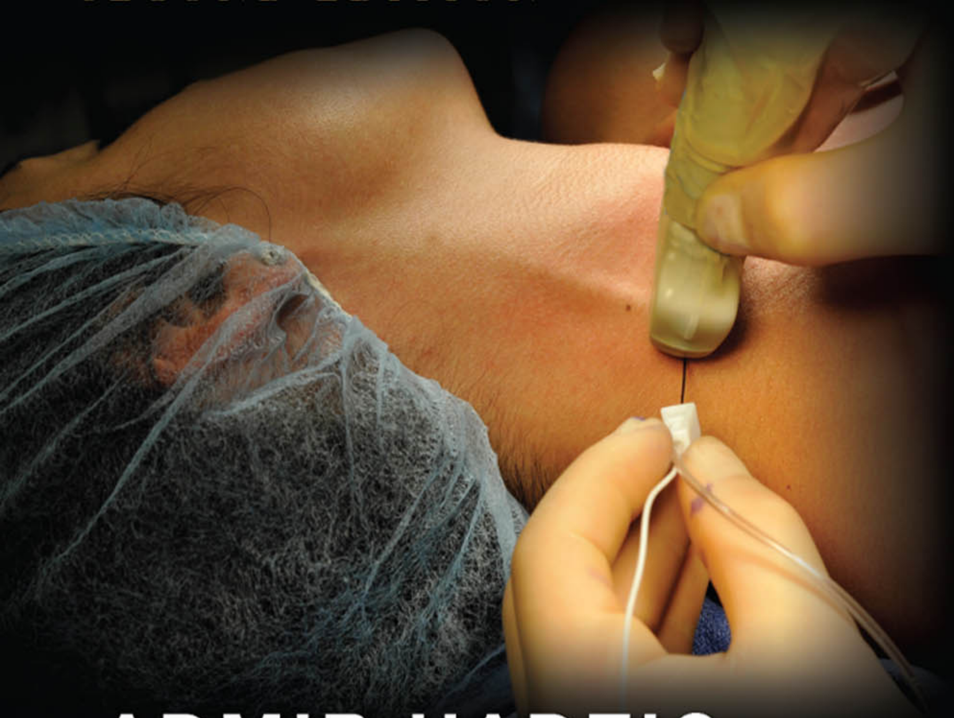
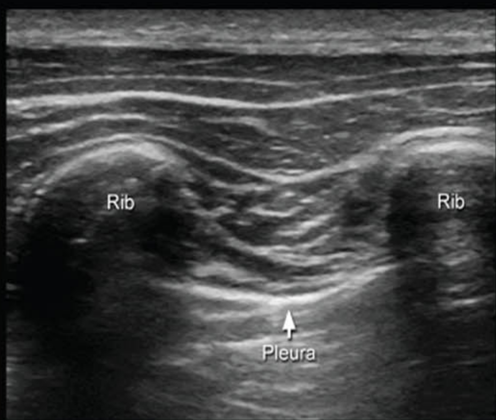
NEW YORK SCHOOL *of* REGIONAL ANESTHESIA

HADZIC'S PERIPHERAL NERVE BLOCKS

AND ANATOMY FOR ULTRASOUND-GUIDED REGIONAL ANESTHESIA

SECOND EDITION





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NEW YORK SCHOOL OF REGIONAL ANESTHESIA

Hadzic's Peripheral Nerve Blocks and Anatomy for Ultrasound-Guided Regional Anesthesia

NOTICE

NEW YORK SCHOOL OF REGIONAL ANESTHESIA

Hadzic's Peripheral Nerve Blocks and Anatomy for Ultrasound-Guided Regional Anesthesia

SECOND EDITION

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DEDICATION

I dedicate this book to Dr. Jerry Darius Vloka,
a peerless scholar whose contribution to and teaching of
regional anesthesia have provided an educational platform and
inspiration for generations of practitioners and academicians alike.
You are a beacon of light and a paragon of scholarship and virtue.
I am profoundly privileged to number you among my closest friends.
May many generations of students slake their thirst at the well of your wisdom,
and may our friendship outpace the ravages of time.

With love and respect,
Admir

"Tell me what company thou keepst, and I'll tell thee what thou art."

Cervantes

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PREFACE

Peripheral Nerve Blocks and Anatomy for Ultrasound-Guided Regional Anesthesia, second edition, is being published at an exciting time in the development of regional anesthesia. Reflecting on the first edition of the book,* we believe its success was due largely to the tried-and-true nature of the material taught. It would not be an overstatement to say that the first edition of this book influenced professional lives of many colleagues and ultimately benefited patients worldwide. The success helped garner the New York School of Regional Anesthesia (NYSORA) additional esteem that it enjoys today. In line with the philosophy of the first edition, this second edition minimizes presentation of theoretical considerations. Instead, the featured techniques and teachings are gleaned directly from the trenches of the clinical practice of regional anesthesia.

In recent years, the field of regional anesthesia, and in particular peripheral nerve blockade, has entered an unprecedented renaissance. This renaissance is due primarily to the widespread introduction of ultrasound-guided regional anesthesia. The ability to visualize the anatomy of interest, the needle–nerve relationship, and the spread of the local anesthetic has resulted in significant growth of interest in and use of peripheral nerve blocks. Regardless, many aspects of ultrasound-guided regional anesthesia still require clarification and standardization. Examples include dilemmas regarding the ideal placement of the needle for successful and safe blockade, the number of injections required for individual techniques, the volume of local anesthetic for successful blockade, the integration of additional monitoring tools such as nerve stimulation and injection pressure monitoring and many others. For these reasons, we decided to defer publication of the second edition and opted to wait for clarification from clinical trials or collective experience to provide more solid recommendations. As a result, just as with the first edition, the second book features only tried-and-true descriptions of peripheral nerve block techniques with wide clinical applicability rather than a plethora of techniques and modifications that have mere theoretical considerations. Where the collective experience has not reached the necessary level to recommend teaching a certain technique (e.g., neuraxial blocks), we opted to feature anatomic considerations rather than vague or inadequately developed technique recommendations, which may lead to disappointments, or possibly complications, if they are adopted without careful consideration.

*The first edition was titled *Peripheral Nerve Blocks: Principles and Practice.*

The second edition is organized as a collection of practical introductory chapters, followed by detailed and unambiguous descriptions of common regional anesthesia block procedures rather than an exhaustive theoretical compendium of the literature. Although ultrasound guidance eventually may become the most prevalent method of nerve blockade globally, most procedures world-wide are still performed using the methods of peripheral nerve stimulation and/or surface landmarks, particularly in the developing world. Because this book has been one of the main teaching sources internationally, we decided to retain the section on the traditional techniques of nerve blockade in addition to the new section on ultrasound-guided regional anesthesia. Since knowledge of surface anatomy is essential for practice of both traditional and ultrasound regional anesthesia procedures, we decided to also add an Atlas of Surface Anatomy (Section 8).

The book is organized in eight sections that progress from the foundations of peripheral nerve blocks and regional anesthesia to their applications in clinical practice. Ultrasound-guided regional anesthesia is a field in evolution, and many of its aspects still lack standardization and clear guidance. For this reason, we decided to produce this new edition as an international collaborative effort. This collaboration resulted in teaching that is based not only on our experience at NYSORA but also is endorsed by a number of opinion leaders in the field from around the globe. I would like to thank them for the contributions, enthusiasm, and passion that they invested in creating the second edition of *Peripheral Nerve Blocks*. This book also would not be what it is without the large extended family of educators and trainees, who took part in the numerous NYSORA educational programs, including our educational outreach program in developing countries in Asia. I thank you immensely for your input, which inspired us to deliver this updated edition, and for your multiple contributions through e-mails, suggestions, and discussion on the NYSORA.com website.

There are no standards of care related to peripheral nerve blocks, despite their widespread use. With this edition, we have tried to standardize the techniques and the monitoring approach during local anesthetic delivery, for both greater consistency and greater safety of peripheral nerve blocks. Different institutions naturally may have different approaches to techniques that they customize for their own needs. The material we present in this volume however, comes from the trenches of clinical practice, so to speak. Most procedures described are accompanied by carefully developed flowcharts to facilitate decision making in clinical practice that the authors themselves use on an everyday basis.

