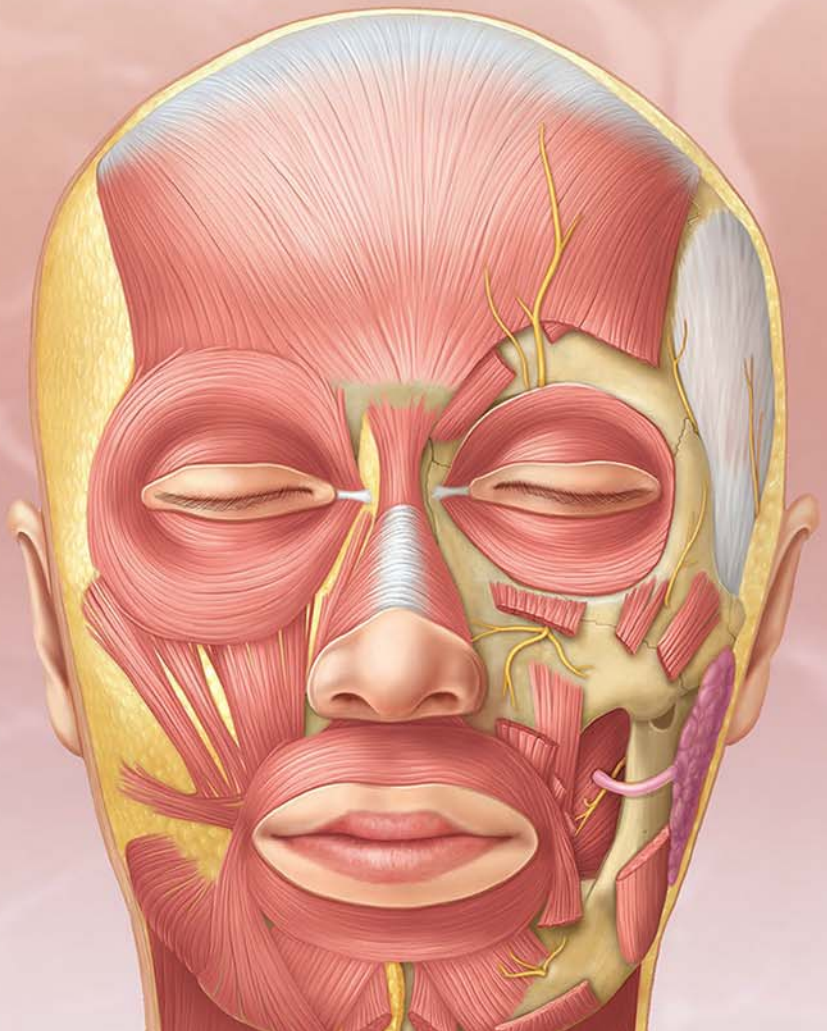
MOORE'S
Essential Clinical Anatomy

SIXTH EDITION

ANNE M. R. AGUR
ARTHUR F. DALLEY



Wolters Kluwer

MOORE'S
Essential Clinical Anatomy

SIXTH EDITION

Acquisitions Editor: Crystal Taylor
Development Editor: Kathleen H. Scogna (freelance); Andrea Vosburgh (in-house)
Editorial Coordinator: Lindsay Ries
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Manufacturing Coordinator: Margie Orzech
Prepress Vendor: Absolute Service, Inc.

Sixth Edition

9 8 7 6 5 4 3 2 1

Printed in China

Library of Congress Cataloging-in-Publication Data

Names: Moore, Keith L., author. | Agur, A. M. R., author. | Dalley, Arthur F., II, author. | Digest of (work): Moore, Keith L. Clinically oriented anatomy.
Title: Moore's essential clinical anatomy / Anne M.R. Agur, Authur F. Dalley II ; founding coauthor (with Anne M.R. Agur) and coauthor for first to fifth editions, Keith L. Moore.
Other titles: Essential clinical anatomy
Description: Sixth edition. | Philadelphia : Wolters Kluwer, [2019] | Preceded by Essential clinical anatomy / Keith L. Moore, Anne M.R. Agur, Arthur F. Dalley II. Fifth edition. [2015]. | Keith L. Moore's name appears first in the previous editions. | Parent text: Clinically oriented anatomy / Keith L. Moore, Arthur F. Dalley, Anne M.R. Agur. Eighth edition. [2018]. | Includes bibliographical references and index.
Identifiers: LCCN 2018048208 | ISBN 9781496369659 (paperback)
Subjects: | MESH: Anatomy | Handbooks
Classification: LCC QM23.2 | NLM QS 39 | DDC 612—dc23 LC record available at https://lccn.loc.gov/2018048208

shop.lww.com

To my husband, Enno, and my family, Kristina, Erik, and Amy, for their support and encouragement.
—AMRA

To Muriel,
my bride, best friend, counselor, and mother of our sons,
and to our family—
Tristan, Lana, Elijah, Finley, Sawyer, and Dashiell; Denver; Skyler, Sara, and Dawson—with love
and great appreciation for their support, understanding, good humor,
and, most of all, patience.
—AFD

In Loving Memory of Marion
My best friend, wife, colleague, mother of our five children, and grandmother of our nine
grandchildren for her love, unconditional support, and understanding.
Wonderful memories keep you in our hearts and minds.
—KLM

And with sincere appreciation for the anatomical donors without whom our studies would not be
possible and for the support and patience of their families.

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Preface

Twenty-two years have passed since the first edition of *Essential Clinical Anatomy* was published. The main aim of the sixth edition is to provide a compact yet thorough textbook of clinical anatomy for students and practitioners in the health care professions and related disciplines. With each edition, we strive to make the book even more student friendly. The basic approach that underlies this textbook is to

- provide a basic text of human clinical anatomy for use in current health sciences curricula.
- present an appropriate amount of clinically relevant anatomical material in a readable and interesting form.
- place emphasis on clinical anatomy that is important for practice.
- provide a concise clinically oriented anatomical overview for clinical courses in subsequent years.
- serve as a rapid review when preparing for examinations, particularly those prepared by the National Board of Medical Examiners.
- offer enough information for those wishing to refresh their knowledge of clinical anatomy.

