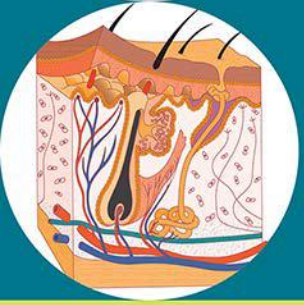

Wound Management

Principles and Practices

FOURTH EDITION

Betsy A. Myers

Wound Management

Principles and Practices

Fourth Edition

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Dedication

To the students of the University of Tennessee at Chattanooga's Physical Therapy Program,
Thank you for helping me grow and for allowing me to be part of your development. Cheers!

Dr. Betsy

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Contents

APPENDICES

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Introduction

There are several distinguishing characteristics of this book that make it a superior learning tool for clinicians and students. First, each chapter begins with a list of key terms and chapter objectives to prepare the reader for the material that follows. Readers are encouraged to use these features as a self-study guide to check their understanding of the information provided. Second, the chapters include numerous tables, figures, and full color photographs of wounds and wound care supplies to assist in highlighting information for readers and creating a link between the written text and actual patients in the clinic. Third, checkpoint questions within each chapter pose clinically relevant questions to promote reader comprehension. Fourth, review questions, located at the end of each chapter, provide an opportunity for readers to master chapter information. Answers to checkpoint and review questions are located in Appendix C to be used as a self-check. Fifth, the text models complete, concise documentation and provides readers with frequent opportunities to practice this vital skill. Sixth, a series of three case studies, located in Appendix B, encourage readers to apply their knowledge of basic science, examination, and interventions into a holistic plan of care for patients with open wounds. Readers are directed through a series of questions to describe photographs of patients with open wounds, hypothesize wound etiology, determine appropriate local wound care, and consider what additional interventions might be appropriate. Readers are encouraged to check their responses with the notes provided.

The text is organized into three major sections. Section I sets the stage for understanding wound care by reviewing basic science. Chapter 1 describes the normal anatomy of the integument and subcutaneous tissues. Chapter 2 reviews wound healing, including the phases of wound healing, wound healing processes, and abnormal wound healing. Chapter 3 presents factors known to adversely affect wound healing, including wound characteristics, local and systemic factors, as well as inappropriate wound care. The fourth edition includes expanded information on understanding and enhancing patient adherence.

Section II provides an overview of the examination of and interventions for patients with open wounds. The chapters cover examination, debridement, management of infection, dressing selection and bandaging, and biophysical agents. The section concludes with a chapter on the holistic management of patients with open wounds that contains detailed information on nutrition and interdisciplinary wound management. By incorporating the most recent research available, the fourth edition provides the latest information on tests and measures, biofilms, infection management, biophysical agents, and nutritional screening.

Section III builds upon the general patient and wound care information of Section II and applies this information to specific wound types, including arterial insufficiency ulcers, venous insufficiency ulcers, pressure injuries, and neuropathic ulcers, as well as burns. Complete case studies have been incorporated into each of these chapters to allow the reader to integrate all aspects of anatomy, physiology, pathophysiology, and the five elements of patient management. A separate chapter addresses miscellaneous wounds such as abrasions, skin tears, surgical wounds, traumatic wounds, different types of bite wounds, wounds due to lymphedema, radiation fibrosis, and pyoderma gangrenosum. Each chapter describes the etiology, risk factors, classification, and characteristics for each wound type. The chapters provide detailed information on physical therapy tests and measures, as well as interventions for the successful management of patients with open wounds due to specific etiologies. Medical and surgical interventions that may apply to patients with open wounds are also discussed to provide the clinician with a better understanding of the valuable role these disciplines play in the management of patients with open wounds. The fourth edition contains the National Pressure Ulcer Advisory Panel's updated staging system for pressure injuries and summarizes current research for the successful management of patients based on wound pathology and presentation. Section III concludes with a chapter on basic dermatology to assist the clinician with screening intact skin.

