CHAPTER 7

Tracts of the Spinal Cord

I. Introduction: Tracts of the Spinal Cord

- consist of fiber bundles that have a common origin and a common termination.
- are somatotopically organized.
- are divided into **ascending and descending pathways**.

II. Ascending Spinal Tracts

- represent functional pathways that convey sensory information from soma or viscera to higher levels of the neuraxis.
- usually consist of a chain of three neurons: first-, second-, and third-order neurons. The first-order neuron is always in the dorsal root ganglion.
- may decussate before reaching their final destination.
- give rise to collateral branches that serve in local spinal reflex arcs.
- include six major tracts:

A. Dorsal column–medial lemniscus pathway (Figure 7-1)

- mediates tactile discrimination, vibration, form recognition, and joint and muscle sensation.
- mediates conscious proprioception.
- receives input from Pacini and Meissner corpuscles, joint receptors, muscle spindles, and Golgi tendon organs (GTOs).

1. **First-order neurons**
   - are located in dorsal root ganglia at all levels.
   - give rise to the **fasciculus gracilis** from the lower extremity.
   - give rise to the **fasciculus cuneatus** from the upper extremity.
   - give rise to axons that ascend in the dorsal columns and terminate in the gracile and cuneate nuclei of the medulla.
2. **Second-order neurons**
   - are located in the gracile and cuneate nuclei of the caudal medulla.
   - give rise to axons, **internal arcuate fibers** that decussate and form a compact fiber bundle, the **medial lemniscus**. The medial lemniscus ascends through the contralateral brainstem to terminate in the ventral posterolateral (**VPL**) nucleus of the thalamus.
3. **Third-order neurons**
   - are located in the VPL nucleus of the thalamus.
   - project via the posterior limb of the internal capsule to the postcentral gyrus, the **somatosensory cortex** (areas 3, 1, and 2).