This edition has been thoroughly revised, keeping in mind the many invaluable comments received from students, colleagues, and reviewers. Key features include the following:

- The art program continues to undergo revision and refinement with each edition. All of the illustrations are full color, highlight important facts, and show anatomy in relation to clinical medicine and surgery. A great effort has been made to further improve clarity of labeling and to place illustrations on the pages being viewed as the illustrations are cited in the text.
- New overview illustrations of the sensory and motor innervation of the upper and lower limbs facilitate integration.
- A description of the structure and function of the enteric nervous system and its unique role in the innervation of the digestive tract has been added that highlights important new information about this system's structure and function.
- New surface anatomy photographs of clinical procedures and their relevant anatomy emphasize the importance of knowledge of clinical anatomy.
- More illustrated clinical correlations, known as "clinical blue boxes," have been included to help students understand the practical value of anatomy. In response to our readers' suggestions, the clinical boxes have been grouped. They are also classified by the following icons to indicate the type of clinical information covered:

Anatomical variations.  These blue boxes feature anatomical variations that may be encountered in the dissection lab or in practice, emphasizing the clinical importance of awareness of such variations.

Life cycle.  These blue boxes emphasize prenatal developmental factors that affect postnatal anatomy and anatomical phenomena specifically associated with stages of life—childhood, adolescence, adult, and advanced age.

Trauma icon.  The effect of traumatic events—such as fractures of bones or dislocations of joints—on normal anatomy and the clinical manifestations and dysfunction resulting from such injuries are featured in these blue boxes.

Diagnostic procedures icon.  Anatomical features and observations that play a role in physical diagnosis are targeted in these blue boxes.

Surgical procedures.  These blue boxes address such topics as the anatomical basis of surgical procedures, such as the planning of incisions and the anatomical basis of regional anesthesia.

Pathology.  The effect of disease on normal anatomy, such as cancer of the breast, and anatomical structures or principles involved in the confinement or dissemination of disease within the body are the types of topics covered in these blue boxes.

- Surface anatomy is integrated into the discussion of each region to demonstrate the relationship between anatomy and physical examination, diagnosis, and clinical procedures.
- Medical images of radiographic, computed tomography (CT), magnetic resonance imaging (MRI), and ultrasonographic studies have been included, often with correlative illustrations. Current diagnostic imaging techniques demonstrate anatomy as it is often viewed clinically.

- Student resources, including case studies accompanied by clinico-anatomical problems and USMLE-style multiple-choice questions, are available to students online at http://thePoint.lww.com/MooreECA6e, providing a convenient and comprehensive means of self-testing and review.
- Instructors may contact their sales representative through http://thePoint.lww.com/MooreECA6e for information about accessing the instructor resources, including images, for use in their teaching and course materials.

The terminology adheres to the *Terminologia Anatomica* (1998) approved by the International Federation of Associations of Anatomists (IFAA). The official English equivalent terms are used throughout the present edition. When new terms are introduced, however, the Latin forms as used in Europe, Asia, and other parts of the world appear in parentheses. The roots and derivation of terms are included to help students understand the meaning of the terminology. Eponyms, although not endorsed by the IFAA, appear in parentheses to assist students during their clinical studies.

The parent of this book, *Clinically Oriented Anatomy* (*COA*), is recommended as a resource for more detailed descriptions of human anatomy and its relationship and importance to medicine and surgery. *Moore's Essential Clinical Anatomy*, in addition to its own unique illustrations and manuscript, has utilized materials from *Clinically Oriented Anatomy* and *Grant's Atlas of Anatomy*.

We again welcome your comments and suggestions for improvements in future editions.

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Acknowledgments

We wish to thank the following colleagues who were invited by the publisher to assist with the development of this sixth edition.

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In addition to reviewers, many people, some of them unknowingly, helped us by discussing parts of the manuscript and/or providing constructive criticism of the text and illustrations in the present and previous editions:

- *Dr. Peter H. Abrahams*, Emeritus Professor of Clinical Anatomy, Warwick Medical School, Coventry, United Kingdom
- *Dr. Edna Becker*, Associate Professor of Medical Imaging, University of Toronto Faculty of Medicine, Toronto, Ontario, Canada
- *Dr. Robert T. Binhammer*, Emeritus Professor of Genetics, Cell Biology and Anatomy, University of Nebraska Medical Center, Omaha, Nebraska
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Art plays a major role in facilitating learning, especially in anatomy. We extend our sincere gratitude and appreciation for the skills, and talents, of our medical illustrator, Jennifer Clements from Wolters Kluwer for this edition. We also thank Kam Yu, who prepared the illustrations for the first edition. We continue to benefit from the extensive surface anatomy project photographed by E. Anne Raynor, Senior Photographer, Vanderbilt Medical Art Group, under the direction of authors Arthur F. Dalley II and Anne M. R. Agur, with the support of Wolters Kluwer.

We wish to thank Dr. Edward C. Weber and Dr. Joel A. Vilensky for their review of clinical material, contributions to the Clinical Box features, and Medical Imaging photos.

Without the expertise and dedication of Kathleen Scogna, freelance developmental editor, this book would not have been possible. Our appreciation and thanks are extended to the editorial and production teams at Wolters Kluwer Health who provided their expertise in the development of this edition: Crystal Taylor, Senior Acquisitions Editor; Andrea Vosburgh, Development Editor; Lindsay Ries, Editorial Coordinator; Jennifer Clements, Art Director; and Joan Sinclair, Production Coordinator. We also thank Harold Medina of Absolute Service, Inc. Finally, thanks to the Sales Division at Wolters Kluwer Health, which has played a key role in the success of this book.

