XIV. NERVOUS SYSTEM

DERMATOMES

(1) Begin with the diagram at left, depicting sensory innervation of an area of skin
(dermatome) and the degree of overlap among contiguous spinal nerve cutaneous branches
and the dermatomes they supply. Color the three spinal nerves and the rectangular borders
of the related dermatomes. Note the overlap. (2) Use very light colors for the four groups of derma-
tomes. Use one color for all dermatomes (represented by bordered spaces) with the letter C, an-
other color for the dermatomes marked with a T, and so on with L and S. Suggestion: carefully out-
lining the collection of C dermatomes with the color used for C, then color in the enclosed area,
focusing on the skin areas serviced by the related spinal nerve; repeat with T, L, and S dermatomes.

SPINAL NERVE
DERMATOME

CUTANEOUS
NERVE OVERLAP

Dermatomes of:
CERVICAL NERVES
C2 - C8
THORACIC NERVES
T1 - T12
LUMBAR NERVES
L1 - L5
SACRAL NERVES
S1 - S5

A dermatome is an area of skin (cutaneous area) supplied by the sensory axons of
a single spinal nerve. The body surface is globally covered by sensory receptors;
thus the entire surface can be appreciated as a map of dermatomes (facial "derma-
tomes" supplied by divisions of the V cranial nerve can be seen on Plate 144). This
map was generated from experimental, clinical, and surgical experiences. It is cor-
collaborated in patients presenting with limited spinal cord deficits (myelopathy), nerve
cord deficits (radiculopathy), and peripheral nerve lesions (neuropathy) including
facial pain (trigeminal neuralgia).

There is overlap among cutaneous branches of neighboring sensory axons of different
spinal nerves. Thus, the border zone between each pair of contiguous derma-
tomes is covered by two branches of different spinal nerves. In spite of some degree
of dermatomal overlap, dermatomal pain or sensory deficits can contribute signifi-
cantly to diagnoses of certain neurologic disorders.

It is important to realize that dermatomes reflect only cutaneous pain and pain
referred to the skin (e.g., nerve root irritation, visceral pain). The neurons of the sen-
sory cortex of the cerebral hemisphere and the thalamus cannot generally localize
myofacial and musculoskeletal pain with strict anatomic accuracy. Such painful areas usually "cross" dermatomal lines. Commonly, visceral pain may also be diffi-
cult to localize; however, it may be referred to cutaneous areas served by the same
spinal nerve(s), making the diagnosis easier, e.g., the pain of inflamed pleura (inner-
ated by C3-C5 spinal nerves) in the lower chest may be felt in the C3-C5 derma-
tomes (shoulder) during deep inspiration.

Finally, note that: (1) C1 has no dermatome because it has no sensory root; (2) C4
and T2 dermatomes overlap on the chest wall because the spinal nerves C5-T1 are
committed to the upper limb; (3) and the same is true in the low back and perineum
with respect to spinal nerves L4-S2 which are committed to the lower limb.
The nerves to the lower limb arise from the lumbar (L1-L4) and sacral (S1-S3) plexuses. These plexuses are formed from anterior rami of the spinal nerves noted. The lumbar plexus is located in the retroperitoneum against the posterior abdominal wall; it is the source of two major nerves to the lower limb. The femoral nerve (L2-L4), giving forth an effusion of nerves just below the inguinal ligament, and in company with the (superficial) femoral artery and vein, innervates quadriceps femoris and sartorius and is sensory to the anterior thigh. Trauma to this nerve is most likely in the pelvis as it passes through or near the psoas muscle (hemorrhage, surgical misadventure, and so on). The obturator nerve (L2-L4) passes along the lateral pelvic wall and through the obturator foramen to break up into branches supplying the adductor muscle group. Like the femoral, it too is subject to trauma in the pelvis. Compressions of the L2-L4 nerve roots can be manifested by complaints in the anterior and medial femoral region. The sacral plexus gives rise to a number of important nerves, the most significant being the sciatic nerve (L4-S3). Roughly the size of your thumb, this nerve passes deep to gluteus maximus into the posterior thigh, innervating the "hamstring" muscles. Just above and behind the knee, it splits into peroneal and tibial components. The common peroneal nerve supplies the lateral leg muscles (superficial peroneal) and the anterolateral leg muscles (deep peroneal). The tibial nerve supplies the posterior leg muscles and the plantar muscles (sole of the foot). Compression of the L4-S1 nerve roots commonly affects the sciatic distribution (e.g., sciatica or pain in the lower limb along the sciatic distribution). More significant compression results in specific leg or foot muscle weakness and sensory loss. S1 radiculopathy is characterized by a loss of the achilles (lensocutaneous) reflex or "ankle jerk." The sciatic can also be injured as it exits the greater sciatic notch or in the buttock. The common peroneal nerve is vulnerable as it rounds the subcutaneous fibular neck; trauma to this nerve may be expressed as "foot drop" (loss of ankle/toe extensors). See the appendix for listing of lower limb muscles and their nerve supply.
XIV. NERVOUS SYSTEM
NERVES TO THE UPPER LIMB

