بسم الله الرحمن الرحيم

﴿ قالوا سبحانك لا علم لنا الا ما علمتنا

إنك انت العليم الحكيم ﴾

صدق الله العظيم

الآيه(32) سوره البقره

INTRODUCTIO

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Main Divisions

❑ **A. Anatomy:**

The human nervous system is a complex of two subdivisions.

1. **CNS**

✓ comprising the brain & spinal cord

✓ enclosed in bone and wrapped in protective coverings (meninges) and fluid-filled spaces.

2. Peripheral nervous system (PNS)

the cranial & spinal nerves.

❑ **B. Physiology**

Functionally, NS is divided into two systems.

1. **Somatic nervous system**

✓ This innervates the structures of the body wall (muscles, skin, and mucous membranes).

2. Autonomic (visceral) nervous system (ANS)

✓ contains portions of the CNS & PNS.

✓ It controls the activities of the smooth muscles and glands of the internal organs (viscera) and the blood vessels and returns sensory information to the brain.

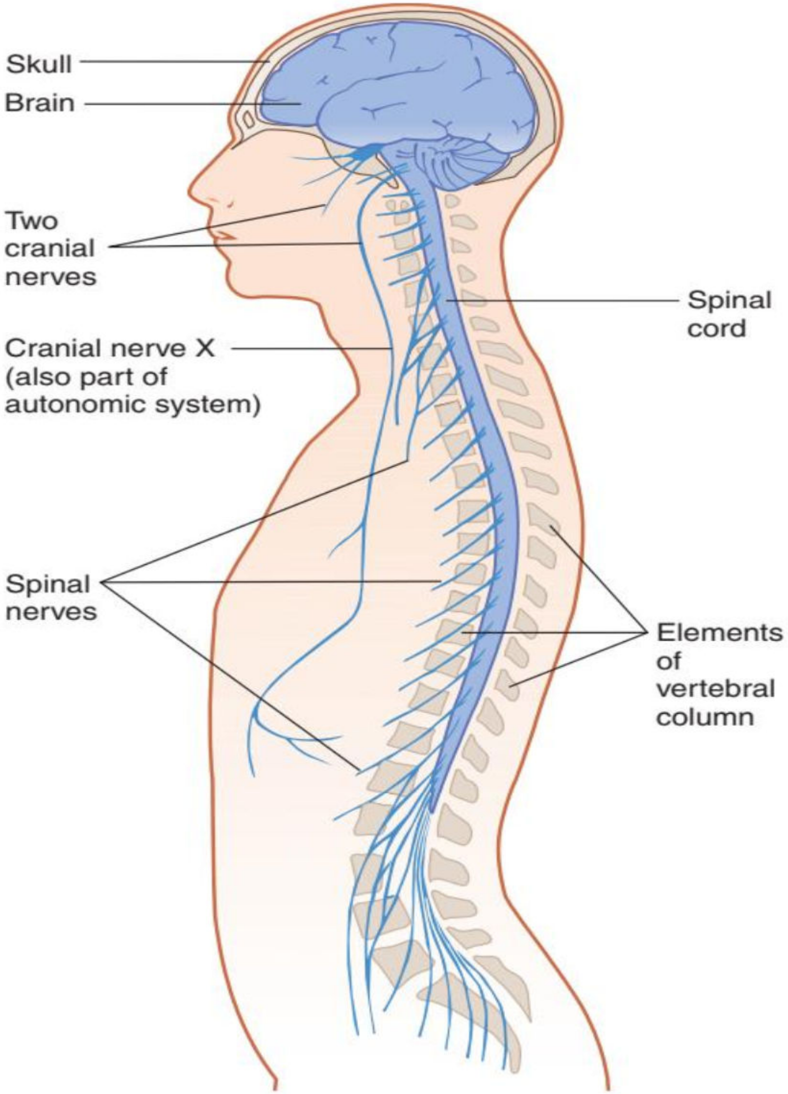

FIGURE 1–1 The structure of the central nervous system and the peripheral nervous system, showing the relationship between the central nervous system and its bony coverings.

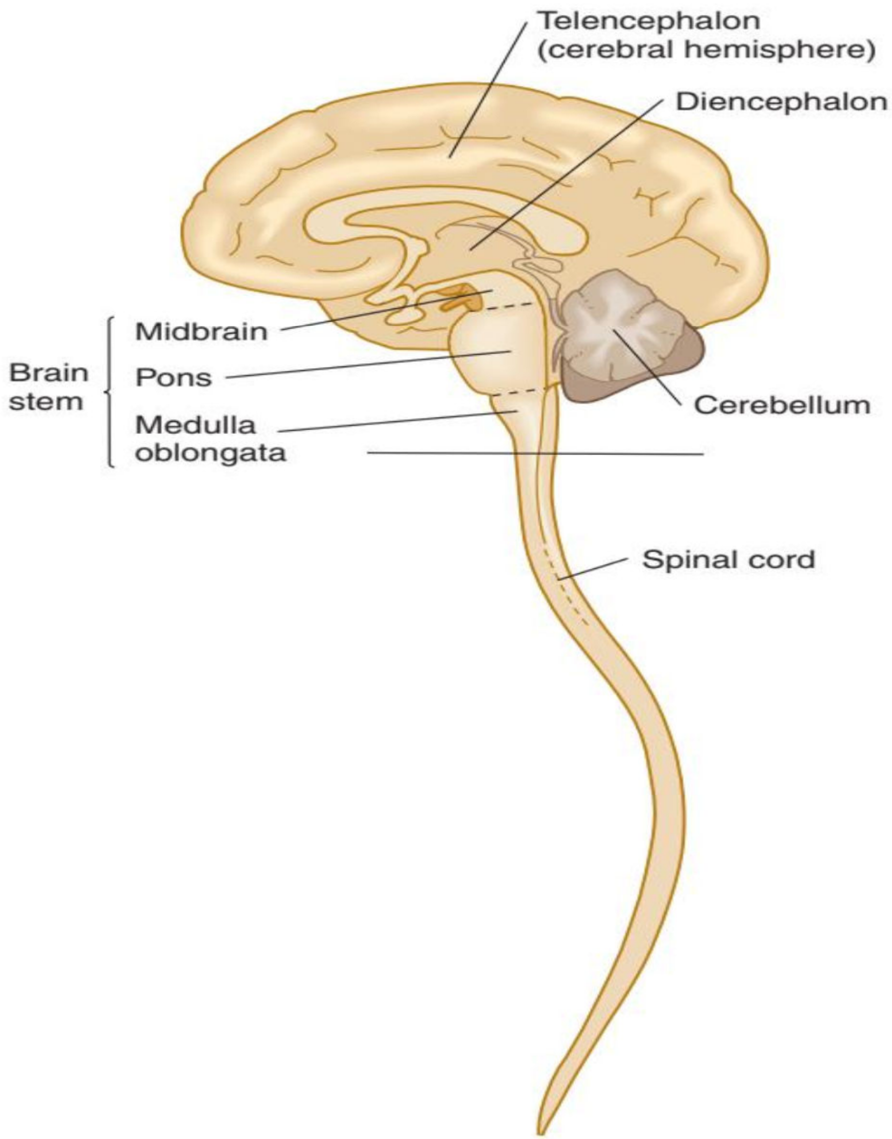

FIGURE 1–2 The two major divisions of the central nervous system, the brain, and the spinal cord, as seen in the midsagittal plane.

TABLE 1–1 Major Divisions of the Central Nervous System.

Brain (en-cephalon)	Cerebrum (forebrain)	Telencephalon	Cerebral cortex
			Subcortical white matter
			Commissures
			Basal ganglia
		Diencephalon	Thalamus
			Hypothalamus
			Epithalamus
			Subthalamus
	Cerebellum	Cerebellar cortex	
		Cerebellar nuclei	
	Brain stem	Midbrain (mesencephalon)	
		Pons	
		Medulla oblongata	
Spinal cord	White matter	Dorsal columns	
		Lateral columns	
		Anterior columns	
	Gray matter		