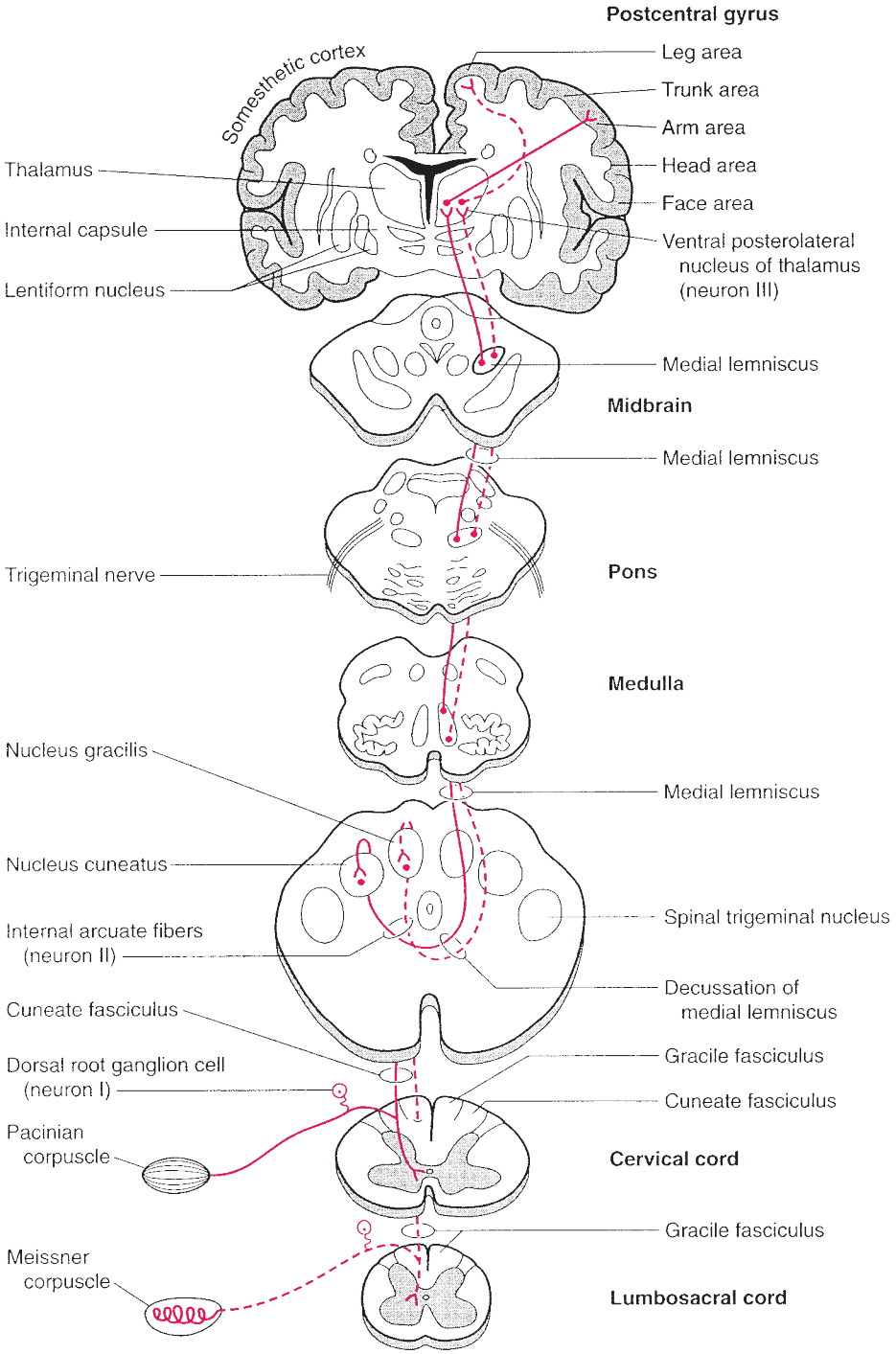


Figure 7-1. The dorsal column–medial lemniscus pathway. Impulses conducted by this pathway mediate discriminatory tactile sense (e.g., touch, vibration, pressure) and kinesthetic sense (e.g., position, movement). The dorsal column system mediates conscious proprioception. (Adapted with permission from Carpenter MB, Sutin J: *Human Neuroanatomy,* 8th ed. Baltimore, Williams & Wilkins, 1983, p 266.)

B. Ventral spinothalamic tract

- with lateral spinothalamic tract comprises anterolateral system.
- is concerned with **light touch**, the sensation produced by stroking glabrous skin with a wisp of cotton.
- receives input from free nerve endings and from Merkel tactile disks.

1. **First-order neurons**
   - are found in dorsal root ganglia at all levels.
   - project axons into the medial root entry zone to second-order neurons in the dorsal horn.
2. **Second-order neurons**
   - are located in the **dorsal horn**.
   - give rise to axons that decussate in the ventral white commissure and ascend in the contralateral ventral funiculus.
   - terminate in the VPL nucleus of the thalamus.
3. **Third-order neurons**
   - are found in the **VPL nucleus** of the thalamus.
   - project via the posterior limb of the internal capsule and corona radiata to the postcentral gyrus (areas 3, 1, and 2).

C. Lateral spinothalamic tract (Figure 7-2)

- mediates itch, pain, and temperature sensation.
- receives input from free nerve endings and thermal receptors.
- receives input from A-δ and C fibers (i.e., fast- and slow-conducting pain fibers, respectively).
- is somatotopically organized with sacral fibers dorsolaterally and cervical fibers ventromedially.

1. **First-order neurons**
   - are found in dorsal root ganglia at all levels.
   - project axons via the **dorsolateral tract of Lissauer** to second-order neurons in the dorsal horn.
   - synapse with second-order neurons in the dorsal horn.
2. **Second-order neurons**
   - are found in the dorsal horn.
   - give rise to axons that decussate in the **ventral white commissure** and ascend in the ventral half of the lateral funiculus.
   - project collaterals to the reticular formation.
   - terminate contralaterally in the VPL nucleus and bilaterally in the intralaminar nuclei of the thalamus.
3. **Third-order neurons**
   - are found in the VPL nucleus and in the intralaminar nuclei.
   a. **VPL neurons**
      - project via the posterior limb of the internal capsule to the somatesthetic cortex of the postcentral gyrus (areas 3, 1, and 2).
   b. **Intralaminar neurons**
      - project to the caudatoputamen and to the frontal and parietal cortex.

D. Dorsal spinocerebellar tract (Figure 7-3)

- transmits unconscious proprioceptive information to the cerebellum.
- receives input from muscle spindles, GTOs, and pressure receptors.
- is involved in fine coordination of posture and the movement of individual muscles of the lower extremity.
- is an uncrossed tract.

1. **First-order neurons**
   - are found in dorsal root ganglia from C8 to S3.
   - provide the afferent limb for muscle stretch reflexes (MSRs) (e.g., the patellar reflex).
   - project via the medial root entry zone to synapse in the **nucleus dorsalis of Clarke**.

