







#### HUMAN ANATOMY, SIXTH EDITION

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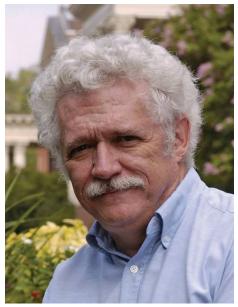
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# ABOUT THE AUTHORS

KENNETH SALADIN is Distinguished Professor of Biology, Emeritus, at Georgia College & State University. He received his B.S. in zoology at Michigan State University and his Ph.D. in parasitology at Florida State University and joined the Georgia College faculty in 1977. His courses have included human anatomy and physiology, introduction to medical physiology, histology, premedical seminar, and animal behavior, among others. He is a member of the Human Anatomy and Physiology Society, American Association of Anatomists, American Physiological Society, Society for Integrative and Comparative Biology, and American Association for the Advancement of Science. He is the author of the best-selling textbook Anatomy & Physiology: The Unity of Form and Function and coauthor, with Robin McFarland, of Essentials of Anatomy & Physiology. Ken has used the earnings from his textbooks to fund ecosystem conservation and restoration in the Galápagos Islands, to support the Charles Darwin Research Station in the Galápagos, to remodel and equip a Georgia College anatomy laboratory, to fund the Honors Program and the university's Natural History Museum, and to establish multiple student scholarships and an endowed chair in biomedical science and premedical mentoring. Ken and his wife Diane live in Milledgeville, Georgia, and have two adult children in North Carolina.

CHRISTINA A. GAN, digital author for the Connect question bank and test bank, has been teaching anatomy and physiology, microbiology, and general biology at Highline College in Des Moines, Washington, since 2004. Before that she taught at Rogue Community College in Medford, Oregon, for six years. Christina earned her M.A. in biology from Humboldt State University, researching the genetic variation of mitochondrial DNA in various salmonid species, and is a member of the Human Anatomy and Physiology Society. When she is not in the classroom or developing digital media, she is climbing, mountaineering, skiing, kayaking, sailing, cycling, and mountain biking throughout the Pacific Northwest.











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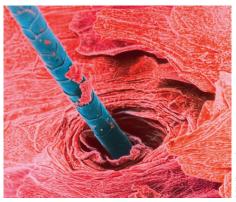
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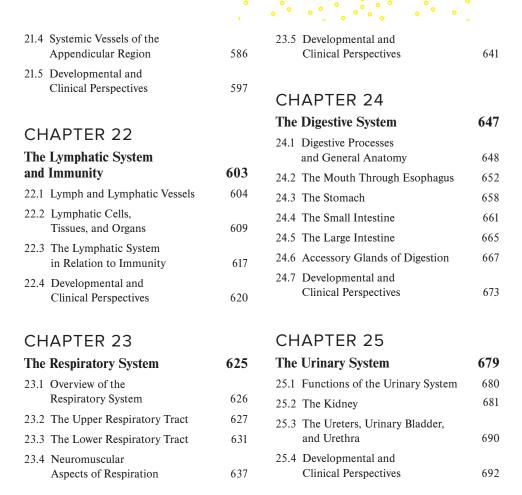
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## PREFACE

Saladin's *Human Anatomy* goes beyond descriptions of body structure to read as a story that weaves together basic science, clinical applications, the history of medicine, and the evolutionary basis of human structure. Saladin combines this humanistic perspective with vibrant photos and art to convey the beauty and excitement of the subject to beginning students.

#### **Changes to the Sixth Edition**

Attending scientific conferences, subscribing to several scientific and medical journals, and engaging in online forums and answering public questions on anatomy, physiology, and health help Ken Saladin stay abreast of advances in the field. In this edition, he introduces newly discovered functions of osteocytes, astrocytes, dendritic cells, the greater omentum, the corneal epithelium, and even eyelashes. He reports new research insights on peroxisome production, tracing white matter tracts of the brain, and endocrine disruptors; new discoveries of cerebral lymphatics, and pulmonary production of blood platelets; and clinical advances in asthma and cancer mortality and survival, cord blood transplants, stem-cell harvesting, and regenerative medicine. These and more examples are listed chapter by chapter later in this section.

In response to users and reviewers, the sixth edition has more concise treatments of gametogenesis, sperm capacitation, fertilization, aneuploidy, and embryology of the sense organs, cardiovascular system, and digestive tract. The muscle chapters are reorganized for better flow, with chapter 10 focusing on the cellular level; chapter 11 on whole-muscle organization, accessory connective tissues, musculoskeletal biomechanics, and the axial musculature; and chapter 12 on the appendicular musculature. Ken has also upgraded some of the book's pedagogical features. There are new, challenging thought questions, and the Study Guide section presents "What's Wrong with These Statements?"—10 statements that all have subtle errors, prompting students to identify what is wrong with them.

#### **New and Enhanced Perspectives**

This sixth edition details enhancements to topics already in the previous edition, including new anatomical imaging techniques, ethnic variations in anatomy, osteon structure and microfractures, vascular aging and hypertension, the scope of the immune system, T cell selection, clinical importance of the cricothyroid ligament, colonic histology, photosensory effects on the pineal gland, musculoskeletal biomechanics, and more.

#### **New Art and Photography**

This edition includes new drawings of motor units, sectional anatomy of the head, hand innervation, the course of the vagus

nerve, the pediatric auditory tube, lumbar puncture, epidermal histology, flat bone structure, gastric and colonic histology, the mechanical advantage of levers, and the spermatic cord. Always watching for opportunities to enhance topics with photos or to replace old photos with better ones, this edition has new photos of diabetic gangrene, rickets, shingles, endemic goiter, muscle histochemistry, rod and cone cell SEMs, an intravenous pyelogram, and ovulation.

#### **Detailed List of Changes**

Chapter by chapter, the sixth edition's most significant changes are as follows:

**Chapter 1, The Study of Human Anatomy,** has added descriptions of dynamic spatial reconstruction, open MRI, and Doppler ultrasound.

Chapter 2, Cytology—The Study of Cells, has new clinical topics including mitochondrial diseases and birth defects arising from primary cilium dysfunctions. It has updates on mitochondrial DNA, the role of gap junctions in the lens and cornea, and peroxisome production. It describes the vascular corrosion cast technique seen in many of the book's SEM photos.

**Chapter 3, Histology—The Study of Tissues,** has new Clinical Applications on biopsy and regenerative medicine, and functional updates on urothelium (transitional epithelium) and epithelial basement membranes.

**Chapter 4, Human Development,** has reduced the level of detail, at reviewer and user suggestions, on gametogenesis, sperm capacitation, fertilization, and aneuploidy.

**Chapter 5, The Integumentary System,** has a new Clinical Application on sunscreens, sunburn, and skin cancer.

Chapter 6, The Skeletal System I: Bone Tissue, has new clinical coverage of osteomalacia, rickets, and osteosarcoma, and updates on osteoporosis, the endocrine role of osteocytes, and limitation of microfractures by osteon structure. It includes enhanced art on flat bone structure.

**Chapter 7, The Skeletal System II: Axial Skeleton,** has a new sectional view of the head and its cavities, and new clinical coverage of cleft palate and lip.

Chapter 8, The Skeletal System III: Appendicular Skeleton, had little need for change but has an upgraded illustration of the clavicle for improvement in its surface features.

Chapter 9, The Skeletal System IV: Joints, updates the material science of joint prostheses.

Chapter 10, The Muscular System I: Muscle Cells, has improved illustrations of the neuromuscular junction, motor units, and the histochemistry of muscle fiber types, and new clinical coverage of rigor mortis and fibromyalgia. Chapters 10 to 12 on the

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muscular system are reorganized so that chapter 10 focuses on the cellular level; chapter 11 discusses the accessory connective tissues of muscle, whole-muscle structure and organization, musculoskeletal biomechanics, and the axial muscles; and chapter 12 discusses the appendicular muscles.

Chapter 11, The Muscular System II: Axial Musculature, now incorporates material moved from chapters 10 and 12 and has enhanced coverage of accessory connective tissues, muscle compartments, muscle-bone attachments, musculoskeletal biomechanics, a new illustration of lever biomechanics, and a clinical update on types and treatment of inguinal hernias.

Chapter 12, The Muscular System III: Appendicular Musculature, updates the treatment of carpal tunnel syndrome.

**Chapter 13, The Nervous System I: Nervous Tissue,** updates astrocyte functions and the role of electrical synapses in neuronal synchrony.

Chapter 14, The Nervous System II: Spinal Cord and Spinal Nerves, now covers lumbar puncture and adds new illustrations of shingles and the distribution of hand innervation from the brachial plexus.

Chapter 15, The Nervous System III: Brain and Cranial Nerves, has new drawings of regional functions of the cerebral cortex and distribution of the vagus nerve; new clinical coverage of stroke and trigeminal neuralgia; and scientific updates on brain senescence, functions of the red nucleus and insula, and mapping of the brain with diffusion tensor imaging.

Chapter 16, The Nervous System IV: Autonomic Nervous System and Visceral Reflexes, has a redrawn figure 16.2 to better compare sympathetic, parasympathetic, and somatic efferent pathways, and it expands slightly on pre- and postganglionic fibers and their neurotransmitters.

Chapter 17, The Nervous System V: Sense Organs, has scientific updates on the roles of the eyelashes, corneal epithelium, and vitreous body; new clinical coverage of phantom pain, macular degeneration, and diabetic retinopathy; new SEM photos of rod and cone cells; a new drawing of the pediatric and adult auditory tubes as related to middle-ear infection; and a more concise treatment of ear and eye embryology.

Chapter 18, The Endocrine System, has enhanced discussions of pineal gland innervation and function, melatonin, the endocrine pancreas, and endemic goiter (with a new photo), and a new interpretation of anterior pituitary chromophobes. It has new clinical coverage of congenital absence of the pituitary gland (panhypopituitarism) and hypo- and hyperthyroidism, and has added a basic pathophysiology of diabetes mellitus.

Chapter 19, The Circulatory System I: Blood, updates the status of cord blood transfusions and the harvesting of stem cells from circulating blood; enhances coverage of the role of blood circulation in thermoregulation and of the role of erythroblasts; and reports a startling new finding on where most blood platelets are produced.

Chapter 20, The Circulatory System II: The Heart, updates the treatment options for patent ductus arteriosis and has a more concise treatment of cardiac embryology.

Chapter 21, The Circulatory System III: Blood Vessels, gives an updated multicultural perspective on vascular aging and hypertension; adds new challenge questions on identifying arteries in a magnetic resonance angiogram and identifying blood vessels used for routine clinical purposes; and treats blood vessel embryology more concisely.

**Chapter 22, The Lymphoid System and Immunity,** now takes an expanded, more contemporary view of the meaning of *immune system*. It reports the recent discovery of cerebral lymphatics and has enhanced discussions of lymphatic vessel peristalsis and lymph flow, the maturation and selection of T cells, and the antigenpresenting role of dendritic cells.

Chapter 23, The Respiratory System, has improved descriptions of the nasal and tracheal mucosae, the bronchial tree, and the cricothyroid ligament in relation to tracheostomy. It updates asthma mortality rates and lung cancer survival, and reports the newly discovered role of the lungs in producing blood platelets.

Chapter 24, The Digestive System, has new clinical coverage of diverticulosis, diverticulitis, hepatitis, cirrhosis, gastroesophageal reflux disease, and gallstones. It has enhanced discussions of mesentery structure and omentum function; dental anatomy and proprioception; salivary gland innervation; anatomy of the ileocecal junction; and ethnic variation in colonic anatomy. It has new illustrations of histology of the stomach and colon, and a more concise treatment of GI embryology.

**Chapter 25, The Urinary System,** adds new coverage of intravenous pyelography and kidney stone treatment, and corrects a common misconception about female urethral sphincters.

Chapter 26, The Reproductive System, has added substantial new clinical content, with Clinical Applications and other discussions of varicocele, uterine fibroids, uterine cancer, endometriosis, sexually transmitted diseases, contraception, testicular cancer, male breast cancer, and male reproductive tract disorders. It has a new endoscopic photo of ovulation, a revision of penile anatomy to focus more on the uncircumcised state, and an update on environmental endocrine disruptors and their effect on fertility.

## **A Storytelling Writing Style**

Students and instructors alike cite Saladin's prose style as the number one attraction of this book. Students doing blind comparisons of Ken Saladin's chapters and those of other anatomy books routinely find Saladin clearly written, easy to understand, and a stimulating, interesting read. Saladin's analogy-rich writing enables students to easily visualize abstract concepts in terms of everyday experience. Consider, for example, from chapter 13:

The dimensions of human neurons are more impressive when we scale them up to the size of familiar objects. If the soma of a spinal motor neuron was the size of a tennis ball, its dendrites would form a huge bushy mass that could fill a 30-seat classroom from floor to ceiling. Its axon would be up to a mile long but a little narrower than a garden hose. This is quite a point to ponder. The neuron must assemble molecules and organelles in its "tennis ball" soma and deliver them through its "mile-long garden hose" to the end of the axon.







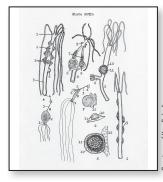
## EVOLUTION OF A STORYTELLER

Ken Saladin's penchant for writing began early. For his tenth-grade biology class, he wrote a 318-page monograph on hydras with 53 original India ink drawings and 10 original photomicrographs. We at McGraw-Hill think of this as Ken's "first book." At a young age, Ken already was developing his technical writing style, research habits, and illustration skills.





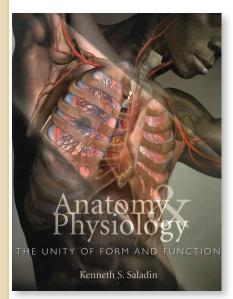
Ken Saladin's "first book," Hydra Ecology (1965)



Some of Ken's first pen-and-ink artwork (1965)

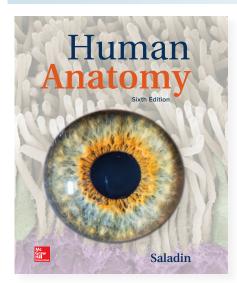


Ken in 1964



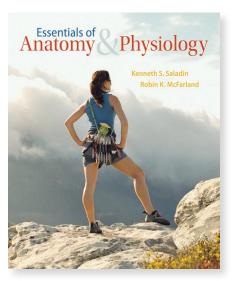
Ken's first textbook published in 1997

Ken served as an A&P textbook reviewer and testbank writer for several years and then embarked on his first book for McGraw-Hill in 1993. He published the first edition of *Anatomy & Physiology: The Unity of Form and Function* in 1997 and his first edition of *Human Anatomy* in 2004. The story continues with *Human Anatomy*, sixth edition.



The story continues in 2019

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Essentials book published in 2013

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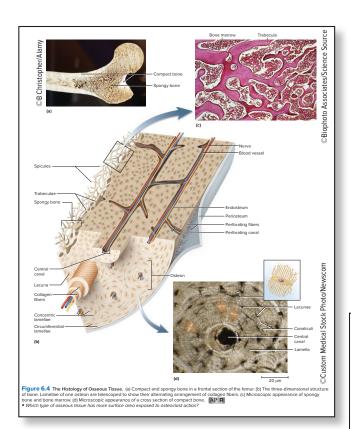


# GUIDED TOUR

#### **Instructive Artwork for Visual** Learners

Saladin's stunning illustrations and photos entice students who regard themselves as "visual learners."