The successful practice of ultrasound-guided regional anesthesia and pain medicine procedures depends greatly on the ability to obtain accurate ultrasound images and the ability to recognize the relevant structures. For these reasons, we decided to add an atlas of ultrasound anatomy for regional anesthesia and pain medicine (Section 7) procedures to this volume. The anatomy examples consist of a pictorial guide with images of the transducer position needed to obtain the corresponding ultrasound image and the cross-sectional gross anatomy of the area being imaged. Once the practitioner absorbs this material, he or she can extrapolate the knowledge of the practical techniques presented to practice virtually any additional regional anesthesia technique. We have expended painstaking efforts to provide cross-sectional anatomy examples where possible. Perfecting the matching of ultrasound and anatomy sections is not always possible because the sonograms and cross-sectional anatomy views are obtained from volunteers and fresh cadavers, respectively. The reader should keep in mind that the ultrasound images are obtained from videos during dynamic scanning. For this reason, the labeled ultrasound images are accurate to the best of our abilities and within the limitations of the ultrasound equipment even when they do not perfectly match the available paired cross-sectional anatomy.

Due to popular demand, we decided to include a DVD containing videos of the most common ultrasound-guided nerve block procedures. Assuming that videos are the most beneficial method for novices and trainees, we decided to include videos of well-established ultrasound-guided nerve blocks that should cover most indications for peripheral nerve blocks. Once trainees have mastered these techniques, they typically require only knowledge about the specific anatomy of the block(s) to be performed to apply the principles learned in the videos to any other nerve block procedure. This is another example of how the atlas of ultrasound anatomy (Section 7) included in the book will be useful. With the wealth of information presented in a systematic fashion, we believe that the Atlas also will be of value to anyone interested in the ultrasound anatomy of peripheral nerve and musculoskeletal systems, including radiologists, sonographers, neurologists, and others.

With this edition of *Peripheral Nerve Blocks and Anatomy for Ultrasound-Guided Regional Anesthesia,* we have tried to provide a wealth of practical information about the modern practice of peripheral nerve blocks and the use of ultrasound in regional anesthesia and to present multiple pathways to troubleshoot common clinical problems. We hope this book will continue to serve as one of the standard teaching texts in anesthesiology, and we thank the readership of previous edition their support and encouragement.

Sincerely,
Admir Hadzic, MD

ACKNOWLEDGMENTS

This book would not be possible without the contributions and support from a number of remarkable people and top professionals in their respective fields.

Most notably, special thanks to Professor Alan Santos, MD, the chair of the Department of Anesthesiology at St. Luke's–Roosevelt Hospitals, where a significant part of the clinical teaching and research of the New York School of Regional Anesthesia (NYSORA) has taken place over the years. Alan's commitment to education and academics, and his leadership have created a unique milieu where faculty and staff drawn to academics can excel and pursue their academic goals with a remarkable departmental support.

Hats off to our current and past fellows in regional anesthesia. You have been immeasurably helpful and a continuing source of inspiration for many projects and NYSORA endeavors, and you have been so much fun to work with as well. In particular, thanks and love go to "NYSORA Angels" Drs. Kim Gratenstein and Colleen Mitgang for the all-around help and positive vibe. I also extend gratitude to our residents who have helped create teaching ideas and a multitude of didactic algorithms through our daily interactions in clinical practice.

Many thanks to my numerous U.S. and international collaborators, whose support, relentless challenges, and innovative didactic material have made a palpable contribution to this project. A bow to you, my colleagues at St. Luke's–Roosevelt Hospital, New York, and our site director, Dr. Kurian Thomas, whose daily organizational skills and clinical leadership made many of our endeavors possible—often magically so—in these times of increasing financial and manpower strain.

Many thanks to my family: foremost, my son Alen Hadžić, my parents Junuz and Safeta Hadžić, my sister Admira, and the entire family for allowing me to work on this book project while depriving them of my presence.

Special thanks to the illustrator, Lejla Hadžić. Her artistic vision and talent adorns this book with a plethora of detailed illustrations. Lejla has been spearheading multiple projects in her own primary area of expertise, restoration of war- and weather-ravaged cultural monuments with a Swedish-based organization, Cultural Heritage Without Borders (CHWB), for which she has received much international acclaim. Many thanks also to Emma Spahic for lending her artistic eye and Photoshop skills to the project.

This book owes a great deal to a number of gifted clinicians, academicians, and regional anesthesia teams from around the globe. Many thanks to Dr. Catherine Vandepitte, who has spent countless hours editing and collating the material. Daquan Xu, MD, has contributed his unmatched organizational skills and knowledge of anatomy and ultrasonography. At the peak of our efforts to produce this book, Daquan actually moved in with me in my apartment on the Hudson River in Lincoln Harbor, across from the Midtown section of Manhattan. While enduring 16- to 18-hour days working on the book in the winter of 2011, Daquan would take five-minute breaks on the balcony to gaze over the skyline of New York. We would stop working only when Daquan became so tired that he could not see the Empire State Building any more. This sign became known as "The Daquan Sign to Quit Working". Boundless appreciation to Dr. Sala-Blanch and his team, Miguel Reina, Ana Carrera, Ana Lopez, and many others, for their support, contribution in vision, and, in particular, original anatomic material. Thank you to Dr. Manoj Karmakar and his team for their cutting-edge contributions to various sections of the atlas of ultrasound anatomy. Thank you to Thomas Clark, who used his unmatched skills in musculoskeletal imaging to muster some great ultrasound anatomy in the Atlas section of the book. Many thanks to Dr. Jeff Gadsden for his contribution and best wishes for success as he takes over the leadership of the Division of Regional Anesthesia at St. Luke's–Roosevelt Hospital, a position I have held for the past 15 years. As he continues to build the division and the regional anesthesia fellowship, I have moved on to multiple other teaching and publishing endeavors. In particular, I will focus on keeping our two textbooks on regional anesthesia current in years to come.

Special thanks to a truly inspiring video team, the Ceho Brothers of *Film Productions Division* of *Stone Tone Records, Inc.* Aziz and Mirza Ceho are award-winning documentary filmmakers who have contributed their immense artistic talent to the accompanying DVD, ***5 Nerve Blocks for 95% of Indications.*** Making a good instructional DVD has proved to be an incredibly time-consuming task. However, we believe our efforts have been justified and we have created a uniquely detailed and true-to-life educational tool. This DVD should be particularly helpful to clinicians who need to adopt a few, uniquely effective nerve block techniques that can be used to provide regional anesthesia to a wide variety of patients.

Many thanks to Brian Belval, senior editor at McGraw-Hill Medical. Brian is one of the most inspirational and insightful managing editors I have ever worked with. I will admit without reservation that this book would not be what it is without his vision and personal touch. Likewise, the unmatchable attention to detail of Robert Pancotti, senior project development editor, has much to do with the quality of this project.

Special thanks to Lorenzo Casertano for loaning his ripped fencing body for the Atlas of Surface Anatomy that adorns Section 8 at the end of the book. Likewise, thank you to Alecia Yufa and Alen Hadžić for modeling for the Atlas and the techniques.

Finally, a word of gratitude to my bandmates from *Big Apple Blues Band* (www.bigappleblues.com), who contributed the original music on all tracks on the ***5 Nerve Blocks for 95% of Indications*** DVD. Barry Harrison, Anthony Kane, Hugh Pool, Zach Zunis, Rich Cohen, Tom Papadatos, and Bruce Tylor are some of the very top cats in the NYC music scene. Their talent and passion have been an important source of inspiration for me on the band stage, in the studio, and in life in general.

Disclosure

I have served as an industry advisor over the course of my career and have received consulting honoraria and research grants in the past from GE, Baxter, Glaxo Smith-Kline Industries SkyPharma, Cadence, LifeTech, and others. I hold an equity position at Macosta Medical USA. Macosta Medical USA owns intellectual property related to injection pressure monitoring and several other patents related to the field of anesthesiology. Finally, I have invested a lifetime's worth of energy and love into building NYSORA over the past 15 years. My passion for regional anesthesia and undying commitment to these multiple endeavors undoubtedly has created biases that may have influenced the teaching in this book; I take full responsibility and stand by all of them.

SECTION 1

Foundations of Peripheral Nerve Blocks

1 Essential Regional Anesthesia Anatomy

Admir Hadzic and Carlo Franco

A good practical knowledge of anatomy is important for the successful and safe practice of regional anesthesia. In fact, just as surgical disciplines rely on surgical anatomy, regional anesthesiologists need to have a working knowledge of the anatomy of nerves and associated structures that does not include unnecessary details. In this chapter, the basics of regional anesthesia anatomy necessary for successful implementation of various techniques described later in the book are outlined.

Anatomy of Peripheral Nerves

All peripheral nerves are similar in structure. The *neuron* is the basic functional unit responsible for the conduction of nerve impulses (Figure 1-1). Neurons are the longest cells in the body, many reaching a meter in length. Most neurons are incapable of dividing under normal circumstances, and they have a very limited ability to repair themselves after injury. A typical neuron consists of a cell body (soma) that contains a large nucleus. The cell body is attached to several branching processes, called dendrites, and a single axon. Dendrites receive incoming messages; axons conduct outgoing messages. Axons vary in length, and there is only one per neuron. In peripheral nerves, axons are very long and slender. They are also called nerve fibers.