Finally, the appendices include a wealth of information, including a glossary of terms, case studies, answers to chapter questions, and total contact casting procedure.

New to This Edition

Several key changes have been made in the fourth edition of this textbook to continue to provide a superior, holistic learning tool for students and clinicians.

- First, the landscape of medicine continues to change, including key foundational documents, such as the Guide to Physical Therapist Practice 3.0. All information and references have been updated to reflect current research and practice.
- Second, over one hundred full-color images of open wounds, procedures, and equipment have been integrated within the textbook. These rich images provide the reader with an outstanding visual representation of the evaluation and management of patients with open wounds or integumentary dysfunction to help bridge the divide between education and practice.
- Third, the text includes the latest information on pressure injuries to reflect the recent revisions of the pressure injury staging system of the National Pressure Ulcer Advisory Panel (along with the European and Asian equivalents).
- Fourth, advancements in scientific understanding of biofilms and wound infection have been incorporated into the text.
- Fifth, the text has been updated to include new information regarding the circulation required for tissue healing and changes in the recommendations for compression and surgical interventions based on ankle-brachial index measurements. In addition, clinicians are given an algorithm to assist with clinical decision making based on wound presentation and circulatory testing.
- Last, the text contains the latest information on the causal factors, examination, and interventions for patients with neuropathic ulcers. This is particularly crucial given the current diabetes epidemic and the 25% lifetime risk of neuropathic ulceration for an individual with diabetes.

Supplements

STUDENT RESOURCES

To access the material on student resources that accompany this book, visit www.pearsonhighered.com/healthprofessionsresources. Click on view all resources and select Physical Therapy from the choice of disciplines. Find this book and you will find the complimentary study materials.

INSTRUCTOR RESOURCES

To access supplementary materials online from Pearson's Instructor Resource Center (IRC), instructors will need to use their IRC login credentials. If they don't have IRC login credentials they will need to request an instructor access code. Go to www.pearsonhighered.com/irc to register for an instructor access code. Within 48 hours of registering, you will receive a confirming e-mail including an instructor access code. Once you have received your code, locate your book in the online catalog and click on the Instructor Resources button on the left side of the catalog product page. Select a supplement, and a login page will appear. Once you have logged in, you can access instructor material for all Pearson textbooks. If you have any difficulties accessing the site or downloading a supplement, please contact Customer Service at http://support.pearson.com/getsupport. This book has the following instructor's resources.

- PowerPoint lecture slides
- TestGen
- Instructor Resources

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- Liana Brinkmeier and Amanda Johnson, my future colleagues, for their time and assistance with compiling references and tracking down articles.
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SECTION I

Basic Science

1

Integumentary Anatomy

LEARNING OBJECTIVES

After reading this chapter, learners will be able to:

1. Describe the normal structure and function of the epidermis.
2. Describe the normal structure and function of the dermis.
3. Describe the normal structure and function of the subcutaneous tissue.
4. State the main cells located within each layer of the integument and describe their functions.
5. Describe the normal structure of deeper tissues that may be exposed in open wounds including muscle, tendon, ligament, joint capsule, and bone.
6. Differentiate between viable and nonviable tissues that may be present in an open wound.
7. Differentiate between superficial, partial-thickness, and full-thickness wounds.

KEY TERMS

Adipose tissue
Basement membrane
Blisters
Callus
Collagen
Dendritic cells
Dermal papillae
Elastin
Epidermis
Fascia
Fibroblasts
Freckles
Full-thickness wound
Hair
Histamine
Keratin
Keratinocytes
Langerhans' cells
Macrophages
Mast cells
Melanin
Melanocytes
Merkel cells
Nails
Open wound
Papillary dermis
Partial-thickness wound
Phagocytizing
Rete pegs
Reticular dermis
Sebaceous gland
Sebum
Stratum basale
Stratum corneum
Stratum granulosum
Stratum lucidum
Stratum spinosum
Subcutaneous tissue
Sudoriferous glands
Superficial wound
White blood cells