Vivid Illustrations with rich textures and shading and bold, bright colors bring anatomy to life.



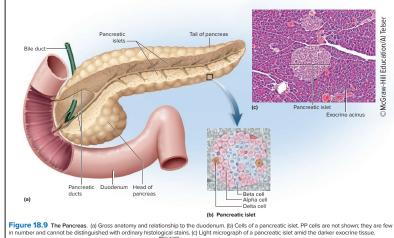
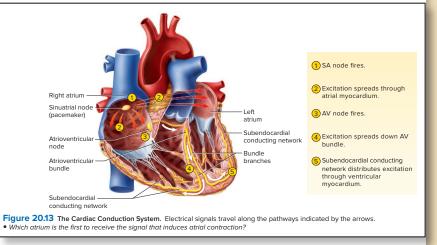


Figure 18.9 The Pancreas. (a) Gross anatomy and relationship to the duodenum. (b) Cells of a pancreatic islet. PP cells are not shown; they are few in number and cannot be distinguished with ordinary histological stains. (c) Light micrograph of a pancreatic islet amid the darker exocrine tissue.

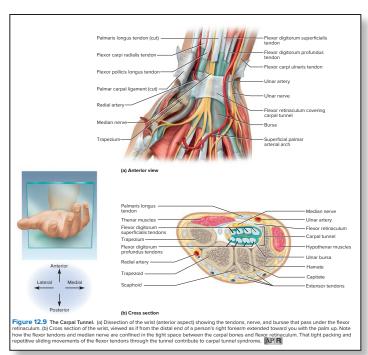
\* What is the function of the exocrine cells in this gland?

Process Figures relate numbered steps in the art with corresponding numbered text descriptions.





**Orientation Tools,** such as dissection planes and a compass on the anatomical art, clarify the perspective from which a structure is viewed.



#### The Psychology of Learning

Having taught human anatomy and histology for 40 years, Saladin knows what works in the classroom and incorporates those approaches into the pedagogy of *Human Anatomy*.

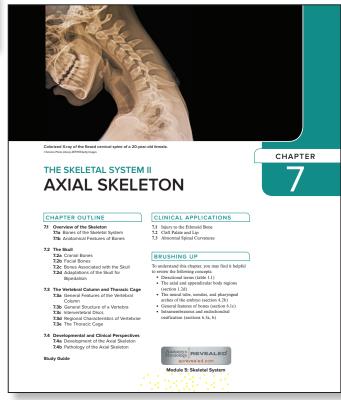
#### **Chapters Organized for Preview and Review**

**Chapter Outline** provides a content preview and facilitates review and study.

**Clinical Applications** pique the interest of health-science students by showing the clinical relevance of the core science.

**Brushing Up** reminds students of the relevance of earlier chapters to the one on which they are currently embarking.

Anatomy & Physiology REVEALED® icons indicate which area of this interactive cadaver dissection program corresponds to the chapter topic.









#### 9.1 Joints and Their Classification

#### **Expected Learning Outcomes**

When you have completed this section, you should be able to

- a. explain what joints are, how they are named, and what
- functions they serve; name and describe the four major classes of joints
- c. name some joints that become solidly fused by bone as
- they age;
  d. describe the three types of fibrous joints and give an example of each;
- distinguish between the three types of sutures; and
- describe the two types of cartilaginous joints and give an example of each.

#### Before You Go On

Answer the following questions to test your understanding of the

- 1. What is the difference between arthrology and kinesiology?
- 2. Explain the distinction between a synostosis, amphiarthrosis, and synarthrosis.
- 3. Give some examples of joints that become synostos with age.
- Name the three types of sutures and describe how they
- Name two synchondroses and two symphyses

#### **Reinforced Learning**

Each section is a conceptually unified topic, framed between a pair of learning "bookends"-a set of learning objectives at the beginning and a set of review and self-testing questions at the end. Each section is numbered for easy reference in lecture, assignments, and ancillary materials. These "bookends" provide the student an optimistic impression of short, easily digestible sections manageable in short bits of reading time.

**Expected Learning Outcomes** give the student a preview of key points to be learned within the next few pages.

Before You Go On prompts the student to pause and spot-check his or her mastery of the previous few pages before progressing to new material.

#### **Vocabulary Building**

Several features help build a student's level of comfort with medical vocabulary.

**Pronunciation Guides** Knowing proper pronunciation is key to remembering and spelling terms. Saladin gives simple, intuitive "pro-NUN-see-AY-shun" guides to help students over this hurdle and widen the student's comfort zone for medical vocabulary.

Word Origins Accurate spelling and insight into medical terms are greatly enhanced by a familiarity with commonly used word roots, prefixes, and suffixes.

Footnotes throughout the chapters help build the student's working lexicon of word elements. An end-of-book Glossary provides clear definitions of the most important or frequently used terms.

Building Your Medical Vocabulary An exercise at the end of each chapter helps students creatively use their knowledge of new medical word elements.

Any point where two bones meet is called a joint (articulation), whether or not the bones are movable at that interface. The science of joint structure, function, and dysfunction is called arthrology. The study of musculoskeletal movement is kinesiology<sup>2</sup> (kih-NEEsee-OL-oh-jee). This is a branch of biomechanics, which deals with a broad variety of movements and mechanical processes in the body, including the physics of blood circulation, respiration, and hearing.

 $^{1}arthro = joint; logy = study of$ <sup>2</sup>kinesio = movement; logy = study of

#### **Building Your Medical Vocabulary**

State a meaning of each word element and give a medical term from this chapter that uses it or a 3. zygo-

9. meso-10. terato-

slight variation of it.

4. tropho-5. cephalo-6. gyneco-

Answers in appendix A

1. haplo-2. gameto-

7. -genesis

8. syn-

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#### **Self-Assessment Tools**

Saladin provides students with abundant opportunities to evaluate their comprehension of concepts. A wide variety of questions from simple recall to analytical evaluation cover all six cognitive levels of Bloom's Taxonomy of Educational Objectives.

Before You Go On questions test simple recall and lower-level interpretation of information read in the previous few pages.

Apply What You Know tests a student's ability to think of the deeper implications or clinical applications of a point he or she just read.

**Apply What You Know** 

Martha is showing a sonogram of her unborn baby to her coworkers. Her friend Betty tells her she shouldn't have sonograms made because X-rays can cause birth defects. Is Betty's concern well founded? Explain.

#### Before You Go On

Answer the following questions to test your understanding of the preceding section:

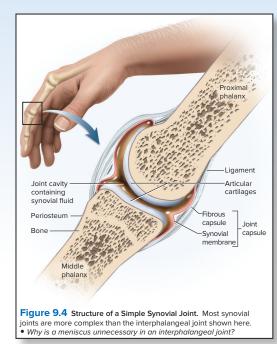
- 12. In what sense can spontaneous abortion be considered a protective mechanism?
- 13. Mutation and nondisjunction both produce chromosomal abnormalities. What is the difference between them?
- Why is a baby more likely to be born with anatomical defects stemming from teratogen exposure at 30 days than from exposure at 10 days?

Testing Your Recall sections at the end of each chapter offer 20 simple recall questions to test retention of terminology and basic ideas.

What's Wrong with These Statements? requires students to concisely explain why the false statements are untrue.

Testing Your Comprehension questions are clinical application and other interpretive essay questions that require the student to apply the chapter's basic science to clinical or other scenarios.

Figure Legend Questions posed in many of the figure legends prompt the student to interpret the art and apply it to the reading.



#### Testing Your Recall

9. The intercostal nerves between the ribs arise from which spinal nerve plexus?
a. cervical
b. brachial
c. lumbar

#### What's Wrong with These Statements?

- Briefly explain why each of the following statements is false, or reword it to make it true.

  1. More people get rheumatoid arthritis than costocarthritis.

  2. A doctor who treats arthritis is called a kinesiologist.

  3. Sprovial joints are also known as synarthross.

  4. The lateral and medial melicid are shock absorbing cartilages in the elbow joint.
- Synovial fluid is secreted by the bursae.
   Several sutures can be found in the long bones of the upper and lower limbs.

#### **Testing Your Comprehension**

- Why are there menisci in the knee joint but not in the elbow, the corresponding joint of the upper limb? Why is there an articular disci in the temporomandibular joint?

   What ligaments would most likely be torn if you slipped and your foot was suddenly forced into an excessively inverted position: (a) the posterior talefolibular and calcaneofibular ligaments, or (b) the medial
- ligament? Explain. What would the resulting condition of the ankle be called?

  3. In order of occurrence, list the joint actions (flexion, pronation, etc.) and the joints where they would occur as you (a) sit down at a table, (b) reach out and pick up an apple, (c) take a bite, and (d) chew it. Assume that you start in anatomical position.
- What structure in the cibow joint serves the same purpose as the anterior cruciate ligament (ACL) of the knee?
   State is strong strong





#### **CLINICAL APPLICATION**

14.2

#### Poliomyelitis and Amyotrophic Lateral Sclerosis

Poliomyelitis<sup>15</sup> and amyotrophic lateral sclerosis<sup>16</sup> (ALS) are two diseases that result from the destruction of motor neurons. In both diseases, the skeletal muscles atrophy from lack of innervation.

Poliomyelitis (polio) is caused by the poliovirus, which destroys motor neurons in the brainstem and anterior horn of the spinal cord. Signs of polio include muscle pain, weakness, and loss of some reflexes, followed by paralysis, muscular atrophy, and sometimes respiratory arrest. The virus spreads through water contaminated by feces. Historically, polio afflicted many children who contracted the virus from contaminated public swimming pools. For a time, the polio vaccine nearly eliminated new cases, but the disease has lately begun to reemerge among children in some countries because of antivaccination politics.

ALS is also known as Lou Gehrig<sup>17</sup> disease after the baseball player who succumbed to it. It is marked not only by the degeneration of motor neurons and atrophy of the muscles, but also sclerosis (scarring) of the lateral regions of the spinal cord—hence its name. Most cases occur when astrocytes fail to reabsorb the neurotransmitter glutamate from the tissue fluid, allowing it to accumulate to a neurotoxic level. The early signs of ALS include muscular weakness and difficulty in speaking, swallowing, and using the hands. Sensory and intellectual functions remain unaffected, as evidenced by the accomplishments of astrophysicist and best-selling author Stephen Hawking (fig. 14.7), who was stricken with ALS while he was in college. Despite near-total paralysis, he had a slowly progressive form of the disease, remained intellectually undiminished, and communicated with the aid of a speech synthesizer and computer. Tragically, many people are quick to assume that those who have lost most of their ability to communicate their ideas and feelings have no ideas and feelings to communicate. To a victim, this may be more unbearable than the loss of motor function itself.



Figure 14.7 Stephen Hawking (1942–2018). "When I was first diagnosed with ALS, I was given two years to live. Now 45 years later, I am doing pretty well" (CNN interview, 2010).

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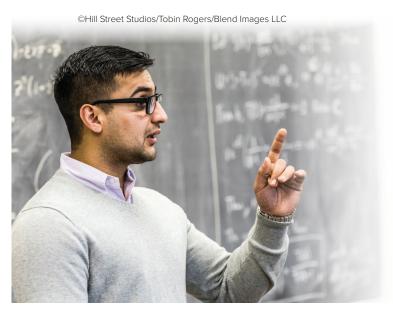
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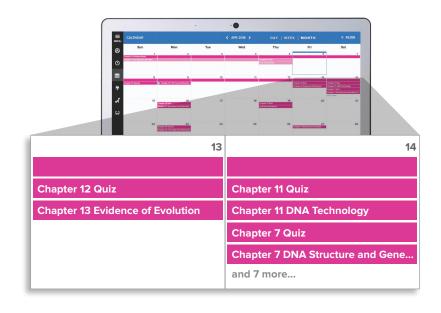
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I wish to thank the hundreds of colleagues who have reviewed my writing over the years and tremendously contributed to the factual accuracy, scientific currency, and presentation style of the book before you. Much of this has come about through revising my flagship book, *Anatomy & Physiology: The Unity of Form and Function*, through eight editions. *Human Anatomy* and my book coauthored with Robin McFarland, *Essentials of Anatomy & Physiology*, have derived their own content improvements as they follow in the wake of the heavily reviewed two-semester textbook.

I wish to thank specifically all of the reviewers of the fifth edition text (listed below). Their feedback has been instrumental to the revision process for this sixth edition. In addition to these commissioned reviews of my chapters, spontaneous feedback from other instructors and from students all over the world has been enormously stimulating and helpful in the incessant effort to approach that elusive asymptote called textbook perfection. I'm deeply appreciative of all the encouragement, information, corrections, and suggestions these readers have sent, and I look forward to many more years of such productive correspondence.

Christina Gan updated the question bank and test bank to closely correlate with the intricate changes made in this sixth edition, and greatly increased the educational value of these books through her work to create self-assessment tools and align McGraw-Hill's Connect resources with the textbook. This has contributed greatly to student and instructor satisfaction with our overall package of learning media, and to the students' success as they master A&P en route to their career aspirations. I am delighted to have Christina on my team.

I would also like to extend appreciation to members of the Life Sciences Book Team at McGraw-Hill Education who have worked with me on this project, including Matthew Garcia, Portfolio Manager; Donna Nemmers, Senior Product Developer; Vicki Krug, Senior Content Project Manager; Lori Hancock, Lead Content Licensing Specialist; Brent dela Cruz, Senior Content Project Manager; David Hash, Lead Designer; and Jeanne Patterson, freelance copy editor. Their efforts have yielded another great edition of the text and its companion media suite of Connect products.

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## LETTER TO STUDENTS

#### Dear Students,

When I was a young boy, I became interested in what I then called "nature study" for two reasons. One was the sheer beauty of nature. I reveled in children's books with abundant, colorful drawings and photographs of animals, plants, minerals, and gems. It was this esthetic appreciation of nature that made me want to learn more about it and made me happily surprised to discover I could make a career of it. At a slightly later age, another thing that drew me still deeper into biology was to discover writers who had a way with words—who could captivate my imagination and curiosity with their elegant prose. Once I was old enough to hold part-time jobs, I began buying zoology and anatomy books that mesmerized me with their gracefulness of writing and fascinating art and photography. I wanted to write and draw like that myself, and I began learning from "the masters." I spent many late nights in my room peering into my microscope and jars of pond water, typing page after page of manuscript, and trying pen and India ink as an art medium. My "first book" was a 318-page paper on some little pond animals called hydras, with 53 illustrations, that I wrote for my tenth-grade biology class when I was 16.

Fast forward about 30 years to when I became a textbook writer, and I found myself bringing that same enjoyment of writing and illustrating to my own anatomy and physiology textbooks. Why? Not only for its intrinsic creative satisfaction, but because I'm guessing that you're like I was—you can appreciate a book that does more than simply give you the information you need. You appreciate, I trust, a writer who makes it *enjoyable* for you through scientific, storytelling prose and a conceptualized way of illustrating things to spark interest and facilitate understanding. Some of you probably think of yourselves as "visual learners" and others as "verbal learners." Either way, I hope this book will serve your learning style.