Connective Tissue

The individual nerve fibers that make up a nerve, like individual wires in an electric cable, are bundled together by connective tissue. The connective tissue of a peripheral nerve is an important part of the nerve. According to its position

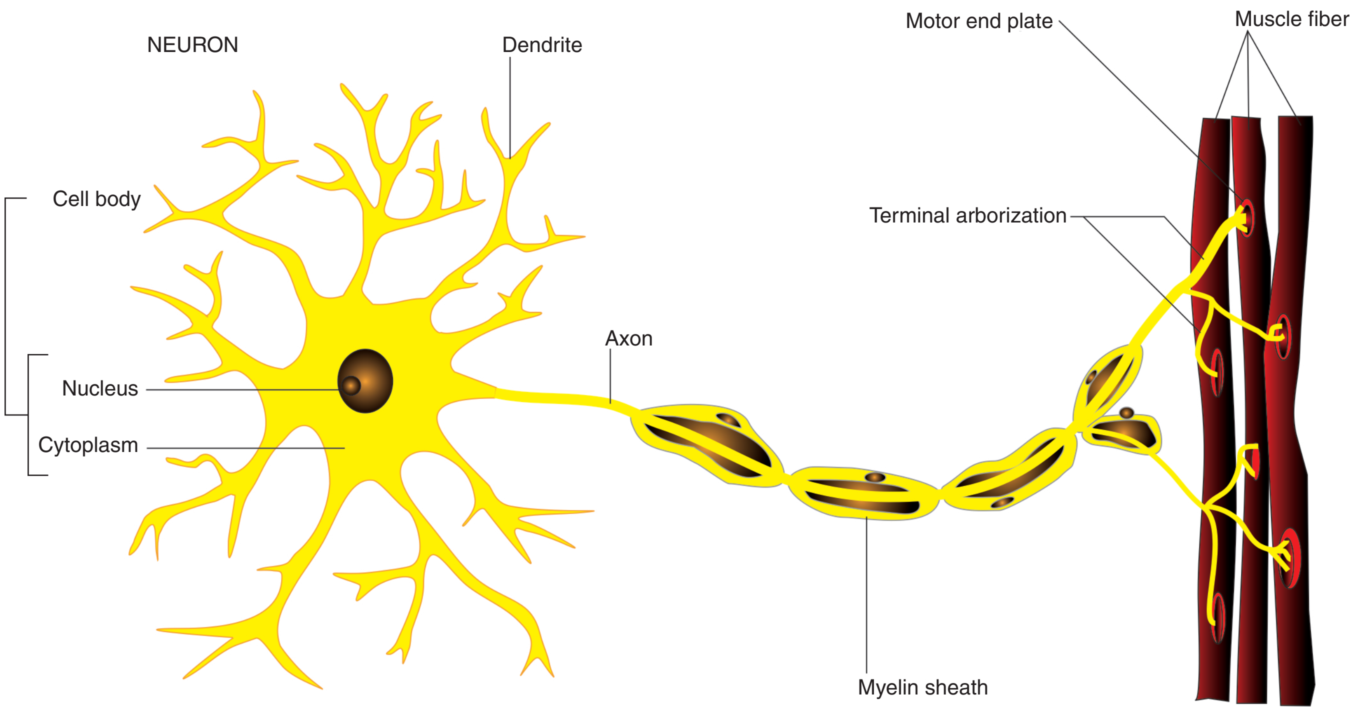

FIGURE 1-1. Organization of the peripheral nerve.

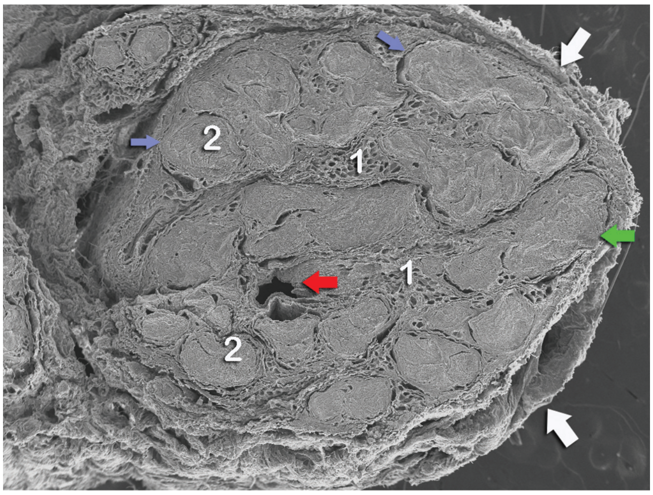

FIGURE 1-2. Histology of the peripheral nerve and connective tissues. *White arrows*: External epineurium (epineural sheath), 1 = Internal epineurium, 2 = fascicles, *Blue arrows*: Perineurium, *Red arrow*: Nerve vasculature *Green arrow*: Fascicular bundle.

in the nerve architecture, the connective tissue is called the epineurium, perineurium, or endoneurium (Figure 1-2). The *epineurium* surrounds the entire nerve and holds it loosely to the connective tissue through which it runs. Each group of axons that bundles together within a nerve forms a fascicle, which is surrounded by perineurium. It is at this level that the nerve–blood barrier is located and constitutes the last protective barrier of the nerve tissue. The *endoneurium* is the fine connective tissue within a fascicle that surrounds every individual nerve fiber or axon.

Nerves receive blood from the adjacent blood vessels running along their course. These feeding branches to larger nerves are macroscopic and irregularly arranged, forming anastomoses to become longitudinally running vessel(s) that supply the nerve and give off subsidiary branches.

Organization of the Spinal Nerves

The nervous system consists of central and peripheral parts. The central nervous system includes the brain and spinal cord. The peripheral nervous system consists of the spinal, cranial, and autonomic nerves, and their associated ganglia. Nerves are bundles of nerve fibers that lie outside the central nervous system and serve to conduct electrical impulses from one region of the body to another. The nerves that make their exit through the skull are known as cranial nerves, and there are 12 pairs of them. The nerves that exit below the skull and between the vertebrae are called spinal nerves, and there are 31 pairs of them. Every spinal nerve has its regional number and can be identified by its association with the adjacent vertebrae (Figure 1-3). In the cervical region, the

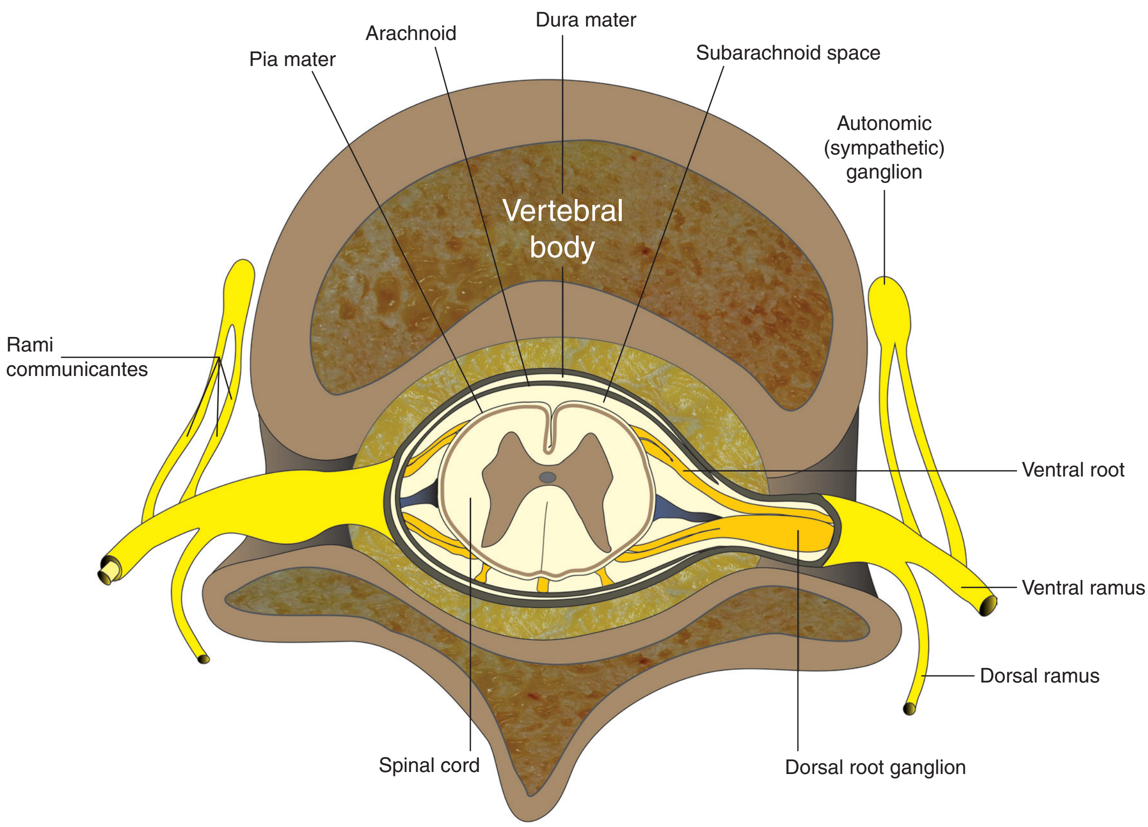

FIGURE 1-3. Organization of the spinal nerve.

