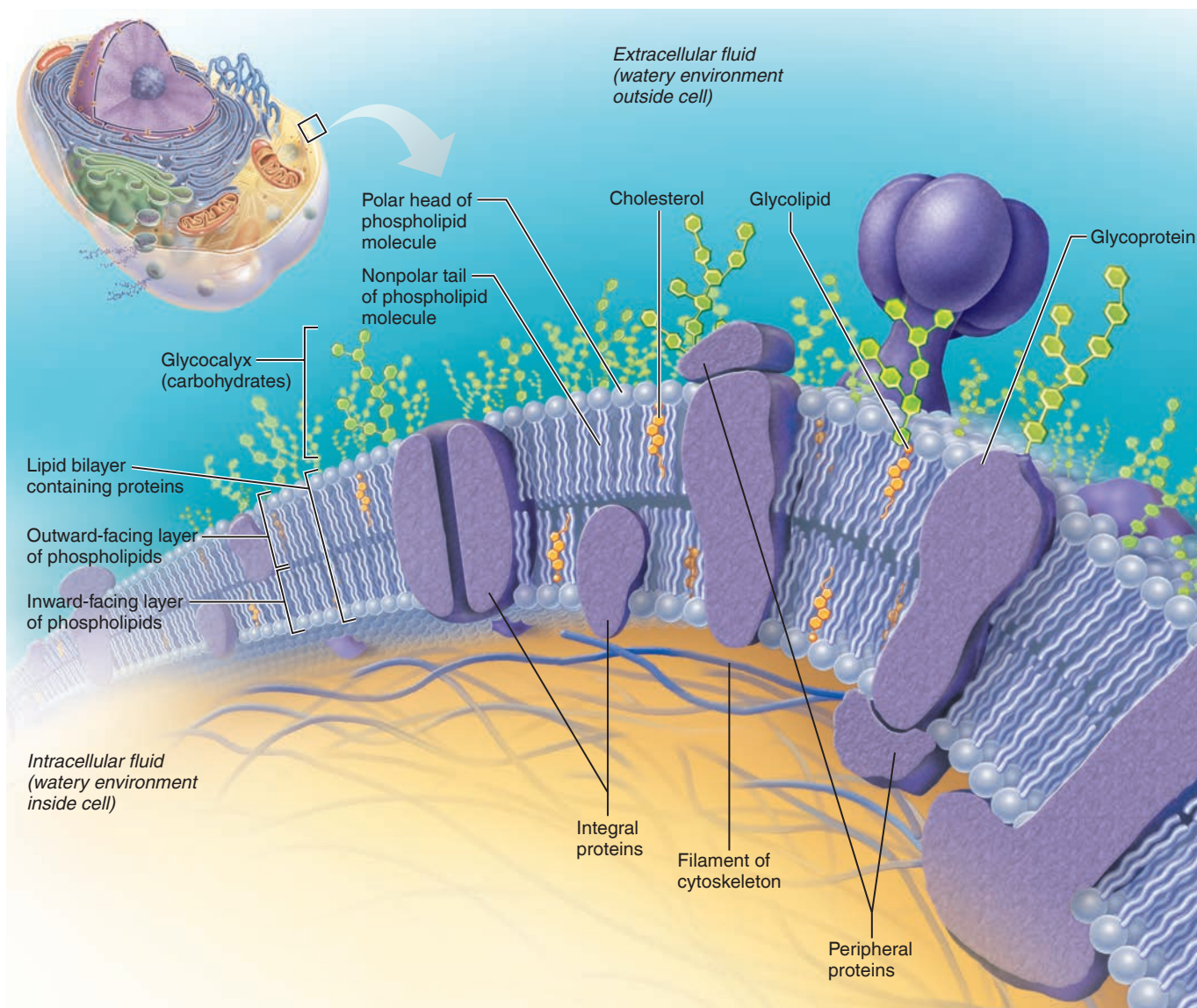


Figure 4.2 Structural details of the plasma membrane.



Instructors may assign this figure as an Art Labeling Activity using **Mastering A&P™**

in cell signaling and cell-to-cell interactions. In some cells, the membrane is thrown into tiny fingerlike projections or folds called **microvilli** (Figure 4.3, p. 58). Microvilli greatly increase the surface area of the cell available for absorption or passage of materials and for the binding of signaling molecules.

Activity 2

Identifying Components of a Plasma Membrane

Identify the phospholipid and protein portions of the plasma membrane in Figure 4.2. Also locate the sugar (*glyco* = carbohydrate) side chains and cholesterol molecules. Identify the microvilli in the generalized cell diagram (Figure 4.3).

Cytoplasm and Organelles

The cytoplasm consists of the cell contents between the nucleus and plasma membrane. Suspended in the **cytosol**, the fluid cytoplasmic material, are many small structures called **organelles** (literally, “small organs”). The organelles are the metabolic machinery of the cell, and they are highly organized to carry out specific functions for the cell as a whole. The cytoplasmic organelles include the ribosomes, smooth and rough endoplasmic reticulum, Golgi apparatus, lysosomes, peroxisomes, mitochondria, cytoskeletal elements, and centrioles.

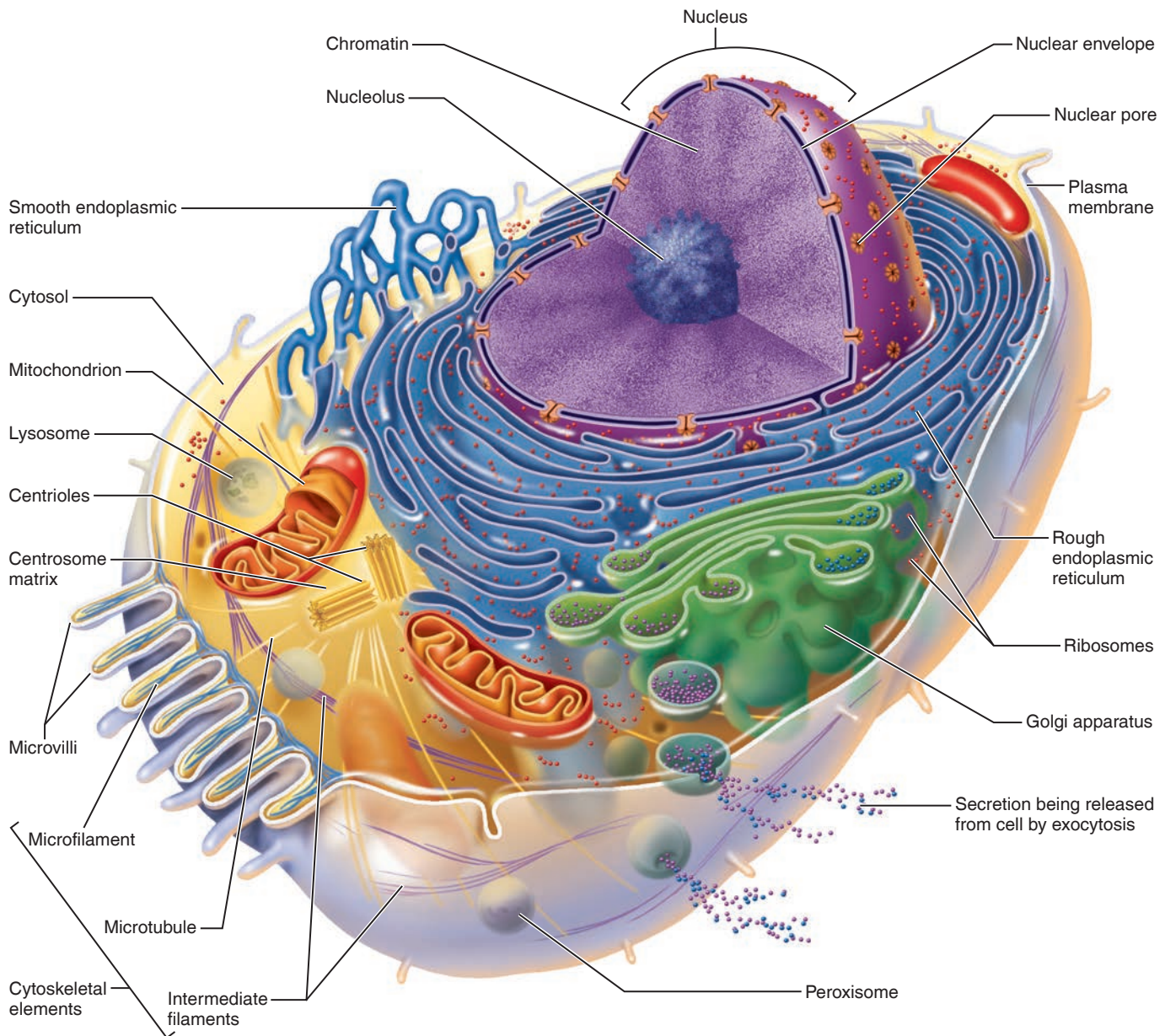


Figure 4.3 Structure of the generalized cell. No cell is exactly like this one, but this composite illustrates features common to many human cells. Not all organelles are drawn to the same scale in this illustration.



Instructors may assign this figure as an Art Labeling Activity using **Mastering A&P™**

Activity 3

Locating Organelles

Each organelle type is described in [Table 4.1](#). Read through the table, and then, as best you can, locate the organelles in Figures 4.1b and 4.3.


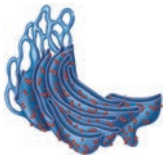
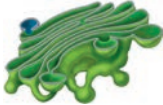





Activity 4

Examining the Cell Model

Once you have located all of these structures in the art (Figures 4.1b and 4.3), examine the cell model (or cell chart) to repeat and reinforce your identifications.

The cell cytoplasm may or may not contain **inclusions**. Examples of inclusions are stored foods (glycogen granules and lipid droplets), pigment granules, crystals of various types, water vacuoles, and ingested foreign materials.

Table 4.1 Summary of Structure and Function of Cytoplasmic Organelles

Organelle		Location and function
Ribosomes		Tiny spherical bodies composed of RNA and protein; floating free or attached to a membranous structure (the rough ER) in the cytoplasm. Actual sites of protein synthesis.
Endoplasmic reticulum (ER)		Membranous system of tubules that extends throughout the cytoplasm; two varieties: rough and smooth. Rough ER is studded with ribosomes; tubules of the rough ER provide an area for storage and transport of the proteins made on the ribosomes to other cell areas. Smooth ER, which has no function in protein synthesis, is a site of steroid and lipid synthesis, lipid metabolism, and drug detoxification.
Golgi apparatus		Stack of flattened sacs with bulbous ends and associated small vesicles; found close to the nucleus. Plays a role in packaging proteins or other substances for export from the cell or incorporation into the plasma membrane and in packaging lysosomal enzymes.
Lysosomes		Various-sized membranous sacs containing digestive enzymes including acid hydrolases; function to digest worn-out cell organelles and foreign substances that enter the cell. Have the capacity of total cell destruction if ruptured and are for this reason referred to as "suicide sacs."
Peroxisomes		Small lysosome-like membranous sacs containing oxidase enzymes that detoxify alcohol, free radicals, and other harmful chemicals. They are particularly abundant in liver and kidney cells.
Mitochondria		Generally rod-shaped bodies with a double-membrane wall; inner membrane is shaped into folds, or cristae; contain enzymes that oxidize foodstuffs to produce cellular energy (ATP); often referred to as "powerhouses of the cell."
Centrioles		Paired, cylindrical bodies that lie at right angles to each other, close to the nucleus. Internally, each centriole is composed of nine triplets of microtubules. As part of the centrosome, they direct the formation of the mitotic spindle during cell division; form the bases of cilia and flagella and in that role are called <i>basal bodies</i> .
Cytoskeletal elements: microfilaments, intermediate filaments, and microtubules		Form an internal scaffolding called the <i>cytoskeleton</i> . Provide cellular support; function in intracellular transport. Microfilaments are formed largely of actin, a contractile protein, and thus are important in cell mobility, particularly in muscle cells. Intermediate filaments are stable elements composed of a variety of proteins and resist mechanical forces acting on cells. Microtubules form the internal structure of the centrioles and help determine cell shape.

Differences and Similarities in Cell Structure

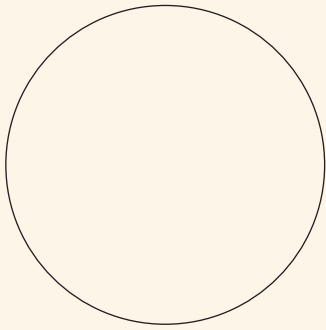
Activity 5

Observing Various Cell Structures

1. Obtain a compound microscope and prepared slides of simple squamous epithelium, smooth muscle cells (teased), human blood, and sperm.
2. Observe each slide under the microscope, carefully noting similarities and differences in the cells. See photomicrographs

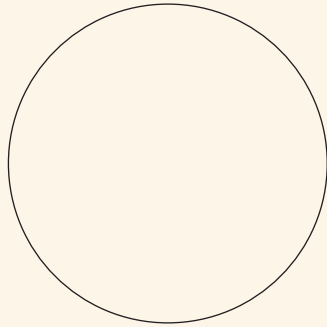
for simple squamous epithelium (Figure 3.5 in Exercise 3) and teased smooth muscle (Figure 6.7c in Exercise 6). The oil immersion lens will be needed to observe blood and sperm. Distinguish the boundaries of the individual cells, and notice the shape and position of the nucleus in each case. When you

Text continues on next page. →



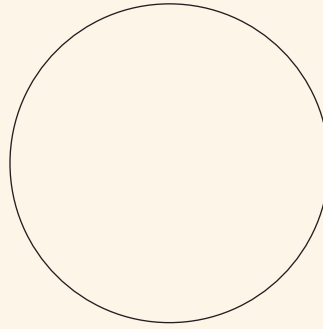
Simple squamous epithelium

Diameter _____



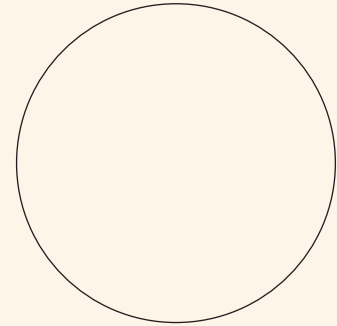
Sperm cells

Length _____



Human red blood cells

Diameter _____



Teased smooth muscle cells

Length _____

look at the human blood smear, direct your attention to the red blood cells, the pink-stained cells that are most numerous. The color photomicrographs illustrating a blood smear (Figure 29.3 in Exercise 29) and sperm (Figure 43.3 in Exercise 43) may be helpful in this cell structure study. Sketch your observations in the circles provided above.

3. Measure the length or diameter of each cell, and record below the appropriate sketch.

4. How do these four cell types differ in shape and size?

How might cell shape affect cell function?

Which cells have visible projections? _____

How do these projections relate to the function of these cells?

Do any of these cells lack a plasma membrane? _____

A nucleus? _____

In the cells with a nucleus, can you discern nucleoli?

Cell Division

The cell cycle is the series of changes that a cell goes through from the time it is formed until it reproduces. The outer ring of **Figure 4.4** shows the two main periods of the cell cycle, interphase (in green) and the mitotic phase (in yellow). **Interphase** is the longer period, during which the cell grows and carries out its usual activities. **Cell division**, or the **mitotic phase**, is the period when the cell reproduces itself by dividing. In an interphase cell about to divide, the genetic material (DNA) is copied exactly via DNA replication. Once this important event has occurred, cell division ensues.