1. Use light colors for A-D. (1) In the upper illustration, color the letters and numbers identifying the five roots of the brachial plexus. Note but do not color the small branches of the plexus as you color the plexus itself. Note in the lower illustration the entire plexus is colored gray. (2) As you color each of the major nerves arising from the plexus, color it in the lower illustration as well. As you color each nerve, try to visualize it on your own limb.

BRACHIAL PLEXUS & MAJOR BRANCHES:
ROOTS C5, C6
UPPER TRUNK:
ROOT C7
MIDDLE TRUNK:
ROOTS C8, T1
LOWER TRUNK:
ANTERIOR DIVISION:
LATERAL CORD:
MUSCULOCUTANEOUS N.
BR. TO MEDIAN N.
MEDIAL CORD:
BR. TO MEDIAN N.
ULNAR N.
POSTERIOR DIVISION:
POSTERIOR CORD:
AXILLARY N.
RADIAL N.

The major nerves to the structures of the upper limb arise from the brachial plexus, formed from the anterior rami of spinal nerves C5-T1 (plus or minus one level). These rami form the roots of the plexus. In the pattern illustrated, further branching and joining of fibers in the neck, supraclavicular area, and axilla result in the formation of the five major nerves of the upper limb.

The brachial plexus is subject to injury (plexopathy) from excessive stretching or traction (e.g., rapid, forceful pulling of the upper limb) and compression (e.g., long-term placement of body weight on axillary or arm pit cushions of crutches). In such injuries, there is great variation in degree of deficit, signs, and symptoms.

The musculocutaneous nerve (C5-7) supplies the anterior arm muscles and is cutaneous in the forearm. Packaged in muscle, it is rarely traumatized. C5 and/or C6 nerve root compression can weaken these muscles. The median nerve (C5-C8, T1; "carpal-nerve’s nerve") supplies the anterior forearm muscles and the thenar muscles. It can be compressed at the carpal tunnel (recall PL-27), resulting in some degree of sensory deficit to fingers 1-3 and weakness in thumb movement (carpal tunnel syndrome). Similar complaints can be associated with a C6 nerve root compression.