first pair of spinal nerves, C1, exits between the skull and the first cervical vertebra. For this reason, a cervical spinal nerve takes its name from the vertebra below it. In other words, cervical nerve C2 precedes vertebra C2, and the same system is used for the rest of the cervical series. The transition from this identification method occurs between the last cervical and first thoracic vertebra. The spinal nerve lying between these two vertebrae has been designated C8. Thus there are seven cervical vertebrae but eight cervical nerves. Spinal nerves caudal to the first thoracic vertebra take their names from the vertebra immediately preceding them. For instance, the spinal nerve T1 emerges immediately caudal to vertebra T1, spinal nerve T2 passes under vertebra T2 and so on.

Origin and Peripheral Distribution of Spinal Nerves

Each spinal nerve is formed by a dorsal and a ventral root that come together at the level of the intervertebral foramen (Figure 1-3). In the thoracic and lumbar levels, the first branch of the spinal nerve carries visceral motor fibers to a nearby autonomic ganglion. Because preganglionic fibers are myelinated, they have a light color and are known as white rami (**Figure 1-4**). Two groups of unmyelinated postganglionic fibers leave the ganglion. Those fibers innervating glands and smooth muscle in the body wall or limbs form the gray ramus that rejoins the spinal nerve. The gray and white rami are collectively called the rami communicantes. Preganglionic or postganglionic fibers that innervate internal organs do not rejoin the spinal nerves. Instead, they form a series of separate autonomic nerves and serve to regulate the activities of organs in the abdominal and pelvic cavities.

The dorsal ramus of each spinal nerve carries sensory innervation from, and motor innervation to, a specific segment of the skin and muscles of the back. The region innervated resembles a horizontal band that begins at the origin of the spinal nerve. The relatively larger ventral ramus supplies the ventrolateral body surface, structures in the body wall, and the limbs. Each spinal nerve supplies a specific segment of the body surface, known as a dermatome.

Dermatomes

A dermatome is an area of the skin supplied by the dorsal (sensory) root of the spinal nerve (**Figures 1-5** and **1-6**). In the head and trunk, each segment is horizontally disposed, except C1, which does not have a sensory component.

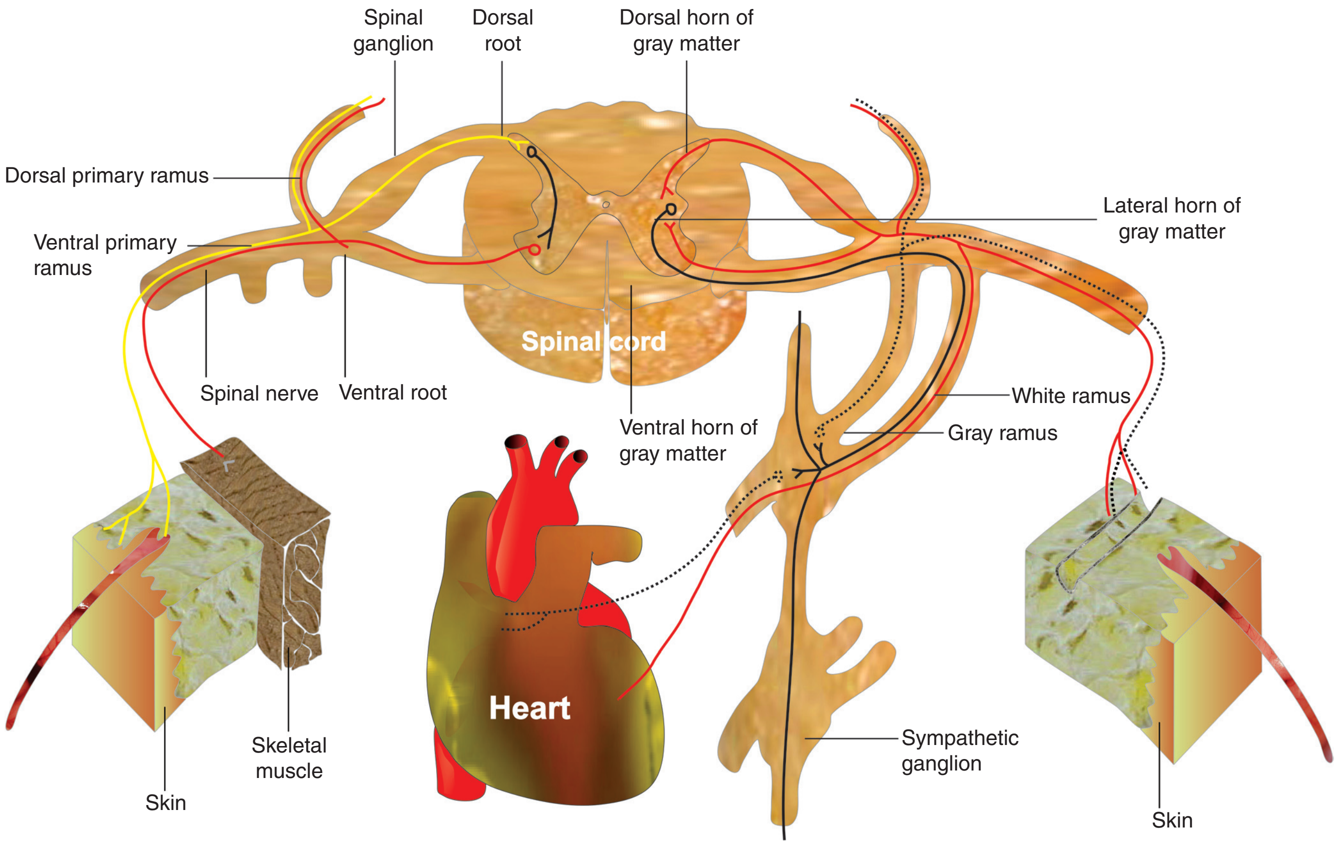

FIGURE 1-4. Organization and function of the segmental (spinal nerve).