Introduction

This chapter describes the normal structure and function of the epidermis, dermis, subcutaneous tissue, and deeper tissues that may be involved in open wounds. In an average person's body, the skin is comprised of 15–25% water,[1] weighs more than 4–5 kg, covers an area nearly 1.2–2.2 m^2, and ranges in thickness from 0.5 to 6.0 mm.[2] The thinnest skin is located on the eyelids and eardrums, while the thickest skin is located on the palms of the hands and the soles of the feet.[3] The integument is the largest organ system of the body,[4] and receives roughly one-third of resting cardiac output.[5] The skin is a connective tissue that consists of cells, fibers, and an extracellular matrix organized into an outer epidermis and an inner dermis (see Figure 1–1). Beneath the dermis is a supportive subcutaneous connective tissue layer. Deeper tissues, including muscle, tendon, ligament, joint capsule, and bone, lie beneath the subcutaneous tissue layer. **Open wounds** involve a break in skin integrity, such as an abrasion, laceration, or ulcer. Open wounds may involve only the epidermis or may extend into deeper tissue layers. While the phases of wound healing apply to both open and closed wounds, the remainder of this text describes only open wounds. Clinicians must be able to identify the extent of tissue involvement in order to classify open wounds and assess wound healing. Clinicians must also be able to differentiate normal, healthy, viable tissues from necrotic tissue and foreign materials that may be present in open wounds. In addition, clinicians must understand the impact tissue damage or loss can have both at the tissue level and for the patient as a whole. Chapter 17 provides detailed information on changes with aging skin.

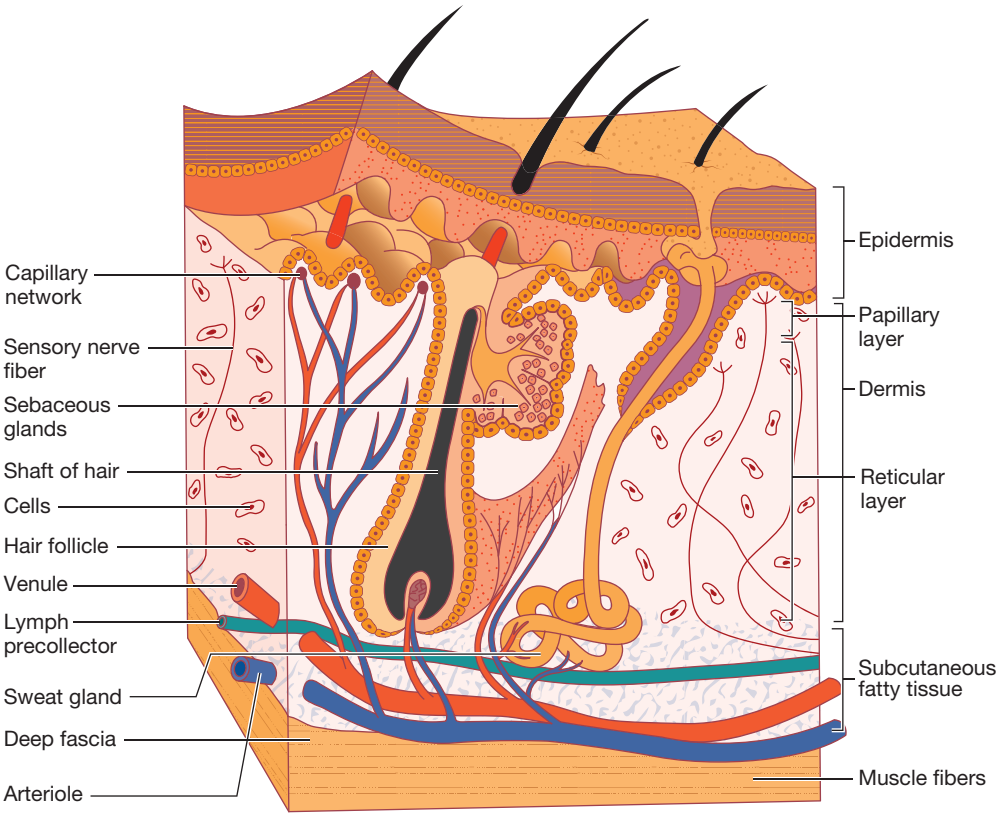

FIGURE 1–1 Skin structure.