Cell division is essential for growth and repair. Cell division, which is also called the **M (mitotic) phase** of the cell cycle, consists of two events called *mitosis* and *cytokinesis*. **Mitosis** is the division of the copied DNA of the mother cell to two daughter nuclei. **Cytokinesis** is the division of the cytoplasm, which begins when mitosis is nearly complete. Although mitosis is usually accompanied by cytokinesis, in some instances cytoplasmic division does not occur, leading to the formation of binucleate or multinucleate cells.

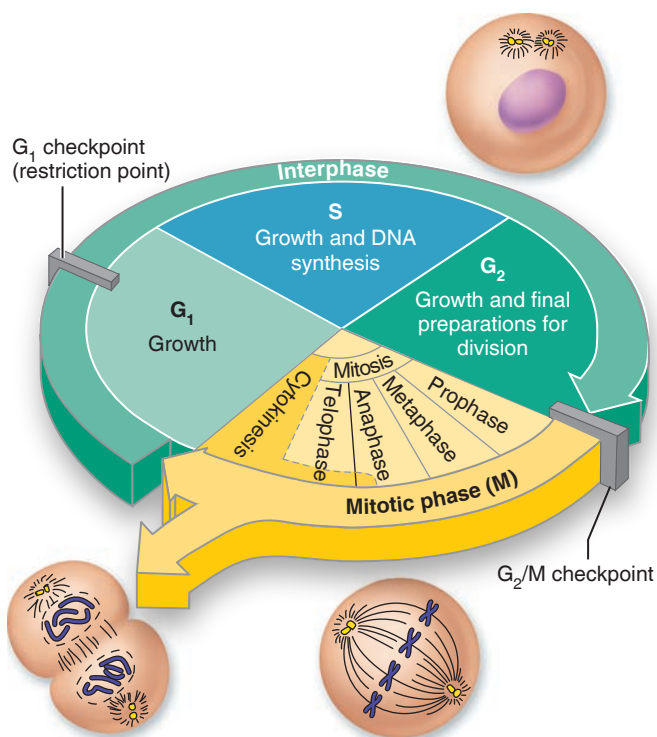


Figure 4.4 The cell cycle. The two main phases are interphase (green in the outer ring) and the mitotic phase (yellow in the outer ring).

The product of **mitosis** is two daughter nuclei that are genetically identical to the mother nucleus. **Meiosis**, which yields four daughter nuclei that differ genetically in composition from the mother nucleus, is used only for the production of gametes (eggs and sperm) for sexual reproduction.

The phases of mitosis include **prophase**, **metaphase**, **anaphase**, and **telophase**. The detailed events of interphase, mitosis, and cytokinesis are described and illustrated in **Figure 4.5** on pp. 62–63.

Mitosis is essentially the same in all animal cells, but depending on the tissue, it takes from 5 minutes to several hours to complete. In most cells, centriole replication occurs during interphase of the next cell cycle.

At the end of cell division, two daughter cells exist—each with a smaller cytoplasmic mass than the mother cell but genetically identical to it. The daughter cells grow and carry out the normal spectrum of metabolic processes until it is their turn to divide.

Cell division is extremely important during the body’s growth period. Most cells divide until puberty, when adult body size is achieved and overall body growth ceases. After this time in life, only certain cells carry out cell division routinely—for example, cells subjected to abrasion (epithelium of the skin and lining of the gut). Other cell populations—such as liver cells—stop dividing but retain this ability should some of them be removed or damaged. Skeletal muscle, cardiac muscle, and most mature neurons almost completely lose this ability to divide and thus are severely handicapped by injury.

Activity 6

Identifying the Mitotic Stages

1. Watch an animation or video presentation of mitosis (if available).
2. Using the three-dimensional models of dividing cells provided, identify each of the mitotic phases illustrated and described in Figure 4.5.
3. Obtain a prepared slide of whitefish blastulas to study the stages of mitosis. The cells of each *blastula* (a stage of embryonic development consisting of a hollow ball of cells) are at approximately the same mitotic stage, so it may be necessary to observe more than one blastula to view all the mitotic stages. Examine the slide carefully, identifying the four mitotic phases and the process of cytokinesis. Compare your observations with the photomicrographs (Figure 4.5), and verify your identifications with your instructor.

Activity 7

“Chenille Stick” Mitosis

1. Obtain a total of eight 3-inch pieces of chenille stick, four of one color and four of another color (e.g., four green and four purple).
2. Assemble the chenille sticks into a total of four chromosomes (each with two sister chromatids) by twisting two sticks of the same color together at the center with a single twist.

What does the twist at the center represent? _____

3. Arrange the chromosomes as they appear in early prophase.

Name the structure that assembles during this phase.

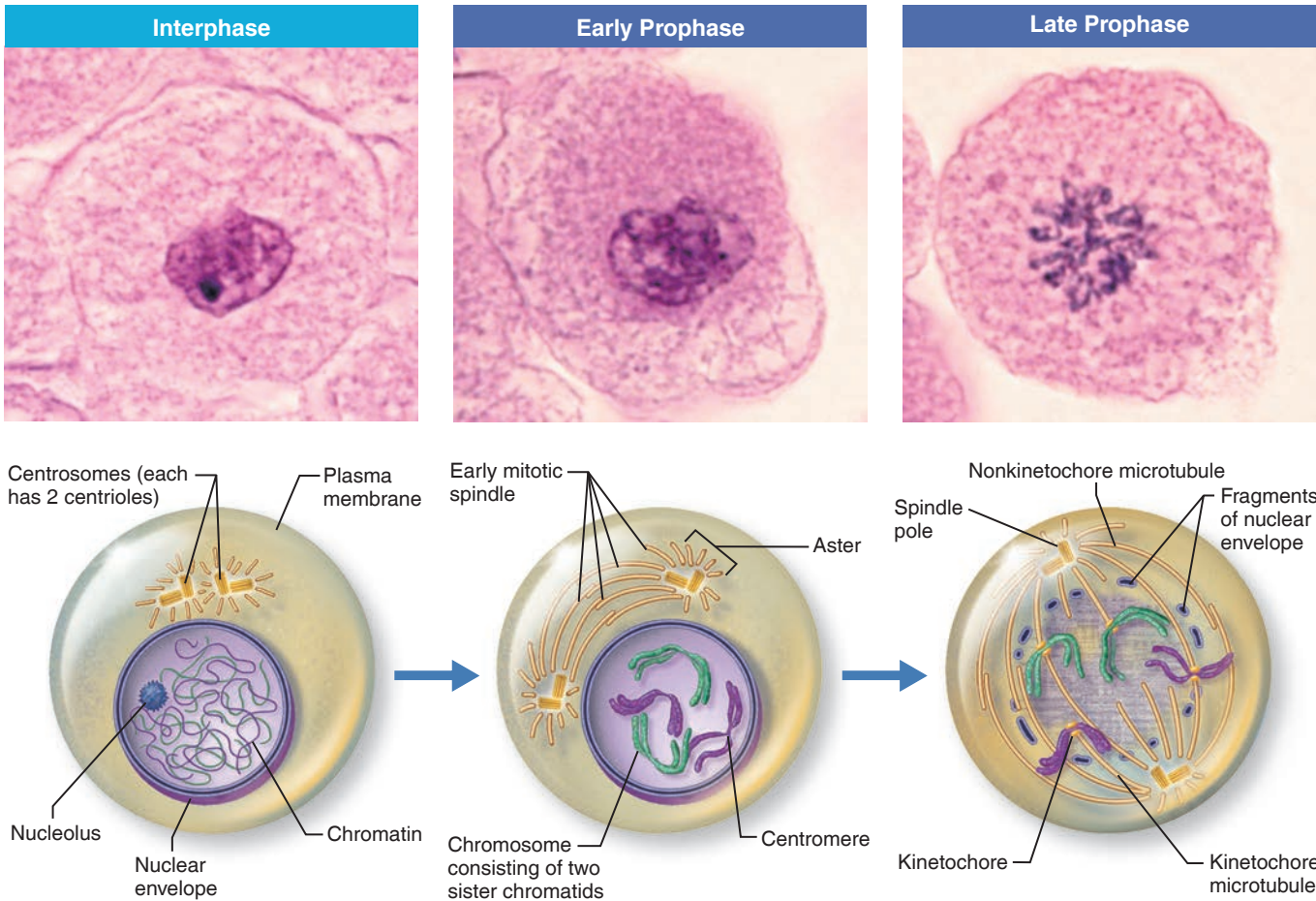
Draw early prophase in the space provided in the Review Sheet (question 6, p. 67).

4. Arrange the chromosomes as they appear in late prophase.

What structure on the chromosome centromere do the growing spindle microtubules attach to? _____

What structure is now present as fragments? _____

Text continues on page 64. →



Interphase

Interphase is the period when the cell carries out its normal metabolic activities and grows. Interphase is not part of mitosis.

- During interphase, the DNA-containing material is in the form of chromatin. The nuclear envelope and one or more nucleoli are intact and visible.
- There are three distinct periods of interphase:
 - G₁: The centrioles begin replicating.
 - S: DNA is replicated.
 - G₂: Final preparations for mitosis are completed, and centrioles finish replicating.

Prophase—first phase of mitosis

Early Prophase

- The chromatin condenses, forming barlike chromosomes.
- Each duplicated chromosome consists of two identical threads, called **sister chromatids**, held together at the **centromere**. (Later when the chromatids separate, each will be a new chromosome.)
- As the chromosomes appear, the nucleoli disappear, and the two centrosomes separate from one another.
- The centrosomes act as focal points for growth of a microtubule assembly called the **mitotic spindle**. As the microtubules lengthen, they propel the centrosomes toward opposite ends (poles) of the cell.
- Microtubule arrays called **asters** (“stars”) extend from the centrosome matrix.

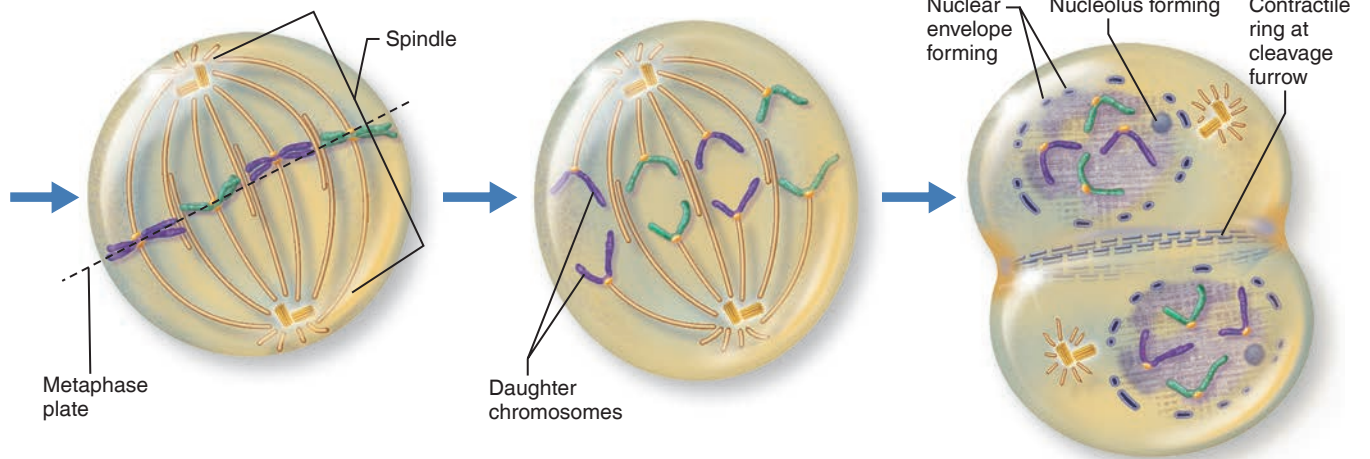
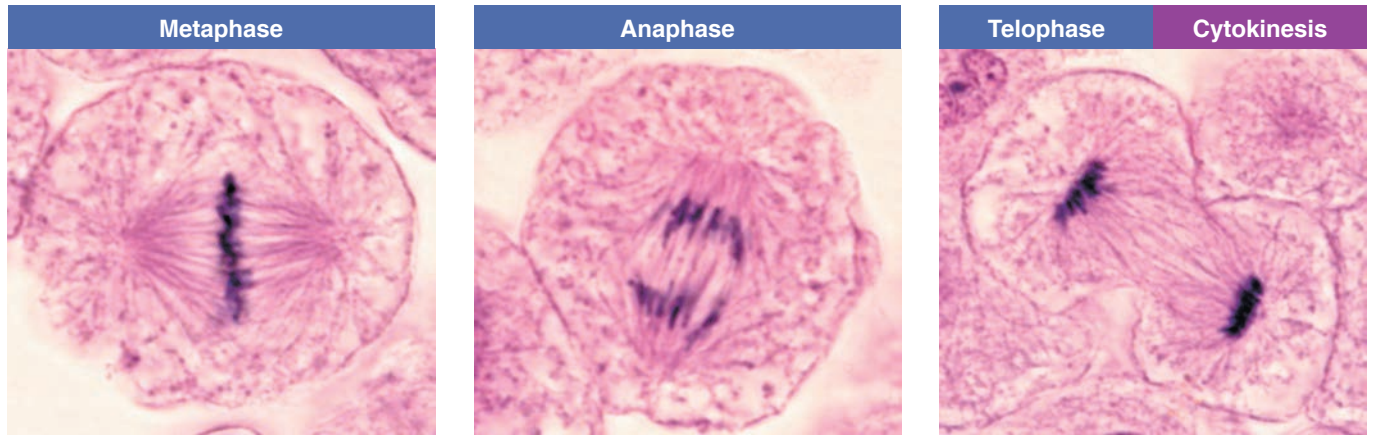
Late Prophase

- The nuclear envelope breaks up, allowing the spindle to interact with the chromosomes.
- Some of the growing spindle microtubules attach to **kinetochores**, special protein structures at each chromosome’s centromere. Such microtubules are called **kinetochore microtubules**.
- The remaining spindle microtubules (not attached to any chromosomes) are called **nonkinetochore microtubules**. The microtubules slide past each other, forcing the poles apart.
- The kinetochore microtubules pull on each chromosome from both poles in a tug-of-war that ultimately draws the chromosomes to the center, or equator, of the cell.

Figure 4.5 The interphase cell and the events of cell division. The cells shown are from an early embryo of a whitefish. Photomicrographs are above; corresponding diagrams are below. (Micrographs approximately 1600 \times .)



Instructors may assign this figure as an Art Labeling Activity using **Mastering A&P™**



Metaphase—second phase of mitosis

- The two centrosomes are at opposite poles of the cell.
- The chromosomes cluster at the midline of the cell, with their centromeres precisely aligned at the **equator** of the spindle. This imaginary plane midway between the poles is called the **metaphase plate**.
- Enzymes act to separate the chromatids from each other.

Anaphase—third phase of mitosis

- The shortest phase of mitosis, anaphase begins abruptly as the centromeres of the chromosomes split simultaneously. Each chromatid now becomes a chromosome in its own right.
- The kinetochore microtubules, moved along by motor proteins in the kinetochores, gradually pull each chromosome toward the pole it faces.
 - At the same time, the microtubules slide past each other, lengthen, and push the two poles of the cell apart.
 - The moving chromosomes look V shaped. The centromeres lead the way, and the chromosomal “arms” dangle behind them.
 - The fact that the chromosomes are short, compact bodies makes it easier for them to move and separate. Diffuse threads of chromatin would trail, tangle, and break, resulting in imprecise “parceling out” to the daughter cells.