I know from my own students, however, that you need more than captivating illustrations and enjoyable reading. Let's face it—A&P is a complex subject and it may seem a formidable task to acquire even a basic knowledge of the human body. It was difficult even for me to learn (and the learning never ends). So in addition to simply writing this book, I've given a lot of thought to pedagogy—the art of teaching. I've designed my chapters to make them easier for you to study and to give you abundant opportunity to check whether you've understood what you read—to test yourself (as I advise my own students) before the instructor tests you. Christina Gan, digital author, also produces rich Connect interactive questions that test your understanding as you progress through each chapter. Students have commended these online questions as extremely helpful in learning human anatomy.

Each chapter is broken down into short, digestible bits with a set of learning goals (Expected Learning Outcomes) at the beginning of each section, and self-testing questions (Before You Go On) just a few pages later. Even if you have just 30 minutes to read during a lunch break or a bus ride, you can easily read or review one of these brief sections. There are also numerous self-testing questions at the end of each chapter, in some of the figure legends, and the occasional Apply What You Know questions dispersed through each chapter. The questions cover a broad range of cognitive skills, from simple recall of a term to your ability to evaluate, analyze, and apply what you've learned to new clinical situations or other problems.

The Guided Tour takes you through the learning aids we've created for you within the book itself and additional study aids available within Connect. I hope you will take a little time to look at the Guided Tour to see what we have to offer you.

I hope you enjoy your study of this book, but I know there are always ways to make it even better. Indeed, what quality you may find in this edition owes a great deal to feedback I've received from students all over the world. If you find any typos or other errors, if you have any suggestions for improvement, if I can clarify a concept for you, or even if you just want to comment on something you really like about the book, I hope you'll feel free to write to me. I correspond quite often with students and would enjoy hearing from you.

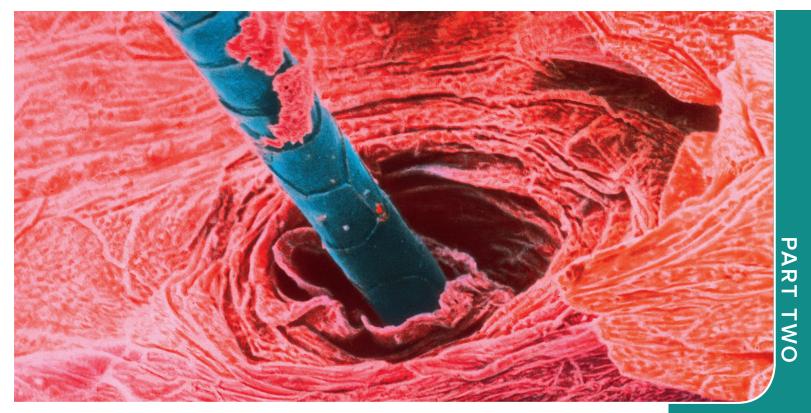
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A human hair emerging from its follicle at the skin surface (SEM) ©SPL/Science Source

# THE INTEGUMENTARY SYSTEM

**CHAPTER** 

5

#### **CHAPTER OUTLINE**

#### 5.1 The Skin and Subcutaneous Tissue

5.1a Functions of the Skin

**5.1b** The Epidermis

**5.1c** The Dermis

**5.1d** The Hypodermis

5.1e Skin Color

**5.1f** Skin Markings

#### 5.2 Hair and Nails

**5.2a** Hair

**5.2b** Nails

#### 5.3 Cutaneous Glands

**5.3a** Sweat Glands

5.3b Sebaceous Glands

**5.3c** Ceruminous Glands

**5.3d** Mammary Glands

#### 5.4 Developmental and Clinical Perspectives

**5.4a** Prenatal Development of the Integumentary System

**5.4b** The Aging Integumentary System

5.4c Skin Disorders

#### Study Guide

#### **CLINICAL APPLICATIONS**

5.1 Tension Lines and Surgery

5.2 Sunscreens, Sunburn, and Skin Cancer

5.3 Skin Grafts and Artificial Skin

#### **BRUSHING UP**

To understand this chapter, you may find it helpful to review the following concepts:

- Cellular junctions (section 2.2e)
- Keratinized stratified squamous epithelium (table 3.3)
- Areolar and dense irregular connective tissues (tables 3.4, 3.5)
- Eccrine, holocrine, and apocrine gland types (section 3.5a)



Module 4: Integumentary System





he first organ system we deal with in this book is also the most visible one—the *integumentary system*, composed of the skin and its glands, hair, and nails. People pay more attention to this system than to any other. Being so visible, its appearance strongly affects our social interactions. Few people venture out of the house without looking in a mirror to see if their skin and hair are presentable. In the United States alone, we spend billions of dollars annually on skin- and hair-care products and cosmetics. A health-care practitioner must not dismiss this as mere vanity, for a positive self-image is important to the attitudes that promote overall health. Care of the integumentary system must be considered as an important part of total patient care.

The appearance of the skin, hair, and nails is a matter of more than esthetics—their inspection is a significant part of a physical examination. They can provide clues not only to their own health, but also to deeper disorders such as liver cancer, anemia, kidney disease, and heart failure. The skin also is the most vulnerable of our organs, exposed to radiation, trauma, infection, and injurious chemicals. Consequently, it needs and receives more medical attention than any other organ system.

# 5.1 The Skin and Subcutaneous Tissue

#### **Expected Learning Outcomes**

When you have completed this section, you should be able to

- a. list the functions of the skin and relate them to its structure:
- b. describe the histological structure of the epidermis, dermis, and subcutaneous tissue;
- c. describe the normal and pathological colors that the skin can have and explain their causes; and
- d. describe the common markings of the skin.

The skin, hair, nails, and cutaneous glands (sweat glands and others) constitute the **integumentary**<sup>1</sup> **system**; the skin alone is called the **integument.** The treatment of this system is a branch of medicine called **dermatology.**<sup>2</sup>

The skin is the body's largest and heaviest organ. In adults, it covers an area of 1.5 to 2.0 m<sup>2</sup> and accounts for about 15% of the body weight. It consists of two layers: a stratified squamous epithelium called the *epidermis* and a deeper connective tissue layer called the *dermis* (fig. 5.1). Below the dermis is another connective tissue layer, the *hypodermis*, which is not part of the skin but is customarily studied in conjunction with it.

Most of the skin is 1 to 2 mm thick, but it ranges from less than 0.5 mm on the eyelids to 6 mm between the shoulder blades. The difference is due mainly to variation in the thickness of the dermis, although skin is classified as thick or thin based on the relative

<sup>1</sup>integument = covering

thickness of the epidermis alone. **Thick skin** covers the palms, soles, and corresponding surfaces of the fingers and toes. Its epidermis alone is about 0.5 mm thick, due to a very thick surface layer of dead cells called the *stratum corneum*. This layer resists the pressure and friction to which the palms and soles are especially subjected. Thick skin has sweat glands but no hair or sebaceous (oil) glands. The rest of the body is covered with **thin skin**, which has an epidermis about 0.1 mm thick, with a thin stratum corneum. It possesses hair, sebaceous glands, and sweat glands.

#### 5.1a Functions of the Skin

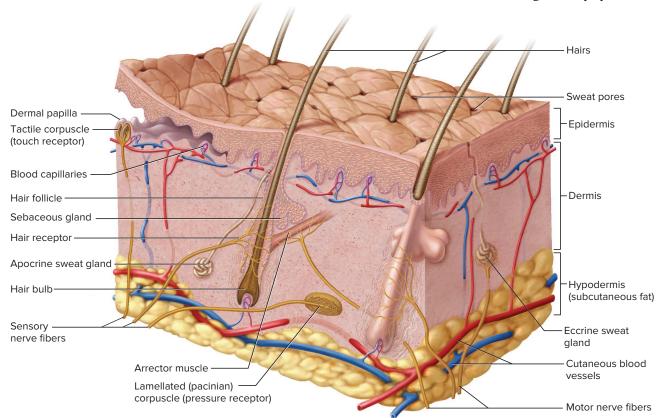
The skin is much more than a container for the body. It has a variety of important functions that go well beyond appearance.

- Resistance to trauma and infection. The skin bears the brunt of
  most physical injuries to the body, but it resists and recovers
  from trauma better than other organs do. The epidermal
  cells are packed with the tough protein keratin and linked by
  strong desmosomes that give the epithelium its durability. Few
  infectious organisms can penetrate the intact skin. Bacteria
  and fungi colonize the surface, but their numbers are kept in
  check by its relative dryness and slight acidity (pH 4-6). Its
  protective acidic film, called the acid mantle, also contains
  antimicrobial chemicals called dermcidin and defensins.
  Immune cells called dendritic cells in the epidermis stand
  guard against pathogens that do breach the surface.
- Water retention. The skin is a barrier to water. It prevents the body from absorbing excess water when one is swimming or bathing, but even more importantly, it prevents the body from losing excess water to the surrounding air.
- 3. **Vitamin D synthesis.** The skin carries out the first step in the synthesis of vitamin D, which is needed for bone development and maintenance (see section 6.3e). The liver and kidneys complete the process.
- 4. **Sensation.** The skin is our most extensive sense organ. It is equipped with a variety of nerve endings that react to heat, cold, touch, texture, pressure, vibration, and tissue injury. These sensory receptors are especially abundant on the face, palms, fingers, soles, nipples, and genitals. There are relatively few on the back and in skin overlying joints such as the knees and elbows. Sensory nerve endings of the skin are named and described in more detail in section 17.1b.
- 5. Thermoregulation. The skin receives 10 times as much blood flow as it needs for its own maintenance, and is richly supplied with nerve endings called thermoreceptors, which monitor the body surface temperature. All of this relates to its great importance in regulating body temperature. The skin can act as our overcoat or our radiator depending on whether we need to retain or lose heat at the moment. When we're cold, the skin retains heat by constricting blood vessels of the dermis (cutaneous vasoconstriction), keeping warm blood deeper in the body. When we're hot, we get rid of excess heat by dilating those vessels (cutaneous vasodilation), allowing more blood to flow close to the surface and radiate heat through the skin. If this isn't enough to restore normal temperature, we sweat. The



 $<sup>^{2}</sup>dermat = skin; logy = study of$ 





**Figure 5.1** Structure of the Skin and Subcutaneous Tissue. The epidermis is peeled up at the upper left corner to show the corrugated dermal—epidermal boundary.

evaporation of sweat can have a powerful cooling effect. If the skin didn't enable us to rid the body of the heat generated by our own metabolism, we would quickly die of hyperthermia.

6. **Nonverbal communication.** The skin is an important means of communication. Humans, like other primates, have much more expressive faces than most mammals. Complex skeletal muscles insert in the dermis and move the skin to create subtle and varied facial expressions (fig. 5.2).





**Figure 5.2** Importance of the Skin in Nonverbal Expression. Primates differ from other mammals in having very expressive faces due to facial muscles that insert on collagen fibers of the dermis and move the skin.

(a) ©GlobalP/Getty Images, (b) ©Joe DeGrandis/McGraw-Hill Education

## **5.1b** The Epidermis

The **epidermis**<sup>3</sup> is a keratinized stratified squamous epithelium, as described in table 3.3. That is, its surface consists of dead cells packed with keratin. Like other epithelia, it lacks blood vessels and depends on the diffusion of nutrients from the underlying connective tissue. It has nerve endings for touch and pain, but most sensations of the skin are due to nerve endings in the dermis.

#### **Cells of the Epidermis**

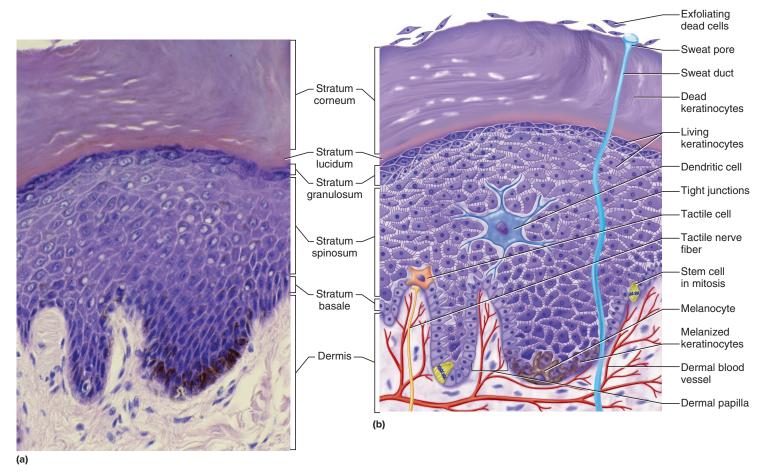
The epidermis is composed of five types of cells (fig. 5.3):

- 1. **Keratinocytes** (keh-RAT-ih-no-sites) are the great majority of epidermal cells and constitute nearly all of the cells visible in a histological section. They are named for their role in synthesizing keratin.
- 2. **Stem cells** are undifferentiated cells that divide and produce the keratinocytes. They are found only in the deepest layer of the epidermis, called the *stratum basale*.
- 3. Melanocytes also occur only in the stratum basale, amid the stem cells and deepest keratinocytes. They synthesize the brown to black pigment *melanin*. They have long branching processes that spread among the keratinocytes and continually shed melanin-containing fragments (*melanosomes*) from their tips. The keratinocytes phagocytize these fragments and accumulate melanin granules on the "sunny side" of



 $<sup>^{3}</sup>epi = above, upon; derm = skin$ 





the nucleus. Like a parasol, the pigment shields the DNA from ultraviolet radiation. Melanocytes are discussed later in relation to ethnic differences in skin color.

- 4. **Tactile cells**, relatively few in number, are receptors for touch. They, too, are found in the basal layer of the epidermis and are associated with an underlying dermal nerve fiber. The tactile cell and its nerve fiber are collectively called a *tactile disc*.
- 5. **Dendritic**<sup>4</sup> **cells** are found in two layers of the epidermis called the *stratum spinosum* and *stratum granulosum* (described in the next section). They are immune cells that originate in the bone marrow and migrate to the epidermis and epithelia of the oral cavity, esophagus, and vagina. The epidermis has as many as 800 dendritic cells per square millimeter. They stand guard against toxins, microbes, and other disease agents that penetrate into the skin. When they detect such invaders, they carry fragments of the foreign matter to the lymph nodes and alert the immune system so the body can defend itself.

#### Layers of the Epidermis

Cells of the epidermis are usually arranged in four to five zones, or strata (five in thick skin), shown in figure 5.3. The following

 $^{4}dendr = tree, branch$ 

description progresses from deep to superficial, and from the youngest to the oldest keratinocytes.

- 1. The **stratum basale** (bah-SAY-lee) consists mainly of a single layer of cuboidal to low columnar stem cells and keratinocytes resting on the basement membrane. Scattered among these are the melanocytes, tactile cells, and stem cells. As the stem cells divide, they give rise to keratinocytes that migrate toward the skin surface and replace lost epidermal cells. The life history of these cells is described in the next section.
- 2. The stratum spinosum (spy-NO-sum) consists of several layers of keratinocytes; in most places, this is the thickest stratum, but on the palms and soles it is usually exceeded by the stratum corneum. The deepest cells of the stratum spinosum continue dividing, but as they're pushed farther upward, they cease. Instead, they produce more and more keratin filaments, which cause the cells to flatten. Therefore, the higher up you look in the stratum spinosum, the flatter the cells appear. Dendritic cells are also found throughout the stratum spinosum, but are not usually visible in tissue sections.