The ulnar nerve (C8-T1; "musician’s nerve") supplies certain muscles of the forearm and most intrinsic muscles of the hand. It is subject to trauma as it passes the elbow in the cubital tunnel, possibly resulting in ulnar-side finger pain, hand weakness, or abnormal little finger position. Similar complaints can be associated with a C8 nerve root compression. The axillary nerve (C5-6) wraps around the neck of the humerus to supply deltoid and teres minor. It is vulnerable to fractures of the humeral neck, possibly resulting in a weak or paralyzed deltoid muscle. The radial nerve (C5-8, T1) supplies the triceps, brachioradialis, and posterior forearm (extensor) muscles moving the wrist and hand. It is subject to damage as it rounds the mid-shaft of the humerus; significant nerve loss here results in "wrist drop" and loss of ability to work the hand (try moving your fingers with your wrist flexed hard). A C7 radiculopathy is characterized by a weak triceps and loss of the triceps jerk (deep tendon reflex). See the appendix for listing of upper limb muscles and their nerve supply.
Spinal nerves and their branches consist of axons of sensory and/or motor neurons ensheathed in fibrous connective tissue. Individual axons are surrounded by thin envelopes of fibrous tissue (endoneurium) containing nerves and capillaries that supply the living axon. Bundles (fascicles) of axons are bound by thicker, more dense coats of fibrous tissue (perineurium). Between (and within) the fascicles are relatively large vessels and nerve bundles. Surrounding the fascicles are circumferentially arranged loose arrays of fibrous tissue contiguous with deep or superficial fascia (epineurium). These supporting tissues stabilize the neurovascular elements and provide a framework for the nerve in its environment.

**THORACIC SPINAL NERVE:**

**POSTERIOR ROOT**
**ANTERIOR ROOT**

**SPINAL NERVE**

**POSTERIOR RAMUS**
**LATERAL BRANCH**
**MEDIAL BRANCH**

**ANTERIOR RAMUS**
(INTERCOSTAL NERVE)
**LAT. CUTANEOUS BR.**
**ANT. CUTANEOUS BR.**

Each spinal nerve leaves an intervertebral foramen and divides into anterior and posterior (primary) rami. The anterior rami supply all parts of the body except the deep (intrinsic) muscles and skin of the back; thus, the anterior ramus is generally larger than its posterior fellow. The anterior rami contribute to networks of interconnecting nerves (plexuses or plexi) supplying the neck, upper limb, pelvis/perineum, and lower limb. In the torso, anterior rami form the intercostal nerves. The distribution pattern of a typical thoracic spinal nerve is shown in the cross section of the thorax. Note the muscular communications; these will be presented in Plate 151. Note the muscular branches of the anterior ramus passing between innermost and internal intercostal muscles, as well as the lateral and anterior cutaneous branches and their distribution in the superficial fascia. Note the areas of overlap between the cutaneous branches of the anterior rami and those of the posterior ramus. This pattern occurs segmentally and bilaterally throughout the thorax; the lower thoracic spinal nerves also supply most of the abdominal wall.

The anterior rami of the cervical spinal nerves (and T1 spinal nerve) form interconnecting networks from which the nerves to the neck and the upper limb are derived (next plate). The anterior rami of the lumbar and sacral spinal nerves form interconnecting plexuses from which the nerves to the pelvis, perineum and lower limb are derived (Plate 149). Thus, the source of an intercostal nerve can be traced to the single spinal nerve forming it, e.g., T6 spinal nerve, whereas the source of a nerve to the limbs is traced to the collection of spinal nerves that form it, e.g., C5-C8 spinal nerves.
Nervous System: Stretch Reflexes

Use light colors for A and C, and use the same colors you used on Pl. 145 for structures D-F. (1) Color the upper two illustrations simultaneously, in numerical sequence 1-6, including the arrows. The small arrows at the end of the muscle segments indicate contraction or stretch. (2) Color the lower two illustrations similarly. Note that the motor neuron synapsing with the inhibitory interneuron, and the related effector, are not colored.


Spinal Nerves/Roots:
- Spinal Nerve Branch
- Posterior Root Ganglion
- Anterior Root

A reflex (bend back) is an involuntary muscle response to a stimulus. It is a fundamental activity of the nervous system; most body movements and movement of viscerally reflexive, e.g., heart rate, respiratory rate, peristalsis of gastrointestinal motion, and so on. Spinal reflexes involve sensory receptors, sensory neurons, interneurons of the spinal cord, motor neurons, and effectors.