Source: Emergency Care 10/e by Limmer/O'Keefe/Grant/Murray/Bergeron.

Epidermis

Epidermal Layers

The **epidermis** is the tough, leathery outer surface of the skin ranging in thickness from 0.06 to 0.6 mm, with the thickest portions located on the palms of the hands and the soles of the feet.[6] The epidermis is arranged into five layers that represent different stages of cellular differentiation (see Figure 1–2). As new cells are formed, older cells elongate and their membranes thicken as they are pushed upward into the next epidermal layer. The deepest layer, the stratum basale, is attached to the dermis below by a thin, acellular **basement membrane**. The basement membrane acts as a scaffolding for the epidermis and a selective filter for substances moving between the epidermis and the dermis.[7] The epidermis is avascular,[8] receiving its blood supply through the diffusion of nutrients from the dermis across the semipermeable basement membrane. The **stratum basale**, sometimes called the stratum germanitivum, is a single row of **keratinocytes**, continuously dividing cells that produce the protective protein **keratin**.[9] The **stratum spinosum** is the next layer. It consists of several rows of more mature keratinocytes, which appear "spiny" under a light microscope because of the keratin filaments.[8] Cells in the basale and spinosum layers are the only ones to receive adequate nutrition from diffusion across the basement membrane[8] and are the only mitotically active cells in the epidermis.[10] Just above the stratum spinosum is the **stratum granulosum**. This layer contains three to five flattened cell rows with increasing concentrations of keratin.[10] As keratinocytes are pushed farther up and away from their dermal blood supply, they slowly die. The **stratum lucidum** is present only in thick skin (palms and soles) and contains a few layers of flattened, dead keratinocytes, which appear clear through a light microscope.[10] The outermost epidermal layer, the **stratum corneum**, or "horny" layer, consists entirely of dead keratinocytes arranged in a brick and mortar fashion.[1] The stratum corneum can be 20–30 cells thick and accounts for up to three-quarters of the thickness of the entire epidermis.[8]