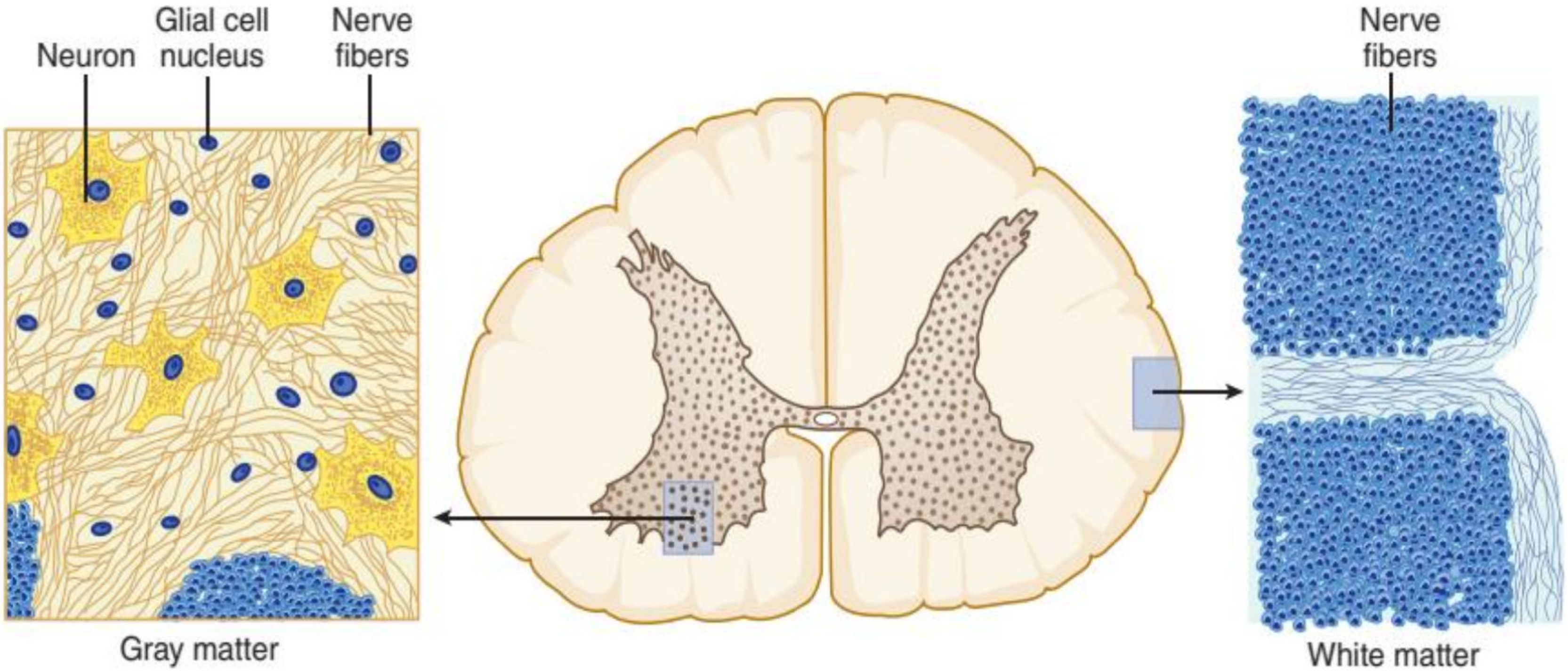

FIGURE 1–3 Cross section through the spinal cord, showing gray matter (which contains neuronal and glial cell bodies, axons, dendrites, and synapses) and white matter (which contains myelinated axons and associated glial cells). (Reproduced, with permission, from Junqueira LC, Carneiro J, Kelley RO: *Basic Histology: Text & Atlas*. 11th ed. McGraw-Hill, 2005.)

FUNCTIONAL UNITS

- The brain, which accounts for about 2% of the body's weight,
- contains many billions (perhaps even a trillion) of **neurons** and **glial cells**.
- **Neurons, or nerve cells,**

✓ **specialized cells** that receive and send signals to other cells through their extensions (nerve fibers, or axons).

✓ The information is processed and encoded in a sequence of electrical or chemical steps that occur very rapidly (in milliseconds).

- **Interneurons,** on the other hand, have small cell bodies + short axons + transmit impulses locally.

- *Nerve cells serving a common function, often with a common target,* ***are frequently grouped together into nuclei***.
- Nerve cells with common form, function, and connections that are grouped together outside the CNS are called **ganglia.**
- Other cellular elements that *support the activity of the neurons* are the **glial cells**, of which there are *several types*.

Glial cells within the brain and spinal cord outnumber neurons **10:1**.

COMPUTATION IN THE NERVOUS SYSTEM

- Nerve cells convey signals to one another at **synapses**.
- **Chemical transmitters are associated with the function of the synapse:** excitation or inhibition.
- A neuron may receive thousands of synapses, *which bring it information from many sources*.

By integrating the excitatory & inhibitory inputs from these diverse sources + producing its own message, each **neuron acts as an information-processing device**.

✓ **a simple monosynaptic chain of two neurons connected by a synapse:** *(eg, the reflex and unconscious contraction of the muscles around the knee in response to percussion of the patellar tendon)*

✓ **polysynaptic neural circuits** in which *many neurons, interconnected by synapses, are involved.*

EXTERNAL ANATOMY OF THE SPINAL CORD

- The spinal cord occupies the upper two-thirds of the adult spinal canal within the vertebral column.
- The cord is normally 42 to 45 cm long in adults and is continuous with the medulla at its upper end.
- The **conus medullaris** is the conical distal (inferior) end of the spinal cord. In adults, the conus ends at *the L1 or L2 level of the vertebral column*.
- The **filum terminale**, consisting of *pia and glial fibers extends from the tip of the conus and attaches to the distal dural sac*.
- The **central canal** is lined with ependymal cells and filled with cerebrospinal fluid. It *opens upward into the inferior portion of the 4th ventricle*.

EXTERNAL ANATOMY OF THE SPINAL CORD

❑ Enlargements:

The enlargements of the cord contain increased numbers of lower motor neurons (LMNs) and provide the origins of the nerves of the upper & lower extremities.

I. **cervical enlargement** (nerves of the brachial plexus)

II. **the lumbosacral enlargement** (nerves of the lumbosacral plexus)

❑ Segments:

The spinal cord consists of approximately 30 segments (see Fig 5–3)

8 cervical (C) segments, **12** thoracic (T) segments (termed dorsal in some texts), **5** lumbar (L) segments, **5** sacral (S) segments, and **a few small** coccygeal (Co) segments—that *correspond to attachments of groups of nerve roots* (Figs 5–3 and 5–4). There are no sharp boundaries between segments within the cord itself.

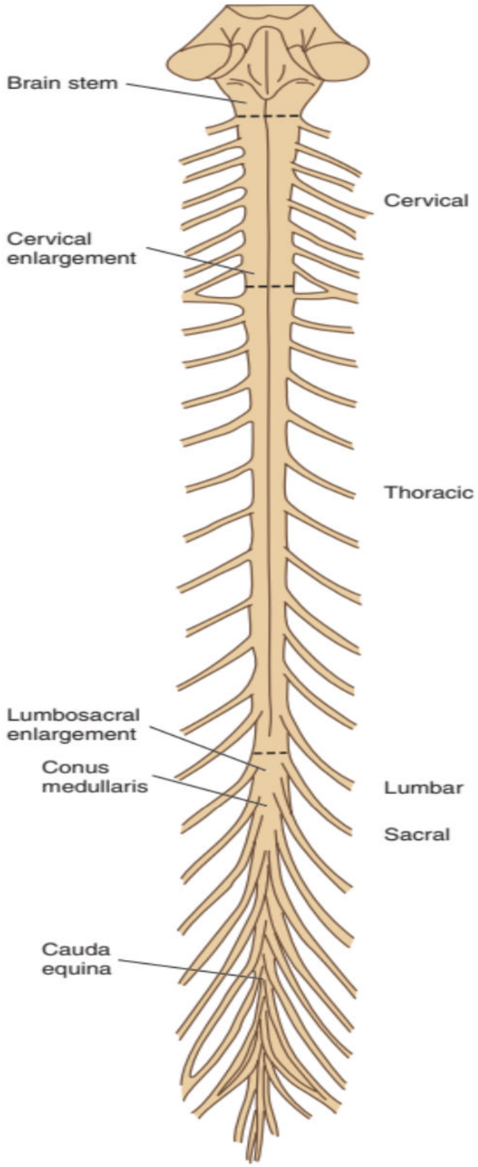

FIGURE 5–3 Schematic dorsal view of isolated spinal cord and spinal nerves.

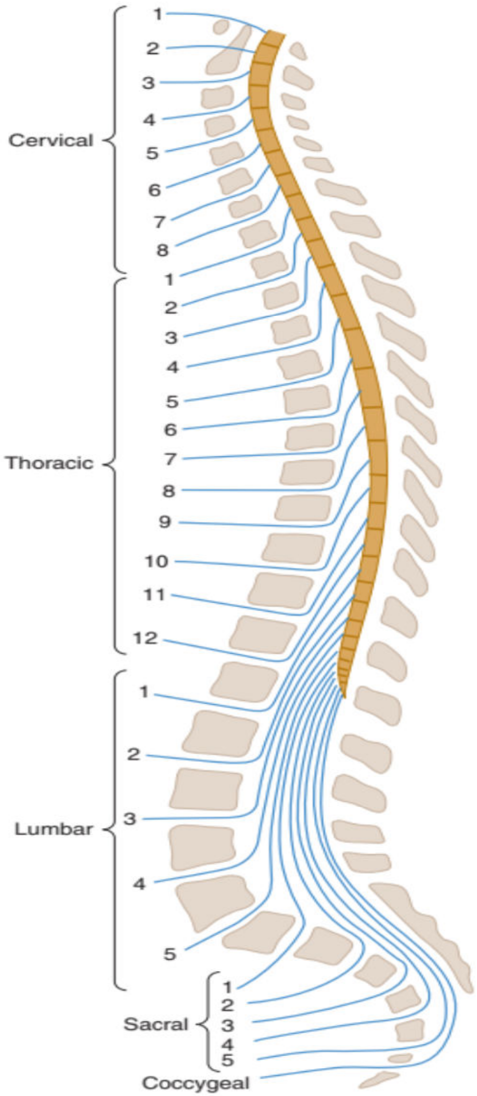

FIGURE 5–4 Schematic illustration of the relationships between the vertebral column, the spinal cord, and the spinal nerves. Note the mismatch between the location of spinal cord segments and of vertebral level where roots exit from the vertebral column. Note also the termination of the spinal cord at the level of the L1 or

- Because the **spinal cord** is <u>*shorter than the vertebral column*</u>, *each spinal cord segment at lower levels is located above the similarly numbered vertebral body.*

A cross section of the spinal cord shows:

- ✓ **a deep anterior median fissure + a shallow posterior (or dorsal) median sulcus,** which divide the cord into symmetric right and left halves joined in the central midportion
- ✓ **The dorsal nerve roots** are attached to the spinal cord along a shallow vertical groove,
- ✓ **the posterolateral sulcus,** which lies at a short distance anterior to the posterior median sulcus.
- ✓ The ventral nerve roots exit in **the anterolateral sulcus**.