The simplest spinal reflex is a monosynaptic reflex involving two neurons and one synapse (myotatic, stretch, or deep tendon reflex). The reflex is activated by stretching the tendon of a specific muscle, such as the tendon of quadriceps femoris at the knee. This can be done with the sharp tap of a small mallet used for such purposes (or with the 5th-digit-side of a hand). The receptors responsive to such a stretch are the neurotendinous (Golgi tendon) organ and the muscle spindle (specialized muscle fibers with nerve endings sensitive to muscle stretch and motor nerves to those muscles which resist stretch and "unload" the spindle). Impulses generated in these receptors (1) are conducted by sensory neurons (2) to the spinal cord (3); these synapse in the gray matter of the anterior horn motor neurons (4). The motor neuron conducts impulses to the end plate of the effector muscle (5). The muscle contracts sufficiently, in the case of the knee reflex ("jerk"), to extend the knee joint momentarily (6).

Polysynaptic Reflex: Pain Receptor - Interneuron: Facilitating (+) - Inhibiting (-)

Polysynaptic reflexes range from simple withdrawal reflexes to complex reflexes involving several segments of the spinal cord and the brain. In the withdrawal reflex shown, extreme heat applied to the hand of an unsuspecting person induces an involuntary hyperextension of the wrist joint by wrist extensors, associated with a simultaneous relaxation and stretch of the antagonist wrist flexor muscles. Obviously, the former cannot occur without yielding of the latter. The main difference between this reflex and the stretch reflex is the interneuron: two facilitating the withdrawal, and one inhibitory contraction of the antagonist (flexors) to the withdrawal.
**Nervous System**

**PNS: Spinal Nerves & Roots**

Use very light colors D through G. Begin with the upper illustration. Color all three pairs of spinal nerves as they emerge from the intervertebral foramina (M). Color the cross sectional view in the center. Color the spinal nerve axons and the arrows representing direction of impulse flow.

**Spinal Nerve Roots:***

**Posterior Root**
- **Sensory Axon**
- **Cell Body**

**Anterior Root**
- **Motor Axon**
- **Cell Body**

**Spinal Nerve, Ramus**: Spinal nerves are collections of axons of sensory and motor neurons (part of the peripheral nervous system or PNS). They are formed from nerve roots that arise directly from the spinal cord. Axons of sensory neurons make up the posterior root, and axons of motor neurons make up most of the anterior root (it has been reported that some 30% of anterior root axons are sensory). The spinal nerves and their roots are arranged segmentally and bilaterally along the length of the spinal cord. Spinal nerves are very short; formed within the intervertebral foramina, they branch just beyond into anterior and posterior rami. The branches of these rami are distributed bodywide below the head and provide a vehicle for acquisition by the central nervous system (CNS) of sensory information from external and internal receptors, and a means of disseminating motor commands to skeletal, smooth, and cardiac muscle, and to glands.

Spinal nerves and their roots have fairly tight quarters. The relations of these nerves and roots can be best appreciated in the cross sectional view. Nerve roots are vulnerable to irritation (radiculitis) from encroaching hypertrophic bone in the lateral recesses (degenerative joint disease), from bulging intervertebral discs (degenerative disc disease) or from cysts, meningeal tumors, and so on. With compression of axons or blood vessels supplying the axons, functional deficits can result (radiculopathy: sensory loss, motor loss, and/or tendon reflex change).

**Nerve Root Relations:**

**Vertebra:**
- **Body**
- **Lamina**
- **Articular Process**
- **Vertebral Canal**
- **Lateral Recess**
- **Intervertebral Foramen**

The posterior roots of spinal nerves consist of peripheral processes (axons) of sensory neurons, unipolar or pseudo-unipolar neuron cell bodies (aggregations of which are called spinal or posterior root ganglia), and central processes (axons) of sensory neurons. The ganglia form obvious swellings in the area of the intervertebral foramina. The axonal endings synapse with neurons in the posterior horn of the spinal cord or enter the posterior columns (recall Plate 139). The anterior roots consist of axons of motor (multipolar) neurons whose cell bodies reside in the anterior horns of the spinal cord. These neurons are known as lower motor neurons or anterior horn cells and represent the final common pathway for motor commands to skeletal muscle. In the T1-L2 regions of the cord, motor neurons of the sympathetic division of the autonomic (visceral) nervous system reside in the lateral horns (not shown); their axons join the anterior roots.
XIV. NERVOUS SYSTEM
PNS: CRANIAL NERVES