Anne M. R. Agur
Arthur F. Dalley II

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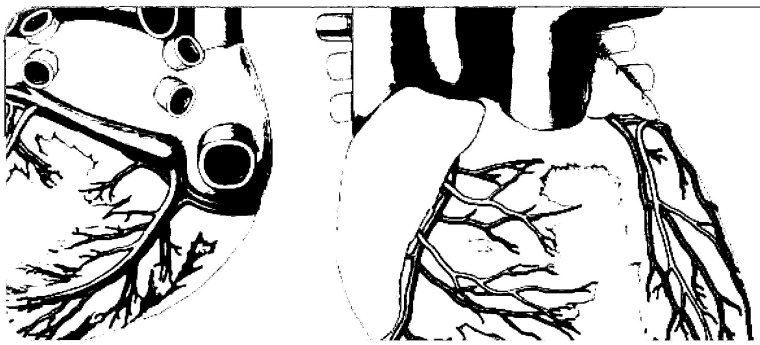

1 Overview and Basic Concepts

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Anatomical Variations


Diagnostic Procedures


Life Cycle


Surgical Procedures


Trauma


Pathology

Essential Clinical Anatomy relates the structure and function of the body to what is commonly required in the general practice of medicine, dentistry, and the allied health sciences. Because the number of details in anatomy overwhelms many beginning students, *Essential Clinical Anatomy* simplifies, correlates, and integrates the information so that it is easier to understand. The *clinical correlation boxes* (blue boxes) and *clinical case studies* (http://thePoint.lww.com) illustrate the clinical applications of anatomy. The *surface anatomy boxes* (orange boxes) provide an understanding of what lies under the skin, and the *medical imaging techniques* (green boxes), included throughout and at the end of each chapter, illustrate how anatomy is visualized clinically.

APPROACHES TO STUDYING ANATOMY

There are three main approaches to studying human gross anatomy: regional, systemic, and clinical (applied). In this introductory chapter, the systemic approach is used; in subsequent chapters, the clinical and regional approaches are used.

Regional anatomy is based on the organization of the body into parts: head, neck, trunk (further subdivided into thorax, abdomen, pelvis/perineum, and back), and paired upper and lower limbs. Emphasis is placed on the relationships of various systemic structures (e.g., muscles, nerves, and arteries) within the region (Fig. 1.1). Each region is not an isolated part and must be put into the context of adjacent regions and of the body as a whole. Surface anatomy is an essential part of the regional approach, providing a knowledge of what structures are visible and/or palpable (perceptible to touch) in the living body at rest and in action. The physical examination of patients is the clinical extension of surface anatomy. In people with stab wounds, for example, the health care worker must be able to visualize the deep structures that might be injured.

Systemic anatomy is an approach to anatomical study organized by *organ systems* that work together to carry out complex functions. None of the organ systems functions in isolation. For example, much of the skeletal, articular, and muscular systems constitute the *locomotor system*. And although the structures directly responsible for locomotion are the muscles, bones, joints, and ligaments, other systems are involved as well. The arteries and veins of the circulatory system supply oxygen to them and remove waste from them, and the nerves of the nervous system stimulate them to act. Brief descriptions of the systems of the body and their fields of study (in parentheses) follow:

- *Integumentary system* (dermatology) consists of the skin (integument) and its appendages, such as the hair and nails.

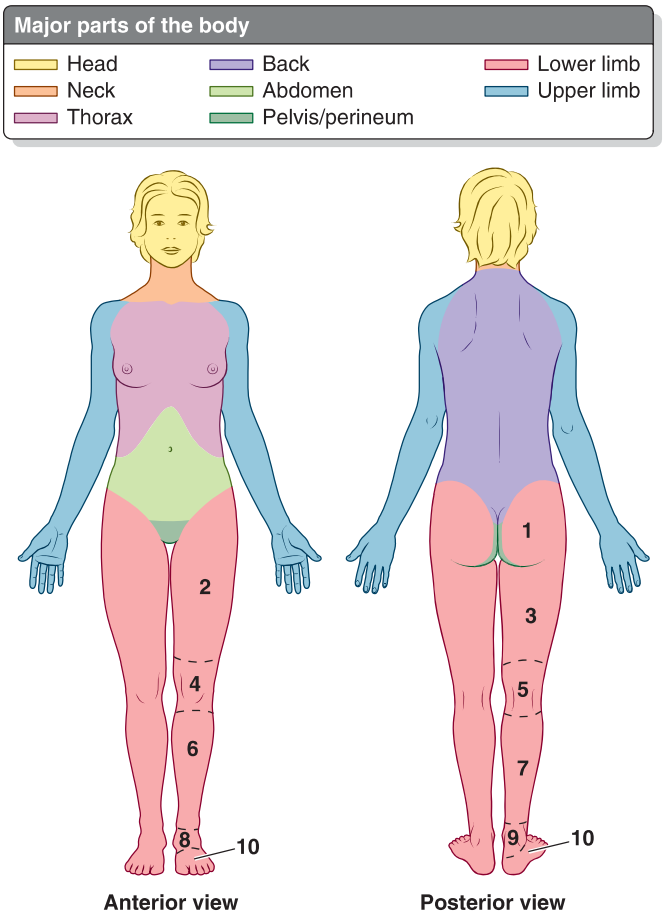


FIGURE 1.1. Anatomical position and regions of body.

The skin, an extensive sensory organ, forms a protective covering for the body.

- *Skeletal system* (osteology, orthopedics) consists of bones and cartilage. It provides support for the body and protects vital organs. The muscular system acts on the skeletal system to produce movements.
- *Articular system* (arthrology) consists of joints and their associated ligaments. It connects the bony parts of the skeletal system and provides the sites at which movements occur.
- *Muscular system* (myology) consists of muscles that act (contract) to move or position parts of the body (e.g., the bones that articulate at joints).
- *Nervous system* (neurology) consists of the *central nervous system* (brain and spinal cord) and the *peripheral nervous system* (nerves and ganglia, together with

their motor and sensory endings). The nervous system controls and coordinates the functions of the organ systems.