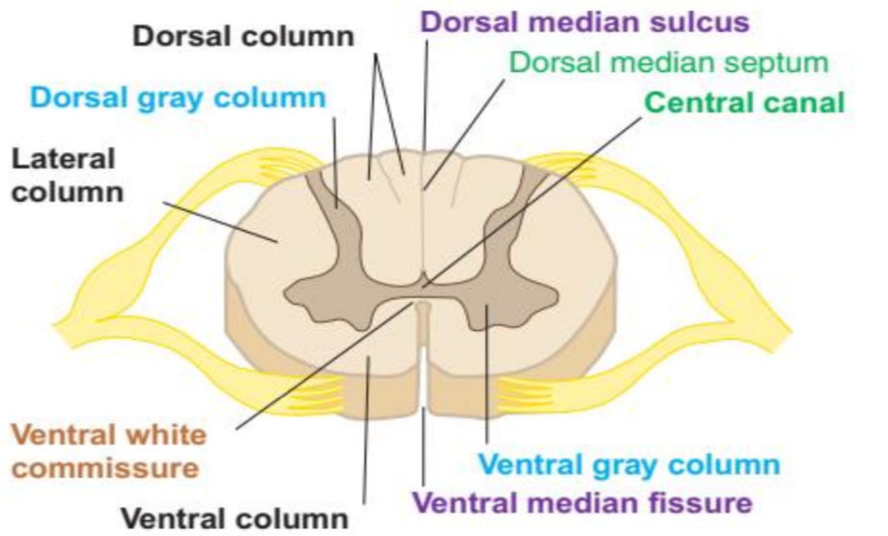

FIGURE 5–5 Anatomy of the spinal cord shown in cross section. Note that the terms "dorsal" and "posterior" are used interchangeably and that "ventral" and "anterior" are also used interchangeably to describe the spinal cord.

EXTERNAL ANATOMY OF THE SPINAL CORD

- **Each segment of the spinal cord gives rise to four roots:** **a ventral** and **a dorsal root** *on the left and a similar pair on the right* (see Fig 5–5).
- The **1st cervical segment** *usually lacks dorsal roots*.
- **Each of the 31 pairs of spinal nerves has** a ventral root + a dorsal root; *each root is made up of 1 to 8 rootlets* (Fig 5–6).
- **Each root consists of** *bundles of nerve fibers*.
- **In the dorsal root of a typical spinal nerve**, close to the junction with the ventral root, lies a dorsal root (spinal) **ganglion**, *a swelling that contains nerve cell bodies that give rise to sensory axons*.
- *The portion of a spinal nerve outside the vertebral column is sometimes referred to as* **a peripheral nerve**. The spinal nerves are divided into groups that correspond to the spinal cord segments (see Fig 5–4).

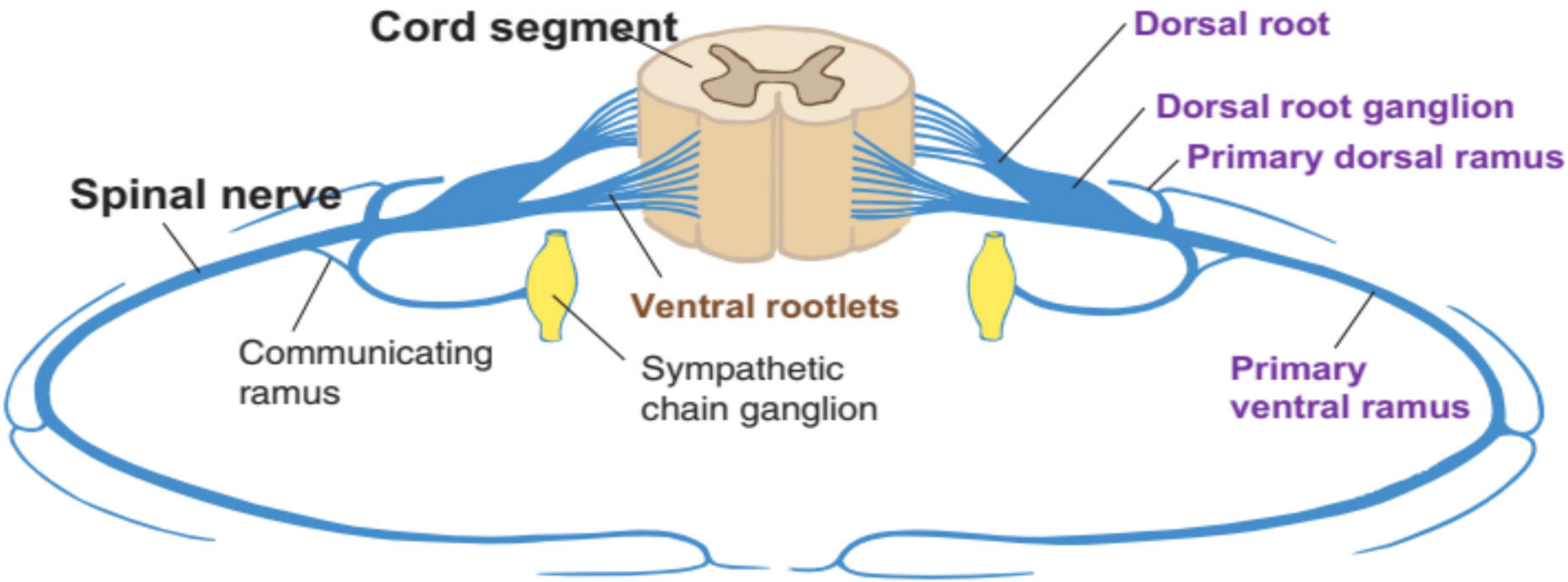

FIGURE 5–6 Schematic illustration of **a cord segment with its roots, ganglia, and branches.**

EXTERNAL ANATOMY OF THE SPINAL CORD

- **The vertebral column** surrounds and protects the spinal cord and normally consists of 7 cervical, 12 thoracic, and 5 lumbar vertebrae as well as the sacrum, which is usually formed by fusion of 5 vertebrae, and the coccyx.
- The nerve roots exit from the vertebral column through **intervertebral foramina**.

✓ **In the cervical spine**, *numbered roots exit the vertebral column **above** the corresponding vertebral body*.

✓ **The C8 root** *exits between vertebral bodies C7 and T1.*

✓ **In the lower parts of the spine,** *numbered roots exit **below** the correspondingly numbered vertebral body.*

Direction of Roots

- Until 3rd month of fetal life, the spinal cord is as long as the vertebral canal. After that, the vertebral column elongates faster than the spinal cord,
- **In adults, the tip of the cord normally lies at the level of the 1st or 2nd lumbar vertebra.**
- Because of the different growth rates of the cord and spine, the cord segments are displaced upward from their corresponding vertebrae, with the greatest discrepancy in the lowest segments (see Fig 5–4).
- **In the lumbosacral region,** the nerve roots descend almost vertically below the cord to form the **cauda equina (horse's tail)**

Ventral Roots	Dorsal Roots
○ **motor outflow tracts from the spinal cord.** ○ **carry :** 1. **the large-diameter alpha motor neuron axons** *to the extrafusal striated muscle fibers*; 2. **the smaller gamma motor neuron axons**, which *supply the intrafusal muscle of the muscle spindles* (Fig 5–7); ; 3. **preganglionic autonomic fibers** at the thoracic, upper lumbar, and midsacral levels 4. **a few afferent,** small-diameter axons that arise *from cells in the dorsal root ganglia and convey sensory information from the thoracic + abdominal viscera.*	○ **largely sensory.** ○ **Each dorsal nerve root (except usually C1) contains afferent fibers from the nerve cells in its ganglion.** ○ **The dorsal roots contain fibers from cutaneous and deep structures (see Table 3–2).** 1. **The largest fibers (Ia)** come from **muscle spindles** and participate in *spinal cord reflexes*; 2. **the medium-sized fibers (A-beta)** convey impulses from **mechanoreceptors** ***in skin and joints***. 3. Most axons in the dorsal nerve roots are **small (C, nonmyelinated; A-delta, myelinated)** and carry information of **noxious (eg, pain)** + **thermal stimuli**.

TABLE 3–2 Nerve Fiber Types in Mammalian Nerve.

Fiber Type	Function	Fiber Diameter (mm)	Conduction Velocity (m/s)	Spike Duration (ms)	Absolute Refractory Period (ms)
A α	Proprioception; somatic motor	12–20	70–120		
β	Touch, pressure	5–12	30–70	0.4–0.5	0.4–1
γ	Motor to muscle spindles	3–6	15–30		
δ	Pain, temperature, touch	2–5	12–30		
B	Preganglionic autonomic	<3	3–15	1.2	1.2
C dorsal root	Pain, reflex responses	0.4–1.2	0.5–2	2	2
sympathetic	Postganglionic sympathetics	0.3–1.3	0.7–2.3	2	2

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TABLE 3–3 Numeric Classification Sometimes Used for Sensory Neurons.