The stratum spinosum is named for an artificial appearance (artifact) created by the histological fixation of tissue specimens. Keratinocytes are firmly attached to each





other by numerous desmosomes, which partly account for the toughness of the epidermis. Histological fixatives shrink the keratinocytes, so they pull away from each other; however, they remain attached by the desmosomes—like two people holding hands while they step farther apart. The desmosomes thus create bridges from cell to cell, giving each cell a spiny appearance from which we derive the word *spinosum*.

- 3. The **stratum granulosum** consists of three to five layers of flat keratinocytes—more in thick skin than thin—and some dendritic cells. The keratinocytes of this layer contain coarse, dark-staining *keratohyalin granules* that give the layer its name. The functional significance of these granules will be explained shortly.
- 4. The **stratum lucidum**<sup>5</sup> (LOO-sih-dum) is a thin translucent zone seen only in thick skin. Here, the keratinocytes are densely packed with a clear protein named *eleidin* (ee-LEE-ih-din). The cells have no nuclei or other organelles. Because organelles are absent and eleidin doesn't stain well, this zone has a pale, featureless appearance with indistinct cell boundaries.
- 5. The **stratum corneum** consists of up to 30 layers of dead, scaly, keratinized cells that form a durable surface layer. It is especially resistant to abrasion, penetration, and water loss.

#### The Life History of a Keratinocyte

Dead cells constantly flake off the skin surface. They float around as tiny white specks in the air, settling on household surfaces and forming much of the dust that accumulates there. Because we constantly lose these epidermal cells, they must be continually replaced.

Keratinocytes are produced deep in the epidermis by the mitosis of stem cells in the stratum basale. Some of the deepest keratinocytes in the stratum spinosum also remain mitotic and thus increase their number. Mitosis requires an abundant supply of oxygen and nutrients, which these deep cells acquire from the blood vessels in the nearby dermis. Once the epidermal cells migrate more than two or three cells away from the dermis, their mitosis ceases. Mitosis is seldom seen in prepared slides of the skin, because it occurs mainly at night whereas most histological specimens are taken during the day.

As new keratinocytes are formed, they push the older ones upward. In 30 to 40 days, a keratinocyte makes its way to the surface and flakes off. This migration is slower in old age and faster in skin that has been injured or stressed. Injured epidermis regenerates more rapidly than any other tissue in the body. Mechanical stress from manual labor or tight shoes accelerates keratinocyte multiplication and results in *calluses* or *corns*, thick accumulations of dead keratinocytes on the hands or feet.

As keratinocytes are shoved upward by the dividing cells below, they flatten and produce more keratin filaments and lipid-filled lamellar granules (membrane-coating vesicles). In the stratum granulosum, four important developments occur: (1) The keratohyalin granules release a protein called *filaggrin*, which binds the cytoskeletal keratin filaments together into coarse, tough bundles. (2) The cells produce a tough layer of *envelope proteins* just beneath the plasma membrane, resulting in a nearly indestructible protein sac around the keratin

bundles. (3) The lamellar granules release a lipid mixture that spreads out over the cell surface and waterproofs it. (4) Finally, as these barriers cut the keratinocytes off from the supply of nutrients from below, their nuclei and other organelles degenerate and the cells die, leaving just the tough waterproof sac of keratin.

The foregoing processes result in an **epidermal water barrier** between the stratum granulosum and the stratum spinosum. This barrier is crucial to retaining water in the body and preventing dehydration. Cells above the barrier quickly die, creating a stratum corneum composed of compact layers of dead keratinocytes and cell fragments. Dead keratinocytes exfoliate (flake off) from the epidermal surface as tiny specks called **dander**. *Dandruff* is composed of clumps of dander stuck together by sebum (oil).

A curious effect of the epidermal water barrier is the way our skin wrinkles when we linger in the bath or a lake. The keratin of the stratum corneum absorbs water and swells, but the deeper layers of the skin do not. The thickening of the stratum corneum forces it to wrinkle. This is especially conspicuous on the tips of the fingers and toes ("prune fingers") because they have such a thick stratum corneum and they lack the sebaceous glands that produce water-resistant oil elsewhere on the body. There may be more to the story than this, however, because the wrinkles don't form when the nerves to the fingers are severed, indicating some role for the nervous system. It has recently been hypothesized that this buckling of the skin may serve a function similar to the tread on a car tire, improving our grip by channeling water away when we press our fingertips to wet surfaces.

#### **5.1c** The Dermis

Beneath the epidermis is a connective tissue layer, the **dermis**. It ranges from 0.2 mm thick in the eyelids to about 4 mm thick in the palms and soles. It is composed mainly of collagen, but also contains elastic and reticular fibers, fibroblasts, and the other cells typical of fibrous connective tissue (described in section 3.3b). It is well supplied with blood vessels, cutaneous glands, and nerve endings. The hair follicles and nail roots are embedded in the dermis. The dermis contains smooth muscles in association with the hair follicles, as described later. In the face, skeletal muscles attach to dermal collagen fibers and produce such expressions as a smile, a wrinkle of the forehead, or the lifting of an eyebrow (see fig. 5.2).

The boundary between the epidermis and dermis is histologically conspicuous and usually wavy (see fig. 5.1). The upward waves are fingerlike extensions of the dermis called **dermal papillae**, <sup>6</sup> and the downward waves are extensions of the epidermis called **epidermal ridges**. The dermal and epidermal boundaries thus interlock like corrugated cardboard, an arrangement that resists slippage of the epidermis across the dermis. If you look closely at your hand and wrist, you will see delicate furrows that divide the skin into tiny rectangular to rhomboidal areas. The dermal papillae produce the raised areas between the furrows. On the fingertips, this wavy boundary forms the *friction ridges* discussed in section 5.1f. In highly sensitive areas such as the lips and genitals, exceptionally tall dermal papillae allow nerve fibers and blood capillaries to come closer to the skin surface. This imparts a redder color and more sensitivity to touch in such areas.



<sup>&</sup>lt;sup>5</sup>lucid = light, clear

 $<sup>^{6}</sup>pap = nipple; illa = little$ 



#### **Apply What You Know**

Dermal papillae are relatively high and numerous in palmar and plantar skin but low and few in number in the face and abdomen. What do you think is the functional significance of this difference?

#### CLINICAL APPLICATION

5.1

#### **Tension Lines and Surgery**

The collagen bundles in the dermis are arranged mostly in parallel rows that run longitudinally to obliquely in the limbs, but encircle the neck, trunk, wrists, and a few other areas. They keep the skin under constant tension and are thus called *tension lines*. If an incision is made in the skin, especially if it is perpendicular to the tension lines, the wound gapes because the collagen bundles pull the edges of the incision apart. Even if the skin is punctured with a circular object such as a nail, the wound gapes with a lemon-shaped opening, the direction of the wound axis being perpendicular to the tension lines. Such gaping wounds are relatively difficult to close and tend to heal with excessive scarring. Surgeons make incisions parallel to the tension lines—for example, making a transverse incision across the abdomen when delivering a baby by cesarean section—so that the incisions will gape less and heal with less scarring.

There are two zones of dermis called the papillary and reticular layers (fig. 5.4). The **papillary layer** (PAP-ih-lair-ee) is a thin zone of areolar tissue in and near the dermal papillae. It is especially rich in small blood vessels. The loosely organized tissue of the papillary layer allows for mobility of leukocytes and other defenses against organisms introduced through breaks in the epidermis.

The **reticular**<sup>7</sup> **layer** of the dermis is deeper and much thicker. It consists of dense irregular connective tissue. Leather is composed of the reticular layer of animal skin, attesting to the toughness of this tissue. The boundary between the papillary and reticular layers is often vague. In the reticular layer, the collagen forms thicker bundles with less room for ground substance, and there are often small clusters of adipocytes. Stretching of the skin in obesity and pregnancy can tear the collagen fibers and produce *striae* (STRY-ee), or stretch marks. These occur especially in areas most stretched by weight gain: the thighs, buttocks, abdomen, and breasts.

There are extensive plexuses of blood vessels at the dermalepidermal boundary, in mid-dermis, and between the dermis and hypodermis. When dermal blood vessels are damaged by such causes as burns and friction from tight shoes, serous fluid can seep out of the vessels and accumulate as a **blister**, separating the epidermis from the dermis until the fluid is either reabsorbed or expelled by rupture of the blister.

<sup>7</sup>reti = network; cul = little

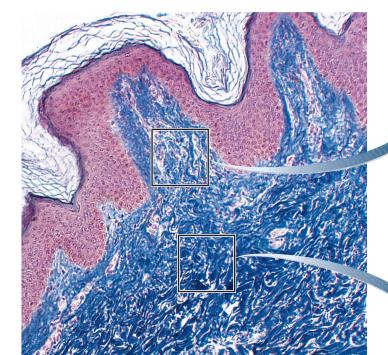
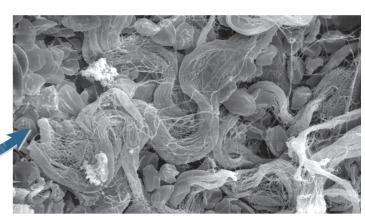


Figure 5.4 The Dermis. (a) Light micrograph of axillary skin, with the collagen stained blue. (b) The papillary layer, made of loose (areolar) tissue,

(a) ©Dennis Strete/McGraw-Hill Education, (b) ©Hossler, Ph.D. Custom Medical Stock Photo/Newscom, (c) ©Susumu Nishinaga/Science Source

forms the dermal papillae. (c) The reticular layer, made of dense irregular connective tissue, forms the deeper four-fifths of the dermis. **AP** 



(b) Papillary layer of dermis



(c) Reticular layer of dermis





## **5.1d** The Hypodermis

Beneath the skin is a layer called the hypodermis<sup>8</sup> (subcutaneous tissue). There is no sharp boundary between the dermis and hypodermis, but the hypodermis generally has more areolar and adipose tissue. It pads the body and binds the skin to the underlying tissues. Drugs are introduced here by hypodermic injection because the subcutaneous tissue is highly vascular and absorbs them quickly.

Subcutaneous fat is hypodermis composed predominantly of adipose tissue. It serves as an energy reservoir and thermal insulation. It is not uniformly distributed; for example, it is virtually absent from the scalp but relatively abundant in the breasts, abdomen, hips, and thighs. The subcutaneous fat is usually about 50% of one's total body fat. It averages about 8% thicker in women than in men, and varies with age. Infants and elderly people have less subcutaneous fat than other people and are therefore more sensitive to cold.

Table 5.1 summarizes the layers of the skin and hypodermis.

#### 5.1e Skin Color

The most significant factor in skin color is melanin, which is produced by melanocytes but accumulates in the keratinocytes of the stratum basale and the stratum spinosum (fig. 5.5). There are two forms of melanin-a brownish black eumelanin<sup>9</sup> and a reddish yellow sulfur-containing pigment, **pheomelanin.** People of different colors have essentially the same number of melanocytes, but in dark-skinned people, the melanocytes produce greater amounts of melanin, the melanin granules in the keratinocytes are more spread out than tightly clumped, and the melanin breaks down more slowly.

TABLE 5.1	Stratification of the Skin and Hypodermis
Layer	Description
Epidermis	Keratinized stratified squamous epithelium
Stratum corneum	Dead, keratinized cells of the skin surface
Stratum Iucidum	Clear, featureless, narrow zone seen only in thick skin
Stratum granulosum	Two to five layers of cells with dark-staining keratohyalin granules; scanty in thin skin
Stratum spinosum	Many layers of keratinocytes, typically shrunken in fixed tissues but attached to each other by desmosomes, which give them a spiny look; progressively flattened the farther they are from the dermis. Dendritic cells are abundant here but are not distinguishable in routinely stained preparations.
Stratum basale	Single layer of cuboidal to columnar cells resting on basement membrane; site of most mitosis; consists of stem cells, keratinocytes, melanocytes, and tactile cells, but these are not all distinguishable with routine stains. Melanin is conspicuous in keratinocytes of this layer in black to brown skin.
Dermis	Fibrous connective tissue, richly endowed with blood vessels and nerve endings. Sweat glands and hair follicles originate here and in hypodermis.
Papillary layer	Superficial one-fifth of dermis; composed of areolar tissue; often extends upward as dermal papillae
Reticular layer	Deeper four-fifths of dermis; dense irregular connective tissue
Hypodermis	Areolar or adipose tissue between skin and muscle

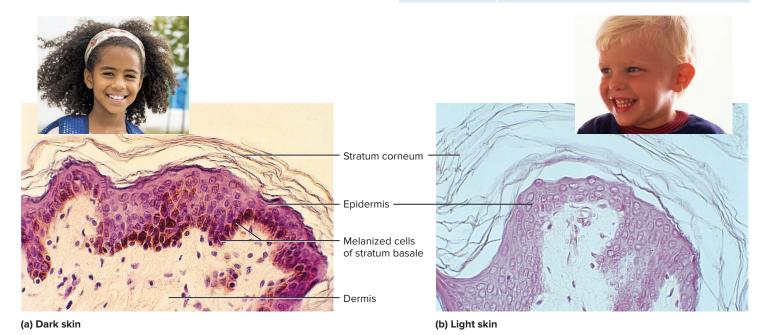


Figure 5.5 Variation in Skin Pigmentation. (a) The stratum basale shows heavy deposits of melanin in dark skin. (b) Light skin shows little or

(a bottom) ©Dennis Strete/McGraw-Hill Education, (a top) ©Lopolo/Shutterstock, (b bottom) ©Dennis Strete/McGraw-Hill Education, (b top) ©Arthur Tilley/Getty Images





 $<sup>^8</sup>$ hypo = below; derm = skin

 $<sup>^{9}</sup>eu = true; melan = black$ 

 $<sup>^{10}</sup>$ pheo = dusky; melan = black

<sup>•</sup> Which of the five types of epidermal cells are the melanized cells in part (a)?



Thus, melanized cells may be seen throughout the epidermis, from stratum basale to stratum corneum. In light-skinned people, the melanin is clumped near the keratinocyte nucleus, so it imparts less color to the cells. It also breaks down more rapidly, so little of it is seen beyond the stratum basale, if even there.

Skin color also varies with exposure to the ultraviolet (UV) rays of sunlight, which stimulate melanin synthesis and darken the skin. A suntan fades as melanin is degraded in older keratinocytes and the keratinocytes migrate to the surface and exfoliate. The amount of melanin also varies substantially from place to place on the body. It is relatively concentrated in freckles and moles; on the dorsal surfaces of the hands and feet as compared with the palms and soles; in the nipple and areola of the breast; around the anus; on the scrotum and penis; and on the lateral surfaces of the female genital folds (labia majora). The contrast between heavily melanized and lightly melanized regions of the skin is more pronounced in some people than in others, but it exists to some extent in nearly everyone.