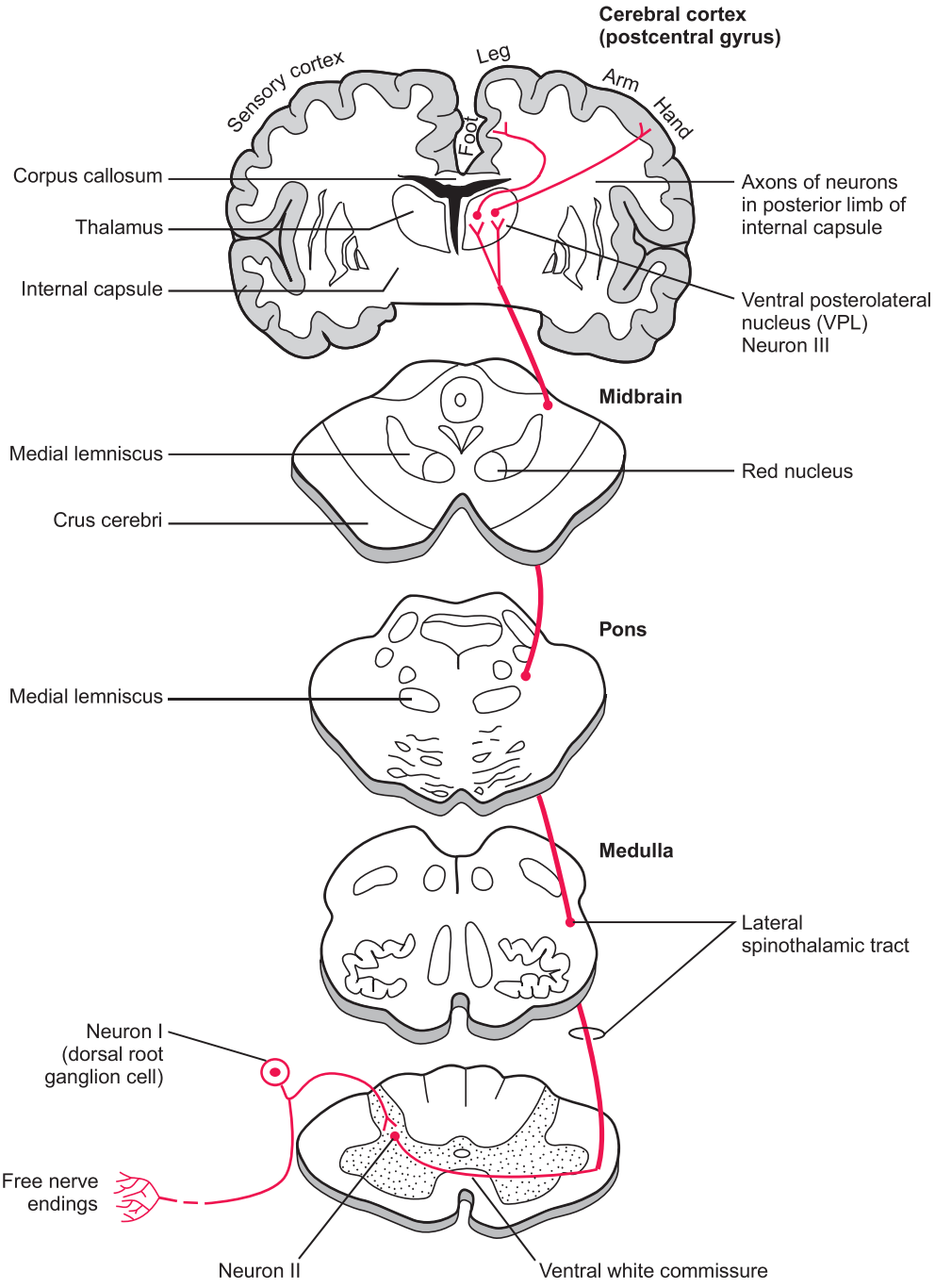


Figure 7-2. The lateral spinothalamic tract. Impulses conducted by this tract mediate pain and thermal sense. Numerous collaterals are distributed to the brainstem reticular formation. (Adapted with permission from Carpenter MB, Sutin J: *Human Neuroanatomy,* 8th ed. Baltimore, Williams & Wilkins, 1983, p 274.)

2. **Second-order neurons**
   - are found in the nucleus dorsalis of Clarke (C8–L3).
   - give rise to axons that ascend in the lateral funiculus and reach the cerebellum via the inferior cerebellar peduncle.
   - contain axons that terminate ipsilaterally as mossy fibers in the cortex of the rostral and caudal cerebellar vermis.

E. Ventral spinocerebellar tract (see Figure 7-3)

- transmits unconscious proprioceptive information to the cerebellum.
- is concerned with coordinated movement and posture of the entire lower extremity.
- receives input from muscle spindles, GTOs, and pressure receptors.
- is a crossed tract.

1. **First-order neurons**
   - are found in the dorsal root ganglia from L1 to S2.
   - provide the afferent limb for MSRs (e.g., the patellar reflex).
   - synapse on **spinal border cells**.
2. **Second-order neurons**
   - are spinal border cells found in the ventral horns (L1–S2).
   - give rise to axons that decussate in the ventral white commissure and ascend lateral to the lateral spinothalamic tract in the lateral funiculus.
   - give rise to axons that enter the cerebellum via the **superior cerebellar peduncle** and terminate contralaterally as mossy fibers in the cortex of the rostral cerebellar vermis.

F. Cuneocerebellar tract (see Figure 7-3)

- is the upper-extremity equivalent of the dorsal spinocerebellar tract.

1. **First-order neurons**
   - are found in the dorsal root ganglia from C2 to T7.
   - project their axons via the fasciculus cuneatus to the caudal medulla, where they synapse in the **accessory cuneate nucleus**, a homolog of the nucleus dorsalis of Clarke.
2. **Second-order neurons**
   - are located in the accessory cuneate nucleus of the medulla.
   - give rise to axons that project to the cerebellum via the **inferior cerebellar peduncle**. These axons terminate ipsilaterally in the arm region of the anterior lobe of the cerebellum.

III. Descending Spinal Tracts (Figures 7-4 and 7-5)

- are concerned with somatic and visceral motor activities.
- have their cells of origin in the cerebral cortex or in the brainstem.