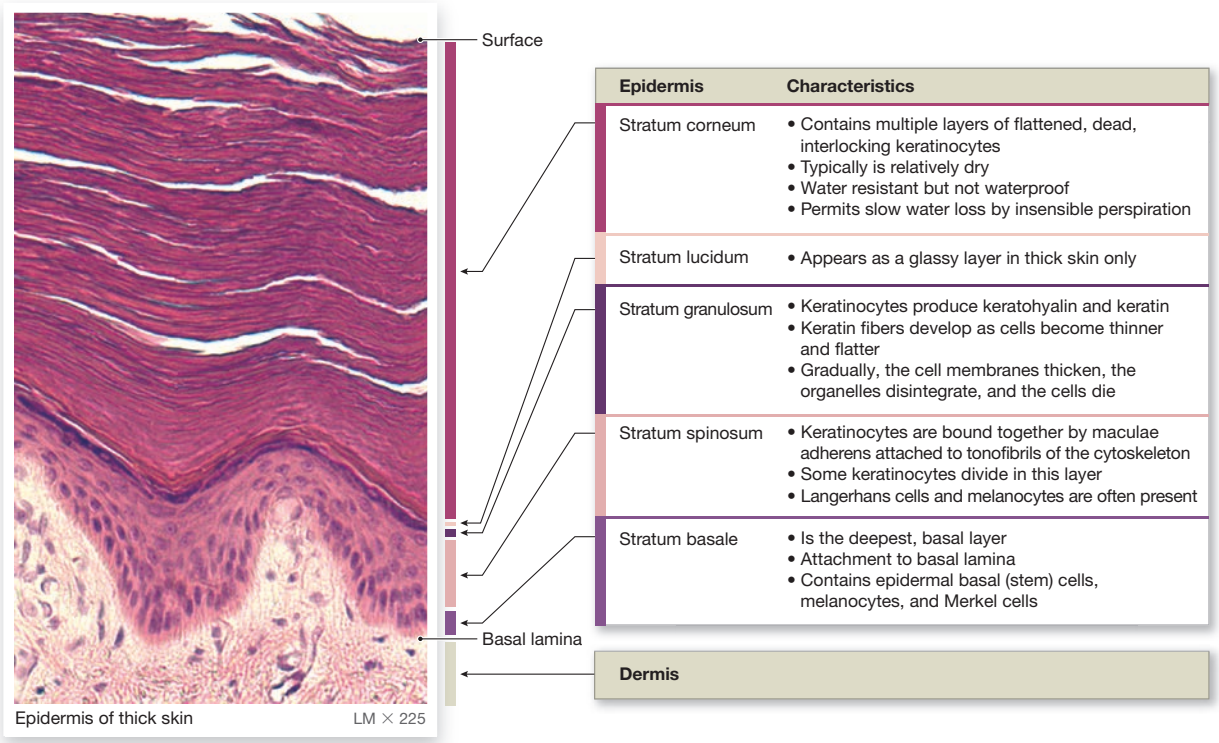

FIGURE 1–2 Epidermal layers.
Source: Martini F, Tallitsch R, Nath J. *Human Anatomy.* Ninth ed. New York: Pearson; 2018.

The many layers of the stratum corneum serve as a physical barrier,[7] protecting the body from trauma and infection. Specialized cell–cell adhesions, including desmosomes, tight junctions, and adherens junctions, along with the lipid matrix outside of the stratum corneum, make the skin water resistant,[11] thereby helping regulate the body's fluid content. The three main lipid classes of the epidermis, cholesterol, free fatty acids, and ceramides, create a chemical barrier to prevent compounds from entering the skin and creating an immune response.[7, 12] Epithelial intercellular junctions also resist mechanical stress.[11] It is likely that interactions between intercellular junctions can be up and down regulated in response to injury.[7] Dead cells of the stratum corneum are constantly abraded and replaced by cells from below. A cell's journey from the stratum basale up through the stratum corneum takes 15–30 days.[9, 10] Occasionally, there is a localized buildup of cells of the stratum corneum due to pressure or friction. This is known as a **callus**.

Epidermal Cell Types

The most abundant of the epidermal cells are keratinocytes.[8] The epidermis contains three other main cell types: melanocytes, Merkel cells, and Langerhans' cells. **Melanocytes**, located in the stratum basale, produce the pigment melanin.[10] **Melanin** protects the skin from the harmful effects of ultraviolet radiation from the sun and gives the skin its color. Skin containing higher quantities of melanin appears darker in color, whereas skin with less melanin appears lighter. A **freckle** is a focal concentration of melanin.[8] Normally, the epidermis ranges in color from pale white to dark brown because of the presence of melanin. Albinism is an inherited condition in which individuals have the normal amount of melanocytes but are unable to produce melanin.[10] **Merkel cells** are specialized mechanoreceptors attached to keratinocytes within the stratum basale by desmosomes that provide information on light touch sensation.[10] **Dendritic cells**, also called **Langerhans' cells**,[13] present in the deeper layers of the epidermis help fight infection by attacking and engulfing foreign material.