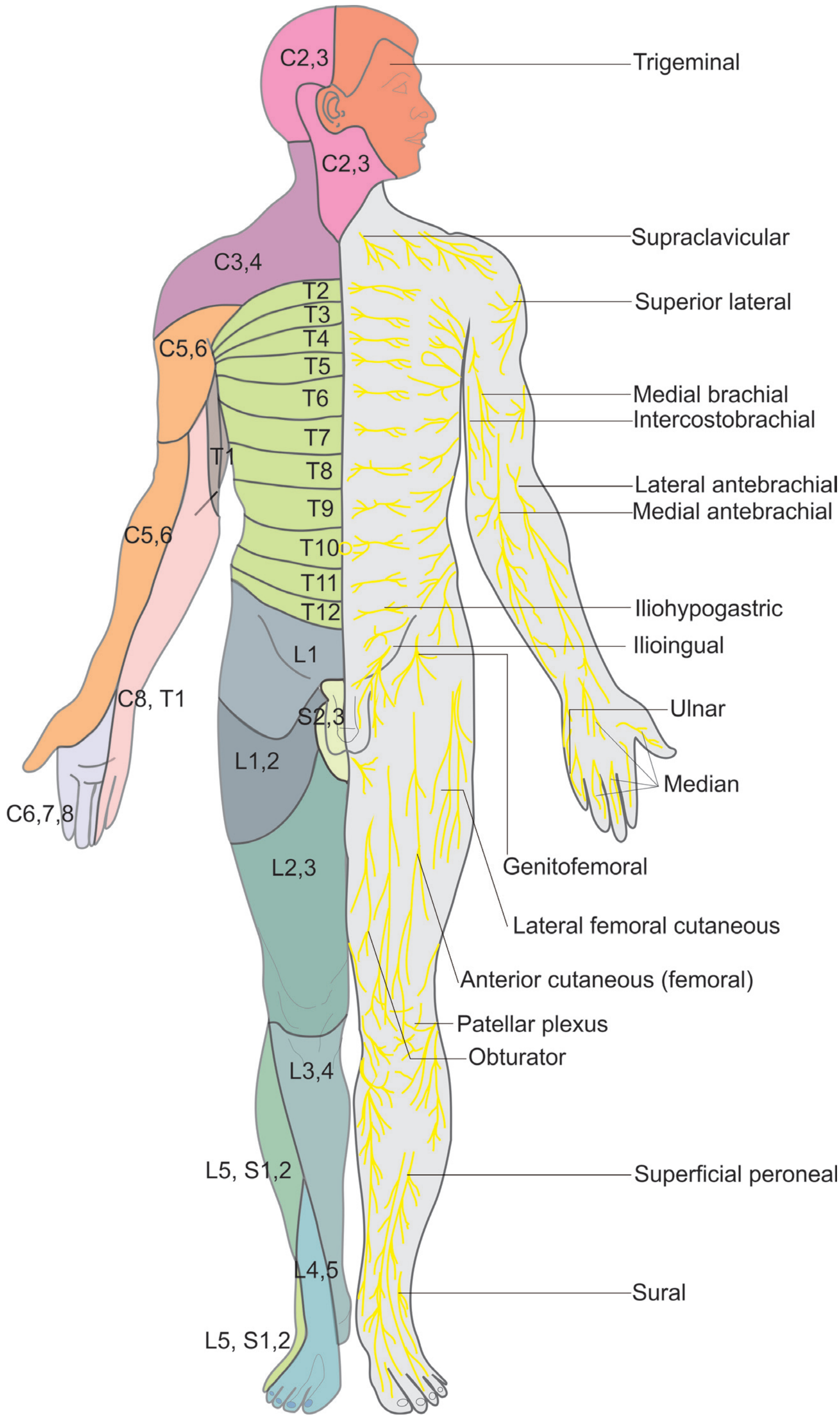

FIGURE 1-5. Dermatomes and corresponding peripheral nerves: front.

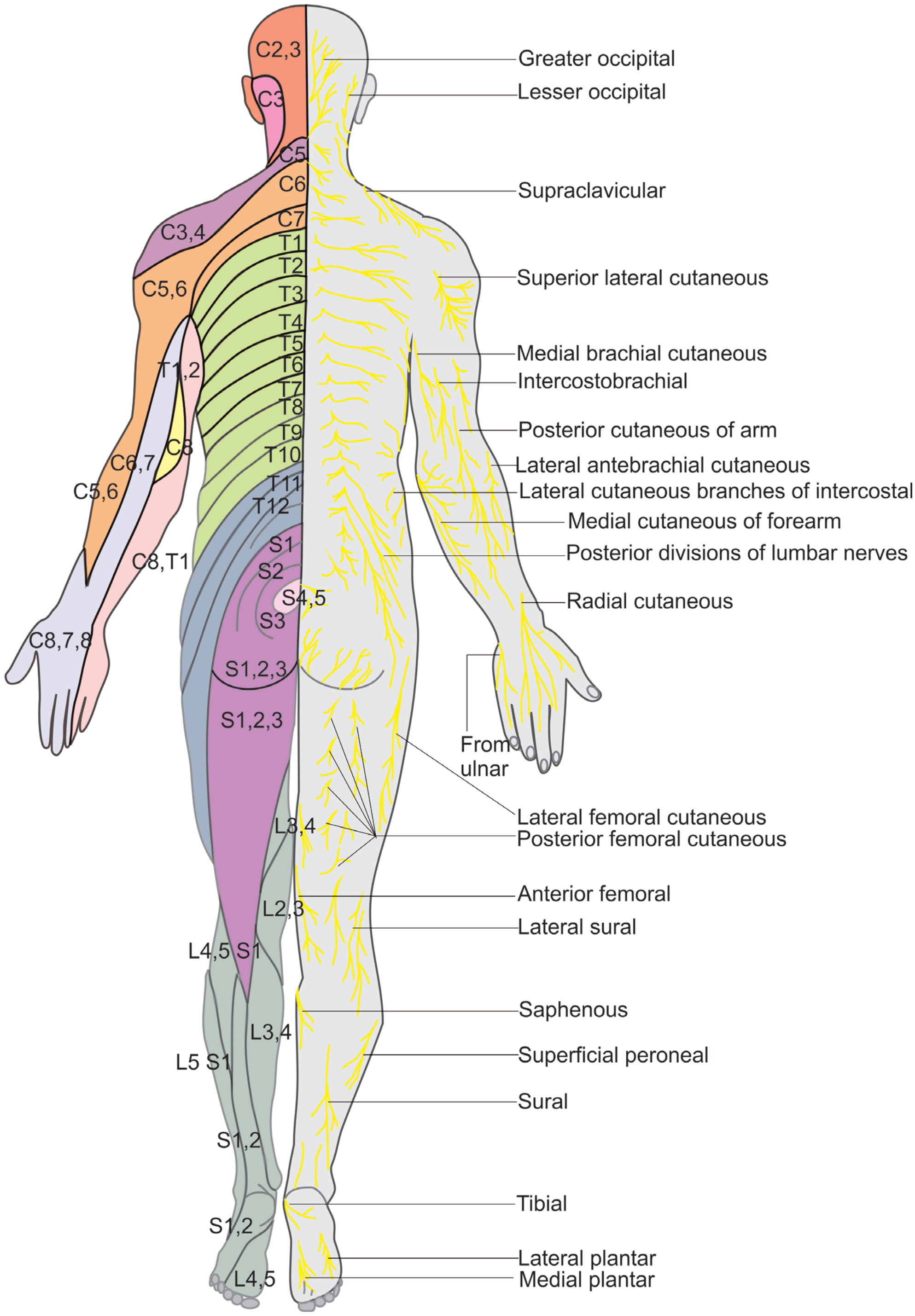

FIGURE 1-6. Dermatomes and corresponding peripheral nerves: back.

The dermatomes of the limbs from the fifth cervical to the first thoracic nerve, and from the third lumbar to the second sacral vertebrae, form a more complicated arrangement due to rotation and growth during embryologic life. There is considerable overlapping of adjacent dermatomes; that is, each segmental nerve overlaps the territories of its neighbors. This pattern is variable among individuals, and it is more of a guide than a fixed map.

Myotomes

A myotome is the segmental innervation of skeletal muscle by a ventral root of a specific spinal nerve (Figure 1-7).

TIPS

- Although the differences between dermatomal, myotomal, and osteotomal innervation are often emphasized in regional anesthesiology textbooks, it is usually impractical to think in those terms when planning a regional block.
- Instead, it is more practical to think in terms of areas of the body that can be blocked by a specific technique.