A. Lateral corticospinal (pyramidal) tract (see Figure 7-4)

- is not fully myelinated until the end of the second year.

1. **Function: the lateral corticospinal tract**
   - is concerned with **volitional skilled motor activity**, primarily of the digits of the upper limb.
   - modulates the transmission of sensory input via the ascending sensory pathways.
   - receives input from the **paracentral lobule**, a medial continuation of the motor and sensory cortices, and subserves the muscles of the contralateral leg and foot.
2. **Origin and termination: the lateral corticospinal tract**
   - arises from lamina V of the cerebral cortex from three cortical areas, in equal proportions: the **premotor cortex** (area 6); the **precentral motor cortex** (area 4); and the **postcentral sensory cortex** (areas 3, 1, and 2).
   - terminates via interneurons on ventral horn motor neurons and sensory neurons of the dorsal horn.
3. **Fibers of the lateral corticospinal tract**
   - number approximately 1 million.
   - are usually (90%) between 1 and 4 μm in diameter.
   - are usually (67%) myelinated.

(text continues on page 114)

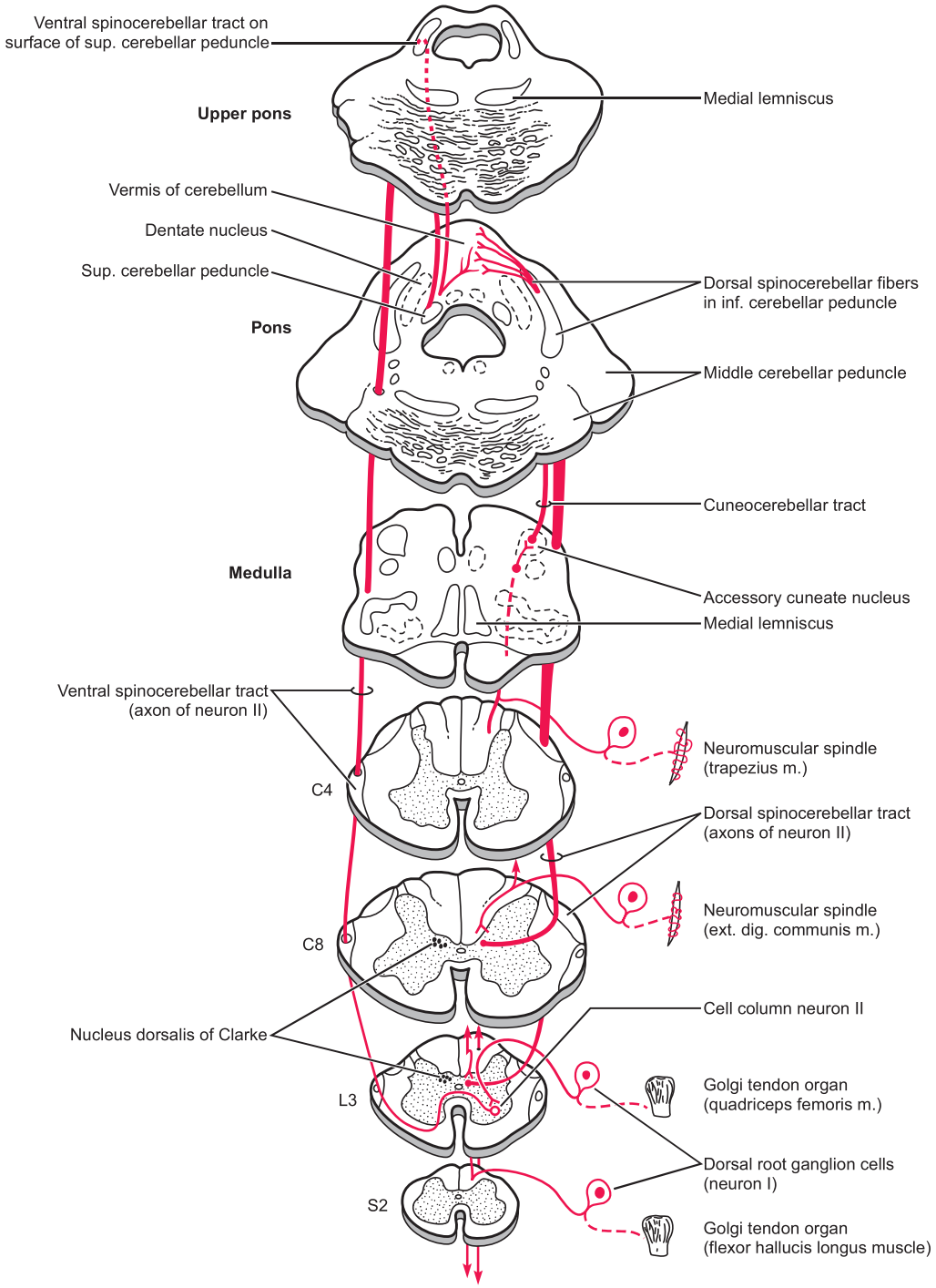


Figure 7-3. Schematic diagram of the ventral and dorsal spinocerebellar tracts and the cuneocerebellar tract. Impulses conducted by these tracts arise from the muscle spindles and the Golgi tendon organs and are conveyed to the spinocerebellum. These tracts mediate unconscious proprioception. Their first-order neurons mediate the myotatic reflexes. (Adapted with permission from Carpenter MB, Sutin J: *Human Neuroanatomy,* 8th ed. Baltimore, Williams & Wilkins, 1983, p 277.)