CN. Use light colors throughout. (1) Beginning with the first cranial nerve, color the title on the left, the large Roman numeral, the cranial nerve (cut), and the related function arrow at lower left; and the Roman numeral and accompanying illustration at upper right. The illustrations generally depict target organs/areas. (2) Note carefully the direction of the function arrows at lower left (sensory/aferent is incoming; motor/efferent is outgoing).

CRANIAL NERVES:
- Olfactory (I)
- Optic (II)
- Oculomotor (III)
- Trochlear (IV)
- Trigeminal (V)
- Abducens (VI)
- Facial (VII)
- Vestibulocochlear (VIII)
- Glossopharyngeal (IX)
- Vagus (X)
- Accessory (XI)
- Hypoglossal (XII)

Here cranial nerves and their general target organs/areas are shown. All motor nerves include proprioceptive (sensory) fibers as well. Cranial nerves I and II are derived from the forebrain; all others are brainstem-derived. Cranial nerve nuclei (neuronal cell bodies) are arranged into seven longitudinal columns in the brain stem. Functionally, these columns are general somatic afferent (GSA) or efferent (GSE), general visceral afferent (GVA) or efferent (GVE), special visceral afferent (SVA) or efferent (SVE), and special somatic afferent (SSA). General columns also exist in the spinal cord for spinal nerves; special columns do not. Somatic includes skin, eye, fascial, and musculoskeletal structures; visceral includes smooth muscle and glands of organs with hollow cavities.

- I SVA: smell-sensitive (olfactory receptors in roof/walls of nasal cavity.
- II SVA: light-sensitive (visual) receptors in retina of eye.
- III GSE: extrinsic eye muscles (ext. lat. rectus and sup. oblique); GVE: parasympathetic to ciliary and pupillary sphincter (eye) muscles via ciliary ganglion in orbit.
- IV GSE: to superior oblique muscle of the eye.
- V GSA: thalamus via three divisions indicated; SVE: to muscles of mastication, tensor tympani, tensor veli palatini, mylohyoid, and digastric muscles.
- VI GSE: to lateral rectus muscle of the eye.
- VII SVA: from taste receptors ant. tongue; GSA: from ext. ear; GVE: parasympathetic to glands of nasal/oral cavity, lacrimal gland (via pterygopalatine ganglion in fossa of same name), submandibular/sublingual salivary gland(s) (via submandibular ganglion in region of same name); SVE: to facial muscles, stapedius (mid. ear), stylohyoid, post. digastric muscles.
- VIII SSA: cochlear part is sound-sensitive; vestibular part is sensitive to head balance and movement (equilibrium).
- IX SVA: from taste receptors pos. tongue; GVA: from mucous membranes of posterior mouth, pharynx, auditory tube, and middle ear; SVE: to pressure and chemical receptors in carotid body and common carotid artery; SVE: to sup. constrictor m. of the pharynx, stylopharyngeus, GVE: parasymp. to parotid gland (via otic ganglion in infratemporal fossa).
- X SVA: from taste receptors at base of tongue and epiglottis; GSA: from ext. ear and ext. aud. canal; GVA: from pharynx, larynx, thoracic and abdominal viscera; SVE: to muscles of palate, pharynx, and larynx; GVE: parasymp. to muscles of thoracic and abdominal viscera (via intramural ganglia).
- XI Cranial root: joins vagus (GVA to laryngeal muscles); spinal root (C1-C5): innervates trapezius and sternocleidomastoid muscles.
- XII GSE: to extrinsic and intrinsic muscles of tongue.