Number	Origin	Fiber Type
I a	Muscle spindle, annulospiral ending	A α
b	Golgi tendon organ	A α
II	Muscle spindle, flower-spray ending; touch, pressure	A β
III	Pain and temperature receptors; some touch receptors	A δ
IV	Pain and other receptors	C

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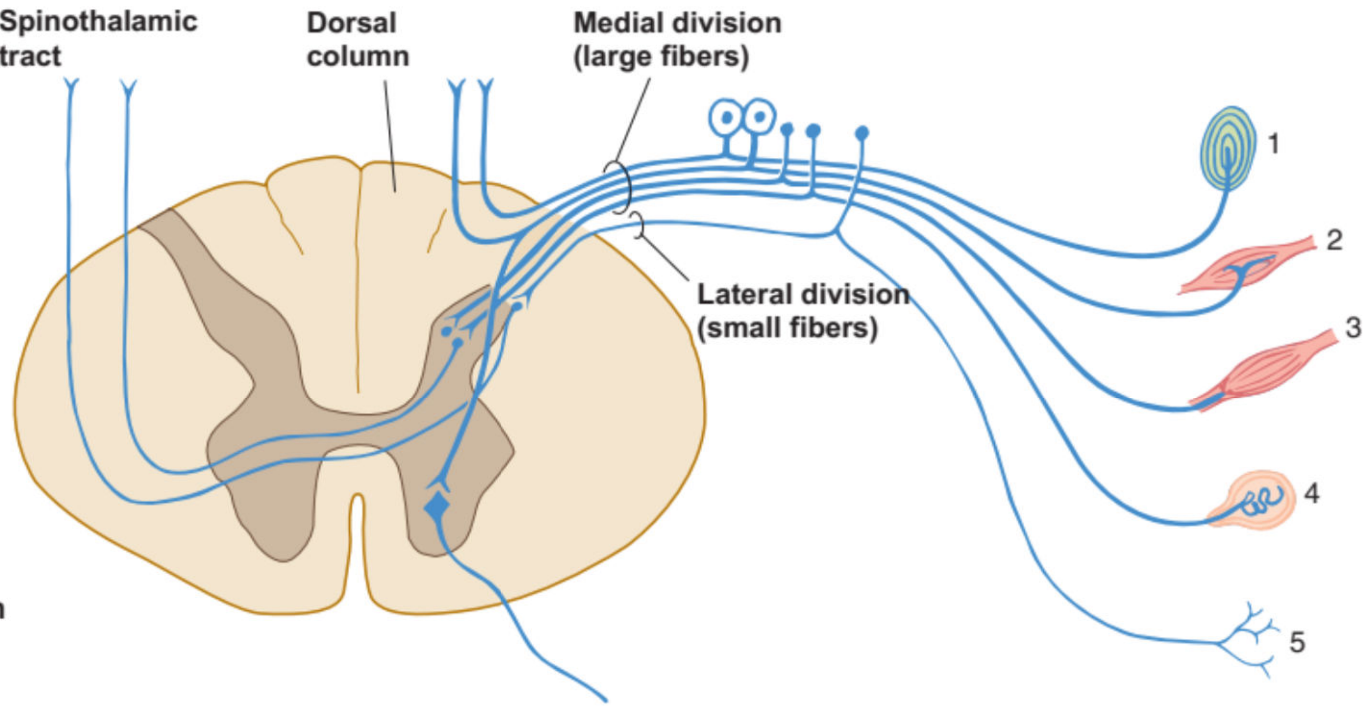


FIGURE 5–7 Schematic illustration of a cord segment with its dorsal root, ganglion cells, and sensory organs. **1: Pacinian corpuscle; 2: muscle spindle; 3: Golgi tendon organ; 4: encapsulated ending; 5: free nerve endings**.

BRANCHES OF TYPICAL SPINAL NERVES

- **A. Posterior Primary Division**

This consists of

I. **a medial branch,** which is in most instances largely sensory,

II. **a lateral branch,** which is mainly motor.

- **B. Anterior Primary Division**

❑ Larger than the posterior primary division,

❑ the anterior primary divisions **form** : the cervical, brachial, and lumbosacral **plexuses.**

❑ In the thoracic region they *remain segmental, as intercostal nerves*.

C. Rami Communicantes

❑ The rami *join the spinal nerves to the sympathetic trunk*.

❑ Only the thoracic + upper lumbar nerves *contain a white ramus communicans*, but the gray ramus is present in all spinal nerves (see Fig 5–6)

D. Meningeal or Recurrent Meningeal Branches

These nerves, also called sinuvertebral nerves, are quite small; they *carry sensory + vasomotor innervation to the meninges.*

TYPES OF NERVE FIBERS

- Nerve fibers can be classified on the basis of their diameter and conduction velocity (Tables 3–2 and 3–3) or on a physioanatomic basis.

A. Somatic Efferent Fibers

✓ These **motor fibers** innervate the skeletal muscles.

✓ They originate in large cells in the anterior (ventral) gray column of the spinal cord and form the ventral root of the spinal nerve.

B. Somatic Afferent Fibers

✓ These fibers convey **sensory information** from the skin, joints, and muscles to CNS .

✓ Their cell bodies are **unipolar cells** in the spinal ganglia that are interposed in the course of dorsal roots (dorsal root ganglia).

- **The peripheral branches** of these ganglionic cells are *distributed to somatic structures*;
- **the central branches** *convey sensory impulses through the dorsal roots to the dorsal gray column and the ascending tracts of the spinal cord*.

TYPES OF NERVE FIBERS

C. Visceral Efferent Fibers

✓ **The autonomic fibers are the** **motor fibers** to the viscera.

I. **Sympathetic fibers from the thoracic segments and L1 and L2** are *distributed throughout the body to the viscera, glands, and smooth muscle*.

II. **Parasympathetic fibers**, which are present in the **middle three sacral nerves**, *go to the pelvic and lower abdominal viscera*.

III. (**Other parasympathetic fibers** are *carried by* **cranial nerves** *III*, *VII*, *IX*, & *X*.)

D. Visceral Afferent Fibers

These fibers convey **sensory information from the viscera**. Their cell bodies are in the dorsal root ganglia.

DERMATOMES

- The *sensory component of each spinal nerve* is distributed to **a dermatome**, a well-defined segmental portion of the skin (Fig 5–8).
- **It is important for all clinicians to remember the following key points:**
- **there is no C1 dermatome** (when a C1 dermatome does exist as an anatomic variant, it covers a small area in the central part of the neck, close to the occiput).
- **The dermatomes for C5, C6, C7, C8, and T1** are confined to the arm, and the **C4 and T2 dermatome**s are contiguous over the anterior trunk.
- The thumb, middle finger, and fifth digit are within the **C6, C7, and C8 dermatomes**, respectively.
- The nipple is at the level of **T4.**
- The umbilicus is at the level of **T10.**

The territories of dermatomes tend to overlap, making it difficult *to determine the absence of a single segmental innervation on the basis of sensory testing* (Fig 5–9).

MYOTOMES

- **myotome** refers to the s*skeletal musculature innervated by motor axons in a given spinal root*.
- The organization of myotomes is the same from person to person, and the **testing of motor functions can be very useful in** determining the extent of a lesion in the nerve, spinal cord segment, or tract, *especially when combined with a careful sensory examination*.
- Most muscles, as indicated , are innervated by motor axons that arise from several adjacent spinal roots. Nevertheless, ***lesions of a single spinal root, in many cases, can cause weakness and atrophy of a muscle.***
- Especially useful to the clinician will be Table 5–2 which lists **segment-pointer muscles**, whose weakness or atrophy may suggest a lesion involving a single nerve root or a pair of adjacent nerve roots

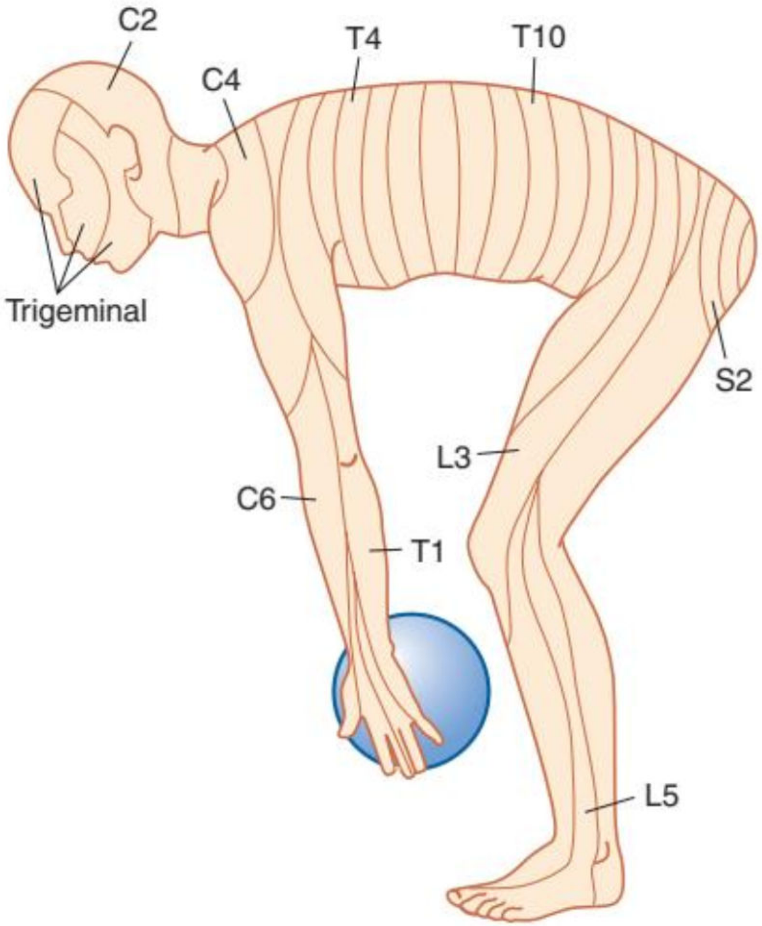


FIGURE 5–8 Segmental distribution of the body viewed in the approximate quadruped position.