Telophase—final phase of mitosis

- Telophase begins as soon as chromosomal movement stops. This final phase is like prophase in reverse.
- The identical sets of chromosomes at the opposite poles of the cell uncoil and resume their threadlike chromatin form.
 - A new nuclear envelope forms around each chromatin mass, nucleoli reappear within the nuclei, and the spindle breaks down and disappears.
 - Mitosis is now ended. The cell, for just a brief period, is binucleate (has two nuclei), and each new nucleus is identical to the original parent nucleus.

Cytokinesis—division of cytoplasm

Cytokinesis begins during late anaphase and continues through and beyond telophase. A contractile ring of actin microfilaments forms the **cleavage furrow** and pinches the cell apart.

Figure 4.5 (continued)

Draw late prophase in the space provided on the Review Sheet (question 6, p. 67).

5. Arrange the chromosomes as they appear in metaphase.

What is the name of the imaginary plane that the chromosomes align along? _____

Draw metaphase in the space provided on the Review Sheet (question 6, p. 67).

6. Arrange the chromosomes as they appear in anaphase.

What does untwisting of the chenille sticks represent?

Each sister chromatid has now become a _____.

Draw anaphase in the space provided on the Review Sheet (question 6, p. 67).

7. Arrange the chromosomes as they appear in telophase.

Briefly list four reasons why telophase is like the reverse of prophase.

Draw telophase in the space provided on the Review Sheet (question 6, p. 67).

4 REVIEW SHEET

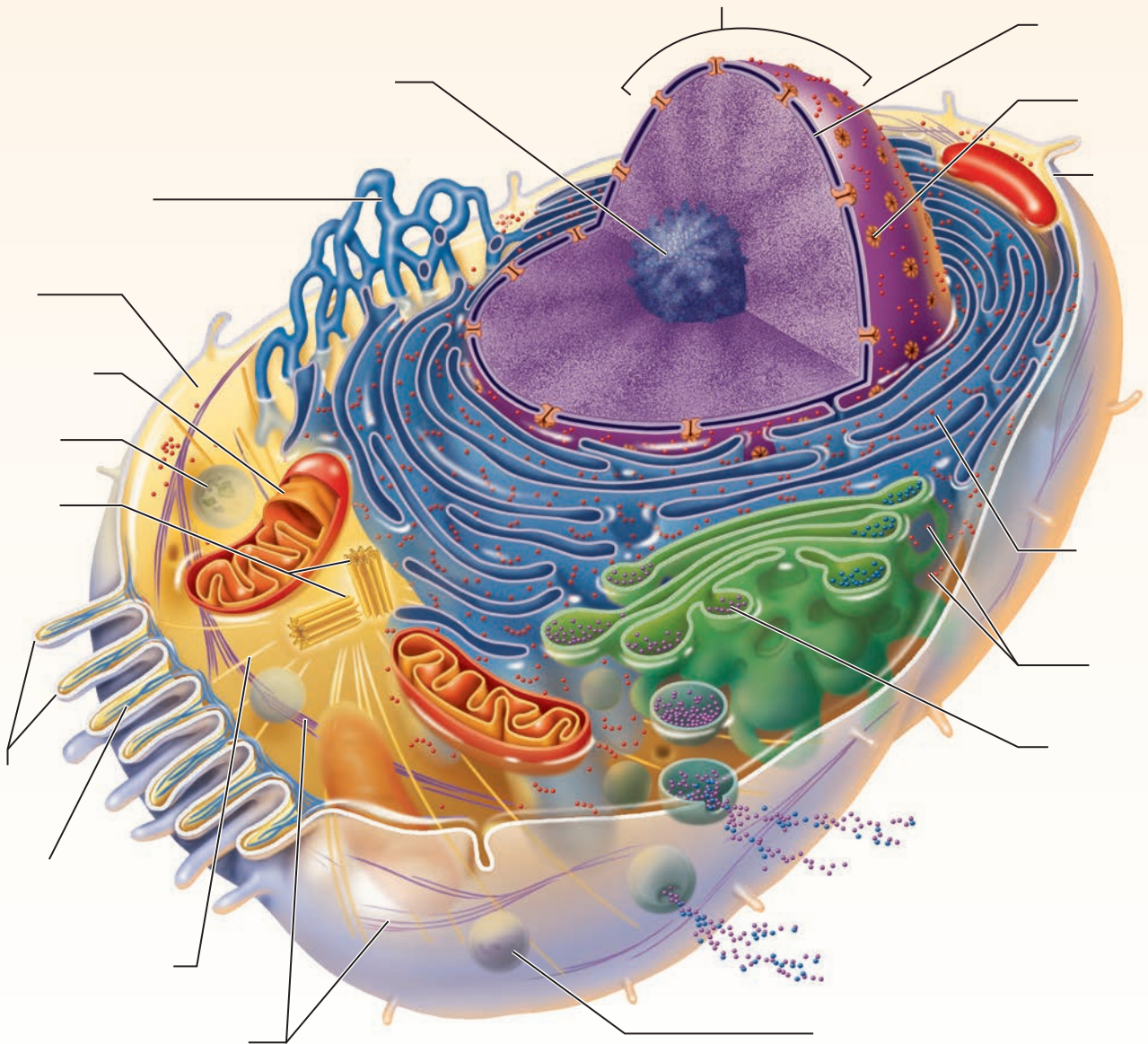
EXERCISE

The Cell: Anatomy and Division

Name _____ Lab Time/Date _____

Anatomy of the Composite Cell

1. Label the cell structures using the leader lines provided.



2. Match each cell structure listed on the left with the correct description on the right.

- | | |
|---------------------------|----------------------------------------------------------------------|
| _____ 1. ribosome | a. main site of ATP synthesis |
| _____ 2. smooth ER | b. encloses the chromatin |
| _____ 3. mitochondrion | c. sac of digestive enzymes |
| _____ 4. nucleus | d. examples include glycogen granules and ingested foreign materials |
| _____ 5. Golgi apparatus | e. forms basal bodies and helps direct mitotic spindle formation |
| _____ 6. lysosome | f. site of protein synthesis |
| _____ 7. centriole | g. forms the external boundary of the cell |
| _____ 8. cytoskeleton | h. site of lipid synthesis |
| _____ 9. inclusion | i. packaging site for ribosomes |
| _____ 10. plasma membrane | j. packages proteins for transportation |
| _____ 11. nucleolus | k. internal cellular network of rodlike structures |

Differences and Similarities in Cell Structure

3. Choose the specimen observed in Activity 5 (squamous epithelium, sperm cells, smooth muscle, or human red blood cells) that fits the description below.

- _____ cell has a flagellum for movement
- _____ cells have an elongated shape (tapered at each end)
- _____ cells are close together
- _____ cells are circular
- _____ cells are thin and flat, with irregular borders
- _____ cells are anucleate (without a nucleus)
- _____ longest cell

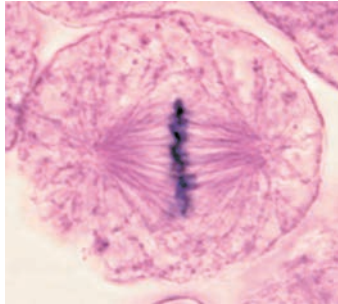
Cell Division

4. What is the function of mitotic cell division? _____

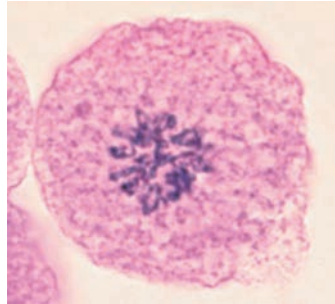
5. Identify the four phases of mitosis shown in the following photomicrographs, and select the events from the key that correctly identify each phase. On the appropriate answer line, write the letters that correspond to these events.

Key:

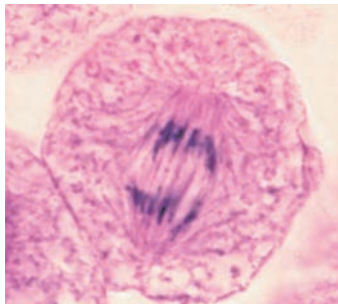
- a. The nuclear envelope re-forms.
- b. Chromosomes line up in the center of the cell.
- c. Chromatin coils and condenses, forming chromosomes.
- d. Chromosomes stop moving toward the poles.
- e. The chromosomes are V shaped.
- f. The nuclear envelope breaks down.
- g. Chromosomes attach to the spindle fibers.
- h. The mitotic spindle begins to form.



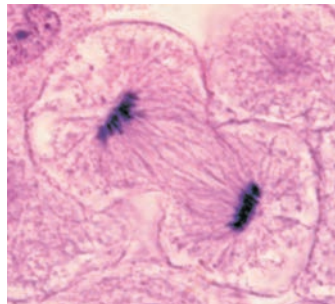
1. Phase: _____
 Events: _____



2. Phase: _____
 Events: _____



3. Phase: _____
 Events: _____



4. Phase: _____
 Events: _____


6. Draw the phases of mitosis for a cell that contains four chromosomes as its diploid, or $2n$, number.

7. Describe the events that occur during interphase.


8. Complete or respond to the following statements:

Division of the 1 is referred to as mitosis. Cytokinesis is division of the 2 . The major structural difference between chromatin and chromosomes is that the latter are 3 . Chromosomes attach to the spindle fibers by undivided structures called 4 . If a cell undergoes mitosis but not cytokinesis, the product is 5 . The structure that acts as a scaffolding for chromosomal attachment and movement is called the 6 . 7 is the period of cell life when the cell is not involved in division. Three cell populations in the body that do not routinely undergo cell division are 8 , 9 , and 10 .

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____
9. _____
10. _____

9.  Plasma cells are key to the immune response because they secrete antibodies. Given that antibodies are made of protein, which membrane-enclosed cell organelle would you expect the plasma cells to have in abundance? Why? _____

10.  Name which organelle you would expect to play the largest role in decomposition of the human body. Why? _____

11.  Some antifungal medications work by blocking DNA synthesis in the fungal cell. Describe where in the cell cycle such a medication would halt the fungal cell and the consequences of this early termination of the cycle. _____

5 EXERCISE

The Cell: Transport Mechanisms and Cell Permeability

Learning Outcomes

- ▶ Define *selective permeability*, and explain the difference between active and passive transport processes.
- ▶ Define *diffusion*, and explain how simple diffusion and facilitated diffusion differ.
- ▶ Define *osmosis*, and explain the difference between isotonic, hypotonic, and hypertonic solutions.
- ▶ Define *filtration*, and discuss where it occurs in the body.
- ▶ Define *vesicular transport*, and describe phagocytosis, pinocytosis, receptor-mediated endocytosis, and exocytosis.
- ▶ List the processes that account for the movement of substances across the plasma membrane, and indicate the driving force for each.
- ▶ Determine which way substances will move passively through a selectively permeable membrane when given appropriate information about their concentration gradients.

Pre-Lab Quiz



Instructors may assign these and other Pre-Lab Quiz questions using **Mastering A&P™**

1. Circle the correct underlined term. A passive process, diffusion / osmosis is the movement of solute molecules from an area of greater concentration to an area of lesser concentration.
2. Molecules with a lower molecular weight
 - a. possess greater potential energy than those with a higher molecular weight
 - b. move less rapidly than those with a higher molecular weight
 - c. possess greater kinetic energy than molecules with a higher molecular weight
 - d. possess lesser kinetic energy than molecules with a higher molecular weight
3. In facilitated diffusion
 - a. molecules move from low to high concentration
 - b. molecules move from high to low concentration
 - c. ATP is released
 - d. ATP is required
4. Circle the correct underlined term. In pinocytosis / phagocytosis, parts of the plasma membrane and cytoplasm extend and engulf a relatively large or solid material.
5. Circle the correct underlined term. In active / passive processes, the cell provides energy in the form of ATP to power the transport process.

Go to **Mastering A&P™** > Study Area to improve your performance in A&P Lab.



> **Lab Tools** > **Pre-Lab Videos**
> **Diffusion and Osmosis**



Instructors may assign new Building Vocabulary coaching activities, Pre-Lab Quiz questions, Art Labeling activities, Pre-Lab Video Coaching Activities for Diffusion and Osmosis, PhysioEx activities, and more using the **Mastering A&P™** Item Library.

Materials

Passive Processes

Diffusion of Dye Through Agar Gel

- ▶ Petri dish containing 12 ml of 1.5% agar-agar
- ▶ Millimeter-ruled graph paper
- ▶ Wax marking pencil
- ▶ 3.5% methylene blue solution (approximately 0.1 M) in dropper bottles
- ▶ 1.6% potassium permanganate solution (approximately 0.1 M) in dropper bottles
- ▶ Medicine dropper

Text continues on next page. →

Diffusion and Osmosis Through Nonliving Membranes

- ▶ Four dialysis sacs
- ▶ Small funnel
- ▶ 25-ml graduated cylinder
- ▶ Wax marking pencil
- ▶ Fine twine or dialysis tubing clamps
- ▶ 250-ml beakers
- ▶ Distilled water
- ▶ 40% glucose solution
- ▶ 10% sodium chloride (NaCl) solution
- ▶ 40% sucrose solution
- ▶ Laboratory balance
- ▶ Paper towels
- ▶ Hot plate and large beaker for hot water bath
- ▶ Benedict's solution in dropper bottle
- ▶ Silver nitrate (AgNO₃) in dropper bottle
- ▶ Test tubes in rack, test tube holder

Experiment 1

- ▶ Deshelled eggs
- ▶ 400-ml beakers
- ▶ Wax marking pencil
- ▶ Distilled water
- ▶ 30% sucrose solution
- ▶ Laboratory balance
- ▶ Paper towels

- ▶ Graph paper
- ▶ Weigh boat

Experiment 2

- ▶ Clean microscope slides and coverslips
- ▶ Medicine dropper
- ▶ Compound microscope
- ▶ Vials of mammalian blood obtained from a biological supply house or veterinarian—at option of instructor
- ▶ Freshly prepared physiological (mammalian) saline solution in dropper bottle
- ▶ 5% sodium chloride solution in dropper bottle
- ▶ Distilled water
- ▶ Filter paper
- ▶ Disposable gloves
- ▶ Basin and wash bottles containing 10% household bleach solution
- ▶ Disposable autoclave bag
- ▶ Paper towels

Diffusion Demonstrations

1. Diffusion of a dye through water

Prepared the morning of the laboratory session with setup time noted. Potassium permanganate crystals are placed in a 1000-ml graduated cylinder, and distilled water is added slowly and with as little turbulence as possible to fill to the 1000-ml mark.

2. Osmometer

Just before the laboratory begins, the broad end of a thistle tube is closed with a selectively permeable dialysis membrane, and the tube is secured to a ring stand. Molasses is added to approximately 5 cm above the thistle tube bulb, and the bulb is immersed in a beaker of distilled water. At the beginning of the lab session, the level of the molasses in the tube is marked with a wax pencil.