Other factors in skin color are hemoglobin and carotene. **Hemoglobin,** the red pigment of blood, imparts reddish to pinkish hues to the skin. Its color is lightened by the white of the dermal collagen. The skin is redder in places such as the lips, where blood capillaries come closer to the surface and the hemoglobin shows through more vividly. Depending on diet, the stratum corneum and subcutaneous fat may take on a yellowish tint by accumulating

#### **CLINICAL APPLICATION**

5.2

#### Sunscreens, Sunburn, and Skin Cancer

Ultraviolet radiation is divided into two wavelength ranges, UVA and UVB. UVA, so-called "tanning rays," have the longer wavelength (320–400 nm) and lower energy of the two. UVB, so-called "burning rays," have a shorter wavelength (290–320 nm) and higher energy level. Tanning salons often advertise that they only use "safe" UVA rays, but UVA can burn as well as tan. It is also responsible for most of the undesirable photoaging effects on the skin (see section 5.4b), and it inhibits the immune system. Both UVA and UVB are now thought to initiate skin cancer. As dermatologists like to say, there is no such thing as a healthy tan.

Many people buy sunscreen according to its sun protection factor (SPF), but may be misled by the concept. SPF is a laboratory measure of protection from UVB radiation. It is advisable to use a minimum SPF of 15 for meaningful protection. It might seem that an SPF of 30 would give twice as much protection as SPF 15, but the relationship between protection and SPF is not linear. An SPF 15 sunscreen protects the skin from 93% of UVB, but SPF 30 protects only slightly more—97%. Although manufacturers compete to produce high-SPF products, higher numbers create a false sense of proportionately greater protection. The Australian government considers SPF values above 30 to be misleading.

Furthermore, effectiveness varies with the amount applied, frequency of reapplication, skin type, and sweating, and as sunscreen is washed off by swimming. People tend to use only one-quarter to one-half as much as needed to provide the SPF rating on the label, and wait too long between reapplications. For effective protection, one should divide the SPF by 2 and reapply sunscreen that many minutes after the onset of sun exposure—that is, every 15 minutes for an SPF of 30.

compounds related to vitamin A and carotene, 11 a yellow pigment acquired from egg yolks and yellow and orange vegetables. This color is often most conspicuous where the stratum corneum is thickest—on the heel and in calluses of the feet.

Variation in ancestral exposure to UV radiation (UVR) is the primary reason for the geographic and ethnic variation in skin color seen today. UVR can have two adverse effects: It causes skin cancer and it breaks down folate (folic acid), a B vitamin needed for normal cell division, fertility, and fetal development. It also has a desirable effect: It stimulates keratinocytes to synthesize vitamin D, which is needed for the absorption of dietary calcium and thus for healthy bone development. Too much UVR and one is at risk of cancer, infertility, and fetal deformities such as spina bifida; too little and one is at risk of bone deformities such as rickets. Consequently, populations native to the tropics and people descended from them tend to have well-melanized skin to screen out excessive UVR. Populations native to far northern and southern latitudes, where the sunlight is weak, tend to have light skin to allow for adequate UVR penetration. Ancestral skin color is thus partly a compromise between vitamin D and folate requirements. Worldwide, women have skin averaging about 4% lighter than men do, perhaps because of their greater need for vitamin D and calcium to support pregnancy and lactation.

But for multiple reasons, there are exceptions. UVR exposure is determined by more than latitude. It increases at higher elevations and in dry air, because the thinner, drier atmosphere filters out less UVR. This helps to explain the darker skin of people indigenous to such localities as deserts, the Andes Mountains, and the high plateaus of Tibet and Ethiopia. Some other exceptions may be the result of human migrations from one latitude to another occurring too recently for their skin color to have adapted to the new level of UVR exposure. Variation may also result from cultural differences in clothing and shelter, intermarriage among people of different geographic ancestries, and darwinian sexual selection—a preference in mate choice for partners of light or dark complexion.

The skin may also exhibit abnormal colors of diagnostic value:

- Cyanosis<sup>12</sup> is blueness of the skin resulting from a deficiency of oxygen in the circulating blood. Oxygen deficiency turns the hemoglobin a reddish violet color, which is lightened to blueviolet as it shows through the white dermal collagen. Oxygen deficiency can result from conditions that prevent the blood from picking up a normal load of oxygen in the lungs, such as airway obstructions in drowning and choking, lung diseases such as emphysema, and respiratory arrest. Cyanosis also occurs in situations such as cold weather and cardiac arrest, when blood flows so slowly through the skin that the tissues consume oxygen faster than freshly oxygenated blood arrives.
- Erythema<sup>13</sup> (ERR-ih-THEE-muh) is abnormal redness of the skin. It occurs in such situations as exercise, hot weather, sunburns, anger, and embarrassment. Erythema is caused by increased blood flow in dilated cutaneous blood vessels or, in sunburn, by dermal pooling of red blood cells that have escaped from damaged capillaries.
- Pallor is a pale or ashen color that occurs when there is so little blood flow through the skin that the white of the dermal collagen





 $<sup>^{1}</sup>carot = carrot$ 

 $<sup>^{12}</sup>$ cyan = blue; osis = condition

 $<sup>^{13}</sup>$ ervth = red; em = blood



- shows through. It can result from emotional stress, low blood pressure, cold temperatures, severe anemia, or circulatory shock.
- Albinism<sup>14</sup> is a genetic lack of melanin that usually results in milky white hair and skin, and blue-gray eyes. Melanin is synthesized from the amino acid tyrosine by the enzyme tyrosinase. Albinism results from inheriting a recessive, nonfunctional tyrosinase gene from both parents.
- Jaundice<sup>15</sup> is a yellowing of the skin and whites of the eyes resulting from high levels of bilirubin in the blood. Bilirubin is a hemoglobin breakdown product. When erythrocytes get old, they disintegrate and release their hemoglobin. The liver and spleen convert hemoglobin to bilirubin and other pigments, which the liver excretes in the bile. Bilirubin can accumulate enough to discolor the skin, however, in such situations as a rapid rate of erythrocyte destruction; when diseases such as cancer, hepatitis, and cirrhosis compromise liver function; and in premature infants, whose liver is not well enough developed to dispose of bilirubin efficiently.
- A hematoma, <sup>16</sup> or bruise, is a mass of clotted blood showing through the skin. It is usually due to accidental trauma (blows to the skin), but it may indicate hemophilia, other metabolic or nutritional disorders, or physical abuse.

#### **Apply What You Know**

An infant brought to a clinic shows abnormally yellow skin. What sign could you look for to help decide whether this was due to jaundice or to a large amount of carotene from strained vegetables in the diet?

#### 5.1f Skin Markings

The skin is marked by many lines, creases, ridges, and patches of accentuated pigmentation. **Friction ridges** are the markings on the fingertips that leave distinctive oily fingerprints on surfaces we touch. They are characteristic of most primates, though their function has long been obscure. They enhance one's sensitivity to texture by vibrating when one strokes an uneven surface, thus stimulating sense organs called *lamellar corpuscles* (see section 17.1b) deeper in the skin. They are also thought to improve one's grasp and aid in the manipulation of small and rough-surfaced objects. Friction ridges form during fetal development and remain essentially unchanged for life. Everyone has a unique pattern of friction ridges; not even identical twins have identical fingerprints.

**Flexion lines (flexion creases)** are lines on the flexor surfaces of the digits, palms, wrists, elbows, and other places (see fig. A.19 in the atlas). They mark sites where the skin folds during flexion of the joints. The skin is tightly bound to the deeper connective tissue along these lines.

Freckles and moles are tan to black aggregations of melanized keratinocytes. Freckles are flat, melanized patches that vary with heredity and exposure to the sun. A mole (nevus) is an elevated patch of melanized skin, often with hair. Moles are harmless and sometimes even regarded as "beauty marks," but they should be watched for changes in color, diameter, or contour that may suggest malignancy (skin cancer).

Birthmarks, or **hemangiomas**, <sup>17</sup> are patches of discolored skin caused by benign tumors of the blood capillaries. *Capillary hemangiomas* (strawberry birthmarks) usually develop about a month after birth. They become bright red to deep purple and develop small capillary-dense elevations that give them a strawberry-like appearance. About 90% of capillary hemangiomas disappear by the age of 5 or 6 years. *Cavernous hemangiomas* are flatter and duller in color. They are present at birth, enlarge up to 1 year of age, and then regress. About 90% disappear by the age of 9 years. A *port-wine stain* is flat and pinkish to dark purple in color. It can be quite large and remains for life.

#### **Before You Go On**

Answer the following questions to test your understanding of the preceding section:

- What is the major histological difference between thick and thin skin? Where on the body is each type of skin found?
- 2. How does the skin help to adjust body temperature?
- List the five cell types of the epidermis. Describe their locations and functions.
- 4. List the five layers of epidermis from deep to superficial. What are the distinctive features of each layer?
- 5. What are the two layers of the dermis? What type of tissue composes each layer?
- Name the pigments responsible for normal skin colors, and explain how certain conditions can produce discolorations of the skin.

#### 5.2 Hair and Nails

#### **Expected Learning Outcomes**

When you have completed this section, you should be able to

- a. distinguish between three types of hair;
- b. describe the histology of a hair and its follicle;
- discuss some theories of the purposes served by various kinds of hair;
- d. describe the life cycle of a hair; and
- e. describe the structure and function of nails.

The hair, nails, and cutaneous glands are the **accessory organs** (appendages) of the skin. Hair and nails consist mainly of dead, keratinized cells. The stratum corneum of the skin is made of pliable *soft keratin*, but the hair and nails are composed mostly of *hard keratin*. Hard keratin is more compact and is toughened by numerous cross-linkages between the keratin molecules.

#### 5.2a Hair

A hair is also known as a **pilus** (PY-lus)—in the plural, *pili* (PY-lye). It is a slender filament of keratinized cells that grows from an oblique tube in the skin called a **hair follicle** (fig. 5.6).





 $<sup>^{14}</sup>alb$  = white; ism = state, condition

<sup>&</sup>lt;sup>15</sup>jaun = yellow

 $<sup>^{16}</sup>hemat = blood; oma = mass$ 

 $<sup>^{17}</sup>hem = blood; angi = vessel; oma = tumor, mass$ 

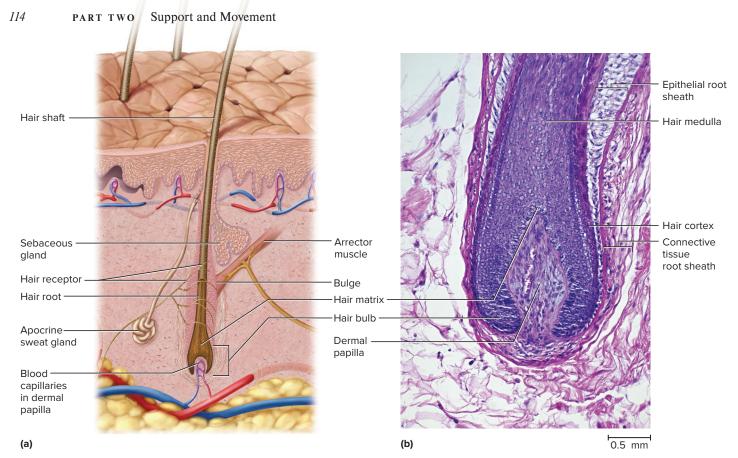


Figure 5.6 Structure of a Hair and Follicle. (a) Anatomy of the follicle and associated structures. (b) Light micrograph of the base of a hair follicle. APIR (b) ©Ed Reschke/Getty Images

#### **Distribution and Types**

Hair occurs almost everywhere on the body except the lips, nipples, parts of the genitals, palms and soles, ventral and lateral surfaces of the fingers and toes, and distal segment of the fingers. The trunk and limbs have about 55 to 70 hairs per square centimeter, and the face has about 10 times as many. There are about 30,000 hairs in a man's beard and about 100,000 in the average person's scalp. The density of hair does not differ much from one person to another or even between the sexes; indeed, it is virtually the same in humans, chimpanzees, and gorillas. Differences in apparent hairiness are due mainly to differences in coarseness and pigmentation.

Not all hair is alike, even on one person. Over the course of our lives, we grow three kinds of hair: downy hair, vellus hair, and terminal hair. **Downy hair (lanugo**<sup>18</sup>) is fine unpigmented hair of the fetus. By the time of birth, most of it is replaced by **vellus hair**, <sup>19</sup> a similarly fine, pale hair. Vellus hair constitutes about two-thirds of the hair of women, one-tenth of the hair of men, and all of the hair of children except for the eyebrows, eyelashes, and hair of the scalp. **Terminal hair** is longer, coarser, and usually more heavily pigmented. It forms the eyebrows and eyelashes; covers the scalp; and after puberty, it forms the axillary and pubic hair, male facial hair, and some of the hair on the trunk and limbs.

#### **Functions of Hair**

In most mammals, hair serves to retain body heat when it is cold, but also to shade the skin from excess solar radiation. Humans have too little hair to serve these purposes except on the scalp, where there is no insulating fat. Hair elsewhere on the body plays a variety of roles that are somewhat speculative, but probably best inferred by comparison to the specialized types and patches of hair in other mammals (table 5.2).

#### Structure of the Hair and Follicle

A hair is divisible into two parts: the **hair shaft** above the skin and **hair root** below the surface. The hair root ends in the dermis or hypodermis

TABLE 5.2	Functions of Hair
Hair of the torso and limbs	Vestigial, but serves a sensory purpose as in detection of small insects crawling on the skin
Scalp hair	Heat retention, protection from sun
Beard, pubic, and axillary (armpit) hair	Advertises sexual maturity; associated with apocrine scent glands in these areas and modulates the dispersal of sexual scents (pheromones) from these glands
Guard hairs (vibrissae)	Help keep foreign objects out of nostrils and auditory canal; eyelashes help keep debris from eyes, trigger protective blink reflex, and disrupt airflow across eye surface to retard evaporation and drying
Eyebrows	Enhance facial expression, may reduce glare of sun and help keep forehead perspiration from eyes

 $<sup>^{18}</sup>$ lan = down, wool

<sup>&</sup>lt;sup>19</sup>vellus = fleece



with a swollen base, the **hair bulb**. The only living cells of a hair are in and near the bulb. The bulb grows around a bud of vascular connective tissue called the **dermal papilla**, which provides the hair with its sole source of nutrition. Immediately above the papilla is a region of actively dividing cells, the **hair matrix**, which is the hair's growth center. All cells higher up are dead.

In cross section, a hair reveals up to three layers. From the inside out, these are the medulla, cortex, and cuticle. The medulla is a core of loosely arranged cells and air spaces. It is most prominent in thick hairs such as those of the eyebrows, but narrower in hairs of medium thickness and absent from the thinnest hairs of the scalp and elsewhere. The **cortex** constitutes most of the bulk of a hair. It consists of several layers of elongated keratinized cells that appear cuboidal to flattened in cross sections. The cuticle is composed of multiple layers of very thin, scaly, surface cells that overlap each other like roof shingles, with their free edges directed upward (see the photo on the opening page of this chapter). Cells lining the follicle are like shingles facing in the opposite direction. They interlock with the scales of the hair cuticle and resist pulling on the hair. When a hair is pulled out, this layer of follicle cells comes with it. The scaly cuticle also keeps the hairs separated so they don't become matted together.