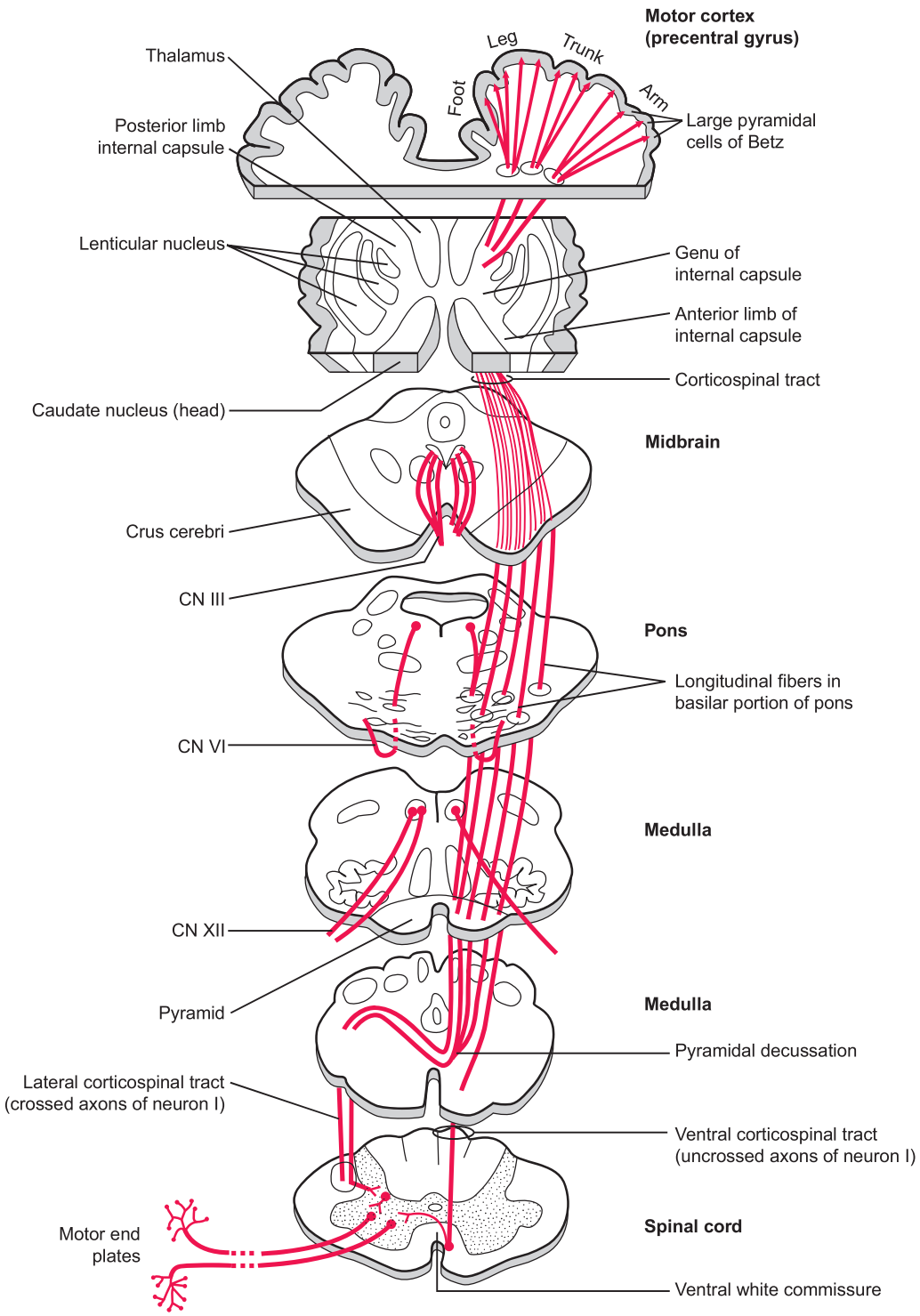


Figure 7-4. The lateral and ventral corticospinal tracts (the pyramidal tracts). These major descending motor pathways mediate volitional motor activity. The cells of origin are located in the premotor, the motor, and the sensory cortices. (Adapted with permission from Carpenter MB, Sutin J: *Human Neuroanatomy,* 8th ed. Baltimore, Williams & Wilkins, 1983, p 285.)