Filtration

- ▶ Ring stand, ring, clamp
- ▶ Filter paper, funnel
- ▶ Solution containing a mixture of uncooked starch, powdered charcoal, and copper sulfate (CuSO₄)
- ▶ 10-ml graduated cylinder
- ▶ 100-ml beaker
- ▶ Lugol's iodine in a dropper bottle

Active Processes

- ▶ Video/animation showing phagocytosis (if available)

Note to the Instructor: See directions for handling wet mount preparations and disposable supplies (p. 43, Exercise 3).

PEX PhysioEx™ 10.0 Computer Simulation Ex.1 on p. PEx-3.

Because of its molecular composition, the plasma membrane is selective about what passes through it. It allows nutrients to enter the cell but keeps out undesirable substances. By the same token, valuable cell proteins and other substances are kept within the cell, and excreta or wastes pass

to the exterior. This property is known as **selective**, or **differential, permeability**. Transport through the plasma membrane occurs in two basic ways. In **passive processes**, concentration or pressure differences drive the movement. In **active processes**, the cell provides energy (ATP) to power the transport process.

Passive Processes

The two important passive processes of membrane transport are *diffusion* and *filtration*. Diffusion is an important transport process for every cell in the body. By contrast, filtration usually occurs only across capillary walls.

Diffusion

Molecules possess **kinetic energy** and are in constant motion. As molecules move about randomly at high speeds, they collide and ricochet off one another, changing direction with each collision (**Figure 5.1**). A **concentration gradient** is present when molecules are unevenly distributed, resulting in an area of higher concentration and an area of lower concentration. **Diffusion** is the movement of molecules from a region of their higher concentration to a region of their lower concentration. Because the driving force for diffusion is the kinetic energy of the molecules, the speed of diffusion depends on molecular

size and temperature. Smaller molecules move faster, and molecules move faster as temperature increases.

There are many examples of diffusion in nonliving systems. For example, if a bottle of ether were uncorked at the front of the laboratory, very shortly thereafter you would be nodding off as the molecules became distributed throughout the room.

In general, molecules diffuse passively through the plasma membrane if they can dissolve in the lipid portion of the membrane, as CO₂ and O₂ can. The unassisted diffusion of solutes (dissolved substances) through a selectively permeable membrane is called **simple diffusion**.

Certain molecules, glucose for example, are transported across the plasma membrane with the assistance of a protein carrier molecule. The substances move by a passive transport process called **facilitated diffusion**. As with simple diffusion,

the substances move from an area of higher concentration to one of lower concentration, that is, down their concentration gradients.

Osmosis

The flow of water across a selectively permeable membrane is called **osmosis**. During osmosis, water moves down its concentration gradient. The concentration of water is inversely related to the concentration of solutes. If the solutes can diffuse across the membrane, both water and solutes will move down their concentration gradients through the membrane. If the particles in solution are nonpenetrating solutes (prevented from crossing the membrane), water alone will move by osmosis and in doing so will cause changes in the volume of the compartments on either side of the membrane.

Diffusion of Dye Through Agar Gel and Water

The relationship between molecular weight and the rate of diffusion can be examined easily by observing the diffusion of two different types of dye molecules through an agar gel. The dyes used in this experiment are methylene blue, which has a molecular weight of 320 and is deep blue in color, and potassium permanganate, a purple dye with a molecular weight of 158. Although the agar gel appears quite solid, it is primarily (98.5%) water and allows the dye molecules to move freely through it.

Activity 1

Observing Diffusion of Dye Through Agar Gel

1. Work with members of your group to formulate a hypothesis about the rates of diffusion of methylene blue and potassium permanganate through the agar gel. Justify your hypothesis.
2. Obtain a petri dish containing agar gel, a piece of millimeter-ruled graph paper, a wax marking pencil, dropper bottles of methylene blue and potassium permanganate, and a medicine dropper.
3. Using the wax marking pencil, draw a line on the bottom of the petri dish dividing it into two sections. Place the petri dish on the ruled graph paper.
4. Create a well in the center of each section using the medicine dropper. To do this, squeeze the bulb of the medicine dropper, and push it down into the agar. Release the bulb as you slowly pull the dropper vertically out of the agar. This should remove an agar plug, leaving a well in the agar. (See **Figure 5.2a**.)
5. Carefully fill one well with the methylene blue solution and the other well with the potassium permanganate solution (Figure 5.2b).

Record the time. _____

6. At 15-minute intervals, measure the distance the dye has diffused from each well by measuring the diameter of the dye. Continue these observations for 1 hour, and record the results in the **Activity 1 chart** (p. 72).

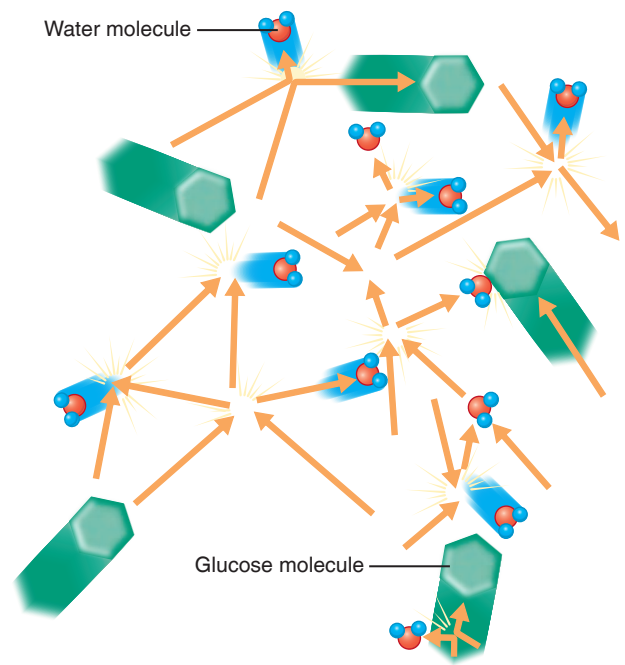


Figure 5.1 Random movement and numerous collisions cause molecules to become evenly distributed.

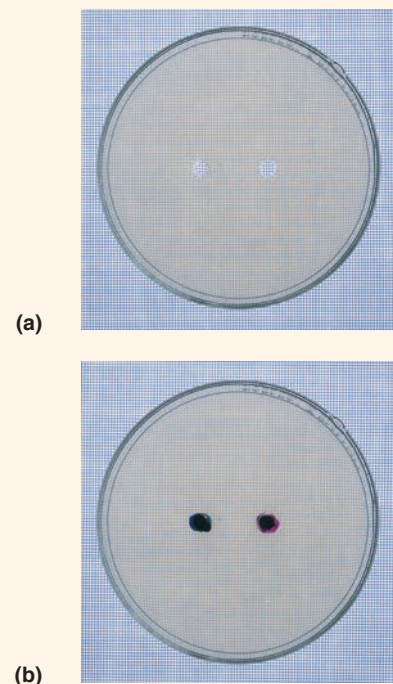


Figure 5.2 Comparing diffusion rates. Agar-plated petri dish as it appears after the placement of 0.1 M methylene blue in one well and 0.1 M potassium permanganate in another.

Text continues on next page. →

Activity 1: Dye Diffusion Results

Time (min)	Diameter of methylene blue (mm)	Diameter of potassium permanganate (mm)
15		
30		
45		
60		

Which dye diffused more rapidly? _____

What is the relationship between molecular weight and rate of molecular movement (diffusion)?

Why did the dye molecules move? _____

Activity 2**Observing Diffusion of Dye Through Water**

1. Go to the diffusion demonstration area, and observe the cylinder containing dye crystals and water set up at the beginning of the lab.

2. Measure the number of millimeters the dye has diffused from the bottom of the graduated cylinder, and record.

_____ mm

3. Record the time the demonstration was set up and the time of your observation. Then compute the rate of the dye's diffusion through water and record below.

Time of setup _____

Time of observation _____

Rate of diffusion _____ mm/min

Activity 3

Instructors may assign a related Pre-Lab Video Coaching Activity using **Mastering A&P™**

Investigating Diffusion and Osmosis Through Nonliving Membranes

The following experiment provides information on the movement of water and solutes through selectively permeable membranes called dialysis sacs. Dialysis sacs have pores of a particular size. The selectivity of living membranes depends on more than just pore size, but using the dialysis sacs will allow you to examine selectivity due to this factor.

1. Read through the experiments in this activity, and develop a hypothesis for each part.

2. Obtain four dialysis sacs, a small funnel, a 25-ml graduated cylinder, a wax marking pencil, fine twine or dialysis tubing clamps, and four beakers (250 ml). Number the beakers 1 to 4 with the wax marking pencil, and half fill all of them with

distilled water except beaker 2, to which you should add 125 ml of the 40% glucose solution.

3. Prepare the dialysis sacs one at a time. Using the funnel, half fill each with 20 ml of the specified liquid (see Activity 3 chart). Press out the air, fold over the open end of the sac, and tie it securely with fine twine or clamp it. Before proceeding to the next sac, rinse it under the tap, and quickly and carefully blot the sac dry by rolling it on a paper towel. Weigh it with a laboratory balance. Record the weight in the **Activity 3 chart**, and then drop the sac into the corresponding beaker. Be sure the sac is completely covered by the beaker solution, adding more solution if necessary. **Figure 5.3** illustrates the configuration of the beakers with the contents of the dialysis sacs and the beaker solutions.

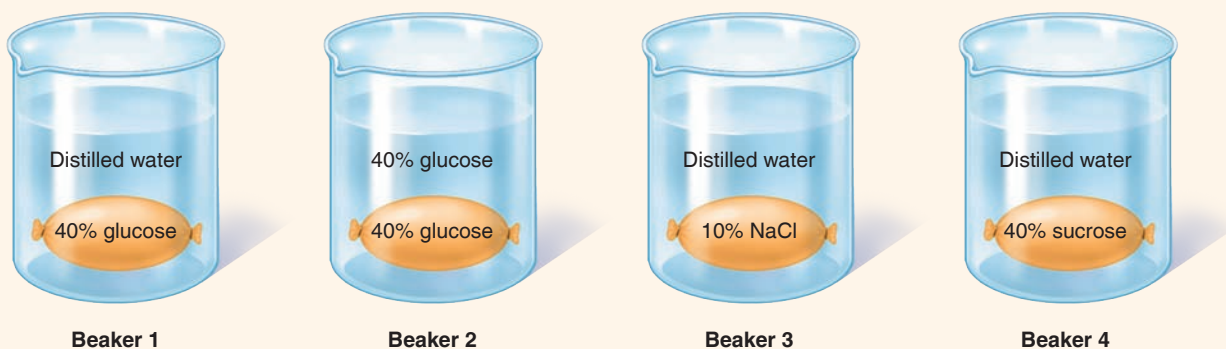


Figure 5.3 Setup for observing diffusion through nonliving membranes.

Activity 3: Experimental Data on Diffusion and Osmosis Through Nonliving Membranes						
Beaker	Contents of sac	Initial weight	Final weight	Weight change	Tests— beaker fluid	Tests— sac fluid
Beaker 1 ½ filled with distilled water	Sac 1, 20 ml of 40% glucose solution				Benedict's test:	Benedict's test:
Beaker 2 ½ filled with 40% glucose solution	Sac 2, 20 ml of 40% glucose solution					
Beaker 3 ½ filled with distilled water	Sac 3, 20 ml of 10% NaCl solution				AgNO ₃ test:	
Beaker 4 ½ filled with distilled water	Sac 4, 20 ml of 40% sucrose solution				Benedict's test:	

- Sac 1: 40% glucose solution
- Sac 2: 40% glucose solution
- Sac 3: 10% NaCl solution
- Sac 4: 40% sucrose solution

Allow the sacs to remain undisturbed in the beakers for 1 hour. Use this time to continue with other experiments.

4. After an hour, boil a beaker of water on the hot plate. Obtain the supplies you will need to determine your experimental results: dropper bottles of Benedict's solution and silver nitrate solution, a test tube rack, four test tubes, and a test tube holder.

5. Quickly and gently blot sac 1 dry and weigh it. (**Note:** Do not squeeze the sac during the blotting process.) Record the weight in the data chart.

Was there any change in weight? _____

Conclusions: _____

Place 5 drops of Benedict's solution in each of two test tubes. Put 4 ml of the beaker fluid into one test tube and 4 ml of the sac fluid into the other. Mark the tubes for identification, and then place them in a beaker containing boiling water. Boil 2 minutes. Cool slowly. If a green, yellow, or rusty red precipitate forms, the test is positive, meaning that glucose is present. If the solution remains the original blue color, the test is negative. Record results in the data chart.

Was glucose still present in the sac? _____

Was glucose present in the beaker? _____

Conclusions: _____

6. Blot gently and weigh sac 2. Record the weight in the data chart.

Was there an *increase* or *decrease* in weight? _____

With 40% glucose in the sac and 40% glucose in the beaker, would you expect to see any net movement of water (osmosis) or of glucose molecules (simple diffusion)?

_____ Why or why not? _____

7. Blot gently and weigh sac 3. Record the weight in the data chart.

Was there any change in weight? _____

Conclusions: _____

Take a 5-ml sample of beaker 3 solution and put it in a clean test tube. Add a drop of silver nitrate (AgNO₃). The appearance of a white precipitate or cloudiness indicates the presence of silver chloride (AgCl), which is formed by the reaction of AgNO₃ with NaCl (sodium chloride). Record results in the data chart.

Text continues on next page. →

Results: _____

Conclusions: _____

8. Blot gently and weigh sac 4. Record the weight in the data chart.

Was there any change in weight? _____

Conclusions: _____

Take a 1-ml sample of beaker 4 solution and put the test tube in boiling water in a hot water bath. Add 5 drops of Benedict's solution to the tube and boil for 5 minutes. The presence of glucose (one of the hydrolysis products of sucrose) in the test tube is indicated by the presence of a green, yellow, or rusty colored precipitate.

Did sucrose diffuse from the sac into the water in the small beaker? _____

Conclusions: _____

9. In which of the test situations did net osmosis occur?

In which of the test situations did net simple diffusion occur?

What conclusions can you make about the relative size of glucose, sucrose, NaCl, and water molecules?

With what cell structure can the dialysis sac be compared?

10. Prepare a lab report for the experiment. (See Getting Started, on Mastering A&P.) Be sure to include in your discussion the answers to the questions proposed in this activity.

Activity 4

Observing Osmometer Results

Before leaving the laboratory, observe the *osmometer demonstration* set up before the laboratory session to follow the movement of water through a membrane (osmosis). Measure the distance the water column has moved during the laboratory period, and record below. (The position of the meniscus [the surface of the water column] in the thistle tube at the beginning of the laboratory period is marked with wax pencil.)

Distance the meniscus has moved: _____ mm

Did net osmosis occur? Why or why not?

Activity 5

Investigating Diffusion and Osmosis Through Living Membranes

To examine permeability properties of plasma membranes, conduct the following experiments. As you read through the experiments in this activity, develop a hypothesis for each part.

Experiment 1

1. Obtain two deshelled eggs and two 400-ml beakers. Note that the relative concentration of solutes in deshelled eggs is about 14%. Number the beakers 1 and 2 with the wax marking pencil. Half fill beaker 1 with distilled water and half fill beaker 2 with 30% sucrose.

2. Carefully blot each egg by rolling it gently on a paper towel. Place a weigh boat on a laboratory balance and tare the balance (that is, make sure the scale reads 0.0 with the weigh boat on the scale). Weigh egg 1 in the weigh boat, record the initial weight in the **Activity 5 chart**, and gently place it into beaker 1. Repeat for egg 2, placing it in beaker 2.