The follicle is a diagonal tube that dips deeply into the dermis and sometimes extends as far as the hypodermis. It has two principal layers: an **epithelial root sheath** and a **connective tissue root sheath** (fig. 5.6b). The epithelial root sheath, which is an extension of the epidermis, lies immediately adjacent to the hair root. Toward the deep end of the follicle, it widens to form a **bulge**, a source of stem cells for follicle growth. The connective tissue root sheath, derived from the dermis, surrounds the epithelial sheath and is somewhat denser than the adjacent dermal connective tissue.

Associated with the follicle are nerve and muscle fibers. Nerve fibers called hair receptors entwine each follicle and respond to hair movements. You can feel their effect by carefully moving a single hair with a pin or by lightly running your finger over the hairs of your arm without touching the skin. Associated with each hair is an arrector muscle (arrector pili<sup>20</sup>)—a bundle of smooth muscle cells extending from dermal collagen fibers to the connective tissue root sheath of the follicle (see figs. 5.1 and 5.6). In response to cold, fear, touch, or other stimuli, the sympathetic nervous system stimulates the arrector to contract and thereby makes the hair stand on end. In other mammals, this traps an insulating layer of warm air next to the skin or makes the animal appear larger and less vulnerable to a potential enemy. In humans, it pulls the follicles into a vertical position and causes "goose bumps," but serves no useful purpose.

#### **Hair Texture and Color**

The texture of hair is related to differences in cross-sectional shape (fig. 5.7)—straight hair is round, wavy hair is oval, and tightly curly hair is relatively flat. Hair color is due to pigment granules in the cells of the cortex. Brown and black hair are rich in eumelanin. Red hair has less eumelanin but a high concentration of pheomelanin. Blond hair has an intermediate amount of pheomelanin but very little eumelanin. Gray and white hair result from a scarcity or absence of melanin in the cortex and the presence of air in the medulla.



A given hair goes through a **hair cycle** consisting of three developmental stages: anagen, catagen, and telogen (fig. 5.8). At any given time, about 90% of scalp follicles are in the **anagen**<sup>21</sup> phase. In this phase, stem cells from the bulge in the follicle multiply and travel downward, pushing the dermal papilla deeper into the skin and forming the epithelial root sheath. Root sheath cells directly above the papilla form the hair matrix. Here, sheath cells transform into hair cells, which synthesize keratin and then die as they are pushed upward away from the papilla. The new hair grows up the follicle, often alongside an old *club hair* left from the previous cycle.

In the catagen<sup>22</sup> phase, mitosis in the hair matrix ceases and sheath cells below the bulge die. The follicle shrinks and the dermal papilla draws up toward the bulge. The base of the hair keratinizes into a hard club and the hair, now known as a club hair, loses its anchorage. Club hairs are easily pulled out by brushing the hair, and the hard club can be felt at the hair's end. When the papilla reaches the bulge, the follicle goes into a resting period called the telogen<sup>23</sup> phase. Eventually, anagen begins anew and the cycle repeats itself. A club hair may fall out during the catagen or telogen phase or as it is pushed out by the new hair in the next anagen phase. We lose about 50 to 100 scalp hairs daily. Fortunately, the hair cycles are asynchronous, so we don't lose all our hairs at once.

In a young adult, scalp follicles typically spend 6 to 8 years in anagen, 2 to 3 weeks in catagen, and 1 to 3 months in telogen. Scalp hairs grow at a rate of about 1 mm per 3 days (10–18 cm/yr) in the anagen phase. Hair grows fastest from adolescence until the 40s. After that, an increasing percentage of follicles is in catagen and telogen rather than the growing anagen phase. Follicles also shrink and begin producing wispy vellus hairs instead of thicker terminal hairs.

Thinning of the hair, or baldness, is called **alopecia**<sup>24</sup> (AL-oh-PEE-she-uh). It occurs to some degree in both sexes and may be worsened by disease, poor nutrition, fever, emotional stress, radiation, or chemotherapy. In the great majority of cases, however, it is simply a matter of aging. **Pattern baldness** is the condition in which hair is lost from select regions of the scalp rather than thinning uniformly across the entire scalp. It results from a combination of genetic and hormonal influences.

Contrary to popular misconceptions, hair and nails don't continue to grow after a person dies, cutting hair doesn't make it grow faster or thicker, and emotional stress can't turn the hair white overnight.

#### 5.2b Nails

Fingernails and toenails are clear, hard derivatives of the stratum corneum. They are composed of very thin, dead, scaly cells, densely packed together and filled with parallel fibers of hard keratin. Most mammals have claws, whereas flat nails are one of the distinguishing characteristics of humans and other primates. Flat nails serve as strong keratinized "tools" that can be used for grooming, picking apart food, and other manipulations. In addition, they allow for more fleshy and sensitive fingertips. Imagine touching a few grains







12/11/18 5:43 PM

 $<sup>^{20}</sup>$  arrect = erect; pili = of a hair

 $<sup>^{21}</sup>$ ana = up; gen = build, produce

 $<sup>^{22}</sup>cata = down$ 

 $<sup>^{23}</sup>$ telo = end

<sup>&</sup>lt;sup>24</sup>alopecia = fox mange





Figure 5.7 The Basis of Hair Color and Texture. Straight hair (a and b) is round in cross section whereas curly hair (c and d) is flatter. Blonde hair (a) has scanty eumelanin and a moderate amount of pheomelanin. Eumelanin predominates in black and brown hair (b). Red hair (c) derives its color predominantly from pheomelanin. Gray and white hair (d) lack pigment and have air in the medulla.

• Which of the hair layers illustrated here corresponds to the scales seen on the hair shafts in the chapter opening photo?

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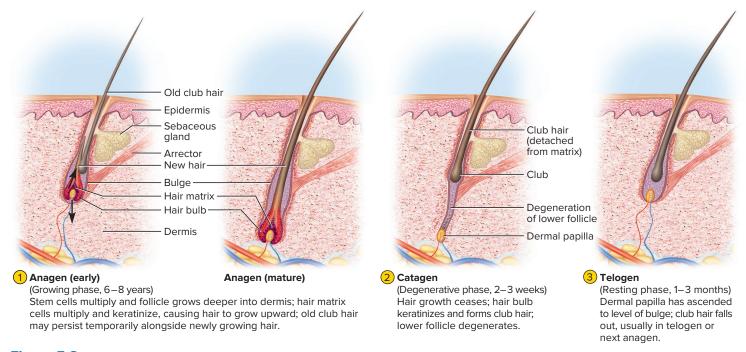


Figure 5.8 The Hair Cycle.



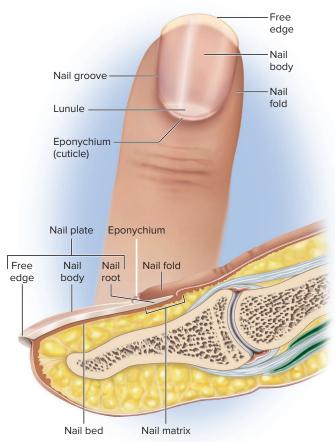


Figure 5.9 Anatomy of a Fingernail. APIR

of salt on a table. The nail, by providing a counterforce or resistance from the other side of the finger, enhances one's sensitivity to such tiny objects.

The hard part of the nail is the **nail plate**, which includes the **free edge** overhanging the tip of the finger or toe; the **nail body**, which is the visible attached part of the nail; and the **nail root**, which extends proximally under the skin (fig. 5.9). The surrounding skin rises a bit above the nail as a **nail fold**, separated from the margin of the nail plate by a **nail groove**. The groove and the space under the free edge accumulate dirt and bacteria and require special attention when scrubbing for duty in an operating room or nursery.

The skin underlying the nail plate is the **nail bed**; its epidermis is called the **hyponychium**<sup>25</sup> (HIPE-o-NICK-ee-um). At the proximal end of the nail, the stratum basale thickens into a growth zone called the **nail matrix**. Mitosis here in the matrix accounts for the growth of the nail—about 1 mm per week in the fingernails and slightly slower in the toenails. The thickness of the matrix obscures the underlying dermal blood vessels and is the reason why an opaque white crescent, the **lunule**<sup>26</sup> (LOON-yule), often appears at the proximal end of a nail. A narrow zone of dead skin, the **cuticle** or **eponychium**<sup>27</sup> (EP-o-NICK-ee-um), commonly overhangs this end of the nail.

The appearance of the fingertips and nails can be valuable in medical diagnosis. The fingertips become swollen or *clubbed*  in response to long-term hypoxemia—a deficiency of oxygen in the blood stemming from conditions such as congenital heart defects and emphysema. Dietary deficiencies may be reflected in the appearance of the nails. An iron deficiency, for example, may cause them to become flat or concave (spoonlike) rather than convex. Contrary to popular belief, adding gelatin to the diet has no effect on the growth or hardness of the nails.

#### **Before You Go On**

Answer the following questions to test your understanding of the preceding section:

- 7. What is the difference between vellus hair and terminal hair?
- Describe the three regions of a hair from its base to its tip, and the three layers of a hair seen in cross section.
- 9. State the function of the dermal papilla, hair receptor, and arrector muscle associated with a hair follicle.
- 10. State a reasonable theory for the different functions of hair of the eyebrows, eyelashes, scalp, nostrils, and axilla.
- 11. Describe some similarities between a nail and a hair.

#### **5.3 Cutaneous Glands**

#### **Expected Learning Outcomes**

When you have completed this section, you should be able to

- a. name two types of sweat glands and describe the structure and function of each;
- b. describe the location, structure, and function of sebaceous and ceruminous glands; and
- c. discuss the distinction between breasts and mammary glands, and explain their respective functions.

The skin has five types of glands: apocrine sweat glands, eccrine sweat glands, sebaceous glands, ceruminous glands, and mammary glands.

#### 5.3a Sweat Glands

Sweat glands are of two kinds, apocrine and eccrine. **Apocrine glands** (fig. 5.10a) occur in the groin, anal region, axilla, and areola, and in mature males, in the beard area. They are absent from the axillary region of Koreans and sparse in the Japanese. Their ducts lead into nearby hair follicles rather than directly to the skin surface. Both apocrine and eccrine sweat glands produce their secretion by exocytosis. Apocrine sweat glands do not secrete their product by the apocrine method shown in figure 3.31; they were named *apocrine* through a misunderstanding, and the name has unfortunately stuck. The secretory part of the gland, however, has a much larger lumen than that of an eccrine gland, so these glands continue to be called apocrine glands to distinguish them functionally and histologically from the eccrine type. Apocrine sweat is thicker and more milky than eccrine sweat because it has more fatty acids in it.



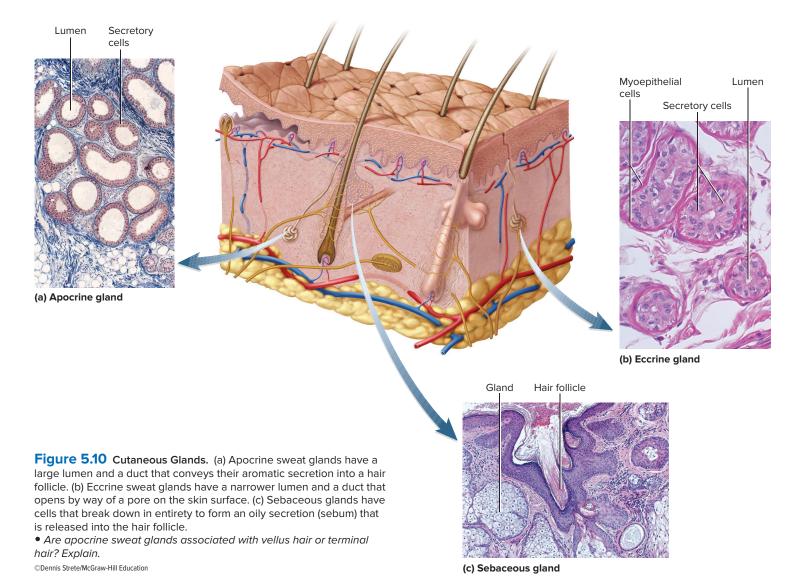


 $<sup>^{25}</sup>$ hypo = below; onych = nail

 $<sup>^{26}</sup>$ lun = moon; ule = little

 $<sup>^{27}</sup>ep = above; onych = nail$ 





Apocrine sweat glands are scent glands that respond especially to stress and sexual stimulation. They are not activated until puberty, and in women, they enlarge and shrink in phase with the menstrual cycle. These facts, as well as experimental evidence, suggest that their function is to secrete *sex pheromones*—chemicals that exert subtle effects on the sexual behavior and physiology of other people. They apparently correspond to the scent glands that develop in other mammals on attainment of sexual maturity. The scent of apocrine sweat is considered attractive or arousing in some cultures. Stale apocrine sweat acquires a rancid odor from the action of bacteria on the lipids in the perspiration. Disagreeable body odor is called *bromhidrosis*. <sup>28</sup> It occasionally indicates a metabolic disorder, but more often reflects inadequate hygiene.

Many mammals have apocrine scent glands associated with specialized tufts of hair. In humans, they occur almost exclusively in regions covered by the pubic hair, axillary hair, and beard, suggesting that they are similar to other mammalian scent glands in function. The hair serves to retain the aromatic secretion and regulate its rate

of evaporation from the skin. Thus, it seems no mere coincidence that women's faces lack both apocrine scent glands and a beard.

Eccrine<sup>29</sup> (merocrine<sup>30</sup>) glands (fig. 5.10b) are widely distributed over the entire body, but are especially abundant on the palms, soles, and forehead. Each is a simple tubular gland with a twisted coil in the dermis or hypodermis and an undulating or coiled duct leading to a sweat pore on the skin surface. This duct is lined by a stratified cuboidal epithelium in the dermis and by keratinocytes in the epidermis. Eccrine perspiration functions to cool the body. It contains sodium chloride, ammonia, urea, and uric acid—wastes that are present also in the urine. There are 3 to 4 million eccrine sweat glands in the skin, with a total mass about equal to that of one kidney.

Amid the secretory cells of eccrine and apocrine glands, there are specialized **myoepithelial**<sup>31</sup> **cells** with properties similar to those of smooth muscle. They contract in response to the sympathetic nervous system and squeeze perspiration up the duct.

<sup>&</sup>lt;sup>29</sup>ec = out; crin = to separate, secrete

<sup>&</sup>lt;sup>30</sup>mero = part; crin = to separate, secrete

 $<sup>^{31}</sup>myo = muscle$ 

 $<sup>^{28}</sup>brom =$ stench; hidros =sweat



#### 5.3b Sebaceous Glands

Sebaceous<sup>32</sup> glands (seh-BAY-shus) (fig. 5.10c) produce an oily secretion called sebum (SEE-bum). They occur everywhere except in thick skin, but are most abundant on the scalp and face. They are flask-shaped and usually clustered around a hair follicle, with short ducts that open into the follicle. Some, however, open directly onto the skin surface. They are holocrine glands with little visible lumen. Their secretion consists of broken-down cells that are replaced by mitosis around the perimeter of the gland. Sebum keeps the skin and hair from becoming dry, brittle, and cracked. The sheen of well-brushed hair is due to sebum distributed by the hairbrush.