Epidermal Appendages

The epidermis has three appendages located within the dermis: hair, glands, and nails. Hair follicles are present everywhere except in the palms and soles. **Hair**, composed of soft keratin, helps regulate body temperature by trapping air between the hair and the skin's surface.[8] Each hair follicle contains a **sebaceous gland** that secretes sebum.[14] If the more superficial epidermis is damaged, as with an abrasion, the deeper epidermal cells that line hair follicles serve as a source of epidermal regeneration.[14] (Chapter 2 provides a detailed description of wound healing.) **Sebum** is an oily substance that lubricates the skin and hair.[10] **Sudoriferous glands**, present everywhere except the lips and ears, secrete sweat into ducts that lead to the skin's surface. Sweat is 99% water mixed with some salts and metabolic waste products.[8] The evaporation of sweat from the skin's surface helps cool the body. In addition, the oily sebum secreted by these glands may slow the growth of bacteria, thus helping reduce infection.[10] **Nails**, located at the dorsal tips of the digits, consist of hard keratin. Nails arise from cells within the stratum basale, protect the terminal digits, and assist with function.[10]

Additional Functions of the Epidermis

The epidermis has many important functions (see Box 1–1).[4] In addition to those described previously, the skin plays an important role in vitamin D synthesis by converting 7-dehydrocholesterol to cholecalciferol when exposed to ultraviolet light. Vitamin D is essential for bone formation and the regulation of calcium levels within the body. For example, without vitamin D, calcium cannot be absorbed from the gastrointestinal system. The epidermis is integral to cosmesis. The outer surface of the skin, hair, and nails adds to each individual's sense of self.

Box 1–1 Functions of the Epidermis

- Provides a physical and chemical barrier
- Regulates fluid
- Provides light touch sensation
- Assists with thermoregulation
- Assists with excretion
- Critical to endogenous vitamin D production
- Contributes to cosmesis/appearance

Checkpoint Question #1

If a wound extends only into the epidermis, will it bleed profusely? Explain your answer.

Dermis

Dermal Layers

The dermis is 2–4 mm thick.[2] Although its layers are much less defined than those of the epidermis, the dermis can be described as consisting of two layers. The thin, superficial **papillary dermis** consists of loosely woven fibers embedded in a gelatinous matrix called ground substance.[8] The ridges and valleys of this layer (**dermal papillae**) conform to the contours of the stratum basale (**rete pegs**).[2] This structural design, and the basement membrane, helps anchor the dermis to the overlying epidermis and protects the epidermal appendages. **Blisters** occur at the junction if there is friction between the epidermis and dermis. In the palms, the epidermal ridges created by dermal papillae form finger prints.[8] The deeper, **reticular dermis** makes up 80% of the dermal thickness and consists of dense, irregularly arranged connective tissue.[8] The many thick fibers of the reticular dermis provide increased structural support to the skin.

The dermis is highly vascular with one terminal capillary loop providing nutrition to approximately 0.77 m^2 to 1.88 mm^2 of skin.[2] The dermal capillaries provide the dermis with its characteristic color, ranging from pale pink to rosy red. Superficial lymphatics are also located within the dermis.[2] The lymphatic system helps return water, proteins, and other substances from the body's tissues to the blood vessels. Healthy dermal tissue should have a shiny or moist appearance because of its high water content and a pink or rosy color due to its high vascularity.[15] Collagen, elastin, and moisture make the dermis elastic and pliable.[2]

Dermal Cell Types

Fibroblasts are the main cells found within the dermis. These cells produce the **collagen** and **elastin** fibers that give the dermis its characteristic strength and flexibility, respectively. **Macrophages** and **white blood cells** within the dermis help fight infection by engulfing harmful substances and releasing destructive enzymes.[8, 13] **Mast cells** are specialized secretory cells throughout the dermis. They produce chemical mediators of inflammation, such as **histamine**. These substances cause vasodilation and attract other cells to the area to help fight infection or repair injury. The dermis also contains several types of sensory receptors that provide information on touch, pressure, vibration, and temperature.[10]