3. After 20 minutes, remove egg 1 and gently blot it and weigh it. Record the weight, and replace it into beaker 1. Repeat for egg 2, placing it into beaker 2. Repeat this procedure at 40 minutes and 60 minutes.

4. Calculate the change in weight of each egg at each time period, and enter that number in the data chart. Also calculate the percent change in weight for each time period and enter that number in the data chart.

Activity 5: Experiment 1 Data from Diffusion and Osmosis Through Living Membranes						
Time	Egg 1 (in distilled H ₂ O)	Weight change	% Change	Egg 2 (in 30% sucrose)	Weight change	% Change
Initial weight (g)		—	—		—	—
20 min						
40 min						
60 min						

How has the weight of each egg changed?

Egg 1 _____

Egg 2 _____

Make a graph of your data by plotting the percent change in weight for each egg versus time.

How has the appearance of each egg changed?

Egg 1 _____

Egg 2 _____

A solution surrounding a cell is **hypertonic** if it contains more nonpenetrating solute particles than the interior of the cell. Water moves from the interior of the cell into a surrounding hypertonic solution by osmosis. A solution surrounding a cell is **hypotonic** if it contains fewer nonpenetrating solute particles than the interior of the cell. Water moves from a hypotonic solution into the cell by osmosis. In both cases, water moved down its concentration gradient. Indicate in your conclusions whether distilled water was a hypotonic or hypertonic solution and whether 30% sucrose was hypotonic or hypertonic.

Conclusions: _____

Experiment 2

Now you will conduct a microscopic study of red blood cells suspended in solutions of varying tonicities. The objective is to determine whether these solutions have any effect on cell shape by promoting net osmosis.

1. The following supplies should be available at your laboratory bench to conduct this experimental series: two clean slides and coverslips, a vial of mammalian blood, a medicine dropper, physiological saline, 5% sodium chloride solution, distilled water, filter paper, and disposable gloves.



Wear disposable gloves at all times when handling blood (steps 2–5).

2. Place a very small drop of physiological saline on a slide. Using the medicine dropper, add a small drop of the blood to the saline on the slide. Tilt the slide to mix, cover with a coverslip, and immediately examine the preparation under the high-power lens. Notice that the red blood cells retain their normal smooth disc shape (Figure 5.4a, p. 76). This is because the physiological saline is **isotonic** to the cells. That is, it contains a concentration of nonpenetrating solutes (e.g., proteins and some ions) equal to that in the cells (same solute/water concentration). Consequently, the cells neither gain nor lose water by osmosis. Set this slide aside.

3. Prepare another wet mount of the blood, but this time use 5% sodium chloride (saline) solution as the suspending medium. Carefully observe the red blood cells under high power. What is happening to the normally smooth disc shape of the red blood cells?

This crinkling-up process, called **crenation**, is due to the fact that the 5% sodium chloride solution is hypertonic to the cytosol of the red blood cell. Under these circumstances, water leaves the cells by osmosis. Compare your observations to the figure above (Figure 5.4b).

4. Add a drop of distilled water to the edge of the coverslip. Fold a piece of filter paper in half and place its folded edge at the opposite edge of the coverslip; it will absorb the saline solution and draw the distilled water across the cells. Watch the red blood cells as they float across the field. Describe the change in their appearance.

Distilled water contains *no* solutes (it is 100% water). Distilled water and very dilute solutions (that is, those containing less than 0.9% nonpenetrating solutes) are hypotonic to the cell. In a hypotonic solution, the red blood cells first “plump up”

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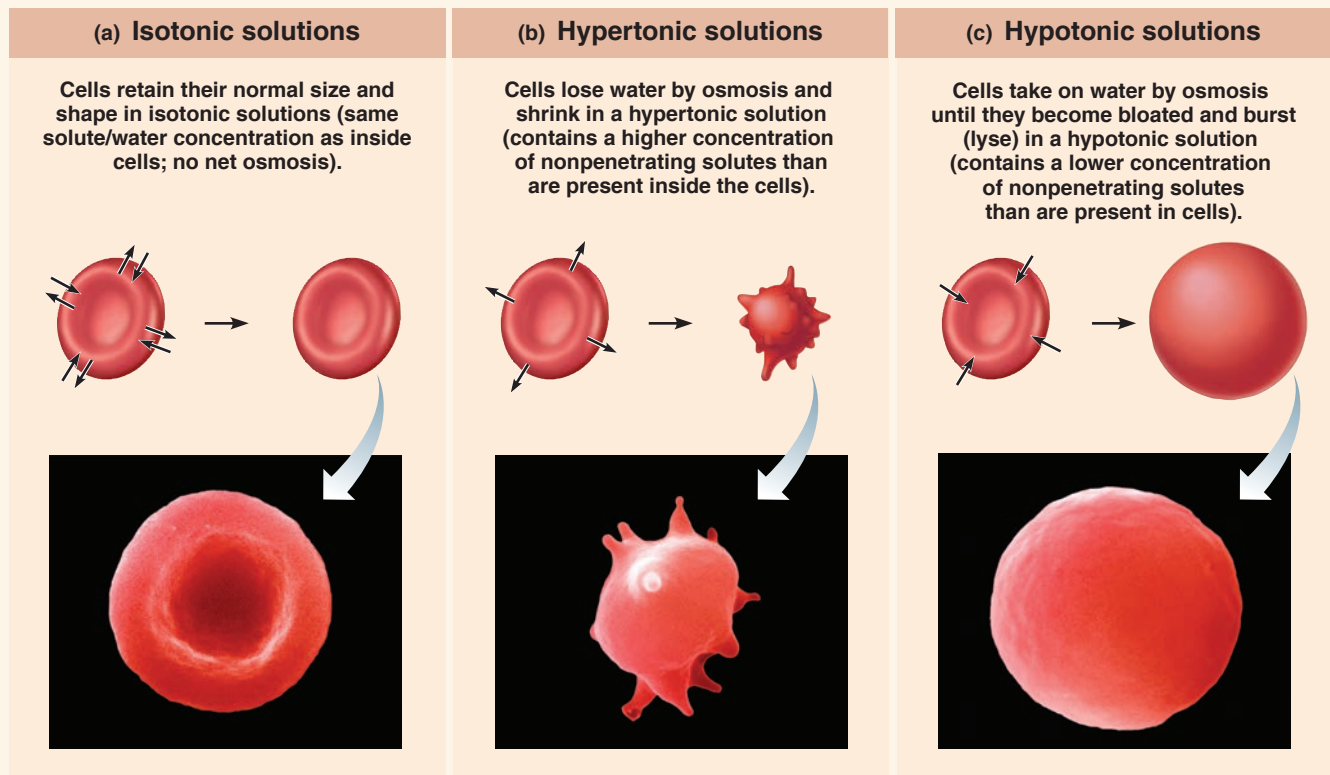


Figure 5.4 Influence of isotonic, hypertonic, and hypotonic solutions on red blood cells.



Instructors may assign this figure as an Art Labeling Activity using **Mastering A&P™**

(Figure 5.4c), but then they suddenly start to disappear. The red blood cells burst as the water floods into them, leaving “ghosts” in their wake—a phenomenon called **hemolysis**.



5. Place the blood-soiled slides and test tube in the bleach-containing basin. Put the coverslips you used into the disposable autoclave bag. Obtain a wash (squirt) bottle containing 10% bleach solution, and squirt the

bleach liberally over the bench area where blood was handled. Wipe the bench down with a paper towel wet with the bleach solution, and allow it to dry before continuing. Remove gloves, and discard in the autoclave bag.

6. Prepare a lab report for experiments 1 and 2. (See Getting Started, on Mastering A&P.) Be sure to include in the discussion answers to the questions proposed in this activity.

Filtration

Filtration is a passive process in which water and solutes are forced through a membrane by hydrostatic (fluid) pressure. For example, fluids and solutes filter out of the capillaries in the kidneys and into the kidney tubules because the blood pressure

in the capillaries is greater than the fluid pressure in the tubules. Filtration is not selective. The amount of filtrate (fluids and solutes) formed depends almost entirely on the pressure gradient (difference in pressure on the two sides of the membrane) and on the size of the membrane pores.

Activity 6

Observing the Process of Filtration

1. Obtain the following equipment: a ring stand, ring, and ring clamp; a funnel; a piece of filter paper; a beaker; a 10-ml graduated cylinder; a solution containing uncooked starch, powdered charcoal, and copper sulfate; and a dropper bottle of Lugol's iodine. Attach the ring to the ring stand with the clamp.
2. Fold the filter paper in half twice, open it into a cone, and place it in a funnel. Place the funnel in the ring of the ring stand and place a beaker under the funnel. Shake the starch solution, and fill the funnel with it to just below the top of the filter paper. When the steady stream of filtrate changes to countable filtrate drops, count the number of drops formed in 10 seconds and record.

_____ drops

When the funnel is half empty, again count the number of drops formed in 10 seconds, and record the count.

_____ drops

3. After all the fluid has passed through the filter, check the filtrate and paper to see which materials were retained by the paper. If the filtrate is blue, the copper sulfate passed. Check both the paper and filtrate for black particles to see whether the charcoal passed. Finally, using a 10-ml graduated cylinder,

put a 2-ml filtrate sample into a test tube. Add several drops of Lugol's iodine. If the sample turns blue/black when iodine is added, starch is present in the filtrate.

Passed: _____

Retained: _____

What does the filter paper represent? _____

During which counting interval was the filtration rate greatest? _____

Explain: _____

What characteristic of the three solutes determined whether or not they passed through the filter paper?

Active Processes

Whenever a cell uses the bond energy of ATP to move substances across its boundaries, the process is an *active process*. Substances moved by active means are generally unable to pass by diffusion. They may not be lipid soluble; they may be too large to pass through the membrane channels; or they may have to move against rather than with a concentration gradient. There are two types of active processes: *active transport* and *vesicular transport*.

Active Transport

Like carrier-mediated facilitated diffusion, **active transport** requires carrier proteins that combine specifically with the transported substance. Active transport may be primary, driven directly by hydrolysis of ATP, or secondary, driven indirectly by energy stored in ionic gradients. In most cases, the substances move against concentration or electrochemical gradients or both. These substances are insoluble in lipid and too large to pass through membrane channels but are necessary for cell life.

Vesicular Transport

In **vesicular transport**, fluids containing large particles and macromolecules are transported across cellular membranes inside membranous sacs called *vesicles*. Like active transport, vesicular transport moves substances into the cell (**endocytosis**) and out of the cell (**exocytosis**). Vesicular transport requires energy,

usually in the form of ATP, and all forms of vesicular transport involve protein-coated vesicles to some extent.

There are three types of endocytosis: phagocytosis, pinocytosis, and receptor-mediated endocytosis. In **phagocytosis** ("cell eating"), the cell engulfs some relatively large or solid material such as a clump of bacteria, cell debris, or inanimate particles (Figure 5.5a, p. 78). When a particle binds to receptors on the cell's surface, cytoplasmic extensions called pseudopods form and flow around the particle. This produces a vesicle called a *phagosome*. In most cases, the phagosome then fuses with a lysosome and its contents are digested. Indigestible contents are ejected from the cell by exocytosis.

In **pinocytosis** ("cell drinking"), also called **fluid-phase endocytosis**, the cell "gulps" a drop of extracellular fluid containing dissolved molecules (Figure 5.5b). Since no receptors are involved, the process is nonspecific. Unlike phagocytosis, pinocytosis is a routine activity of most cells, allowing them a way of sampling the extracellular fluid. It is particularly important in cells that absorb nutrients, such as cells that line the intestines.

The main mechanism for *specific* endocytosis of most macromolecules is **receptor-mediated endocytosis** (Figure 5.5c). The receptors for this process are plasma membrane proteins that bind only certain substances. This exquisitely selective mechanism allows cells to concentrate material that is present only in small amounts in the extracellular fluid. The ingested vesicle may fuse with a lysosome that either digests or releases

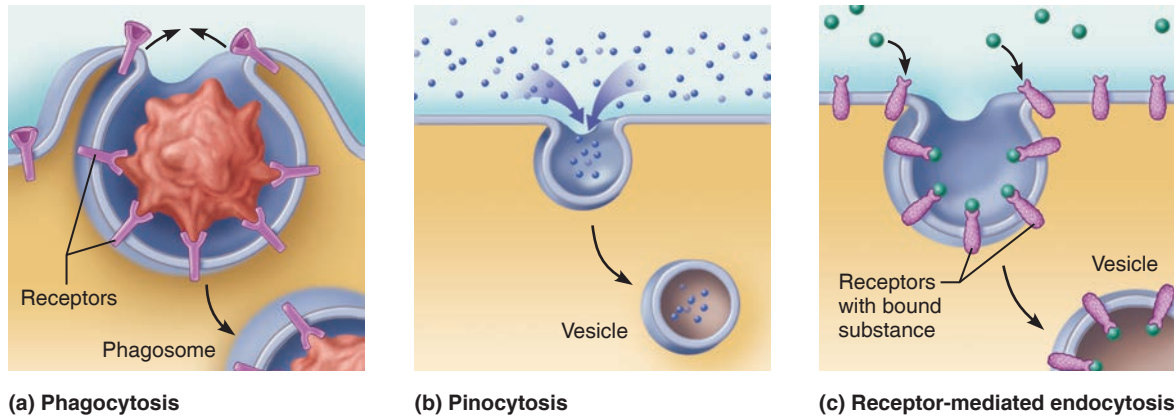


Figure 5.5 Three types of endocytosis. (a) In phagocytosis, cellular extensions flow around the external particle and enclose it within a phagosome. (b) In pinocytosis, fluid and dissolved solutes enter the cell in a tiny vesicle. (c) In receptor-mediated endocytosis, specific substances attach to cell-surface receptors and enter the cell in protein-coated vesicles.



Instructors may assign this figure as an Art Labeling Activity using **Mastering A&P™**

its contents, or it may be transported across the cell to release its contents by exocytosis. The latter case is common in endothelial cells lining blood vessels because it provides a quick means to get substances from blood to extracellular fluid. Substances taken up by receptor-mediated endocytosis include enzymes, insulin and some other hormones, cholesterol (attached to a transport protein), and iron.

Exocytosis is a vesicular transport process that ejects substances from the cell into the extracellular fluid. The substance to be removed from the cell is first enclosed in a protein-coated vesicle called a **secretory vesicle**. In most cases, the vesicle migrates to the plasma membrane, fuses with it, and then ruptures, spilling its contents out of the cell. Exocytosis is used for hormone secretion, neurotransmitter release, mucus secretion, and ejection of wastes.

Activity 7

Observing Phagocytosis

Go to the video viewing area and watch the video demonstration of phagocytosis (if available).

Note: If you have not already done so, complete Activity 2 (*Observing Diffusion of Dye Through Water*, p. 72) and Activity 4 (*Observing Osmometer Results*, p. 74).

5 EXERCISE

REVIEW SHEET

The Cell: Transport Mechanisms and Permeability



Instructors may assign a portion of the Review Sheet questions using **Mastering A&P™**

Name _____ Lab Time/Date _____

Choose all answers that apply to questions 1 and 2, and place their letters on the response blanks to the right.