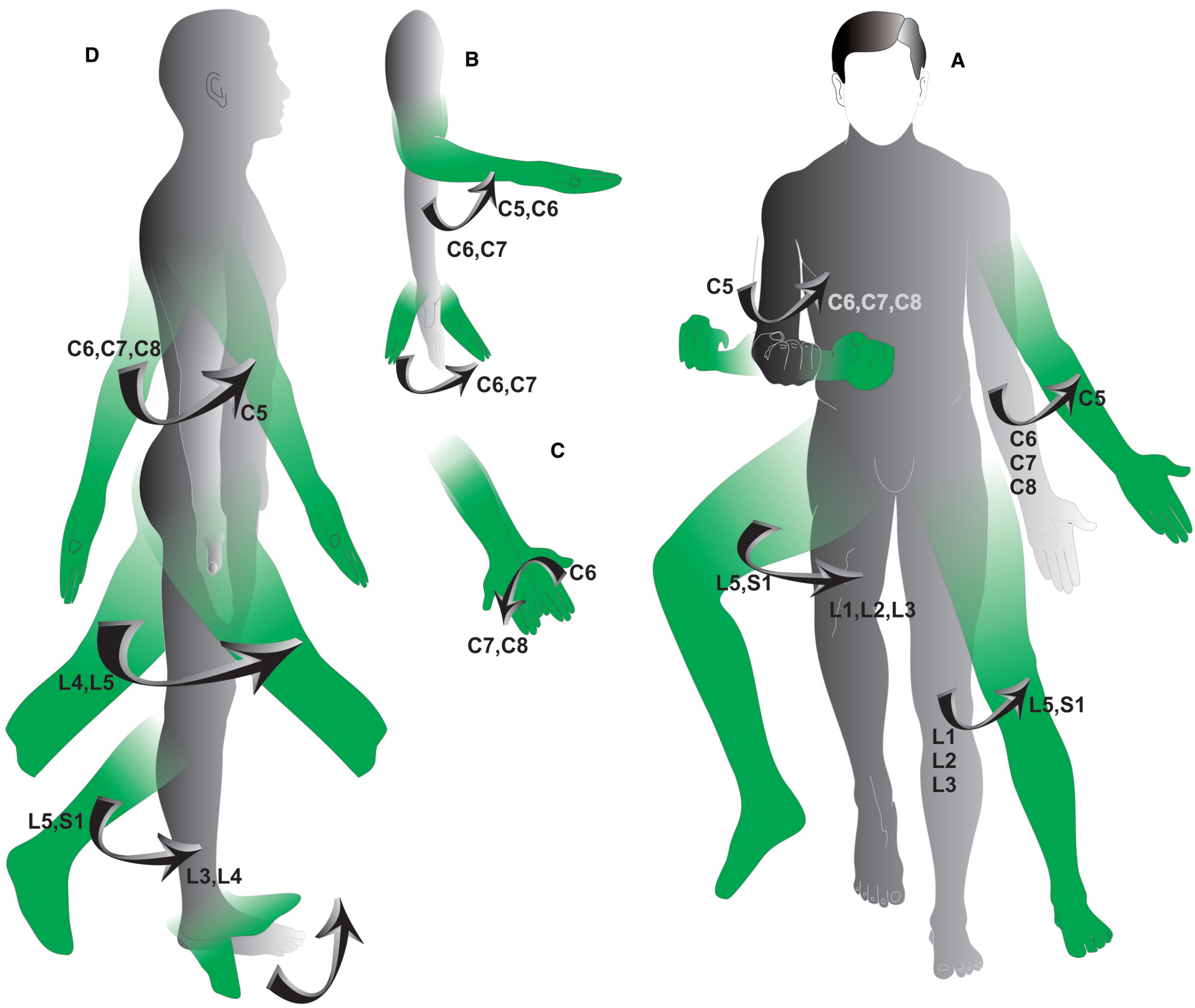

FIGURE 1-7. Motor innervation of the major muscle groups. (A) Medial and lateral rotation of shoulder and hip. Abduction and adduction of shoulder and hip. (B) Flexion and extension of elbow and wrist. (C) Pronation and supination of forearm. (D) Flexion and extension of shoulder, hip, and knee. Dorsiflexion and plantar flexion of ankle, lateral views.

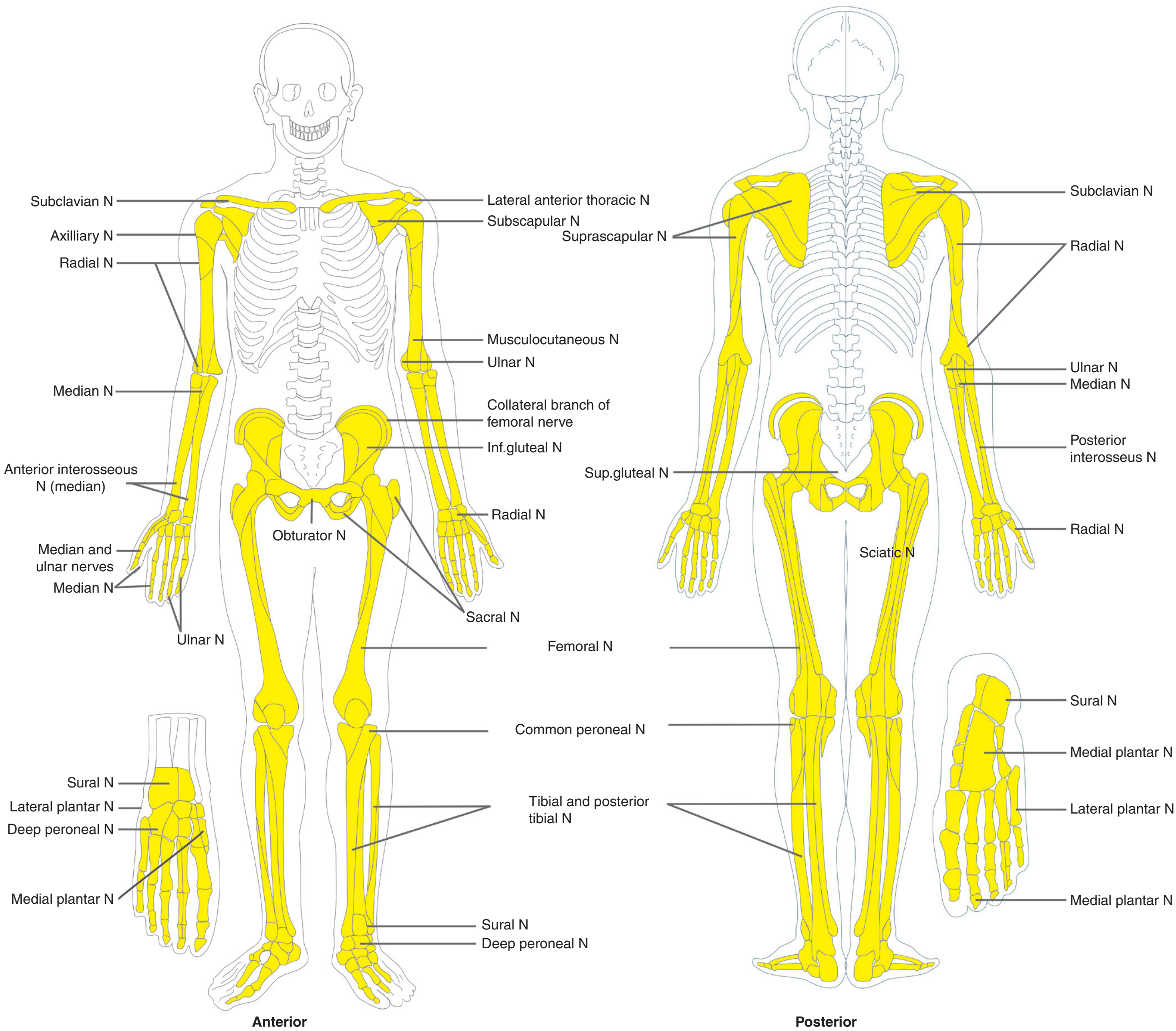

FIGURE 1-8. Osteotomes.

Osteotomes

The innervation of the bones follows its own pattern and does not coincide with the innervation of more superficial structures (Figure 1-8).

Nerve Plexuses

Although the dermatomal innervation of the trunk is simple, the innervation of the extremities, part of the neck, and pelvis is highly complex. In these areas, the ventral rami of the spinal nerves form an intricate neural network; nerve fibers coming from similar spinal segments easily reach different terminal nerves. The four major nerve plexuses are the cervical plexus, brachial plexus, lumbar plexus, and sacral plexus.

The Cervical Plexus

The cervical plexus originates from the ventral rami of C1-C5, which form three loops (Figures 1-9 and 1-10). Branches from the cervical plexus provide sensory innervation of part of the scalp, neck, and upper shoulder and motor innervation to some of the muscles of the neck, the thoracic cavity, and the skin (Table 1-1). The phrenic nerve, one of the larger branches of the plexus, innervates the diaphragm.