#### 5.3c Ceruminous Glands

**Ceruminous glands** (seh-ROO-mih-nus) are modified apocrine glands found only in the external ear canal. Their yellow waxy secretion combines with sebum and dead epidermal cells to form earwax, or **cerumen.**<sup>33</sup> They are simple, coiled, tubular glands with ducts leading to the skin surface of the ear canal. Cerumen keeps the eardrum pliable, waterproofs the canal, kills bacteria, and coats the guard hairs of the ear, making them sticky and more effective in blocking foreign particles from entering the canal.

#### **5.3d Mammary Glands**

Mammary glands are milk-producing glands that develop within the breasts (mammae) under conditions of pregnancy and lactation. They are not synonymous with the breasts, which are present in both sexes and which, even in females, usually contain only small traces of mammary gland. Mammary glands are modified apocrine sweat glands that produce a richer secretion than other apocrine glands

TABLE 5.3 Cuta	neous Glands					
Gland Type	Definition					
Sudoriferous glands	Sweat glands					
Apocrine	Sweat glands that function as scent glands; found in the regions covered by the pubic, axillary, and male facial hair; open by ducts into hair follicles					
Eccrine	Sweat glands that function in evaporative cooling; widely distributed over the body surface; open by ducts onto the skin surface					
Sebaceous glands	Oil-producing glands associated with hair follicles					
Ceruminous glands	Glands of the ear canal that produce cerumen (earwax)					
Mammary glands	Milk-producing glands located in the breasts					

 $<sup>^{32}</sup>$ seb = fat, tallow; aceous = possessing

and channel it through ducts to a nipple for more efficient conveyance to the offspring. The mammary glands are discussed in more detail in section 26.3g. Table 5.3 summarizes the cutaneous glands.

#### **Before You Go On**

Answer the following questions to test your understanding of the preceding section:

- 12. How do eccrine and apocrine sweat glands differ in structure and function?
- 13. What types of hair are associated with apocrine glands? Why?
- 14. What other type of gland is associated with hair follicles? How does its mode of secretion differ from that of sweat glands?
- 15. What is the difference between a breast and mammary gland? What other type of cutaneous gland is most closely related to mammary glands?

# **5.4 Developmental and Clinical Perspectives**

#### **Expected Learning Outcomes**

When you have completed this section, you should be able to

- a. describe the prenatal development of the skin, hair, and nails:
- describe the three most common forms of skin cancer;
   and
- c. discuss the three classes of burns and the priorities in burn treatment.

## 5.4a Prenatal Development of the Integumentary System

#### Skin

The epidermis develops from the embryonic ectoderm and the dermis from the mesoderm. In week 4 of embryonic development, ectodermal cells multiply and organize into two layers—a superficial periderm of squamous cells and a deeper basal layer (fig. 5.11). In week 11, the basal layer gives rise to a new intermediate layer of cells between these two. From then until birth, the basal layer is known as the germinative layer. Its cells remain for life as the stem cells of the stratum basale. Cells of the intermediate layer synthesize keratin and become the first keratinocytes. These cells organize into three layers—the stratum spinosum, granulosum, and corneum—as the periderm is sloughed off into the amniotic fluid. By week 21, the periderm is gone and the stratum corneum is the outermost layer of the fetal integument.

Beneath the developing epidermis, the mesoderm differentiates into a gelatinous connective tissue called mesenchyme. Mesenchymal cells begin producing collagenous and elastic fibers





 $<sup>^{33}</sup>cer = wax$ 



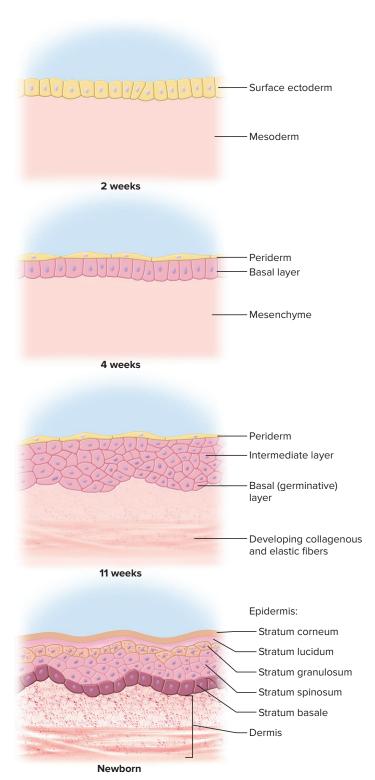


Figure 5.11 Prenatal Development of the Epidermis and Dermis.

by week 11, and the mesenchyme takes on the characteristics of typical fibrous connective tissue. Dermal papillae appear along the dermal-epidermal boundary in the third month. Blood vessels appear in the dermis late in week 6. At birth, the skin has 20 times as many blood vessels as it needs to support its metabolism. The excess may help to regulate the body temperature of the newborn.

#### **Hair and Nails**

The first hair follicles appear around the end of the second month on the eyebrows, eyelids, upper lip, and chin; follicles don't appear elsewhere until the fourth month. At birth, there are about 5 million hair follicles in both sexes; no additional follicles form after birth.

A hair follicle begins as a cluster of ectodermal cells called a hair bud, which pushes down into the dermis and elongates into a rodlike hair peg (fig. 5.12). The lower end of the peg expands into a hair bulb. The dermal papilla first appears as a small mound of tissue just below the bulb, then expands into the bulb itself. Ectodermal cells overlying the papilla form the germinal matrix, a mass of mitotically active cells that produce the hair root. The first hair to develop in the fetus is downy hair, which appears in week 12 and is abundant by week 20. By the time of birth, most of it is replaced by vellus hair.

The first indications of nail development are epidermal thickenings that appear on the ventral surfaces of the fingers around 10 weeks and on the toes around 14 weeks. They soon migrate to the dorsal surfaces of the digits, where they form a shallow depression called the *primary nail field*. The margins of the nail field are the nail folds. In the proximal nail fold of each digit, the germinal layer of epidermis develops into the nail root. Mitosis in the root produces the keratinocytes that become compressed into the hard nail plate. The nail plate reaches the fingertips by 8 months and the toe tips by birth.

#### **Glands**

Sebaceous glands begin to bud from the sides of a hair follicle about 4 weeks after the hair bulb begins to elongate (fig. 5.12). Mature sebaceous glands are present on the face by 6 months and secrete very actively before birth. Their sebum mixes with epidermal and peridermal cells to form a white, greasy skin coating called the *vernix caseosa*. The vernix protects the skin from abrasions and from the amniotic fluid, which can otherwise cause the fetal skin to chap and harden. Its slipperiness also aids in the birth passage through the vagina. The vernix is anchored to the skin by the lanugo and later by the vellus hair. Sebaceous glands become largely dormant by the time of birth, and are reactivated at puberty under the influence of the sex hormones.

Apocrine sweat glands also develop as outgrowths from the hair follicles. They appear over most of the body at first, but then degenerate except in the limited areas described earlier—especially in the axillary and genital regions. Like the sebaceous glands, they become active at puberty.

Eccrine sweat glands develop as buds of the embryonic germinative layer that grow and push their way down into the dermis (fig. 5.12). These buds develop at first into solid cords of epithelial tissue, but cells in the center of the cord later degenerate to form the lumen of the sweat duct, while cells at the lower end differentiate into secretory and myoepithelial cells.

#### 5.4b The Aging Integumentary System

Senescence (age-related degeneration) of the integumentary system often becomes noticeable by the late 40s. The hair turns grayer and thinner as melanocyte stem cells die out, mitosis slows down, and





 $<sup>^{34}</sup>$ vernix = varnish; case = cheese; osa = having the qualities of



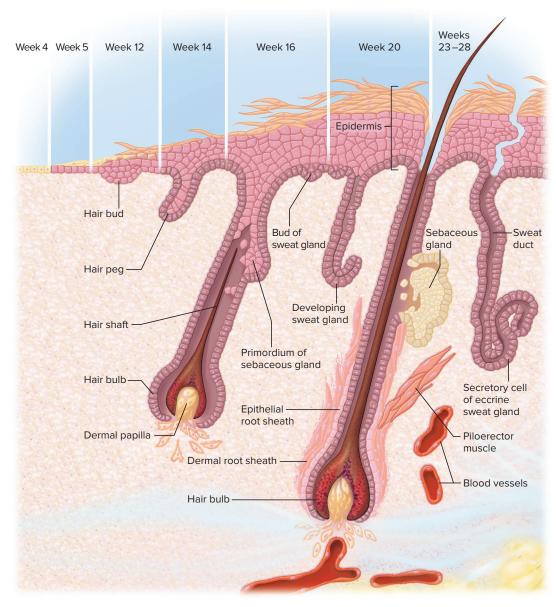


Figure 5.12 Prenatal Development of a Hair Follicle and Cutaneous Glands.

dead hairs are not replaced. Atrophy of the sebaceous glands leaves the skin and hair drier. As epidermal mitosis declines and collagen is lost from the dermis, the skin becomes almost paper-thin and translucent. It becomes looser because of a loss of elastic fibers and flattening of the dermal papillae. If you pinch a fold of skin on the back of a child's hand, it quickly springs back when you let go; do the same on an elderly person, and the skin fold remains longer. Because of its loss of elasticity, aged skin sags to various degrees and may hang loosely from the arms and other places.

Cutaneous blood vessels become fewer and more fragile in old age. The skin may redden as broken vessels leak into the connective tissue, and aged skin bruises more easily. Many older people exhibit *rosacea*—patchy networks of tiny, dilated blood vessels visible especially on the nose and cheeks. Injured skin heals slowly in old age because of diminished circulation and a relative scarcity of immune cells and fibroblasts. Dendritic cells decline by as much as 40% in

the aged epidermis, leaving the skin more susceptible to recurring infections.

Thermoregulation can be a problem in old age because of the atrophy of cutaneous blood vessels, sweat glands, and subcutaneous fat. Older people are more vulnerable to hypothermia in cold weather and heatstroke in hot weather. Heat waves and cold spells take an especially heavy toll among elderly poor people who suffer from a combination of reduced homeostasis and inadequate housing.

Degeneration of the skin is accelerated by excessive exposure to UV radiation. This *photoaging* accounts for more than 90% of the changes that people find medically troubling or cosmetically disagreeable: skin cancer; yellowing and mottling of the skin; age spots (*solar lentigines*, pronounced len-TIDJ-ih-neez), which resemble enlarged freckles on the back of the hand and other sun-exposed areas; and wrinkling, which especially affects the most exposed







areas of skin (face, hands, and arms). Sun-damaged skin shows many malignant and premalignant cells, extensive damage to the dermal blood vessels, and dense masses of coarse, frayed elastic fibers underlying the surface wrinkles and creases.

#### 5.4c Skin Disorders

Because it is the most exposed of all our organs, skin is not only the most vulnerable to injury and disease, but is also the one place where we are most likely to notice anything out of the ordinary. We focus here on two particularly common and serious disorders, skin cancer and burns. Other skin diseases are briefly summarized in table 5.4.

#### Skin Cancer

Skin cancer is induced by UV radiation. It occurs most often on the head and neck, where exposure is greatest. It is most common in fair-skinned people and the elderly, who have had the longest lifetime UV exposure and have less melanin to shield the keratinocyte DNA from radiation. The popularity of sun tanning, however, has caused an alarming increase in skin cancer among younger people. While sunscreens protect against sunburn, there is no evidence that they afford protection from skin cancer (see Clinical Application 5.2). Skin cancer is one of the most common cancers, but it is also one of the easiest to treat and has one of the highest survival rates when it is detected and treated early.

There are three types of skin cancer named for the epidermal cells in which they originate: basal cell carcinoma, squamous cell carcinoma, and melanoma. The three types are also distinguished from each other by the appearance of their lesions<sup>35</sup> (zones of tissue

**Basal cell carcinoma**<sup>36</sup> is the most common type. It is the least deadly because it seldom metastasizes, but if neglected, it can cause severe facial disfigurement. It arises from cells of the stratum basale and eventually invades the dermis. On the surface, the lesion first appears as a small, shiny bump. As the bump enlarges, it often develops a central depression and a beaded "pearly" edge (fig. 5.13a).

Squamous cell carcinoma arises from keratinocytes of the stratum spinosum. The lesion has a raised, reddened, scaly appearance and later forms a concave ulcer with raised edges (fig. 5.13b). The chance of recovery is good with early detection and surgical removal, but if it goes unnoticed or is neglected, this cancer tends to metastasize to the lymph nodes and can be lethal.

Melanoma is a skin cancer that arises from the melanocytes, often in a preexisting mole. It accounts for no more than 5% of skin cancers, but it is the sixth most frequently diagnosed cancer in the United States and is the most deadly form of skin cancer. It can be treated surgically if it is caught early, but if it metastasizes-which it does quickly-it is unresponsive to chemotherapy. The prognosis for metastatic melanoma has generally been grim, with the average

#### **TABLE 5.4** Some Disorders of the Integumentary System Acne Inflammation of the sebaceous glands, especially beginning at puberty; follicle becomes blocked with keratinocytes

and sebum and develops into a blackhead (comedo) composed of these and bacteria; continued inflammation of follicle results in pus production and pimples

**Dermatitis** Any inflammation of the skin, typically marked by itching and redness; often contact dermatitis, caused by exposure to toxins such as poison ivy

Eczema (ECK-zeh-mah) Itchy, red, "weeping" skin lesions caused by an allergy, usually beginning before age 5; may progress to thickened, leathery, darkly pigmented patches of skin

Recurring, reddened plaques covered with silvery scale; sometimes disfiguring; possibly caused by an autoimmune Psoriasis (so-RY-ah-sis) response; runs in families

A fungal infection of the skin (not a worm) that sometimes grows in a circular pattern; common in moist areas such Ringworm as the axilla, groin, and foot (athlete's foot)

Rosacea (ro-ZAY-she-ah) A red rashlike area, often in the area of the nose and cheeks, marked by fine networks of dilated blood vessels; worsened by hot drinks, alcohol, and spicy food

> Benign, elevated, rough lesions caused by human papillomaviruses (HPV). Common warts appear most frequently in late childhood on the fingers, elbows, and other areas of skin subject to stress. Plantar warts occur on the soles and venereal warts on the genitals. Warts can be treated by freezing with liquid nitrogen, electric cauterization (burning), laser vaporization, surgical excision, and some medicines such as salicylic acid.

#### You can find other integumentary system disorders discussed in the following places.

Abnormal skin coloration (section 5.1e) Birthmarks (section 5.1f) Burns (section 5.4c)

Pemphigus vulgaris (Clinical Application 2.1) Skin cancer (section 5.4c)

Warts



<sup>&</sup>lt;sup>35</sup>lesio = injure

<sup>&</sup>lt;sup>36</sup>carcin = cancer; oma = tumor





(a) Basal cell carcinoma



(b) Squamous cell carcinoma



(c) Melanoma

Figure 5.13 Typical Lesions of the Three Forms of Skin Cancer.

(a) Basal cell carcinoma. (b) Squamous cell carcinoma. (c) Melanoma.

• Which of the ABCD rules can you identify in part (c)?