TABLE 5-2 Segment-Pointer Muscles.

Muscle	Spinal Root	Function of Muscle
Diaphragm	C3, C4	Respiration
Deltoid	C5	Arm abduction
Biceps	C5	Forearm flexion
Brachioradialis	C6	Forearm flexion
Triceps	C7	Extension of forearm
Quadriceps femoris	L3, L4	Knee extension
Tibialis anterior	L4	Dorsiflexion of foot
Extensor hallucis longus	L5	Dorsiflexion of great toe
Gastrocnemius	S1	Plantar flexion

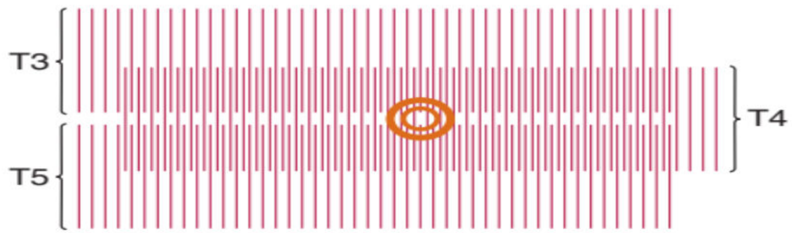


FIGURE 5–9 Diagram of the position of the nipple in the sensory skin fields of the third, fourth, and fifth thoracic spinal roots showing the overlapping of the cutaneous areas.

INTERNAL DIVISIONS OF THE SPINAL CORD

Gray Matter

A. Columns

- A cross section of the spinal cord shows an H-shaped internal mass of gray matter surrounded by white matter (see Fig 5–5).
- The gray matter is made up of two symmetric portions joined across the midline by **a transverse connection (commissure) of gray matter** that *contains the minute central canal or its remnants*. This gray matter extends the entire length of the spinal cord, and is considered to consist of columns.

I. **The ventral (or anterior) gray column** (also called the ventral, or anterior, horn) is in front of the central canal. It contains the cells of origin of the fibers of the ventral roots, including alpha + gamma motor neurons (**"lower" motor neurons**).

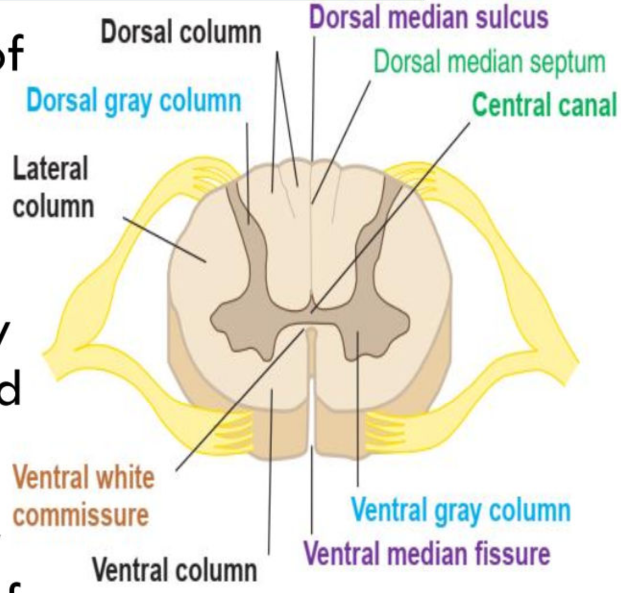


FIGURE 5–5 Anatomy of the spinal cord shown in cross section. Note that the terms "dorsal" and "posterior" are used interchangeably and that "ventral" and "anterior" are also used interchangeably to describe the spinal cord.

INTERNAL DIVISIONS OF THE SPINAL CORD

Gray Matter

A. Columns

II. The intermediolateral gray column (or horn)

- lies between the dorsal & ventral gray columns + a prominent lateral triangular projection in the thoracic and upper lumbar regions but not in the midsacral region.
- It contains preganglionic cells for the autonomic nervous system.
- **Within spinal segments T1 to L2,** → **preganglionic sympathetic neurons** within the intermediolateral gray column → rise to sympathetic axons that leave the spinal cord within the ventral roots → travel to the **sympathetic ganglia**
- **Within spinal segments S2, S3, and S4**, there are sacral parasympathetic neurons within intermediolateral gray column. → rise to **preganglionic parasympathetic axons** that leave spinal cord within the sacral ventral roots.
- **After projecting to the pelvic viscera within the pelvic nerves**, these parasympathetic axons **synapse** on **postganglionic parasympathetic neurons** that project to the pelvic viscera.

INTERNAL DIVISIONS OF THE SPINAL CORD

Gray Matter

A. Columns

III. The dorsal gray column (also called the posterior,or dorsal horn)

- reaches almost to the posterolateral (dorsolateral) sulcus.
- A compact bundle of small fibers, the dorsolateral fasciculus (Lissauer's tract), part of the pain pathway,
- lies on the periphery of the spinal cord.

The form and quantity of the gray matter vary at different levels of the spinal cord (Fig 5–10).

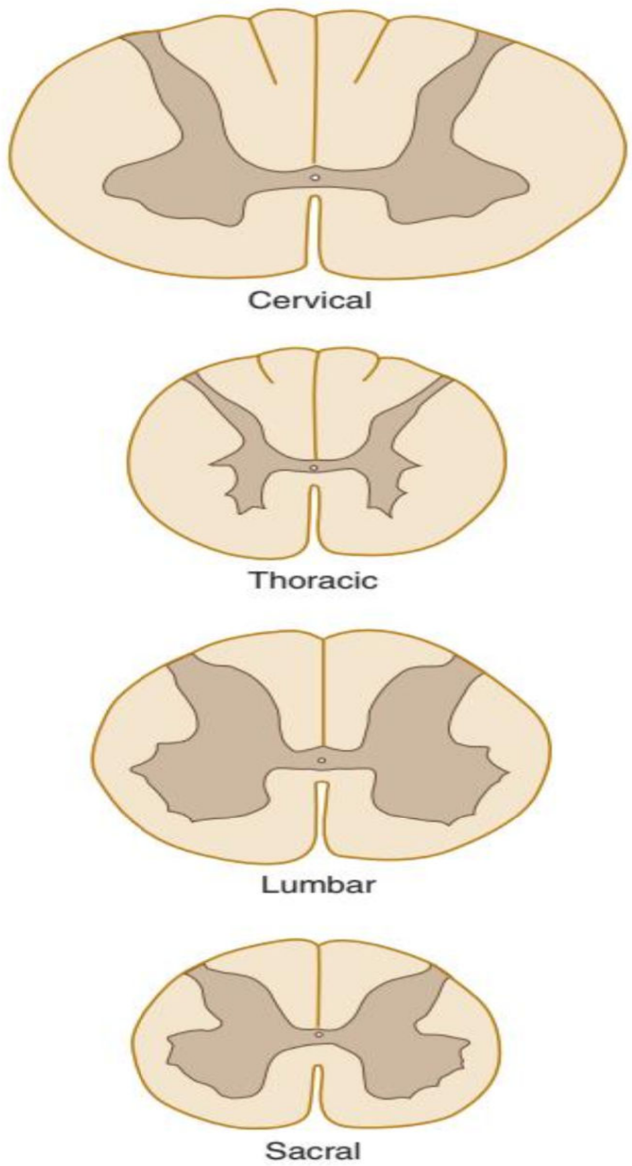


FIGURE 5–10 Transverse sections of the spinal cord at various levels.

INTERNAL DIVISIONS OF THE SPINAL CORD

Gray Matter

B. Laminas

- A cross section of the gray matter of the spinal cord shows a number of laminas (layers of nerve cells), termed **Rexed's laminae** after the neuroanatomist who described them (Fig 5–11).
- **As a general principle,** **superficial laminae** tend to be involved in *pain signaling*, while **deeper laminae** are involved in *non-painful* as well as *painful sensation*.

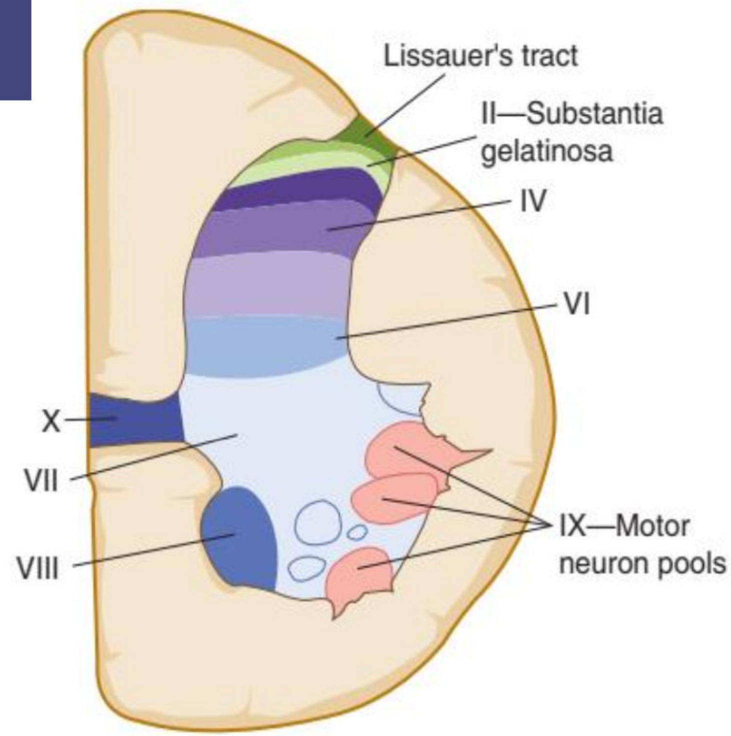


FIGURE 5–11 Laminas of the gray matter of the spinal cord (only one-half shown).