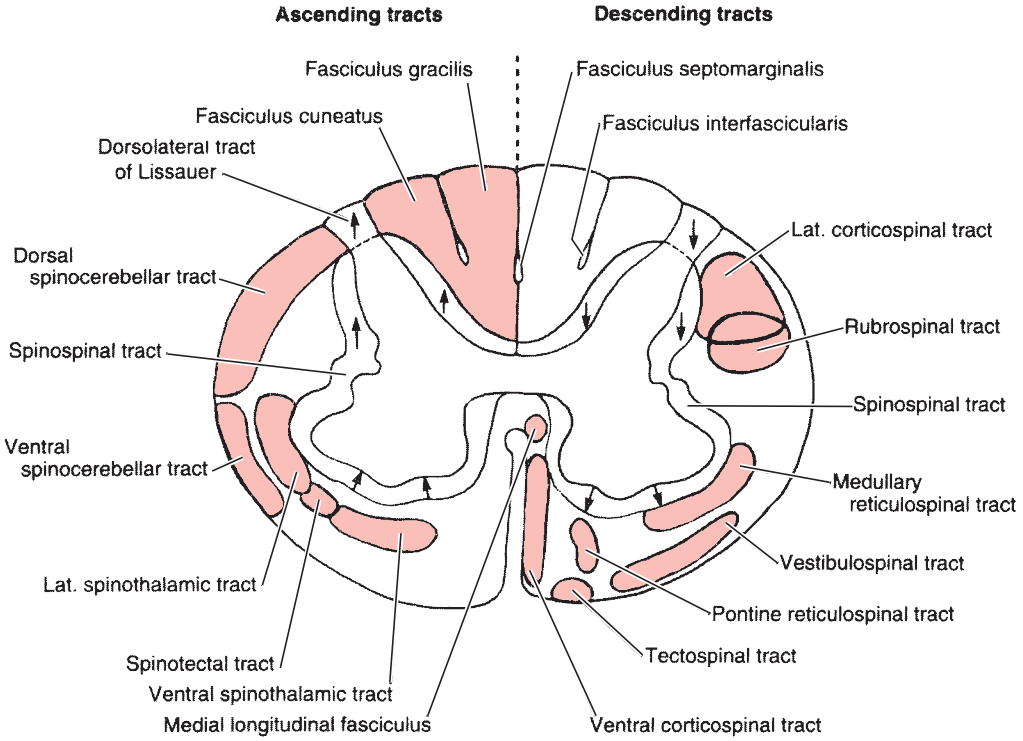


Figure 7-5. Schematic diagram of the major ascending and descending pathways of the spinal cord. The spinospinal system surrounds the spinal gray matter. Ascending tracts are shown on the *left*; descending tracts are shown on the *right*. (Adapted with permission from Carpenter MB: *Core Text of Neuroanatomy,* 3rd. ed. Baltimore, Williams & Wilkins, 1985, p 97.)

- represent 4% of the fibers of the tract, with diameters greater than 20 µm. These are the axons of the **giant cells of Betz**.
- Betz cells are found in the precentral gyrus and in the anterior paracentral lobule.

4. **Course: the lateral corticospinal tract**
   - passes through the posterior limb of the internal capsule.
   - passes through the middle three-fifths of the **crus cerebri** (basis pedunculi) of the midbrain.
   - passes through the base of the pons.
   - constitutes the pyramid of the medulla.
   - undergoes a 90% decussation in the caudal medulla.
   - lies in the dorsal quadrant of the lateral funiculus of the spinal cord.
5. **Transection**
   - results in **spastic hemiparesis** with the Babinski sign.

B. Ventral corticospinal tract (see Figure 7-4)

- is a small uncrossed tract that decussates at spinal cord levels in the ventral white commissure.
- is concerned with the control of axial muscles.

C. Rubrospinal tract (see Figure 7-5)

- arises in the contralateral red nucleus of the midbrain.
- plays a role in the control of flexor tone.
- is ventral to the lateral corticospinal tract.