Functions

The dermis has five main functions (see Box 1–2).[10] First, its vasculature provides nutritional support for itself and the epidermis. Second, if the outer epidermal layer is traumatized, the keratinocytes within the epidermal appendages that extend into the dermal layer will multiply to help restore normal skin integrity. Third, many of the cells within the dermis help protect the body from infection by **phagocytizing** (engulfing and destroying) dead and foreign materials and initiating inflammation. Fourth, the dermis can play a role in thermoregulation by dilating the superficial vasculature to help dissipate body heat or by constricting these vessels to help conserve body heat. In fact, cutaneous blood flow is ten- to twentyfold more than is needed for tissue oxygenation and metabolism to help with thermoregulation.[3] Fifth, the neural supply adds to the ability of the epidermis to provide information about the external environment.

Box 1–2 Functions of the Dermis

- Supports and nourishes epidermis
- Houses epidermal appendages
- Assists with infection control
- Assists with thermoregulation
- Provides sensation

Because the skin has so many important functions, loss of skin integrity can lead to serious and wide-ranging problems. For example, an individual with a deep burn covering the trunk and face would have an increased risk of infection and would lose massive amounts of fluid without intravenous fluid replacement. Once skin integrity is restored, the patient would be unable to sweat in the involved

area, leading to skin that is easily abraded and traumatized. Loss of skin over such a large surface area would also decrease the patient's ability to dissipate heat by the evaporation of sweat from the skin's surface. Loss of melanocytes would increase the risk of sunburn and make the new skin pale in color, and loss of nerve endings would decrease the ability to perceive light touch. The resultant scars would alter the patient's physical appearance, potentially affecting self-esteem. The astute clinician remembers the link between skin structure and function when working with patients with integumentary injuries such as this. Holistic care should address not only the short-term problems associated with the loss of skin integrity but also the long-term issues such as scar management and skin care to prevent secondary complications.

Subcutaneous Tissue

Subcutaneous tissue, sometimes called the hypodermis, supports the skin. It consists of adipose tissue and fascia.[10] **Adipose tissue** is highly vascular, loose connective tissue that stores fat, which provides energy, cushioning, and insulation (see Figure 1–3).[2] Fat-soluble vitamins, A, D, E, and K, are stored in adipose tissue.[16] Healthy adipose tissue has a glistening white to pale yellow appearance but may appear darker if dehydrated. **Fascia** is highly fibrous connective tissue that may be regularly or haphazardly arranged (see Figure 1–4). Fascia separates and surrounds structures and facilitates movement between adjacent structures, including muscle, tendon, and bone.[10] Deeper lymphatic vessels are located within the subcutaneous tissue as well.[10] Subcutaneous tissue provides cushioning over bony prominences, such as the greater trochanter of the femur, thus decreasing the risk of pressure injuries.

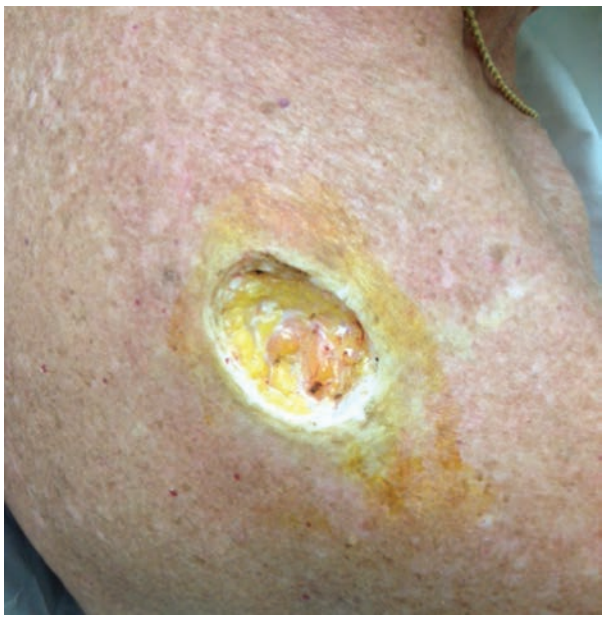

FIGURE 1–3 Superior view of patient's right posterior shoulder. A basal cell carcinoma was excised along with a wide margin of healthy tissue leaving exposed subcutaneous adipose tissue.