INTERNAL DIVISIONS OF THE SPINAL CORD

Gray Matter

B. Laminas

1. **Lamina I:** This thin marginal layer contains neurons that respond to **noxious stimuli** and *send axons to the contralateral spinothalamic tract*.
2. **Lamina II:** Also known as **substantia gelatinosa**, this lamina is made up of small neurons, some of which respond to **noxious stimuli**. **Substance P**, **a neuropeptide** involved in pathways mediating **sensibility to pain**, is found in high concentrations in laminas I and II.
3. **Laminas III and IV:** These are referred to together as the **nucleus proprius**. Their main input is from fibers that convey **position + light touch sense**.
4. **Lamina V:** This layer contains cells that respond to both **noxious + visceral afferent stimuli.**

INTERNAL DIVISIONS OF THE SPINAL CORD

Gray Matter

B. Laminas

5. **Lamina VI:** This deepest layer of the dorsal horn contains neurons that respond to **mechanical signals from joints + skin**.

6. **Lamina VII:** This is a large zone that contains the cells of **the dorsal nucleus (Clarke's column)** medially as well as a large portion of the ventral gray column. Clarke's column contains cells that give rise to the **posterior spinocerebellar tract**. Lamina VII also contains the intermediolateral nucleus (or intermediolateral cell column) in thoracic and upper lumbar regions. **Preganglionic sympathetic fibers** project from cells in this nucleus, via the ventral roots and white rami communicantes, to sympathetic ganglia.

INTERNAL DIVISIONS OF THE SPINAL CORD

Gray Matter

B. Laminas

groups in the medial and lateral portions of the ventral gray column. **The medial portion** (also termed the **medial motor neuron column**) contains the ***LMNs that innervate axial musculature (ie, muscles of the trunk and proximal parts of the limbs***). **The lateral motor neuron column** contains ***LMNs for the distal muscles of the arm and leg***. In general, **flexor muscles** are innervated by motor neurons located *close to the central canal*, whereas **extensor muscles** are innervated by motor neurons located *more peripherally* (Fig 5–12).

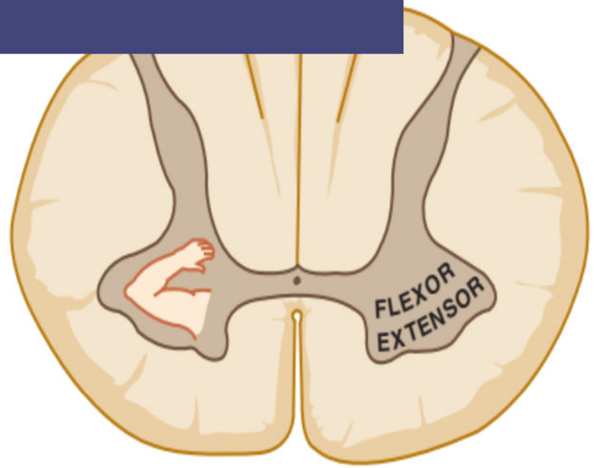


FIGURE 5–12 Diagram showing the **functional localization of motor neuron groups** in the **ventral gray horn of a lower cervical segment** of the spinal cord.

8. **Lamina X:** This represents the small neurons around the central canal or its remnants.

INTERNAL DIVISIONS OF THE SPINAL CORD

White Matter

A. Columns

- The spinal cord has white columns (funiculi):

I. **dorsal** (also termed posterior),

(lies between the posterior median sulcus and the posterolateral sulcus).

In the cervical and upper thoracicregions, the dorsal column is divided into

A. **gracile fasciculus:** a medial portion) and

B. **cuneate fasciculus:** a lateral portion.

I. **lateral,** (lies between the posterolateral sulcus and the anterolateral sulcus).

II. **ventral** (also termed anterior)—*around the spinal gray columns*

lies between the anterolateral sulcus and the anterior median fissure.(see Fig 5–5).

INTERNAL DIVISIONS OF THE SPINAL CORD

White Matter

B. Tracts

- composed of myelinated and unmyelinated nerve fibers.
- **The fast-conducting myelinated fibers** form bundles (fasciculi) that ascend or descend for varying distances.
- **Glial cells** (oligodendrocytes, ***which form myelin***, and astrocytes) lie between the fibers.
- **Fiber bundles with a common function are called tracts.**
- Some tracts **decussate** or cross the midline from one side of the spinal cord or brain.

PATHWAYS IN WHITE MATTER

I- Descending Fiber Systems

A. CORTICOSPINAL TRACT

- a large bundle of myelinated axons that descends through the brain stem via called the **medullary pyramid tract** and then largely crosses over (decussates) downward into the lateral white columns.
- These tracts contain more than 1 million axons; the majority are myelinated.
- contain the axons of:

I. UMN (ie, neurons of the cerebrum and subcortical brain stem that descend and provide input to the AHCs of the spinal cord).

II. These AHCs, which project directly to muscle and control muscular contraction, are called LMN.

- **Arising from:** the cerebral cortex (primarily the precentral motor cortex (area 4), and the premotor area(area 6).
- **The great majority of axons** in the corticospinal system *decussate in the pyramidal decussation within the medulla* and descend within **the lateral corticospinal tract** (Fig 5–13 and Table 5–3).
- **terminate** throughout the **ventral gray column** + at the **base of the dorsal column**.

LMNs supplying the muscles of the distal extremities receive:

I. **Some of the LMNs** receive **direct monosynaptic input from the lateral corticospinal tract**;

II. **other LMNs are innervated by interneurons (via polysynaptic connection).**

A. CORTICOSPINAL TRACT

About 10% of the corticospinal fibers that descend from the hemisphere **do not decussate in the medulla** but rather descend uncrossed in the **anterior (or ventral) corticospinal tract** and are located in the anterior white matter column of the spinal cord.

✓ **After descending within the spinal cord**, many of these fibers

- **decussate**, via the **anterior white commissure**, and then
- project to **interneurons** (which project to LMNs) *but connect directly to LMNs of contralateral side.*

A small fraction (0–3%) of the corticospinal axons descend, without decussating, as uncrossed fibers within the **lateral corticospinal tract.**

- These axons **terminate** in the base of the posterior horn + intermediate gray matter of SC
- They provide synaptic input **(probably via polysynaptic circuits)** to LMNs:

controlling axial (ie, trunk and proximal limb) musculature involved in maintaining body posture.