- *Circulatory system* (angiology) consists of the cardiovascular and lymphatic systems, which function in parallel to distribute fluids within the body.
  - *Cardiovascular system* (cardiology) consists of the heart and blood vessels that propel and conduct blood through the body.
  - *Lymphoid system* consists of a network of lymphatic vessels that withdraws excess tissue fluid (lymph) from the body's interstitial (intercellular) fluid compartment, filters it through lymph nodes, and returns it to the bloodstream.
- *Digestive* or *alimentary system* (gastroenterology) consists of the organs and glands associated with the ingestion, mastication (chewing), deglutition (swallowing), digestion and absorption of food, and the elimination of feces (solid wastes) after the nutrients have been absorbed.
- *Respiratory system* (pulmonology) consists of the air passages and lungs that supply oxygen and eliminate carbon dioxide. The control of airflow through the system produces tone, which is further modified into speech.
- *Urinary system* (urology) consists of the kidneys, ureters, urinary bladder, and urethra, which filter blood and subsequently produce, transport, store, and intermittently excrete liquid waste (urine).
- *Reproductive system* (obstetrics and gynecology for females, andrology for males) consists of the gonads (ovaries and testes) that produce oocytes (eggs) and sperms and the other genital organs concerned with reproduction.
- *Endocrine system* (endocrinology) consists of discrete ductless glands (e.g., thyroid gland) as well as cells of the intestine and blood vessel walls and specialized nerve endings that secrete hormones. Hormones are distributed by the cardiovascular system to reach receptor organs in all parts of the body. These glands influence metabolism and coordinate and regulate other processes (e.g., the menstrual cycle).

Clinical (applied) anatomy emphasizes aspects of the structure and function of the body important in the practice of medicine, dentistry, and the allied health sciences. It encompasses both the regional and the systemic approaches to studying anatomy and stresses clinical application.

ANATOMICOMEDICAL TERMINOLOGY

Anatomy has an international vocabulary that is the foundation of medical terminology. This nomenclature enables precise communication among health professionals worldwide as well as among scholars in basic and applied health sciences.

Although *eponyms* (names of structures derived from the names of people) are not used in official anatomical terminology, those commonly used by clinicians appear in parentheses throughout this book to aid students in their clinical years. Similarly, formerly used terms appear in parentheses on first mention—for example, internal thoracic artery (internal mammary artery). The terminology in this book conforms to the *Terminologia Anatomica: International Anatomical Terminology* (Federative Committee on Anatomical Terminology, 1998).

Anatomical Position

All anatomical descriptions are expressed in relation to the anatomical position (Fig. 1.1) to ensure that the descriptions are not ambiguous. The anatomical position refers to people—regardless of the actual position they may be in—as if they were standing erect, with their

- Head, eyes (gaze), and toes directed anteriorly (forward).
- Upper limbs by the sides with the palms facing anteriorly.
- Lower limbs close together with the feet parallel and the toes directed anteriorly.

Anatomical Planes and Sections

Anatomical descriptions relating to sectional anatomy and planar medical imaging (e.g., CT or MRI—see "Medical Imaging" at the end of this chapter) are based on conceptual planes that intersect the body in the anatomical position (Fig. 1.2). There are unlimited sagittal, frontal, transverse, and oblique planes, but there is only one median plane.

- **Median (median sagittal) plane** is the vertical plane passing longitudinally through the center of the body, dividing it into right and left halves.
- **Sagittal planes** are vertical planes passing through the body *parallel to the median plane*. It is helpful to give a point of reference to indicate the position of a specific plane—for example, a sagittal plane through the midpoint of the clavicle. A plane parallel to and near the median plane may be referred to as a *paramedian plane*.
- **Frontal (coronal) planes** are vertical planes passing through the body *at right angles to the median plane*, dividing it into anterior (front) and posterior (back) portions—for example, a frontal plane through the heads of the mandible.
- **Transverse planes** are planes passing through the body *at right angles to the median and frontal planes*. A transverse plane divides the body into superior (upper) and inferior (lower) parts—for example, a transverse plane through the umbilicus. Radiologists refer to transverse planes as *transaxial planes* or simply *axial planes*.
- **Oblique planes or sections** are planes or sections that do not align with the preceding planes.

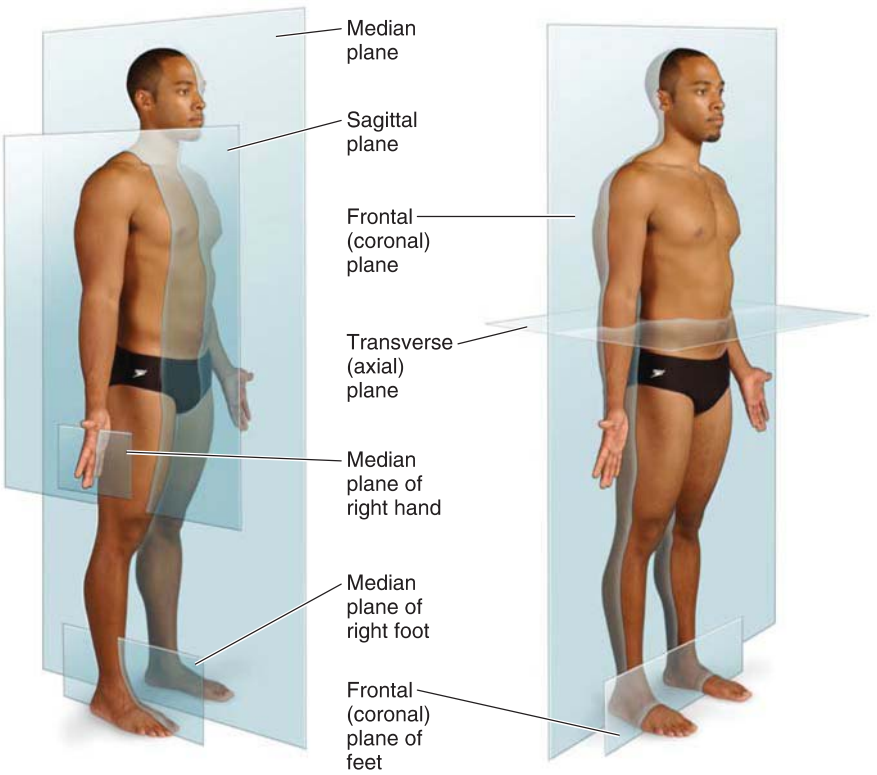


FIGURE 1.2. Planes of body.