FIGURE 1–4 The plantar fascia is exposed on the plantar aspect of this patient's foot. The fascia can be identified by the regular arrangement of the fibers. Note the dark color of the fascia indicating that, although it is intact, it is no longer a viable tissue.

Deeper Tissues

Because some wounds may extend beyond the subcutaneous tissue layer, it is important to understand the normal structure and appearance of deeper tissues. Muscles consist of regularly arranged fibers surrounded by fascia.[10] Muscle has a rich vascular supply, making it appear dark red in color and bleed readily if traumatized. In contrast, nonviable muscle will appear gray or black in color. Tendons are regularly arranged collagen fibers that may be enclosed in a fibrous sheath.[10] Ligaments and joint capsules consist of dense connective tissue. Ligamentous fibers are regularly arranged, whereas joint capsules have fibers running in varied directions.[10] When healthy, these tissues are glistening white in appearance. If nonviable, these tissues will appear dry or leathery, will be dark in color, and/or may no longer

FIGURE 1–5 Dorsal view of patient's left foot with exposed deep tissues including tendon sheath and metal hardware implanted for fracture stabilization of metatarsal fracture.

Checkpoint Question #2

Your patient presents with an open blister on the posterior heel secondary to poor-fitting shoes. What tissues are involved with this type of injury?

be continuous. Healthy bone will have a shiny, smooth, and milky white appearance and will feel hard when probed. Abnormal appearances include a moth-eaten, irregular surface or a bruised or dark discoloration. Severe pressure injuries, diabetic ulcers, or burns, such as electrical burns, are likely to involve deeper tissues.

Depth of Tissue Involvement

By knowing the normal structure of the integument, subcutaneous, and deeper tissues, the clinician is able to determine the extent of tissue involvement in an open wound. Two examples will help clarify this point. First, consider a patient with a wound on the plantar aspect of the midfoot. The clinician would expect to find relatively thick integument that is free of hair follicles. If the wound extends beyond the integument, the clinician would expect to find the plantar fascia, fibrous tissue that appears pale yellow in color. If the wound penetrates through the fascia, the clinician may notice muscle, tendon, or bone within the wound bed. Alternatively, consider a patient with a wound over the superior, lateral thigh. The clinician would expect to find thinner skin than on the plantar aspect of the foot and evidence of hair growth. If the wound extends beyond the integument, the clinician may expect to find a variable amount of adipose tissue, pending wound location and the patient's percent body fat. If the wound extends farther toward the greater trochanter, there may be regularly arranged fascia from the tensor fascia lata or tendon from the attachments of the lateral rotators of the hip at the greater trochanter. If the clinician notes the presence of bone in the wound bed, it is likely the greater trochanter of the femur.

The extent of tissue involvement is typically categorized as superficial, partial-thickness, or full-thickness (see Table 1–1 and Figure 1–6). **Superficial wounds** affect only the epidermis. An example of a superficial wound would be an abrasion where the top layer of the integument has been removed,[17] revealing the top layer of the dermis. **Partial-thickness wounds** involve the epidermis and part of the underlying dermis.[18] A second-degree burn such as a deep sunburn that results in blistering and peeling (described in Section III of the text) is an example of a partial-thickness wound. In **full-thickness wounds**, tissue injury extends through both the epidermis and dermis to the subcutaneous tissue layer.[18] Full-thickness wounds may be further categorized as subcutaneous or subdermal tissue wounds if deeper tissues such as tendon, muscle, and/or bone are involved. A stage 4 pressure injury with exposed bone in the wound bed (described in Section III of the text) is an example of a full-thickness wound.

Checkpoint Question #3

Your patient's foot ulcer measures 5.0 cm length × 3.6 cm width × 0.8 cm depth. You conclude the ulcer involves what tissues?