1. The movement of molecules _____

- a. reflects the kinetic energy of molecules
- b. reflects the potential energy of molecules
- c. is ordered and predictable
- d. is random and erratic

2. Speed of molecular movement _____

- a. is higher in larger molecules
- b. is lower in larger molecules
- c. increases with increasing temperature
- d. decreases with increasing temperature
- e. reflects kinetic energy

3. Summarize below the results of Activity 3, Investigating Diffusion and Osmosis Through Nonliving Membranes.

Sac 1: 40% glucose suspended in distilled water

Did glucose diffuse out of the sac? _____ Did the sac weight change? _____

Explanation: _____

Sac 2: 40% glucose suspended in 40% glucose

Was there net movement of glucose into or out of the sac? _____

Explanation: _____

Did the sac weight change? _____

Explanation: _____

Sac 3: 10% NaCl suspended in distilled water

Was there net movement of NaCl out of the sac? _____

Direction of net osmosis: _____

Sac 4: 40% sucrose suspended in distilled water

Was there net movement of sucrose out of the sac? _____

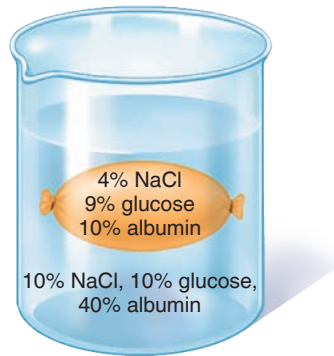
Explanation: _____

Direction of net osmosis: _____

4. What single characteristic of the selectively permeable membranes *used in the laboratory* determines the substances that can pass through them? _____

In addition to this characteristic, what other factors influence the passage of substances through living membranes?

5. A semipermeable sac filled with a solution containing 4% NaCl, 9% glucose, and 10% albumin is suspended in a solution with the following composition: 10% NaCl, 10% glucose, and 40% albumin. The diagram below illustrates the solutes inside and outside of the sac. Assume that the sac is permeable to all substances except albumin. With respect to net movement, state whether each of the following will (a) move into the sac, (b) move out of the sac, or (c) not move.



glucose: _____ albumin: _____

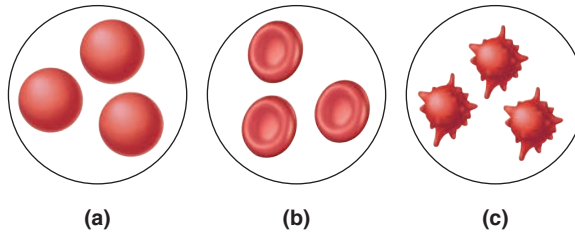
water: _____ NaCl: _____

6. Summarize below the results of Activity 5, Experiment 1 (Investigating Diffusion and Osmosis Through Living Membranes—the egg). List and explain your observations.

Egg 1 in distilled water: _____

Egg 2 in 30% sucrose: _____

7. The diagrams below represent three microscope fields containing red blood cells. Which field contains a hypertonic solution?
 _____ The cells in this field are said to be _____. Which field contains an isotonic bathing solution? _____
 Which field contains a hypotonic solution? _____ What is happening to the cells in this field? _____



8. What determines whether a molecule uses simple or facilitated diffusion?

9. Characterize membrane transport as fully as possible by choosing all the phrases that apply and inserting their letters on the answer blanks.

Passive processes: _____ Active processes: _____

- a. account for the movement of fats and respiratory gases through the plasma membrane
- b. include phagocytosis and pinocytosis
- c. include osmosis, simple diffusion, and filtration
- d. occur against concentration and/or electrical gradients
- e. use hydrostatic pressure or molecular energy as the driving force


10. For the osmometer demonstration (Activity 4), explain why the level of the water column rose during the laboratory session.


11. What is the similarity and the difference between endocytosis and exocytosis?

12. What is the similarity and the difference between phagocytosis and pinocytosis?

13. State two differences between primary active transport and secondary active transport. _____

14. During a blood transfusion, a patient is given an isotonic saline (NaCl) solution. What would be the effect of administering a hypertonic saline solution? _____

15.  Drinking too much plain water in a short period of time can result in water intoxication. As a result, blood plasma will become hypotonic. What effect do you think this would have on cells, and why? _____

16.  Receptor-mediated endocytosis is used to remove low-density lipoproteins (LDLs) from circulating in the blood. Explain the effect that defective LDL receptors would have on a patient's cholesterol levels and overall risk for heart disease. (Hint: LDLs are the "bad cholesterol.")

6 EXERCISE

Classification of Tissues

Learning Outcomes

- ▶ Name the four primary tissue types in the human body, and state a general function of each.
- ▶ Name the major subcategories of the primary tissue types, and identify the tissues of each subcategory microscopically or in an appropriate image.
- ▶ State the locations of the various tissues in the body.
- ▶ List the general function and structural characteristics of each of the tissues studied.

Pre-Lab Quiz



Instructors may assign these and other Pre-Lab Quiz questions using **Mastering A&P™**

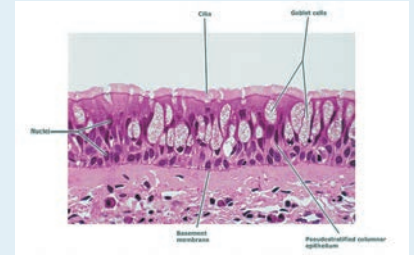
1. Epithelial tissues can be classified according to cell shape. _____ epithelial cells can either be scale shaped or cube shaped.
 - a. Columnar
 - b. Cuboidal
 - c. Squamous
 - d. Transitional
2. All connective tissue is derived from an embryonic tissue known as:
 - a. cartilage
 - b. ground substance
 - c. mesenchyme
 - d. reticular
3. All the following are examples of connective tissue *except*:
 - a. bones
 - b. ligaments
 - c. neurons
 - d. tendons
4. What tissue type acts as a soft packaging material?
5. How many basic types of muscle tissue are there? _____

The human body is organized into structural levels of organization. The simplest level is the chemical level, where atoms combine to form molecules. Molecules form organelles, the functional units of cells. The cellular level is the functional unit of life. In humans and other multicellular organisms, cells function together to maintain homeostasis in the body.

Groups of cells that are similar in structure and function are called **tissues**. The four primary tissue types—epithelium, connective tissue, nervous tissue, and muscle—have distinctive structures, patterns, and functions. The four primary tissues are further divided into subcategories, as described shortly.

To perform specific body functions, the tissues are organized into **organs** such as the heart, kidneys, and lungs. Most organs contain several representatives of the

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> Lab Tools > Practice Anatomy Laboratory > Histology



Instructors may assign new Building Vocabulary coaching activities, Pre-Lab Quiz questions, Art Labeling activities, Practice Anatomy Lab Practical questions (PAL), and more using the **Mastering A&P™** Item Library.

Materials

- ▶ Compound microscope
- ▶ Immersion oil
- ▶ Prepared slides of simple squamous, simple cuboidal, simple columnar, stratified squamous (nonkeratinized), stratified cuboidal, stratified columnar, pseudostratified ciliated columnar, and transitional epithelium
- ▶ Prepared slides of mesenchyme; of adipose, areolar, reticular, and dense (both regular and irregular connective tissues); of hyaline and elastic cartilage; of fibrocartilage; of bone (x.s.); and of blood
- ▶ Prepared slide of nervous tissue (spinal cord smear)
- ▶ Prepared slides of skeletal, cardiac, and smooth muscle (I.s.)



Figure 6.1 Levels of structural organization.

primary tissues, and the arrangement of these tissues determines the organ's structure and function. Thus **histology**, the study of tissues, complements a study of gross anatomy and provides the structural basis for a study of organ physiology.

The next level of organization is the organ system level, where organs work together. **Figure 6.1** summarizes the structural level of organization in the body from the simplest to the most complex.

Epithelial Tissue

Epithelial tissue, or an **epithelium**, is a sheet of cells that covers a body surface or lines a body cavity. It occurs in the body as (1) covering and lining epithelium and (2) glandular epithelium.

Epithelial functions include protection, absorption, filtration, excretion, secretion, and sensory reception. For example, the epithelium covering the body surface protects against bacterial invasion and chemical damage. Epithelium specialized to absorb substances lines the stomach and small intestine. In the kidney tubules, the epithelium absorbs, secretes, and filters. Secretion is a specialty of glandular epithelium.

The following characteristics distinguish epithelial tissues from other types:

- **Polarity.** The membranes always have one free surface, called the *apical surface*, and typically that surface is significantly different from the *basal surface*.
- **Specialized contacts.** Cells fit closely together to form membranes, or sheets of cells, and are bound together by specialized junctions.
- **Supported by connective tissue.** The cells are attached to and supported by an adhesive **basement membrane**, which is an acellular material secreted partly by the epithelial cells (*basal lamina*) and connective tissue cells (*reticular lamina*) that lie next to each other.
- **Avascular but innervated.** Epithelial tissues are supplied by nerves but have no blood supply of their own (are avascular). Instead they depend on diffusion of nutrients from the underlying connective tissue.
- **Regeneration.** If well nourished, epithelial cells can easily divide to regenerate the tissue. This is an important characteristic because many epithelia are subjected to a good deal of abrasion.

The covering and lining epithelia are classified according to two criteria—arrangement or relative number of layers and cell shape (**Figure 6.2**). On the basis of arrangement, epithelia are classified as follows:

- **Simple** epithelia consist of one layer of cells attached to the basement membrane.
- **Stratified** epithelia consist of two or more layers of cells.

Based on cell shape, epithelia are classified into three categories:

- **Squamous** (scalelike)
- **Cuboidal** (cubelike)
- **Columnar** (column-shaped)

The terms denoting shape and arrangement of the epithelial cells are combined to describe the epithelium fully. *Stratified epithelia* are named according to the cells at the apical surface of the epithelial sheet, not those resting on the basement membrane.

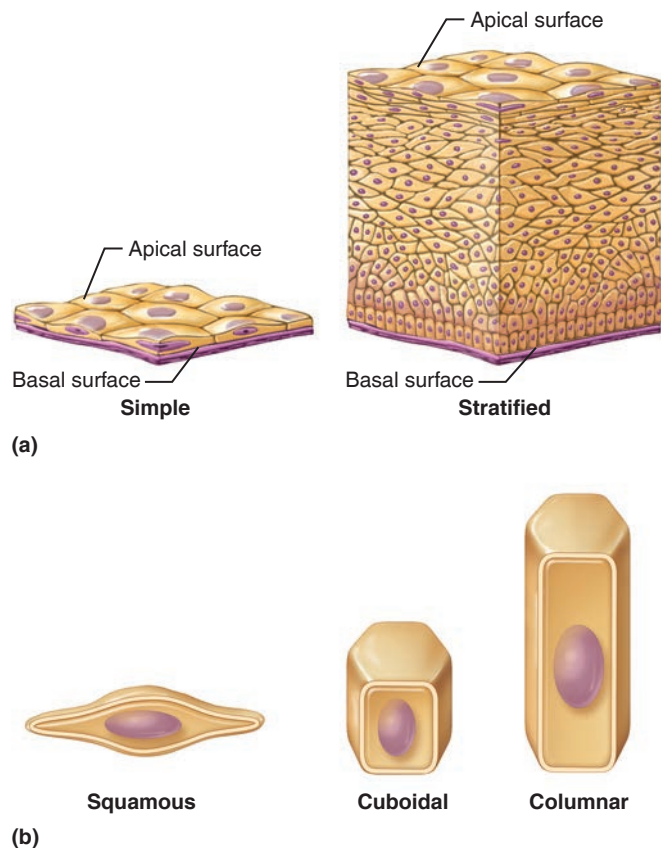


Figure 6.2 Classification of epithelia. (a) Classification based on number of cell layers. (b) Classification based on cell shape.

There are, in addition, two less easily categorized types of epithelia.

- **Pseudostratified epithelium** is actually a simple columnar epithelium (one layer of cells), but because its cells vary in height and the nuclei lie at different levels above the basement membrane, it gives the false appearance of being stratified. This epithelium is often ciliated.
- **Transitional epithelium** is a rather peculiar stratified squamous epithelium formed of rounded, or “plump,” cells with the ability to slide over one another to allow the organ to be stretched. Transitional epithelium is found only in urinary system organs subjected to stretch, such as the bladder. The superficial cells are flattened (like true squamous cells) when the organ is full and rounded when the organ is empty.

Epithelial cells forming glands are highly specialized to remove materials from the blood and to manufacture them into new materials, which they then secrete. There are two types of glands, *endocrine* and *exocrine*. **Endocrine glands** lose their surface connection (duct) as they develop; thus they are referred to as ductless glands. They secrete hormones into the extracellular fluid, and from there the hormones enter the blood or the lymphatic vessels that weave through the glands. **Exocrine glands** retain their ducts, and their secretions empty through these ducts either to the body surface or into body cavities. The exocrine glands include the sweat and oil glands, liver, and pancreas.

The most common types of epithelia, their characteristic locations in the body, and their functions are described in **Figure 6.3**.

Activity 1

Examining Epithelial Tissue Under the Microscope

Obtain slides of simple squamous, simple cuboidal, simple columnar, stratified squamous (nonkeratinized), pseudostratified ciliated columnar, stratified cuboidal, stratified columnar, and transitional epithelia. Examine each carefully, and notice how the epithelial cells fit closely together to form intact sheets of cells, a necessity for a tissue that forms linings or the coverings of membranes. Scan each epithelial type for modifications for specific functions, such as cilia (motile cell projections that help

to move substances along the cell surface), and microvilli, which increase the surface area for absorption. Also be alert for goblet cells, which secrete lubricating mucus. Compare your observations with the descriptions and photomicrographs in Figure 6.3.

While working, check the questions in the Review Sheet at the end of this exercise. A number of the questions there refer to some of the observations you are asked to make during your microscopic study.

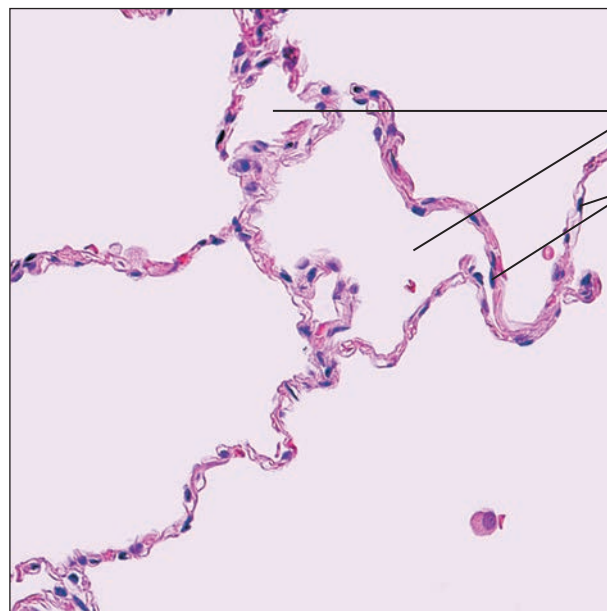
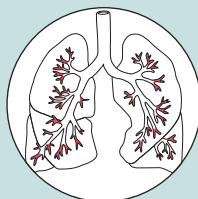
(a) Simple squamous epithelium

Description: Single layer of flattened cells with disc-shaped central nuclei and sparse cytoplasm; the simplest of the epithelia.



Function: Allows materials to pass by diffusion and filtration in sites where protection is not important; secretes lubricating substances in serosae.

Location: Kidney glomeruli; air sacs of lungs; lining of heart, blood vessels, and lymphatic vessels; lining of ventral body cavity (serosae).