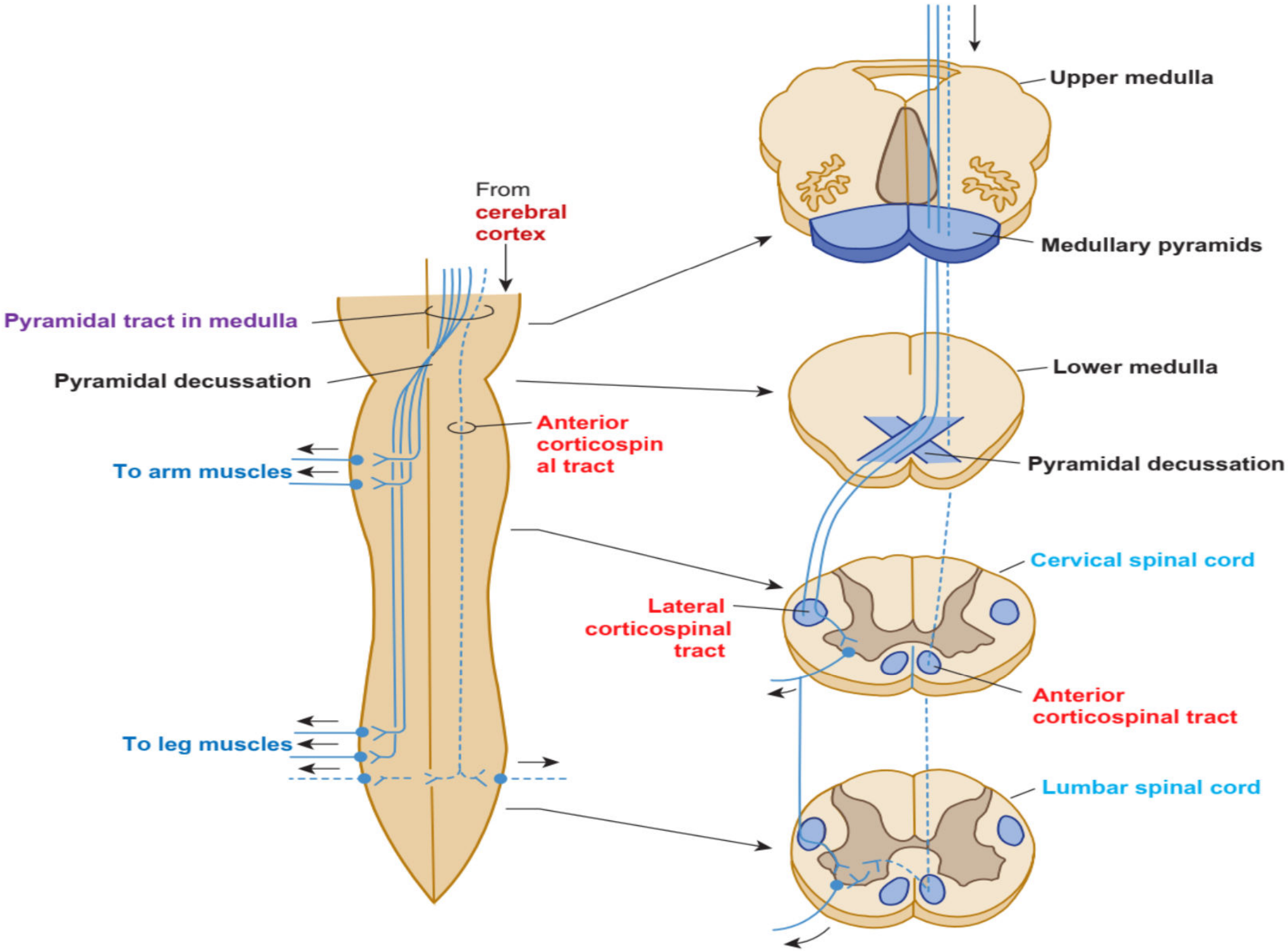


FIGURE 5–13 Schematic illustration of the course of corticospinal tract fibers in the spinal cord, together with cross sections at representative levels. This and the following schematic illustrations show the cord in an upright position.

A. CORTICOSPINAL TRACT

- The lateral corticospinal tract is relatively new in phylogenetic terms, present **only in mammals**, and most **highly developed in primates.**

- It provides the descending pathway that controls **voluntary**, **highly skilled**, and **fractionated movements**.

- In addition to the lateral corticospinal tract, which decussates and is the **largest descending motor pathway**, there are ***two smaller descending motor pathways in the spinal cord***. **These pathways are uncrossed.**

B. VESTIBULOSPINAL TRACTS

two major components to the vestibulospinal tracts:

I. **lateral vestibulospinal tract**

arise from the lateral vestibular nucleus in the brain stem ➡ course downward, ➡ uncrossed, in the ventral white column of the spinal cord.

II. **medial vestibulospinal tract**

arise in the medial vestibular nucleus in the brain stem ➡ descend within the cervical spinal cord, with both crossed and uncrossed components, to **terminate** at cervical levels.

The vestibulospinal system provide

synaptic inputs to interneurons in Rexed's laminae VII + VIII, which project to both alpha &gamma LMNs.

excitatory input to LMNs for extensor ms.

facilitates quick movements in reaction to sudden changes in body position (eg, falling)

provides control of antigravity ms.

C. RUBROSPINAL TRACT

I- input from the **contralateral deep cerebellar nuclei** (via the superior cerebellar peduncle)

+

the **motor cortex bilaterally**.

arises in the contralateral red nucleus in the brain stem and courses in the lateral white column.

synapse on interneurons in the spinal cord.

II-sensorimotor cortex

several nuclei in the **reticular formation** of the brain stem,

sends fibers to the spinal cord in the form of the reticulospinal tract in the lateral column.

terminate on interneurons

spinal cord

gamma motor neurons

D. RETICULOSPINAL SYSTEM

- **arises in** the **reticular formation** of the brain stem and
- **descends in** both the **ventral (influence gamma motor neurons and thus various spinal reflexes) & lateral white columns**.
- Both crossed and uncrossed descending fibers are present.
- **terminating on dorsal gray column neurons**
- **FUNCTION** - ***may modify the transmission of sensation from the body, especially pain.***
- **- *Inhibits the antigravity muscles (extensors).***

E. DESCENDING AUTONOMIC SYSTEM

- **Arising from** the hypothalamus + brain stem.

- **poorly defined fiber system projects to**

preganglionic sympathetic neurons in the thoracolumbar spinal cord (lateral column)

+

preganglionic parasympathetic neurons in sacral segments

- **FUNCTION** ***modulate autonomic functions, such as blood pressure, pulse and respiratory rates, and sweating.***

F. TECTOSPINAL TRACT

- **arises from** the superior colliculus in the roof (tectum) of the midbrain and
- then courses in the contralateral ventral white column to
- provide synaptic input to ventral gray interneurons.
- **FUNCTION** ***It causes head turning in response to sudden visual or auditory stimuli***.

descend only to the cervical segments of the spinal cord.

G. MEDIAL LONGITUDINAL FASCICULUS

- arises from vestibular nuclei in the brain stem.
- As it descends, it runs close to, and intermingles with, the tectospinal tract.
- Some of its fibers descend into the cervical spinal cord to terminate on ventral gray interneurons.
- **FUNCTION** ***It coordinates head and eye movements***.

descend only to the cervical segments of the spinal cord.

TABLE 5–3 Descending Fiber Systems in the Spinal Cord.

System	Function	Origin	Ending	Location in Cord
Lateral corticospinal (pyramidal) tract	Fine motor function (controls distal musculature) Modulation of sensory functions	Motor + premotor cortex	Anterior horn cells (interneurons and LMNs)	Lateral column (crosses in medulla at pyramidal decussation)
Anterior corticospinal tract	Gross + postural motor function (proximal & axial musculature)	Motor + premotor cortex	Anterior horn neurons (interneurons and LMNs)	Anterior column (uncrossed until after descending,when some fibers decussate)
Vestibulospinal tract	Postural reflexes	Lateral + medial vestibular nucleus	Anterior horn inter-neurons + motor neurons (for extensors)	Ventral column
Rubrospinal	Motor function	Red nucleus	Ventral horn interneurons	Lateral column
Reticulospinal	Modulation of sensory transmission (especially pain) Modulation of spinal reflexes	Brain stem reticular formation	Dorsal + ventral horn	Anterior column
Descending autonomic	Modulation of autonomic functions	Hypothalamus+ brain stem nuclei	Preganglionic autonomic neurons	Lateral columns
Tectospinal	Reflex head turning	Midbrain	Ventral horn inter-neurons	Ventral column
Medial longitudinal fasciculus	Coordination of head and eye movements	Vestibular nuclei	Cervical gray	Ventral column

ASCENDING FIBER SYSTEMS

- All afferent axons in the dorsal roots have their cell bodies in the dorsal root ganglia (Table 5–4).
- Different ascending systems decussate at different levels.
- In general, ascending axons synapse within the spinal cord before decussating.

A. DORSAL COLUMN TRACTS

- part of the **medial lemniscal system**,
- **FUNCTION:** ***convey well-localized sensations of fine touch, vibration, two-point discrimination, and proprioception (position sense) from the skin + joints.***
- **ascend,** without crossing, in the dorsal white column of the spinal cord to the lower brain stem (Fig 5–14).

✓ The **fasciculus gracilis** carries *input from the lower half of the body*, *with fibers that arise from the lowest, most medial segments*.

✓ The **fasciculus cuneatus** carries *input from the upper half of the body*, with *fibers from the lower (thoracic) segments more medial than the higher (cervical) ones*.

Thus, **one dorsal column** *contains fibers from all segments of the ipsilateral half of the body arranged in an orderly somatotopic fashion from medial to lateral* (Fig 5–15).

A. DORSAL COLUMN TRACTS

- **terminate** on neurons in the gracile + cuneate nuclei (dorsal column nuclei) in the lower medulla. **(second-order neurons)**
- across the midline via the **lemniscal decussation** (also called the internal arcuate tract) and the **medial lemniscus** to the thalamus.
- From the **ventral posterolateral thalamic nuclei**, sensory information is relayed upward to **TERMINAT** the **somatosensory cortex**.