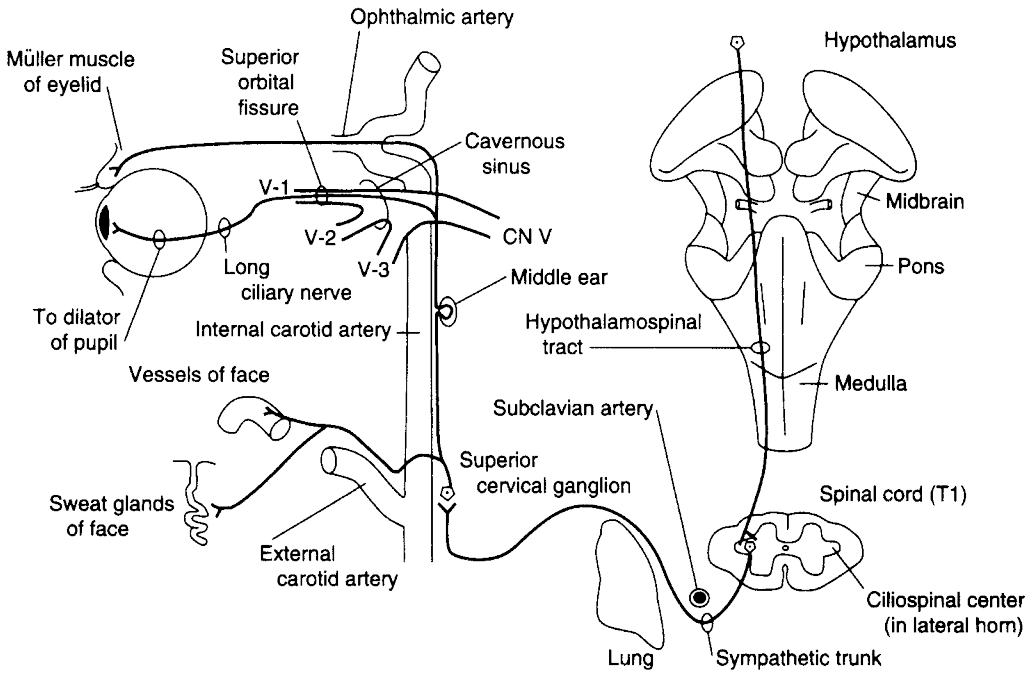


Figure 7-6. The oculosympathetic pathway. Hypothalamic fibers project to the ipsilateral ciliospinal center of the intermediolateral cell column at T1. The ciliospinal center projects preganglionic sympathetic fibers to the superior cervical ganglion. The superior cervical ganglion projects perivascular postganglionic sympathetic fibers through the tympanic cavity, cavernous sinus, and superior orbital fissure to the dilator muscle of the iris. Interruption of this pathway at any level results in Horner syndrome. *CN* = cranial nerve. (Reprinted with permission from Fix, JD: *High-Yield Neuroanatomy,* 3rd ed. Philadelphia, Lippincott Williams & Wilkins, 2005, p 67.)

D. Vestibulospinal tract (see Figure 7-5)

- arises from the giant cells of Deiters in the ipsilateral lateral vestibular nucleus.
- plays a role in the control of extensor tone.
- is located in the ventral funiculus.

E. Descending autonomic tracts (Figure 7-6)

- project to sympathetic (T1–L3) and parasympathetic (S2–S4) centers in the spinal cord.
- innervate the ciliospinal center (T1–T2), a pupillary center; interruption of this hypothalamospinal tract (found in the dorsal quadrant of the lateral funiculus) results in **Horner syndrome**.

IV. Clinical Correlations

A. Upper motor neurons (UMNs)

- are cortical neurons that give rise to corticobulbar or corticospinal tracts.
- are found in brainstem nuclei that influence lower motor neurons (LMNs) (e.g., lateral vestibular nucleus, red nucleus).
- terminate directly on or via interneurons on LMNs.

B. UMN lesions

- are caused by damage to the neurons (or their axons) that innervate LMNs.

1. **Acute-stage lesions**
   - result in transient spinal shock, including:
     a. **Flaccid paralysis**
     b. **Areflexia**
     c. **Hypotonia**
2. **Chronic-stage lesions**
   - result in:
     a. **Spastic paresis**
     b. **Hypertonia**
        - occurs with increased tone in antigravity muscles (i.e., flexors of arms and extensors of legs).
     c. **Reduction or loss of superficial abdominal and cremasteric reflexes**
     d. **Extensor toe response (Babinski sign)**
     e. **Clonus**
        - is a repetitive, sustained MSR (e.g., ankle clonus).

C. LMNs

- are neurons that directly innervate skeletal muscles.
- are found in the ventral horns of the spinal cord.
- are found in the motor nuclei of CN III, CN IV to CN VII, and CN IX to CN XII.

D. LMN lesions

- result from damage to motor neurons or their peripheral axons.
- result in:
  1. **Flaccid paralysis**
  2. **Areflexia**
  3. **Muscle atrophy**
  4. **Fasciculations and fibrillations**

REVIEW TEST

1. The ability to recognize an unseen familiar object placed in the hand depends on the integrity of which pathway?

(A) Spinospinal tract
(B) Dorsal column
(C) Dorsal spinocerebellar tract
(D) Spino-olivary tract
(E) Spinothalamic tract

2. The spinal tract involved with the control of trunk muscles is the

(A) cuneocerebellar
(B) vestibulospinal
(C) ventral corticospinal
(D) lateral corticospinal
(E) ventral spinocerebellar

3. The sensation produced by a wisp of cotton on one's fingertip is mediated by the

(A) cuneocerebellar tract
(B) dorsal column–medial lemniscus pathway
(C) ventral spinocerebellar tract
(D) ventral corticospinal tract
(E) ventral spinothalamic tract

4. First-order neurons of the ventral spinocerebellar tract

(A) are found in dorsal root ganglia at all levels
(B) provide the afferent limb for muscle stretch reflexes
(C) project axons into the medial root entry zone
(D) give rise to the fasciculus cuneatus
(E) project axons via the tract of Lissauer

5. Acute-stage upper motor neuron lesions result in

(A) hypertonia
(B) spastic paresis
(C) flaccid paralysis
(D) extensor toe response
(E) clonus

Questions 6 to 10

The response options for items 6 to 10 are the same. Select one answer for each item in the set.