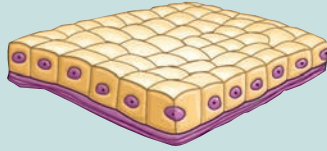


Photomicrograph: Simple squamous epithelium forming part of the alveolar (air sac) walls (140 \times).

Figure 6.3 Epithelial tissues. Simple epithelia (a).

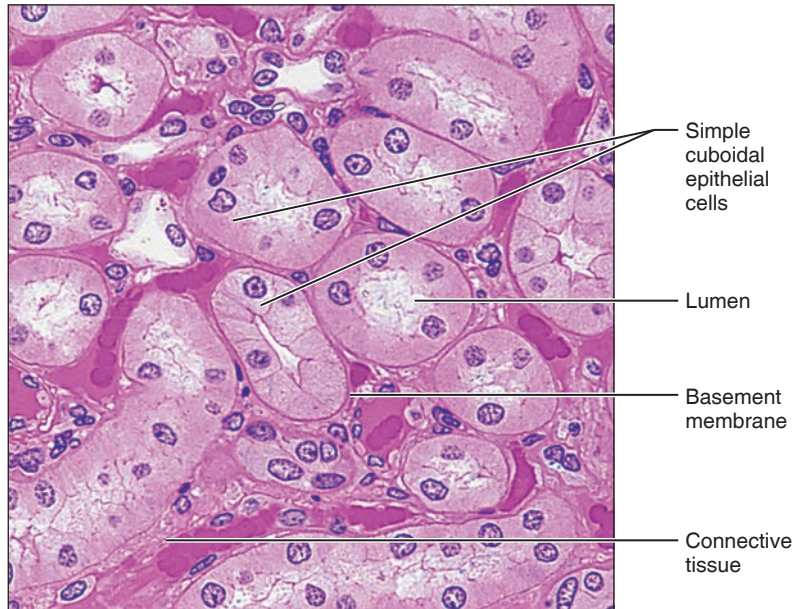
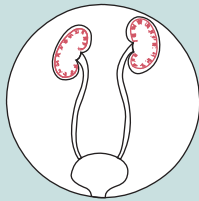
(b) Simple cuboidal epithelium

Description: Single layer of cubelike cells with large, spherical central nuclei.



Function: Secretion and absorption.

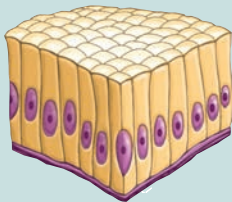
Location: Kidney tubules; ducts and secretory portions of small glands; ovary surface.



Photomicrograph: Simple cuboidal epithelium in kidney tubules (430 \times).

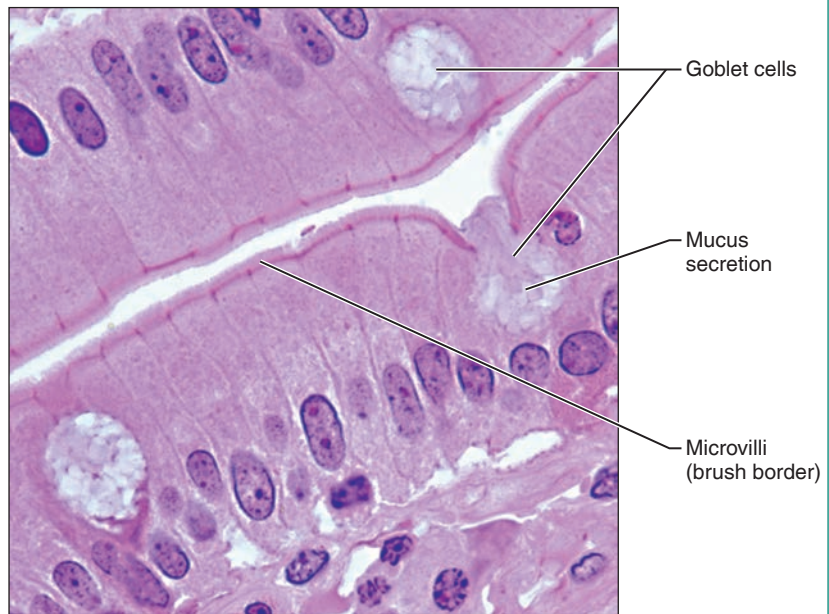
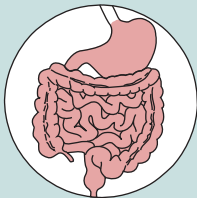
(c) Simple columnar epithelium

Description: Single layer of tall cells with *round to oval* nuclei; some cells bear cilia; layer may contain mucus-secreting unicellular glands (goblet cells).



Function: Absorption; secretion of mucus, enzymes, and other substances; ciliated type propels mucus (or reproductive cells) by ciliary action.

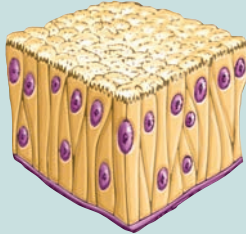
Location: Nonciliated type lines most of the digestive tract (stomach to rectum), gallbladder, and excretory ducts of some glands; ciliated variety lines small bronchi, uterine tubes, and some regions of the uterus.



Photomicrograph: Simple columnar epithelium containing goblet cells from the small intestine (640 \times).

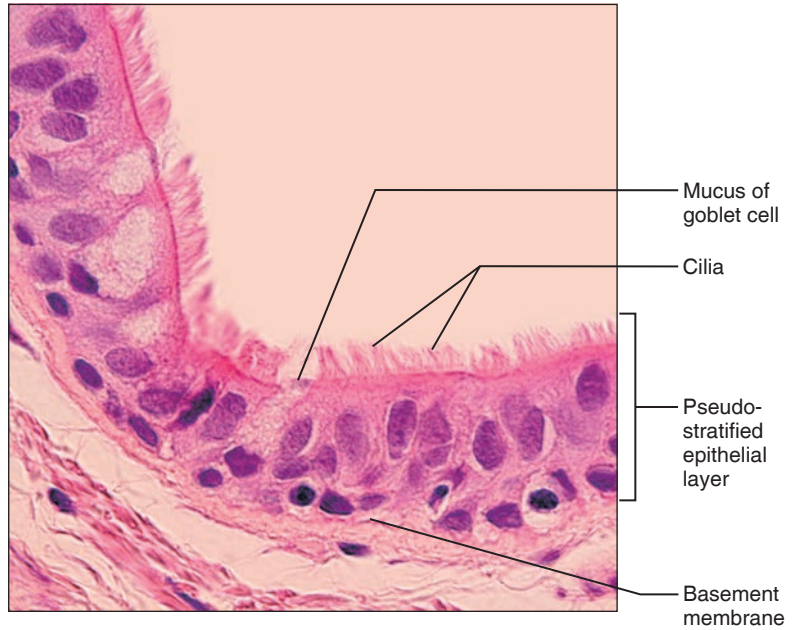
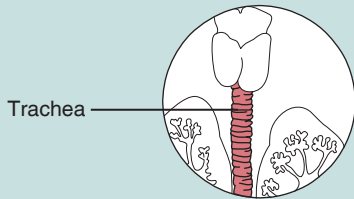
(d) Pseudostratified columnar epithelium

Description: Single layer of cells of differing heights, some not reaching the free surface; nuclei seen at different levels; may contain mucus-secreting goblet cells and bear cilia.



Function: Secretes substances, particularly mucus; propulsion of mucus by ciliary action.

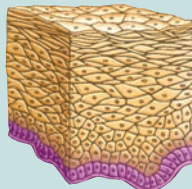
Location: Nonciliated type in male's sperm-carrying ducts and ducts of large glands; ciliated variety lines the trachea, most of the upper respiratory tract.



Photomicrograph: Pseudostratified ciliated columnar epithelium lining the human trachea (530 \times).

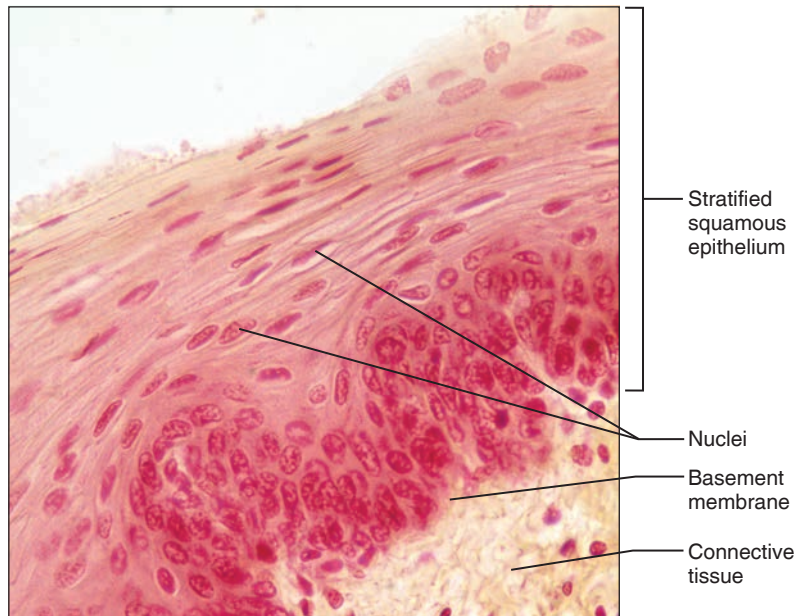
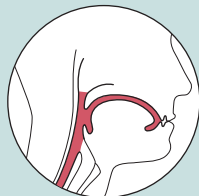
(e) Stratified squamous epithelium

Description: Thick membrane composed of several cell layers; basal cells are cuboidal or columnar and metabolically active; surface cells are flattened (squamous); in the keratinized type, the surface cells are full of keratin and dead; basal cells are active in mitosis and produce the cells of the more superficial layers.



Function: Protects underlying tissues in areas subjected to abrasion.

Location: Nonkeratinized type forms the moist linings of the esophagus, mouth, and vagina; keratinized variety forms the epidermis of the skin, a dry membrane.

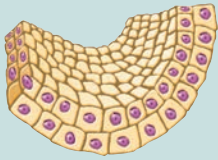


Photomicrograph: Stratified squamous epithelium lining the esophagus (280 \times).

Figure 6.3 (continued) Stratified epithelia **(d)** and **(e)**.

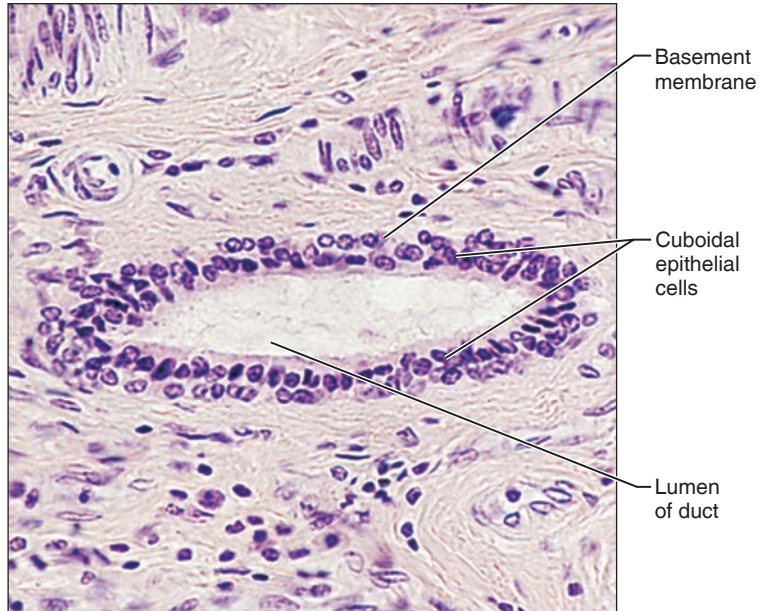
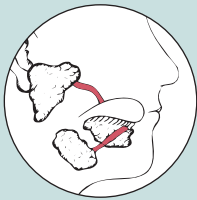
(f) Stratified cuboidal epithelium

Description: Generally two layers of cubelike cells.



Function: Protection.

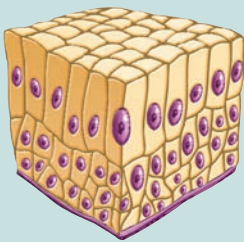
Location: Largest ducts of sweat glands, mammary glands, and salivary glands.



Photomicrograph: Stratified cuboidal epithelium forming a salivary gland duct (290×).

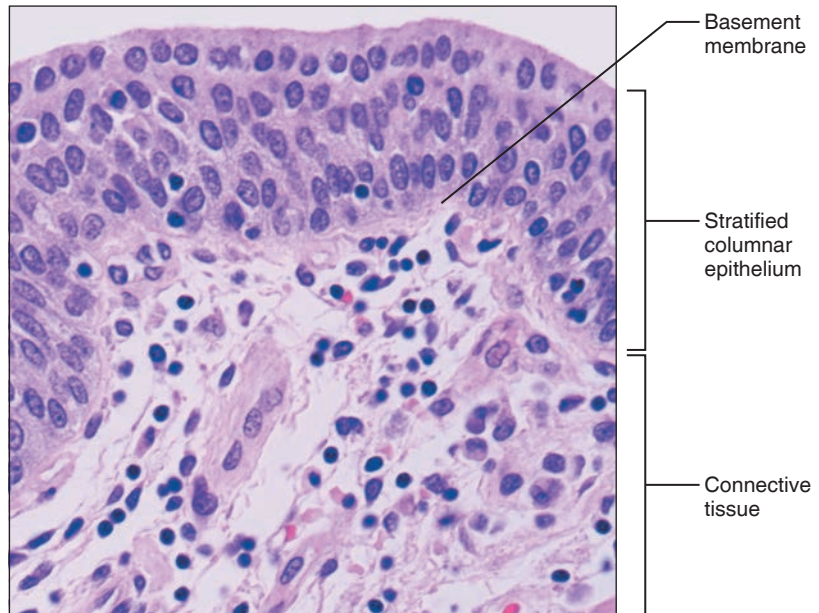
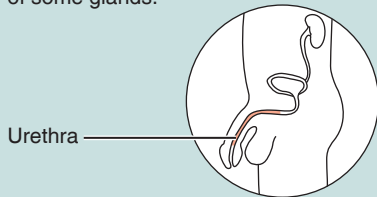
(g) Stratified columnar epithelium

Description: Several cell layers; basal cells usually cuboidal; superficial cells elongated and columnar.



Function: Protection; secretion.

Location: Rare in the body; small amounts in male urethra and in large ducts of some glands.

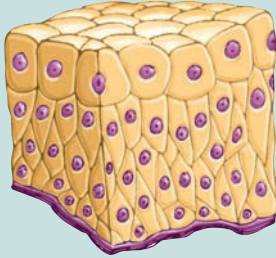


Photomicrograph: Stratified columnar epithelium lining of the male urethra (290×).

Figure 6.3 (continued) Epithelial tissues. Stratified epithelia **(f)** and **(g)**.