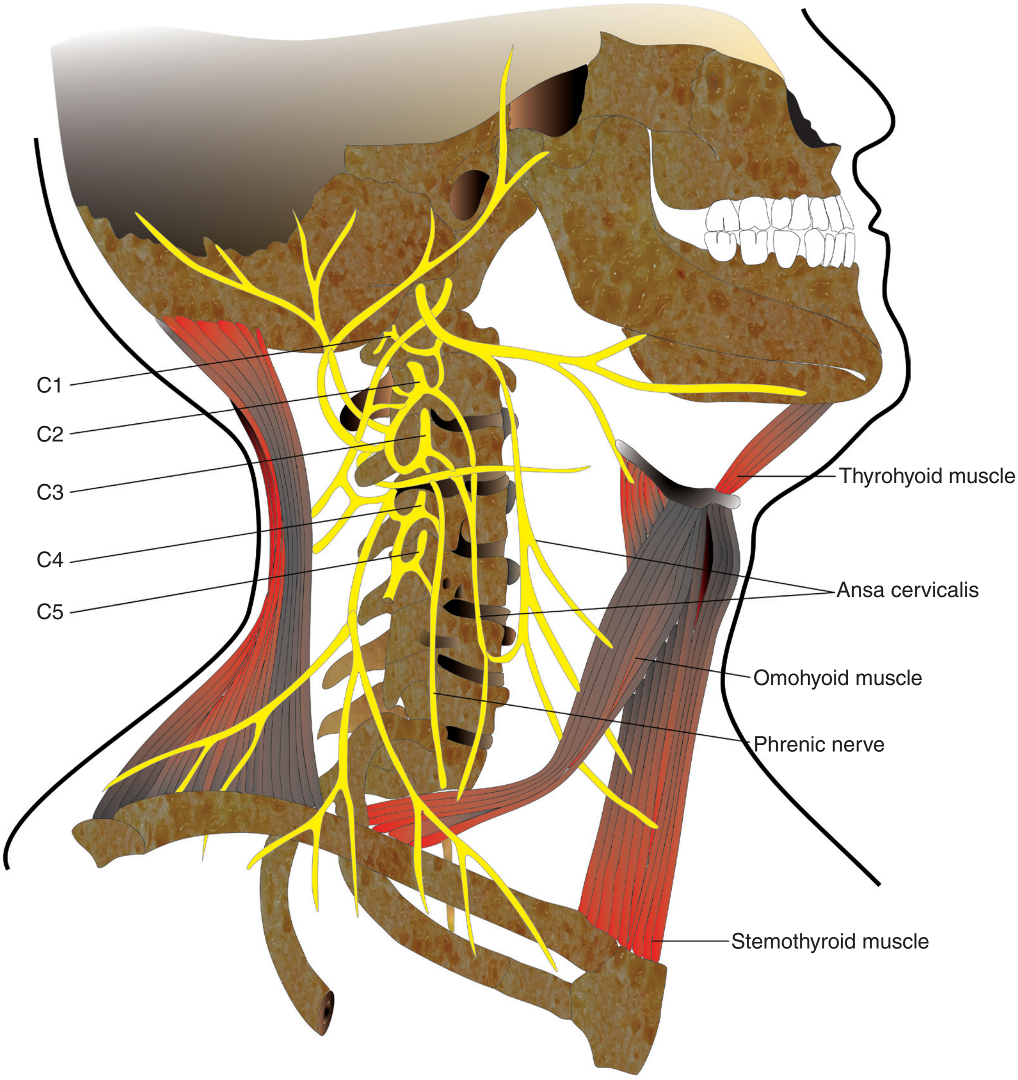

FIGURE 1-9. Organization of the cervical plexus.

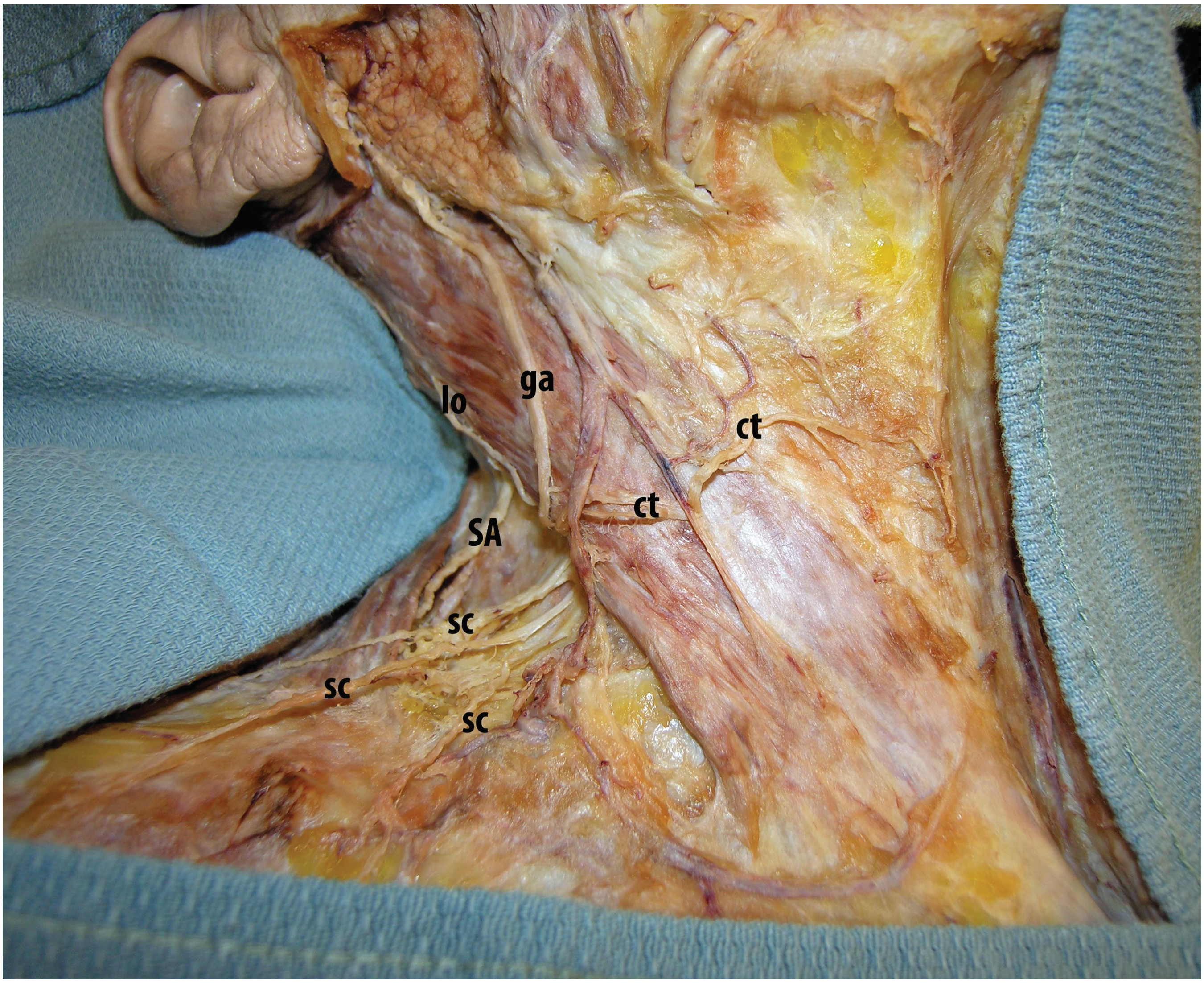

FIGURE 1-10. Superficial cervical plexus branches. ct, transverse cervical; ga, greater auricular; lo, lesser occipital; sc, supraclavicular. Also shown is the spinal accessory nerve (SA).

TABLE 1-1 Organization and Distribution of the Cervical Plexus

NERVES	SPINAL SEGMENTS	DISTRIBUTION
Ansa cervicalis (superior and inferior branches)	C1-C4	Five of the extrinsic laryngeal muscles (sternothyroid, sternohyoid, omohyoid, geniohyoid, and thyrohyoid) by way of N XII
Lesser occipital, transverse cervical, supraclavicular, and greater auricular nerves	C2-C3	Skin of upper chest, shoulder, neck, and ear
Phrenic nerve	C3-C5	Diaphragm
Cervical nerves	C1-C5	Levator scapulae, scalene muscles, sternocleidomastoid, and trapezius muscles (with N XI)

The Brachial Plexus

The brachial plexus is both larger and more complex than the cervical plexus (Figures 1-11, 1-12, 1-13, 1-14A,B, 1-15A,B, and 1-16). It innervates the pectoral girdle and upper limb. The plexus is formed by five roots that originate from the ventral rami of spinal nerves C5-T1. The roots converge to form the superior (C5-C6), middle (C7), and inferior (C8-T1) trunks (Table 1-2). The trunks give off three anterior and three posterior divisions as they approach the clavicle. The divisions rearrange their fibers to form the lateral, medial, and posterior cords. The cords give off the terminal branches. The lateral cord gives off the musculocutaneous nerve, and the lateral root of the median nerve. The medial cord gives off the medial root of the median nerve and the ulnar nerve. The posterior cord gives off the axillary and radial nerves.