(A) Cuneocerebellar tract
(B) Cuneate fasciculus
(C) Dorsal spinocerebellar tract
(D) Lateral corticospinal tract
(E) Lateral spinothalamic tract
(F) Lissauer tract
(G) Vestibulospinal tract

Match each statement below with the appropriate spinal cord tract.

6. Contains axons from the giant cells of Deiters

7. Is the upper extremity equivalent of a tract that arises from the cells of Clarke column

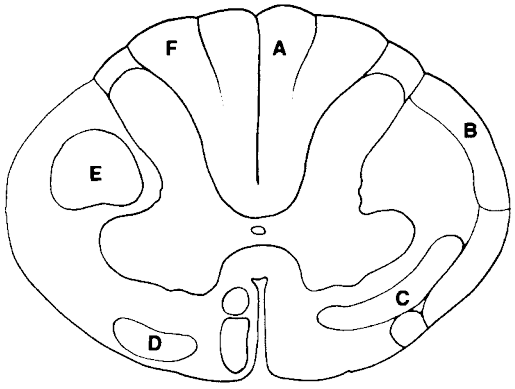
8. Conveys nociceptive input from the contralateral side of the body

9. Contains axons from the giant cells of Betz

10. Contains ipsilateral pain fibers that have their second-order neurons in the dorsal horn

Questions 11 to 18

Match the description of a spinal cord tract in items 11 to 18 with the appropriate lettered structure shown in the figure.



11. Projects to the cerebellum via the inferior cerebellar peduncle

12. Mediates pain and temperature sensation

13. Cells of origin are found in the precentral gyrus

14. Mediates two-point tactile discrimination from the hand

15. Myelination is not fully achieved until the end of the second year

16. Transection results in spasticity

17. Plays a role in regulating extensor tone

18. Transmits vibration sensation from the ankle

A ANSWERS AND EXPLANATIONS

1–B. The ability to recognize the form and texture of an unseen familiar object is called stereognosis. This is an important function of the dorsal column–medial lemniscus system.

2–C. The ventral corticospinal tract is concerned with the control of axial muscles, including the muscles of the trunk and head.

3–E. The ventral spinothalamic tract is concerned with light touch, the sensation produced by stroking glabrous skin with a wisp of cotton.

4–B. First-order neurons of the ventral spinocerebellar tract provide the afferent limb for muscle stretch reflexes. They are found in the dorsal root ganglia from L1 to S2 and synapse on spinal border cell. First-order neurons of the ventral spinothalamic and dorsal spinocerebellar tracts project axons into the medial root entry zone; first-order neurons of the dorsal column–medial lemniscus pathway give rise to the fasciculus gracilis and cuneatus; and first-order neurons of the lateral spinothalamic tract project axons via the dorsolateral tract of Lissauer.

5–C. Acute-stage upper motor neuron lesions result in transient spinal shock, which includes flaccid paralysis, areflexia, and hypotonia. Chronic-stage lesions result in spastic paresis, hypertonia, reduction or loss of superficial abdominal and cremasteric reflexes and extensor toe response, and clonus.

6–G. The vestibulospinal tract arises from the giant cells of Deiters found in the ipsilateral lateral vestibular nucleus of the pons. The vestibulospinal tract facilitates extensor muscle tone.

7–A. The cuneocerebellar tract is the upper extremity equivalent of the dorsal spinocerebellar tract, which arises from the cells of the Clarke column. The cuneocerebellar tract arises from cells of the accessory cuneate nucleus, a homolog of the nucleus of Clarke.

8–E. The lateral spinothalamic tract conveys nociceptive input from the contralateral side of the body.

9–D. The lateral corticospinal tract contains axons from the giant cells of Betz. The giant pyramidal cells of Betz are found in the precentral gyrus and in the anterior paracentral lobule.

10–F. The dorsolateral tract of Lissauer contains ipsilateral pain fibers that have their second-order neurons in the dorsal horn.

11–B. The dorsal spinocerebellar tract projects unconscious proprioceptive information (muscle spindles and GTOs) to the cerebellum via the inferior cerebellar peduncle.

12–C. The lateral spinothalamic tract lies between the ventral spinocerebellar tract and the ventral horn. It mediates pain and temperature sensation.

13–E. The lateral corticospinal tract has its cells of origin in the premotor, motor, and sensory cortices. The precentral gyrus and the anterior paracentral lobule are motor cortices and contain the motor homunculus. The lateral corticospinal gives rise to one-third of the fibers of the corticospinal (pyramidal) tract.

14–F. The fasciculus cuneatus mediates two-point tactile discrimination from the hand.

15–E. The corticospinal (pyramidal) tracts are not fully myelinated until the end of the second year. For this reason, the Babinski sign may be elicited in young children.

16–E. Transection of the lateral corticospinal tract results in spastic paresis (exaggerated MSRs and clonus).

17–D. The vestibulospinal (lateral) tract, found ventral to the ventral horn, plays a role in regulating extensor tone.

18–A. The fasciculus gracilis transmits vibratory sensation (pallesthesia) from the lower extremities.

Some authors refer to the spinothalamic tracts as the anterolateral system.