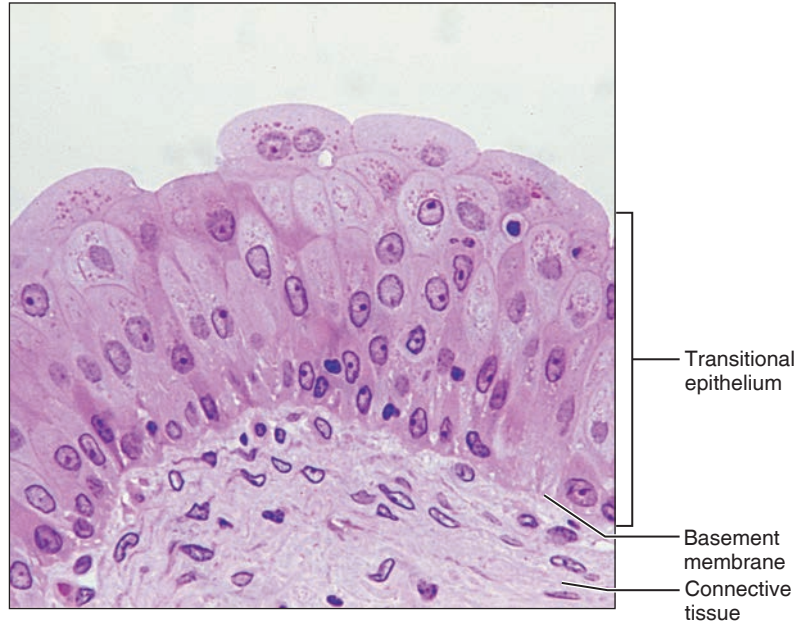
(h) Transitional epithelium

Description: Resembles both stratified squamous and stratified cuboidal; basal cells cuboidal or columnar; surface cells dome shaped or squamouslike, depending on degree of organ stretch.



Function: Stretches readily and permits distension of urinary organ by contained urine.

Location: Lines the ureters, urinary bladder, and part of the urethra.



Photomicrograph: Transitional epithelium lining the urinary bladder, relaxed state (365 \times); note the bulbous, or rounded, appearance of the cells at the surface; these cells flatten and become elongated when the bladder is filled with urine.

Figure 6.3 (continued) Stratified epithelia **(h)**.

Connective Tissue

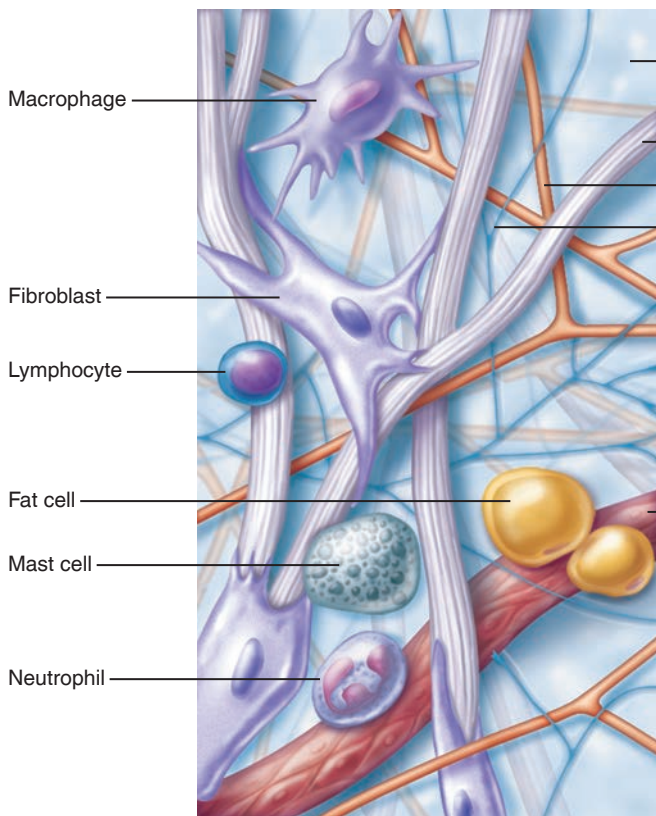
Connective tissue is found in all parts of the body as discrete structures or as part of various body organs. It is the most abundant and widely distributed of the tissue types.

There are four main types of adult connective tissue. These are **connective tissue proper**, **cartilage**, **bone**, and **blood**. Connective tissue proper has two subclasses: **loose connective tissues** (areolar, adipose, and reticular) and **dense connective tissues** (dense regular, dense irregular, and elastic). **Connective tissues** perform a variety of functions, but they primarily protect, support, insulate, and bind together other tissues of the

body. For example, bones are composed of connective tissue (**bone**, or **osseous tissue**), and they protect and support other body tissues and organs. The ligaments and tendons (**dense regular connective tissue**) bind the bones together or connect skeletal muscles to bones.

Areolar connective tissue (Figure 6.4, p. 90) is a soft packaging material that cushions and protects body organs. **Adipose** (fat) tissue provides insulation for the body tissues and a source of stored energy.

Cell types



Extracellular matrix

Ground substance

Fibers

- Collagen fiber
- Elastic fiber
- Reticular fiber

Capillary

Figure 6.4 Areolar connective tissue: A model connective tissue. This tissue underlies epithelia and surrounds capillaries. Note the various cell types and the three classes of fibers (collagen, reticular, elastic) embedded in the ground substance.



Instructors may assign this figure as an Art Labeling Activity using **Mastering A&P™**

The characteristics of connective tissue include the following:

- **Common origin.** All connective tissues are derived from embryonic tissue (*mesenchyme*).
- **Degrees of vascularity.** Many types of connective tissue have a rich blood supply. Exceptions include cartilage, which is avascular, and dense connective tissue, which is poorly vascularized.
- **Extracellular matrix.** There is a great deal of noncellular, nonliving material (matrix) between the cells of connective tissue. The composition and amount of matrix vary for connective tissues.

The extracellular matrix has two components—ground substance and fibers. The **ground substance** is composed chiefly of interstitial fluid, cell adhesion proteins, and proteoglycans. Depending on its specific composition, the ground substance may be liquid, semisolid, gel-like, or very hard. When the matrix is firm, as in cartilage and bone, the connective tissue cells

reside in cavities in the matrix called *lacunae*. The fibers, which provide support, include **collagen** (white) **fibers**, **elastic** (yellow) **fibers**, and **reticular** (fine collagen) **fibers**. Of these, the collagen fibers are most abundant.

The connective tissues have a common structural plan seen best in *areolar connective tissue* (Figure 6.4). Since all other connective tissues are variations of areolar, it is considered the model, or prototype, of the connective tissues. Notice that areolar tissue has all three varieties of fibers, but they are sparsely arranged in its transparent gel-like ground substance (Figure 6.4). The cell type that secretes its matrix is the *fibroblast*, but a wide variety of other cells (including phagocytic cells, such as macrophages, and certain white blood cells and mast cells that act in the inflammatory response) are present as well. The more durable connective tissues, such as bone, cartilage, and the dense connective tissues, characteristically have a firm ground substance and many more fibers.

Figure 6.5 lists the general characteristics, location, and function of some of the connective tissues found in the body.

Activity 2

Examining Connective Tissue Under the Microscope

Obtain prepared slides of mesenchyme; of adipose, areolar, reticular, dense regular, elastic, and dense irregular connective tissue; of hyaline and elastic cartilage and fibrocartilage; of osseous connective tissue (bone); and of blood. Compare your observations with the views illustrated in Figure 6.5.

Distinguish the living cells from the matrix. Pay particular attention to the denseness and arrangement of the matrix. For example, notice how the matrix of the dense regular and dense irregular connective tissues, respectively making up tendons and the dermis of the skin, is packed with collagen fibers. Note also that in the *regular* variety (tendon), the fibers are all running in the same direction, whereas in the dermis they appear to be running in many directions.

While examining the areolar connective tissue, notice how much empty space there appears to be (*areol* = small empty space), and distinguish the collagen fibers from the coiled elastic fibers. Identify the starlike fibroblasts. Also, try to locate a **mast cell**, which has large, darkly staining granules in its cytoplasm (*mast* = stuffed full of granules). This cell type releases

histamine, which makes capillaries more permeable during inflammation and allergies.

In adipose tissue, locate a “signet ring” cell, a fat cell in which the nucleus can be seen pushed to one side by the large, fat-filled vacuole that appears to be a large empty space. Also notice how little matrix there is in adipose (fat) tissue. Distinguish the living cells from the matrix in the dense connective tissue, bone, and hyaline cartilage preparations.

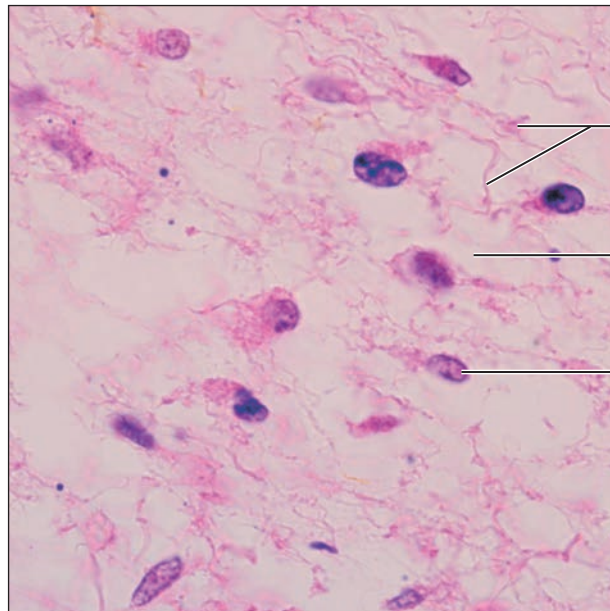
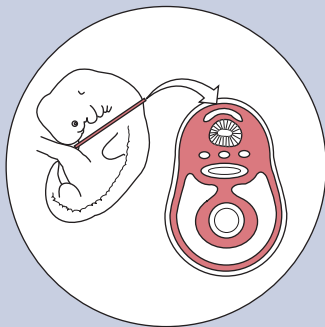
Scan the blood slide at low and then high power to examine the general shape of the red blood cells. Then, switch to the oil immersion lens for a closer look at the various types of white blood cells. How does the matrix of blood differ from all other connective tissues?

(a) Embryonic connective tissue: mesenchyme

Description: Embryonic connective tissue; gel-like ground substance containing fibers; star-shaped mesenchymal cells.

Function: Gives rise to all other connective tissue types.

Location: Primarily in embryo.



Fibers
Ground substance
Mesenchymal cell

Photomicrograph: Mesenchymal tissue, an embryonic connective tissue (627×); the clear-appearing background is the fluid ground substance of the matrix; notice the fine, sparse fibers.

Figure 6.5 Connective tissues. Embryonic connective tissue (a).

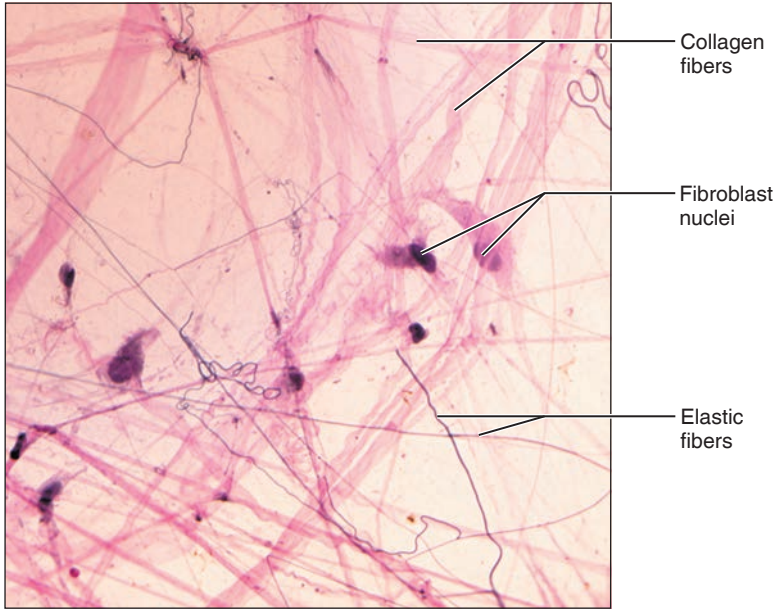
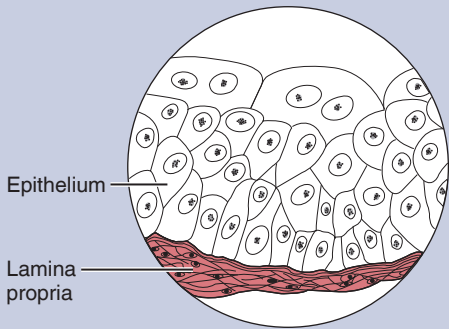


(b) Connective tissue proper: loose connective tissue, areolar

Description: Gel-like matrix with all three fiber types; cells: fibroblasts, macrophages, mast cells, and some white blood cells.

Function: Wraps and cushions organs; its macrophages phagocytize bacteria; plays important role in inflammation; holds and conveys tissue fluid.

Location: Widely distributed under epithelia of body, e.g., forms lamina propria of mucous membranes; packages organs; surrounds capillaries.



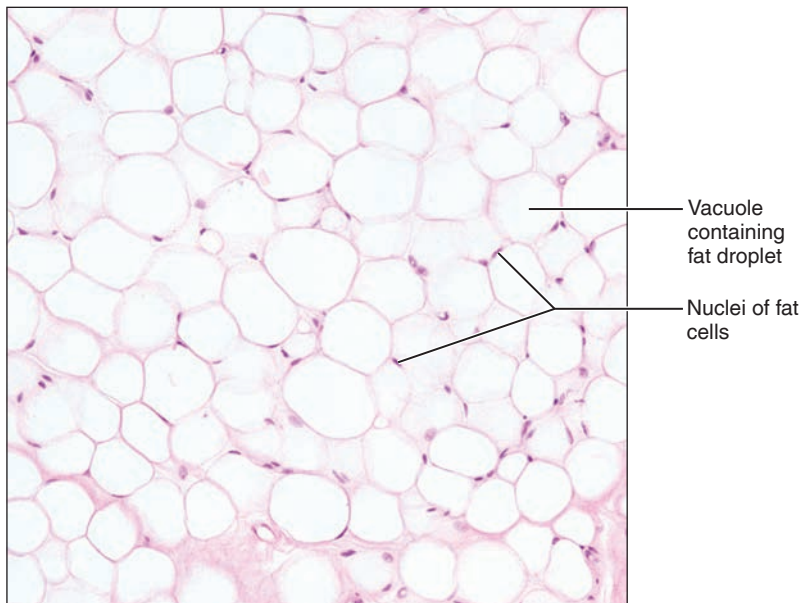
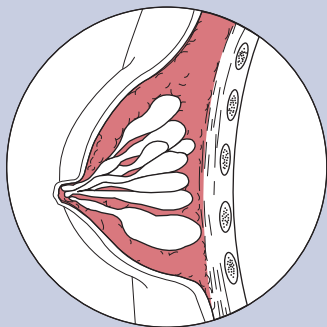
Photomicrograph: Areolar connective tissue, a soft packaging tissue of the body (365x).

(c) Connective tissue proper: loose connective tissue, adipose

Description: Matrix as in areolar, but very sparse; closely packed adipocytes, or fat cells, have nucleus pushed to the side by large fat droplet.

Function: Provides reserve fuel; insulates against heat loss; supports and protects organs.

Location: Under skin; around kidneys and eyeballs; within abdomen; in breasts.



Photomicrograph: Adipose tissue from the subcutaneous layer under the skin (110x).

Figure 6.5 (continued) Connective tissues. Connective tissue proper **(b)** and **(c)**.