Terms of Relationship and Comparison

Various adjectives, arranged as pairs of opposites, describe the relationship of parts of the body in the anatomical position and compare the position of two structures relative to each other. These pairs of adjectives are explained and illustrated in Figure 1.3. For example, the eyes are superior to the nose, whereas the nose is inferior to the eyes.

Combined terms describe intermediate positional arrangements:

- **Inferomedial** means nearer to the feet and closer to the median plane—for example, the anterior parts of the ribs run inferomedially.
- **Superolateral** means nearer to the head and farther from the median plane.

Proximal and **distal** are directional terms used when describing positions—for example, whether structures are nearer to the trunk or point of origin (i.e., proximal). **Dorsum** refers to the superior or dorsal (back) surface of any part that protrudes anteriorly from the body, such as the *dorsum of the foot*, *hand*, *penis*, or *tongue*. It is easier to understand why these surfaces are considered dorsal if one thinks of a quadrupedal plantigrade animal that walks on its soles, such as a dog. The **sole (plantar surface)** indicates the inferior aspect or bottom of the foot, much of which is in contact with the ground when standing barefoot. The **palm (palmar surface)** refers to the flat anterior aspect of the hand, excluding the five digits, and is the opposite of the dorsum of the hand.

Terms of Laterality

Paired structures having right and left members (e.g., the kidneys) are **bilateral**, whereas those occurring on one side only (e.g., the spleen) are **unilateral**. **Ipsilateral** means occurring on the same side of the body; the right thumb and right great toe are ipsilateral, for example. **Contralateral** means occurring on the opposite side of the body; the right hand is contralateral to the left hand.

Terms of Movement

Various terms describe movements of the limbs and other parts of the body (Fig. 1.4). Although most movements take place at joints where two or more bones or cartilages articulate with one another, several nonskeletal structures exhibit movement (e.g., tongue, lips, and eyelids). Movements taking place at joints are described relative to the axes around which the part of the body moves and the plane in which the movement takes place—for example, flexion and extension of the shoulder take place in the sagittal plane around a frontal (coronal) axis.