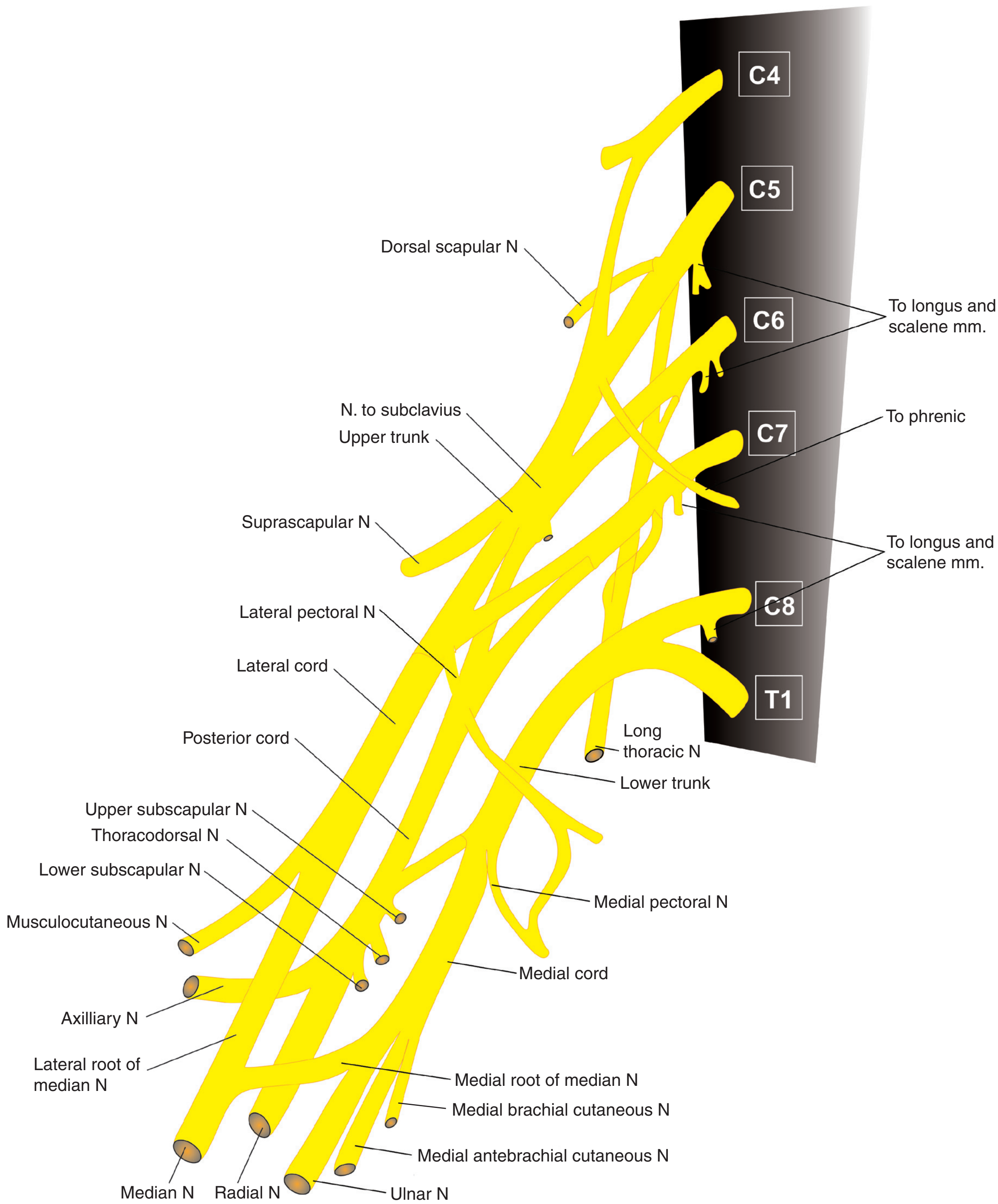

FIGURE 1-11. Organization of the brachial plexus.

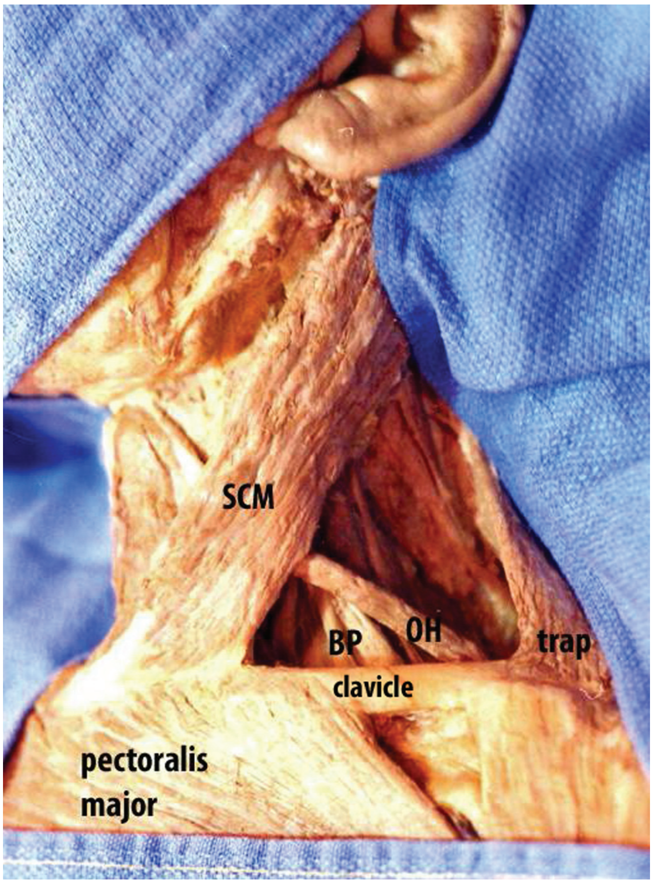

FIGURE 1-12. View of the posterior triangle of the neck, located above the clavicle between the sternocleidomastoid (SCM) in front and the trapezius (trap) behind. It is crossed by the omohyoid muscle (OH) and the brachial plexus (BP).

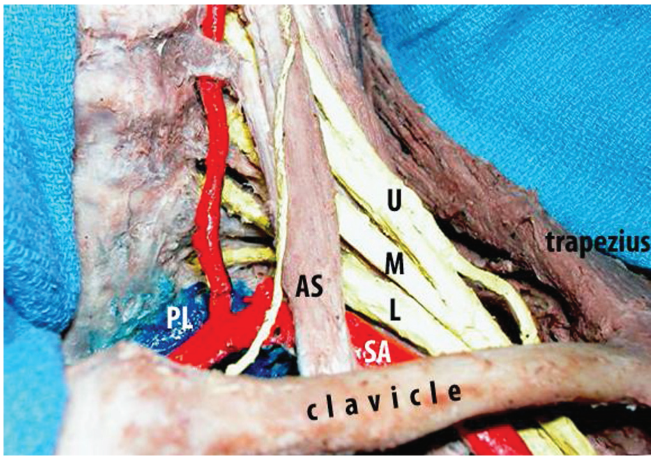

FIGURE 1-13. The brachial plexus (in yellow) at the level of the trunks (U, M, and L) occupies the smallest surface area in its entire trajectory. Also shown are the dome of the pleura (PL) in blue, the subclavian artery (SA) and the vertebral artery, both in red. The phrenic nerve, in yellow, is seen traveling anterior to the anterior scalene muscle (AS).

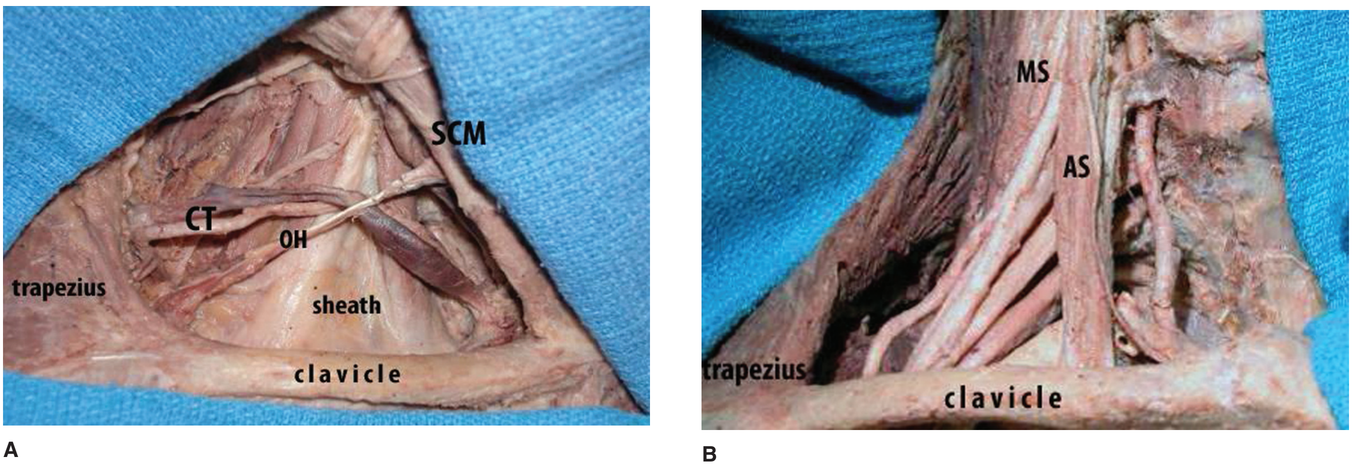

FIGURE 1-14. (A) A thick fascia layer (sheath) covers the brachial plexus in the posterior triangle. Also seen is part of the sternocleidomastoid muscle (SCM), the cervical transverse vessels (CT), and the omohyoid muscle (OH). (B) Once the sheath is removed, the brachial plexus can be seen between the anterior scalene (AS) and middle scalene (MS) muscles. (Part A reproduced with permission from Franco CD, Rahman A, Voronov G, et al. Gross anatomy of the brachial plexus sheath in human cadavers. Reg Anesth Pain Med. 2008;33(1):64-69. Part B reproduced from Franco CD, Clark L. Applied anatomy of the upper extremity. *Tech Reg Anesth Pain Mgmt.* 2008;12(3):134-139, with permission from Elsevier.)