(a) ©jax10289/Shutterstock, (b) ©Science Photo Library/Alamy, (c) Source: National Cancer Institute (NCI)

patient living only 6 months from diagnosis, and only 5% to 14% of patients surviving with it for 5 years. The greatest risk factor for melanoma next to UV exposure is a family history of the disease. It has a relatively high incidence in men, in redheads, and in people who experienced severe sunburns in childhood.

It is important to distinguish a mole from melanoma. A mole usually has a uniform color and even contour, and it is usually no larger than 6 mm wide, about equal to the diameter of the eraser on a new wooden pencil. If it becomes malignant, however, it forms a large, flat, spreading lesion with a scalloped border (fig. 5.13c). The American Cancer Society suggests an "ABCD rule" for recognizing melanoma: A for asymmetry (one side of the lesion looks different from the other); B for border irregularity (the contour is not uniform but wavy or scalloped); C for color (often a mixture of brown, black, tan, and sometimes red and blue); and D for diameter (greater than 6 mm).

Skin cancer is treated by surgical excision, radiation therapy, or destruction of the lesion by heat (electrodesiccation) or cold (cryosurgery). Hope for surviving metastatic melanoma is rising with new targeted therapies. One treatment uses a radioisotope bound to melanocyte-stimulating hormone, which binds selectively to melanocytes and thus targets the very cells that compose the tumor.

#### **Burns**

**Burns** are commonly caused by UV radiation, fires, kitchen spills, or excessively hot bath water, but they also can be caused by other forms of radiation, strong acids and bases, or electrical shock. Burn deaths result primarily from fluid loss, infection, and the toxic effects of **eschar**<sup>37</sup> (ESS-car)—the burned, dead tissue.

Burns are classified according to the depth of tissue involvement (fig. 5.14). **First-degree burns** involve only the epidermis and are marked by redness, slight edema, and pain. They heal in a few days and seldom leave scars. Most sunburns are first-degree burns.

Second-degree burns involve the epidermis and part of the dermis but leave at least some of the dermis intact. First- and second-degree burns are therefore also known as partial-thickness burns. A second-degree burn may be red, tan, or white and is blistered and painful. It may take from 2 weeks to several months to heal and may leave scars. The epidermis regenerates by division of epithelial cells in the hair follicles and sweat glands and those around the edges of the lesion. Severe sunburns and many scalds are second-degree burns.

Third-degree burns are the leading cause of accidental death in the United States. They are also called full-thickness burns because the epidermis and dermis are completely destroyed. Sometimes even deeper tissue is damaged (hypodermis, muscle, and bone). (Some authorities call burns that extend to the bone fourth-degree burns.) Since no dermis remains, the skin can regenerate only from the edges of the wound. Third-degree burns often require skin grafts (see Clinical Application 5.3). If a third-degree burn is left to itself to heal, contracture (abnormal connective tissue fibrosis) and severe disfigurement may result.

#### **Apply What You Know**

A third-degree burn may be surrounded by painful areas of first- and second-degree burns, but the region of the third-degree burn is painless. Explain the reason for this lack of pain.





 $<sup>^{37}</sup>$ eschar = scab



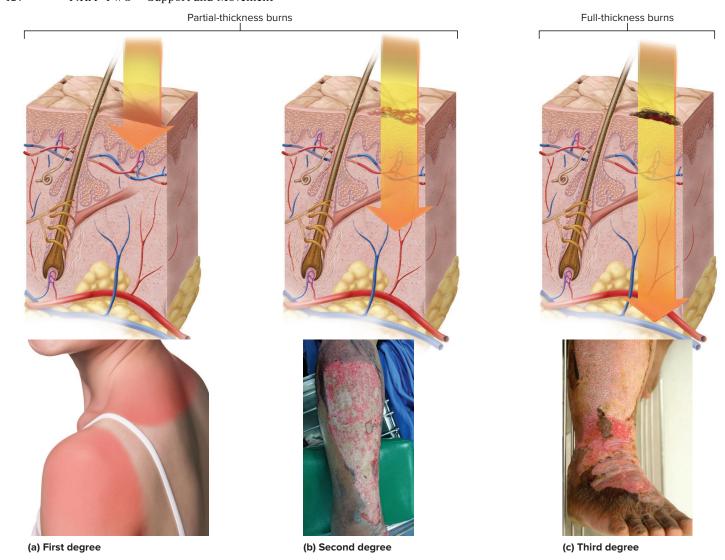


Figure 5.14 Three Degrees of Burns. (a) First-degree burn, involving only the epidermis. (b) Second-degree burn, involving the epidermis and part of the dermis. (c) Third-degree burn, extending through the entire dermis and often involving even deeper tissue.

(a) ©Dmitrii Kotin/Alamy, (b) ©krit\_manavid/Shutterstock, (c) ©Anukool Manoton/Shutterstock

#### **CLINICAL APPLICATION**

5.3

#### Skin Grafts and Artificial Skin

Third-degree burns leave no dermis to regenerate what was lost and, therefore, require skin grafts. Ideally, these should come from elsewhere on the same patient's body (autografts<sup>38</sup>) so there is no problem with immune rejection, but this may not be feasible in patients with extensive burns. A skin graft from another person (called an allograft<sup>39</sup> or homograft<sup>40</sup>) or even skin from another species (called a heterograft<sup>41</sup> or xenograft<sup>42</sup>), such as pig skin, may be used. However, allografts and heterografts are rejected by the immune system and therefore provide only a temporary barrier to infection and fluid loss.

At least two bioengineering companies produce artificial skin as a temporary burn covering. One such product is made by culturing fibroblasts on a collagen gel to produce a dermis, then culturing keratinocytes on this substrate to produce an epidermis. This is used to treat not only burn patients but also patients with leg and foot ulcers caused by diabetes mellitus. Another new technology available in some countries is a spray-on skin graft. A bit of epidermis the size of a postage stamp is taken from a burn patient and enzymatically broken up into separate cells. The cell suspension is then sprayed onto areas of second-degree burns or other skin lesions. Within a week, this can grow into an area of healthy skin the size of a book page.

 $<sup>^{38}</sup>auto = self$ 

 $<sup>^{39}</sup>$ allo = different, other

 $<sup>^{40}</sup>$ homo = same

 $<sup>^{41}</sup>$ hetero = different

 $<sup>^{42}</sup>$ xeno = strange, alien



#### **Before You Go On**

Answer the following questions to test your understanding of the preceding section:

- 16. What adult skin layer arises from the germinative layer of the fetus?
- 17. What is the vernix caseosa of the fetus? What purpose does it serve?
- 18. What types of cells are involved in each type of skin cancer?
- 19. Which type of skin cancer is most dangerous? What are its early warning signs?
- 20. What is the difference between a first-, second-, and third-degree burn?

## STUDY GUIDE

#### **Assess Your Learning Outcomes**

To test your knowledge, discuss the following topics with a study partner or in writing, ideally from memory.

#### 5.1 The Skin and Subcutaneous Tissue

- The difference between the integumentary system and integument, and the branch of medicine that deals with this system
- 2. The two principal layers of the skin and alternative terms for the connective tissue beneath the skin
- 3. The range of thicknesses of the skin, the basis for distinguishing thick skin from thin skin, and where those two types of skin are located
- 4. The multiple functions of the skin and what aspects of skin structure contribute to these functions
- 5. The five epidermal cell types and their respective functions
- The four to five strata seen in thin and thick skin, their order of occurrence, and the distinguishing histological features of each stratum
- 7. The histological distinctions between thin and thick skin
- 8. The life history of a keratinocyte from the time of its mitotic birth to the time it dies and flakes off the skin surface, and how the stages of its development correlate with the histological appearance of the epidermal strata
- The significance of the epidermal water barrier, what it is composed of, and how keratinocytes produce it
- 10. The composition of the dermis, including its fiber and cell types and the diverse small organs that it contains
- 11. The structure of the dermal-epidermal boundary, the names of its interlocking troughs and ridges, and how and why the appearance of this boundary differs from one region of the body to another
- 12. The difference between the papillary and reticular layers of the dermis—where they

- are seen, their tissue composition, and their functional difference
- 13. The histological composition of the hypodermis and how it differs from the dermis
- 14. The pigments responsible for normal skin colors, the two types of melanin, and reasons for the differences between light and dark skin
- 15. A variety of pathological skin colors and what causes such variations
- 16. The various kinds of lines, creases, and other markings of the skin

#### 5.2 Hair and Nails

- The protein composition of hair and nails and how this compares to the dominant epidermal protein
- 2. The distinction between a hair and its follicle, and their general structural relationship
- The three types of human hair and their differences in appearance, bodily location, and occurrence over the human life span
- 4. The functions of human hair of various types and bodily locations
- 5. The three regions of a hair from its base to the portion above the skin; where it gets its nourishment; and which region serves as the hair's growth zone
- The three zones of a hair seen in cross section, from its core to its surface, including the differences between these zones in cell morphology
- 7. The layers of a hair follicle and the functional significance of its bulge
- 8. Nerves and muscles associated with a hair, and their functions
- 9. Factors that account for differences in hair color and texture (straight, wavy, or curly)
- 10. Stages in the life cycle of a hair, the principal processes that occur in each stage, and approximately how long each stage lasts
- 11. Types of hair thinning and factors that contribute to it
- 12. The morphology of the nails, and how variations in appearance can be of diagnostic value in certain diseases and disorders

#### 5.3 Cutaneous Glands

- 1. The two types of sweat glands and how they differ in histological appearance, bodily distribution, function, and development over the human life span
- 2. The function and locations of sebaceous glands, and how they differ from sweat glands in their method of secretion
- The location of the ceruminous glands, how cerumen differs from the product secreted by these glands, and what functions are served by cerumen
- Why the terms mammary gland and breast are not synonymous, and how mammary glands compare and contrast with apocrine sweat glands

#### 5.4 Developmental and Clinical Perspectives

- 1. Stages in the embryonic development of the epidermis from the ectoderm, and how the dermis differs from the epidermis in its origin and mode of development
- 2. How the hair and nails develop from the embryonic epidermis
- Where and how sebaceous glands arise in the embryo; the nature of the vernix caseosa; and how the vernix caseosa, along with the fetal downy hair and vellus hair, protect the fetus
- How the two types of sweat glands differ in their prenatal development and how they differ in childhood versus in and beyond puberty
- Ways in which the adult skin changes with age, especially in the elderly, and how this is influenced by one's lifetime history of UV exposure
- The three types of skin cancer and how they differ in the cells of origin, relative frequency in the population, and relative risk of metastasis and mortality
- 7. Distinguishing characteristics of the three degrees of burns







#### **Testing Your Recall**

1.	Cells	of	the	 are	keratinized	and
	dead.					

- a. papillary layer
- b. stratum spinosum
- c. stratum basale
- d. stratum corneum
- e. stratum granulosum
- 2. The epidermal water barrier forms at the point where epidermal cells
  - a. enter the telogen stage.
  - b. pass from stratum basale to stratum spinosum.
  - c. pass from stratum spinosum to stratum granulosum.
  - d. form the epidermal ridges.
  - e. exfoliate.
- 3. Which of the following skin conditions or appearances would most likely result from liver failure?
  - a. pallor
  - b. erythema
  - c. pemphigus vulgaris
  - d. jaundice
  - e. melanization
- 4. All of the following interfere with microbial invasion of the skin *except* 
  - a. the acid mantle.
  - b. melanin.
  - c. cerumen.
- d. keratin.
- e. sebum.

- 5. The hair on a 6-year-old's arms is
  - a. vellus hair.
  - b. downy hair.
  - c. pilorum.
  - d. terminal hair.
  - e. rosacea.
- 6. Which of the following terms is *least* related to the rest?
- a. lunule
- b. nail plate
- c. hyponychium
- d. free edge
- e. cortex
- 7. Which of the following is a scent gland?
  - a. an eccrine gland
  - b. a sebaceous gland
  - c. an apocrine gland
  - d. a ceruminous gland
  - e. a holocrine gland
- 8. \_\_\_\_\_ are skin cells with a sensory role.
- a. Tactile cells
- b. Dendritic cells
- c. Granulosum cells
- d. Melanocytes
- e. Keratinocytes
- 9. The embryonic periderm becomes part of
  - a. the vernix caseosa.
  - b. the downy hair.
  - c. the stratum corneum.
  - d. the stratum basale.
  - e. the dermis.

- 10. Which of the following skin cells alert the immune system to pathogens?
  - a. fibroblasts
  - b. melanocytes
  - c. keratinocytes
  - d. dendritic cells
  - e. tactile cells
- 11. Two common word roots that refer to the skin in medical terminology are \_\_\_\_\_ and

12.	A muscle t	hat causes	s a	hair	to	stand	on	end
	is called a	'an						

- 13. The most abundant protein of the epidermis is \_\_\_\_\_, while the most abundant protein of the dermis is \_\_\_\_\_.
- 14. Blueness of the skin due to low oxygen concentration in the blood is called \_\_\_\_\_.
- 15. Projections of the dermis toward the epidermis are called \_\_\_\_\_.16. Cerumen is more commonly known as
- 17. The holocrine glands that secrete into a
- hair follicle are called \_\_\_\_\_.

  18. The scaly outermost layer of a hair is called
- 19. A hair is nourished by blood vessels in a connective tissue projection called the
- A \_\_\_\_\_ burn destroys part of the dermis, but not all of it.

Answers in appendix A

## **Building Your Medical Vocabulary**

State a meaning of each word element and give a medical term from this chapter that uses it or a slight variation of it.

- 1. dermato-
- 2. epi-

- 3. sub-
- 4. pap-
- 5. melano-
- 6. cyano-
- 7. lucid-
- 8. -illa

- 9. pilo-
- 10. carcino-

Answers in appendix A

## What's Wrong with These Statements?

Briefly explain why each of the following statements is false, or reword it to make it true.

- 1. Basal cell carcinoma is the rarest form of skin cancer and rarely metastasizes.
- 2. Epidermal mitosis occurs only in the stratum spinosum.
- 3. The dermis is composed mainly of keratin.
- 4. Vitamin D is synthesized by certain cutaneous glands.
- 5. Dermal ridges are relatively small in areas of skin subjected to the most mechanical stress.









- The hair cuticle is composed of dead cells, whereas the living cells of a hair are found in its cortex.
- 7. The three layers of the skin are the epidermis, dermis, and hypodermis.
- People of African descent have a much higher density of epidermal melanocytes than do people of northern European descent.
- 9. Melanoma is the most common and deadly form of skin cancer.
- 10. Other than the scalp, most of the hair on a young child's body is downy hair (lanugo).

Answers in appendix A

#### **Testing Your Comprehension**

- Many organs of the body contain numerous smaller organs, perhaps even thousands.
   Describe an example of this in the integumentary system.
- 2. Some aspects of human form and function are less mystifying, easier to explain, if we consider comparative anatomy and our evolutionary history. Describe an example of
- this in the anatomy of the integumentary system.
- 3. We have seen in this chapter that the dermis has two tissue layers, not just one. How does this exemplify the unity of form and function, a theme introduced in chapter 1?
- 4. Cold weather does not normally interfere with oxygen uptake by the blood, but it can cause cyanosis anyway. Why?
- 5. Why is it important for the epidermis to be effective, but not *too* effective, in screening out UV radiation?