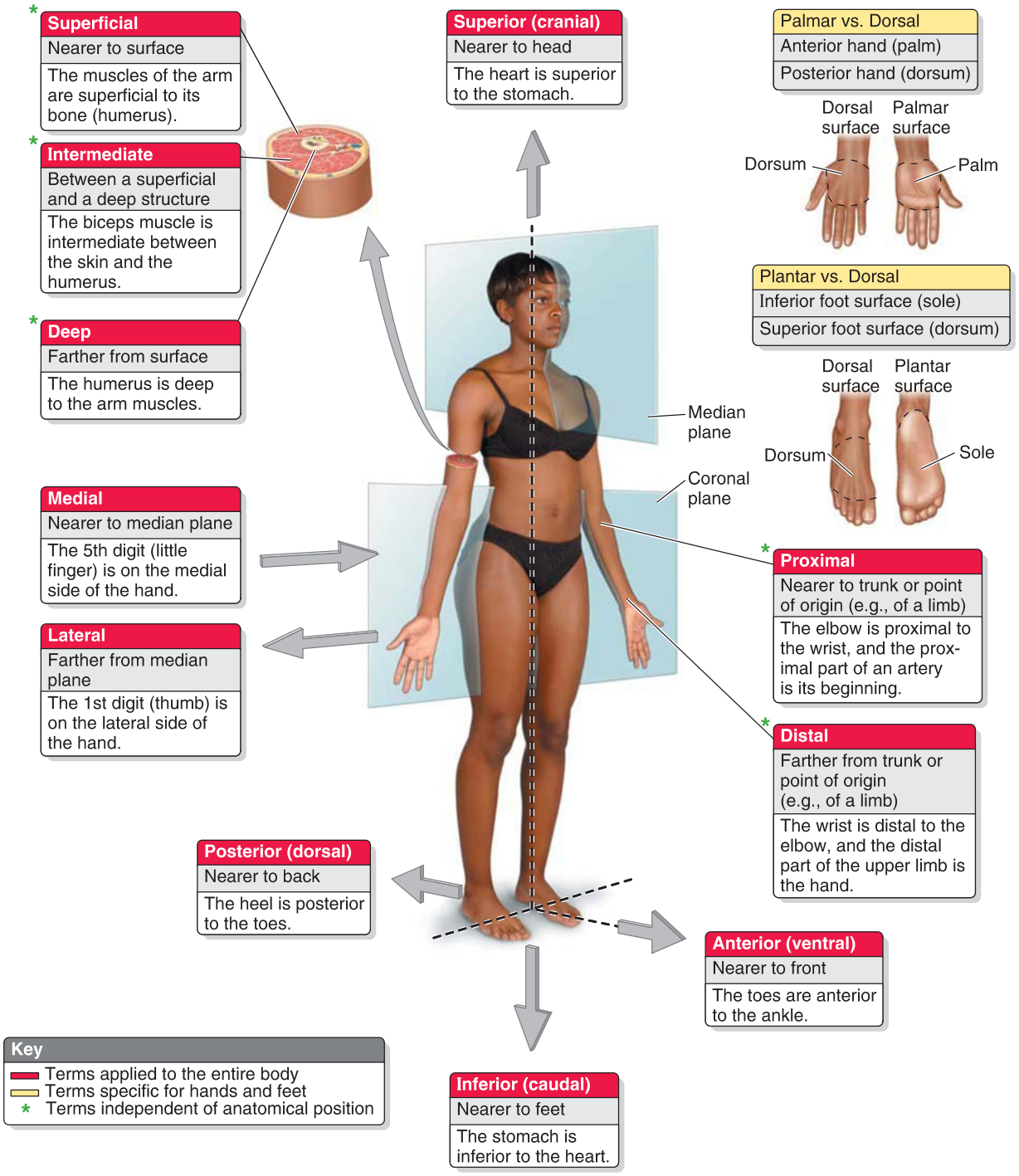
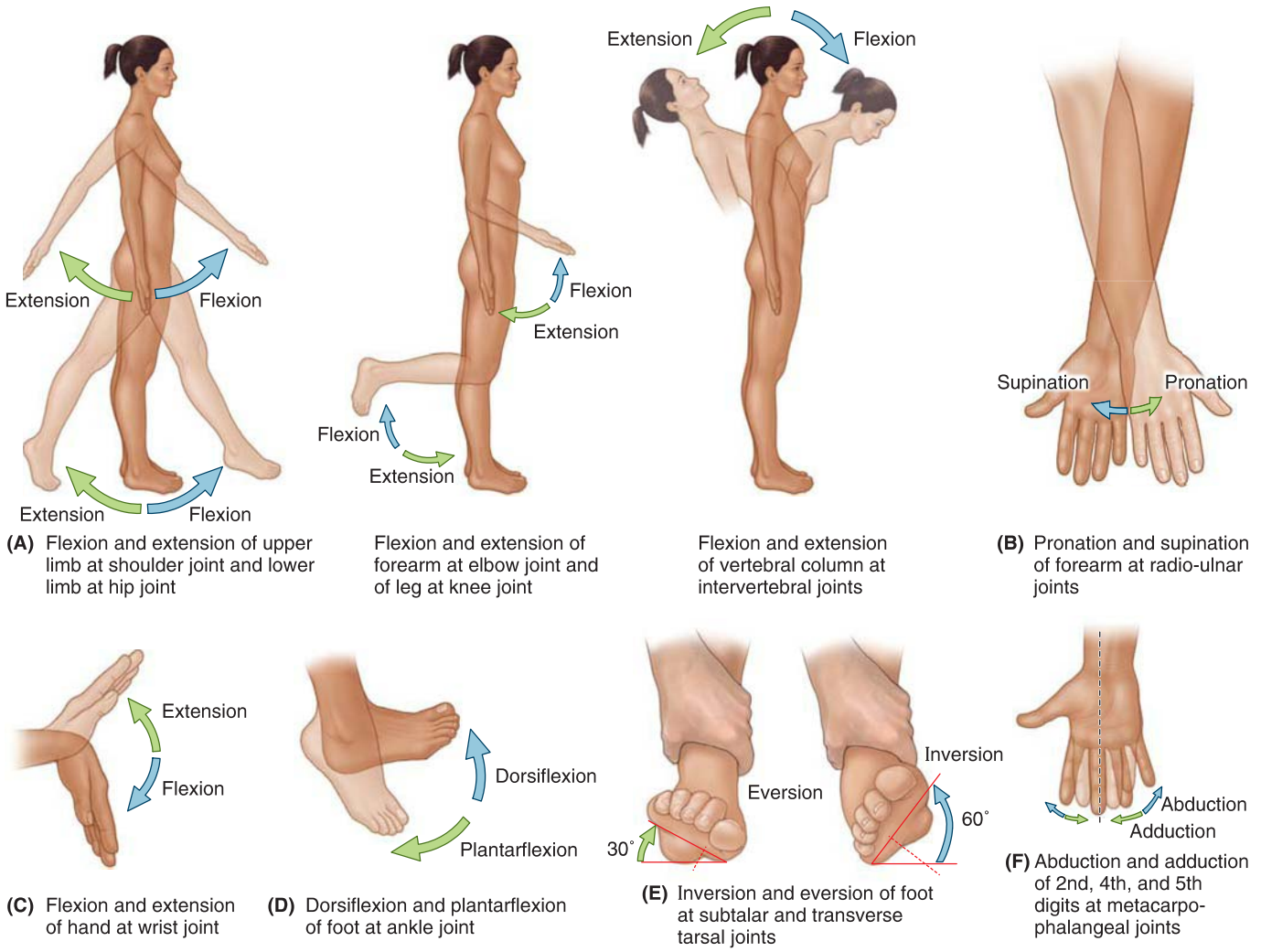


FIGURE 1.3. Terms of relationship and comparison. These terms describe the position of one structure to another.

Anatomical Variations

Although anatomy books describe the structure of the body observed in most people (i.e., the most common pattern), the structure of individuals and even the right and left sides of the same individual may vary considerably in the details. Students are often frustrated because the bodies they are examining or dissecting do not conform to the atlas or textbook they are using. Students should expect anatomical variations when dissecting or studying prosected specimens. The bones of the skeleton vary not only in their basic shape but also in the details of surface structure. There is also a wide variation in the size, shape, and form of the



(A) Flexion and extension of upper limb at shoulder joint and lower limb at hip joint

Flexion and extension of forearm at elbow joint and of leg at knee joint

Flexion and extension of vertebral column at intervertebral joints

(B) Pronation and supination of forearm at radio-ulnar joints

(C) Flexion and extension of hand at wrist joint

(D) Dorsiflexion and plantarflexion of foot at ankle joint

(E) Inversion and eversion of foot at subtalar and transverse tarsal joints

(F) Abduction and adduction of 2nd, 4th, and 5th digits at metacarpophalangeal joints

FIGURE 1.4. Terms of movement. These terms describe movements of the limbs and other parts of the body; most movement takes place at joints where two or more bones or cartilages articulate with each other. *(continued)*

attachment of muscles. Similarly, there is variation in the method of division of vessels and nerves, and the greatest variation occurs in veins. Apart from racial and sexual differences, humans exhibit considerable genetic variation. Approximately 3% of newborns show one or more significant congenital anomalies (Moore et al., 2016).

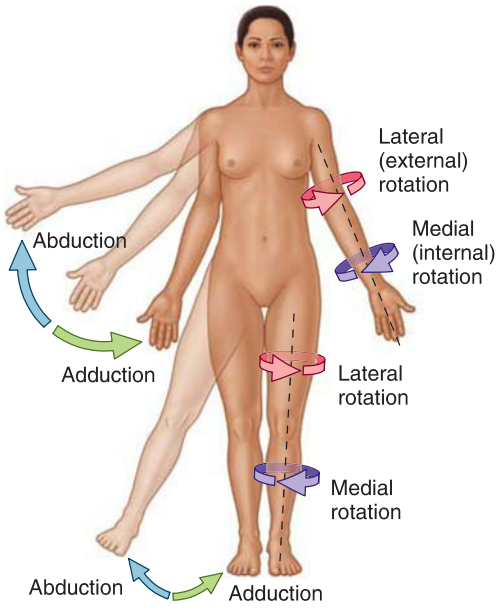
INTEGUMENTARY SYSTEM

The skin, the largest organ of the body, is readily accessible and is one of the best indicators of general health (Swartz, 2014). *The skin serves the following functions*:

- *Protection* for the body from environmental effects, such as abrasions and harmful substances
- *Containment* of the tissues, organs, and vital substances of the body, preventing dehydration
- *Heat regulation* through sweat glands, blood vessels, and fat deposits
- *Sensation* (e.g., pain) by way of superficial nerves and their sensory endings
- *Synthesis and storage* of vitamin D

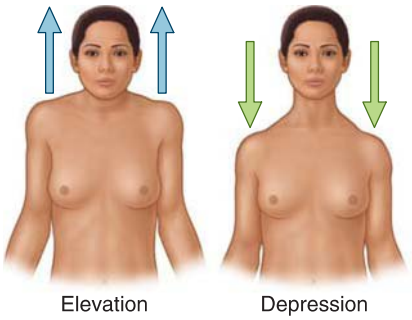
The skin consists of a superficial cellular layer, the epidermis, which creates a tough protective outer surface, and a basal (deep) regenerative and pigmented connective tissue layer, the dermis (Fig. 1.5A).

The **epidermis** is a keratinized stratified (layered) epithelium with a tough outer surface composed of keratin (a fibrous protein). The outer layer of the epidermis is continuously "shed" or rubbed away with replacement of new cells from the basal layer. This process renews the epidermis of the entire body every 25–45 days. The epidermis is avascular (no blood vessels or lymphatics) and is nourished by the vessels in the underlying dermis. The skin is supplied by afferent nerve endings that are sensitive to touch, irritation (pain), and temperature. Most nerve terminals are in the dermis, but a few penetrate the epidermis.

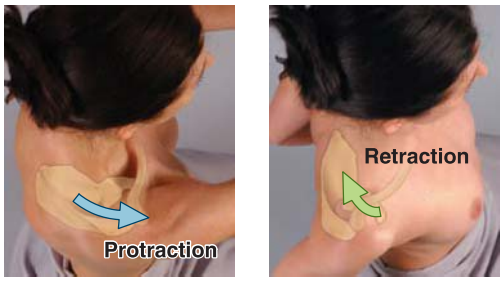


(G) Abduction and adduction of right limbs and rotation of left limbs at glenohumeral and hip joints

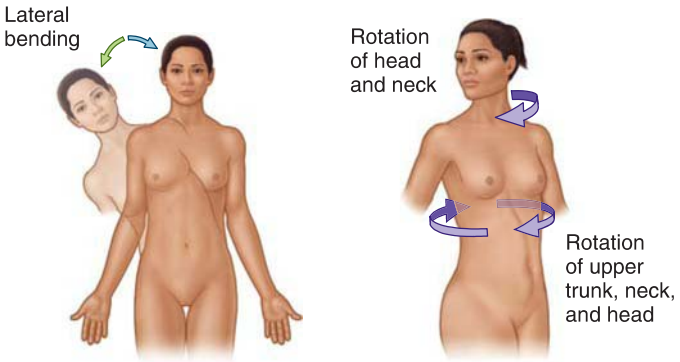
(H) Circumduction (circular movement) of lower limb at hip joint



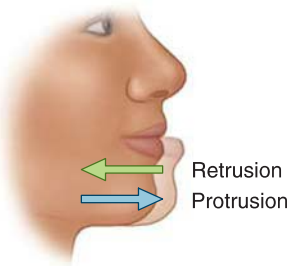
(I) Elevation and depression of shoulders (scapula and clavicle)



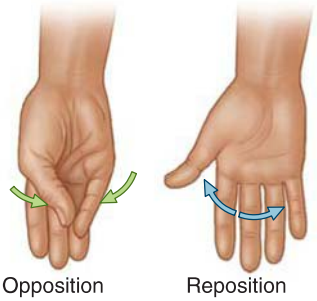
(K) Protraction and retraction of scapula on thoracic wall



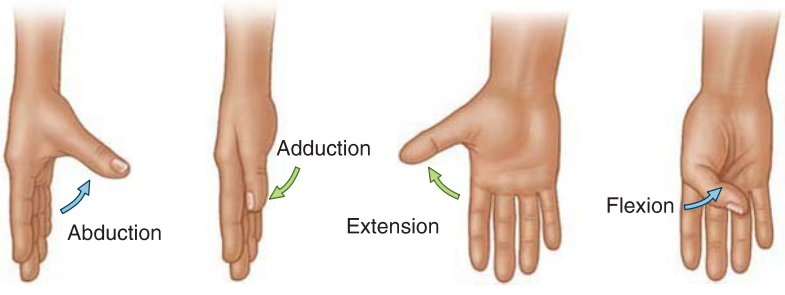
(J) Lateral bending (lateral flexion) of trunk and rotation of upper trunk, neck, and head



(L) Protrusion and retrusion of mandible (jaw) at temporomandibular joints



(M) Opposition and reposition of thumb and little finger at carpometacarpal joint of thumb combined with flexion at metacarpophalangeal joints



(N) The thumb is rotated 90 degrees relative to other structures. Abduction and adduction at metacarpophalangeal joint occurs in a sagittal plane; flexion and extension at metacarpophalangeal and interphalangeal joints occurs in frontal planes, opposite to these movements at other joints.

FIGURE 1.4. Terms of movement. *(continued)*

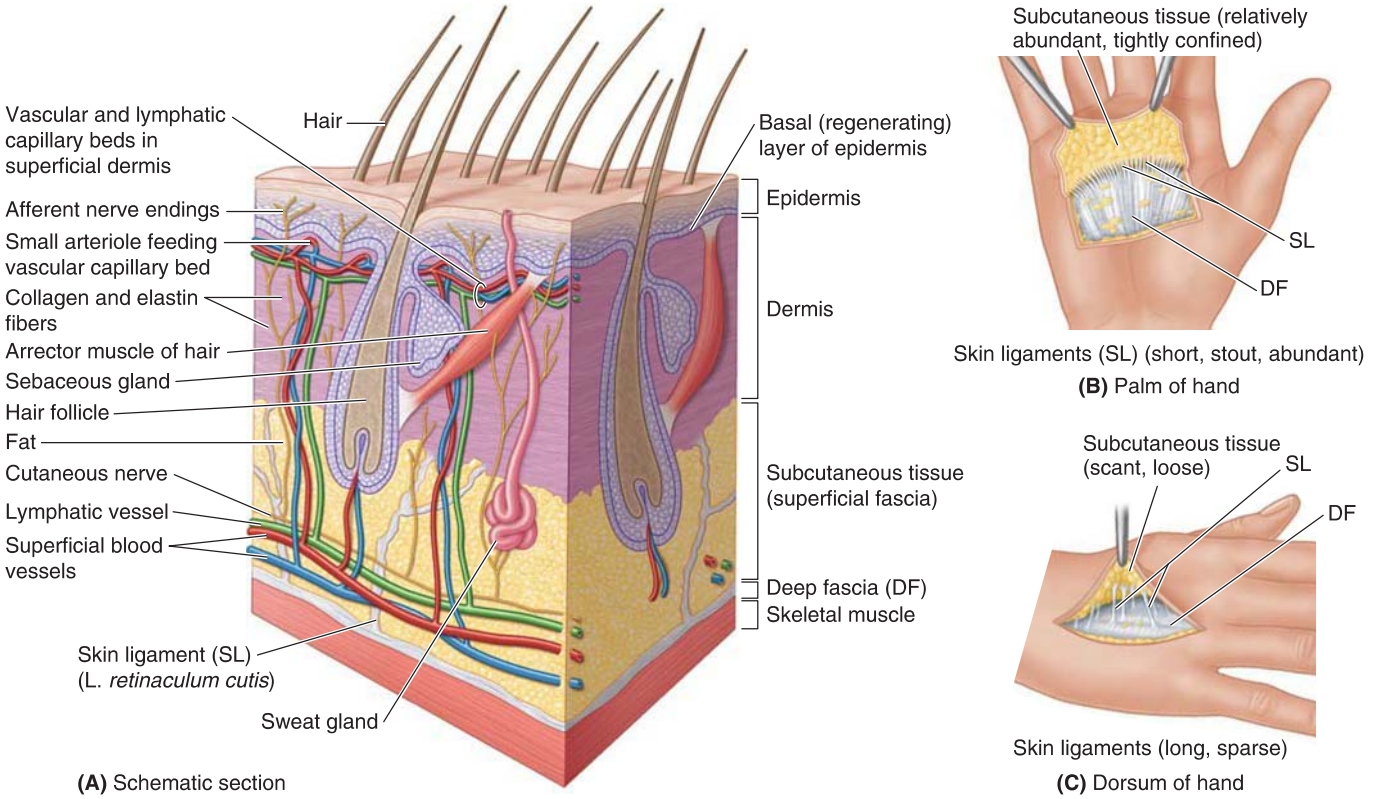


FIGURE 1.5. Structure of skin and subcutaneous tissue. A. Skin and some of its specialized structures. **B.** Skin ligaments of palm of hand. The skin of the palm, like that of the sole of the foot, is firmly attached to the underlying deep fascia. **C.** Skin ligaments of dorsum of hand. The long, relatively sparse skin ligaments allow the mobility of the skin in this region.

The **dermis** is formed by a dense layer of interlacing *collagen* and *elastic fibers*. These fibers provide skin tone and account for the strength and toughness of the skin. The primary direction of collagen fibers determines the characteristic tension lines (cleavage lines) and wrinkle lines in the skin. The deep layer of the dermis contains hair follicles, with their associated smooth arrector (L. *arrector pili*) muscles and sebaceous glands. Contraction of the **arrector muscles** erects the hairs (causing goose bumps), thereby compressing the sebaceous glands and helping them secrete their oily product onto the skin. Other integumentary structures include the hair, nails, mammary glands, and the enamel of teeth.

The **subcutaneous tissue** (superficial fascia) is composed of loose connective tissue and fat. Located between the dermis and underlying deep fascia, the subcutaneous tissue contains the deepest parts of the sweat glands, the blood and lymphatic vessels, and cutaneous nerves. The subcutaneous tissue provides for most of the body's fat storage, so its thickness varies greatly depending on the person's nutritional state. **Skin ligaments** (L. *retinacula cutis*), consisting of numerous small fibrous bands, extend through the subcutaneous tissue and attach the deep surface of the dermis to the underlying deep fascia (Fig. 1.5B,C). The length and density of these ligaments determine the mobility of the skin over deep structures.

The **deep fascia** is a dense, organized connective tissue layer, devoid of fat, that envelops most of the body deep to the skin and subcutaneous tissue. Extensions from its internal surface

- Invest deeper structures, such as individual muscles and neurovascular bundles (**investing fascia**)
- Divide muscles into groups or compartments (**intermuscular septa**)
- Lie between the musculoskeletal walls and the serous membranes lining body cavities (**subserous fascia**)

The deep fascia also forms (1) **retinacula**, which hold tendons in place during joint movement, and (2) **bursae** (closed sacs containing fluid), which prevent friction and enable structures to move freely over one another.

In living people, **fascial planes** (interfascial and intrafascial) are potential spaces between adjacent fascias or fascia-lined structures. During surgical procedures, surgeons take advantage of these planes, separating structures to create actual spaces that allow access to deeper structures. These planes are often fused in embalmed cadavers.