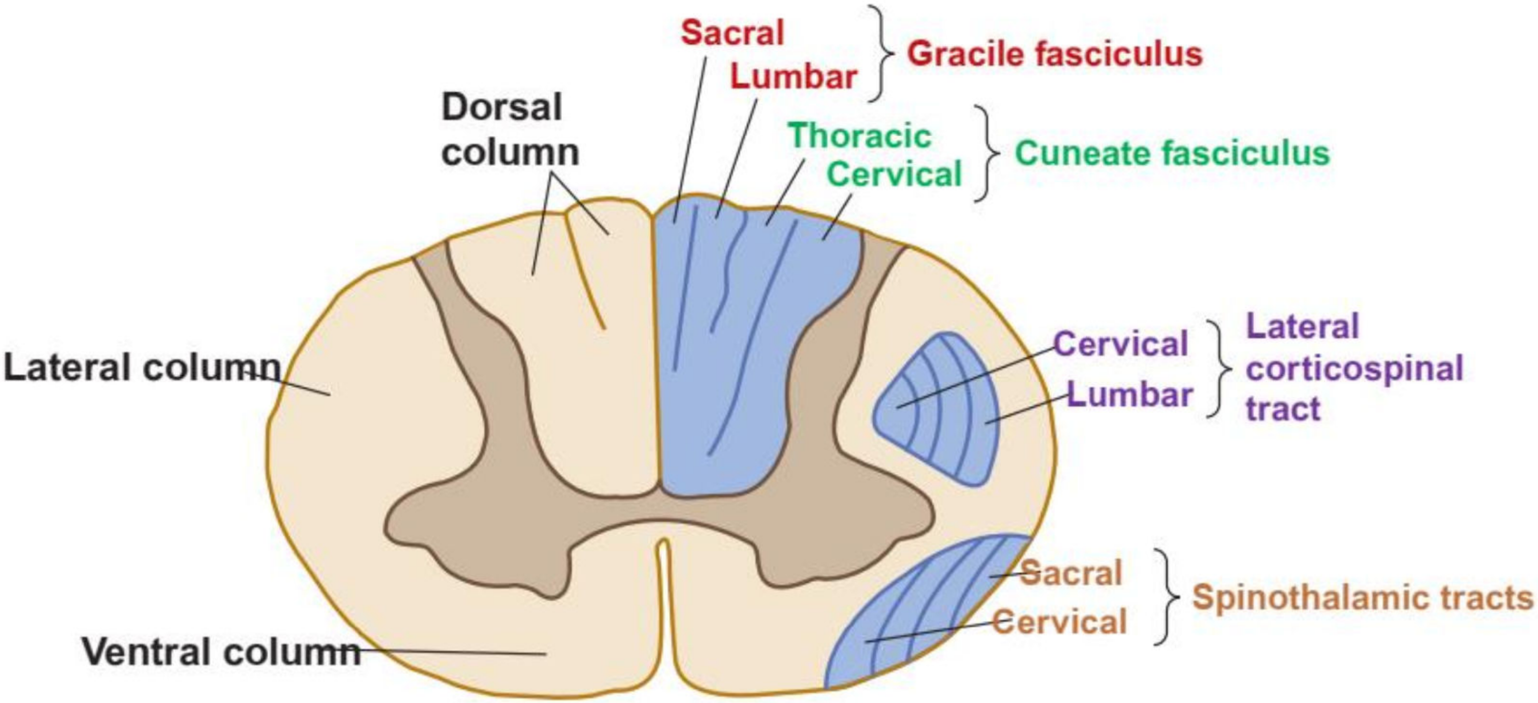


FIGURE 5–15 Somatotopic organization **(segmental arrangement)** in the spinal cord.

The spinothalamic tracts, *like the dorsal column system, show* somatotopic organization *(see Fig 5–15). Sensation from :*

- **sacral parts of the body** is carried in *lateral parts of the spinothalamic tracts*,
- **cervical regions** are carried by fibers in *medial parts of the spinothalamic tracts*.

B. SPINOTHALAMIC TRACTS

Small-diameter sensory axons conveying the sensations of ***sharp (noxious) pain***, ***temperature***, and ***crudely localized touch*** course upward, after

- entering the spinal cord via the **dorsal root**, *for one or two segments at the periphery of the dorsal horn.*
- *These short, ascending stretches of incoming fibers that are termed the* ***dorsolateral fasciculus****, or* ***Lissauer's tract****,*
- *then synapse with dorsal column neurons, especially in* ***laminas I, II, and V*** *(Figs 5–11 and 5–16).*
- *After one or more synapses, subsequent fibers* ***cross to the opposite side of the spinal cord*** *and then ascend within the* ***spinothalamic tracts****,* ***also called the*** ***ventrolateral (or anterior) system****.*

I. ***The anterior spinothalamic tract*** *carries information about* ***light touch****, and*

II. ***the lateral spinothalamic tract*** *conveys* ***pain*** *and* ***temperature sensibility*** *upward.*

- *Axons of the spinothalamic tracts*
- *project rostrally after sending branches to the* ***reticular formation*** *in the brain stem and project to the* **thalamus** ***(ventral posterolateral, intralaminar thalamic nuclei).***

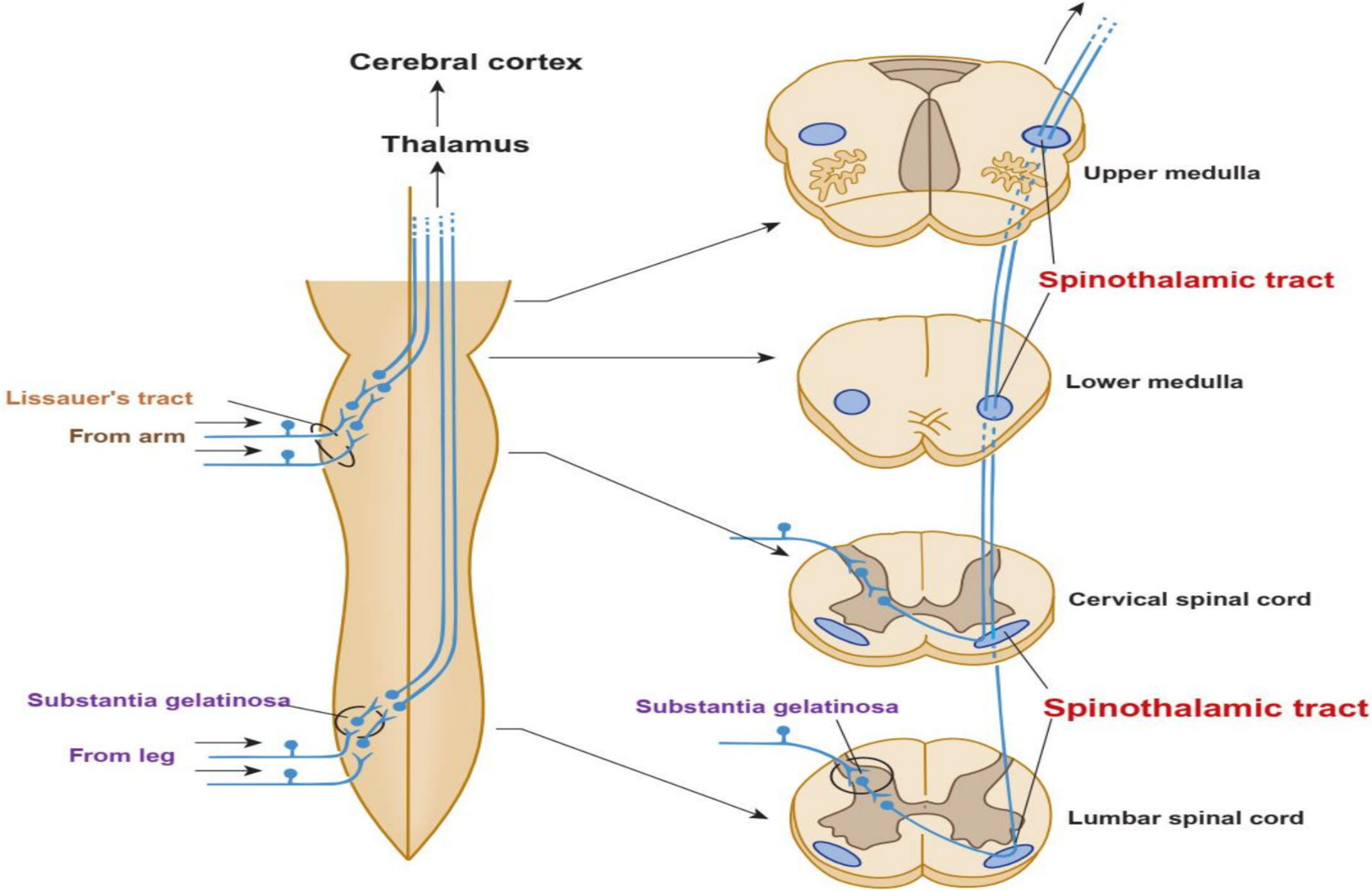


FIGURE 5–16 The spinothalamic (ventrolateral) system in the spinal cord.

C. CLINICAL CORRELATIONS

The second-order neurons of both the dorsal column system and spinothalamic tracts decussate.

The pattern of decussation is different

the dorsal column system

- cross in the lemniscal decussation in the medulla;
- these second-order sensory axons are called **internal arcuate fibers** where they cross.

the spinothalamic tracts

cross at every segmental level in the spinal cord.

This fact aids in determining whether a lesion is in the brain or the spinal cord.
With lesions in the brain stem or higher, deficits of pain perception, touch sensation, and proprioception are **all contralateral to the lesion**.
With spinal cord lesions, however, the deficit in pain perception is **contralateral to the lesion**, whereas the other deficits are **ipsilateral**.

D. SPINORETICULAR PATHWAY

ill-defined spinoreticular tract courses within the ventrolateral portion of the spinal cord,

- arising from cord neurons and ending (without crossing) in the reticular formation of the brain stem.
- This tract plays an important role in the sensation of pain, especially **deep, chronic pain**

E. SPINOCEREBELLAR TRACTS

(lesser importance in human neurology) provide input **from** spinal cord **to** cerebellum

1. Dorsal spinocerebellar tract:

1st order	Afferent fibers from muscle and skin (which convey information from muscle spindles, Golgi tendon organs, and touch & pressure receptors) enter the spinal cord **via dorsal roots at levels T1 to L2.**
2nd order neurons	➢ **dorsal nucleus of Clarke** (sacral and lower lumbar levels) ➢ **the accessory cuneate nucleus** (for the upper extremity)
3rd order neurons	Both tracts remain on the ipsilateral side of the spinal cord, ascending via the inferior cerebellar peduncle to terminate in the paleocerebellar cortex..

2. Ventral spinocerebellar tract

2nd order neurons	Rexed's laminae V, VI, and VII in lumbar and sacral segments of the spinal cord largely but not entirely crossed
3rd order neurons	axons that ascend through the superior cerebellar peduncle to the paleocerebellar cortex

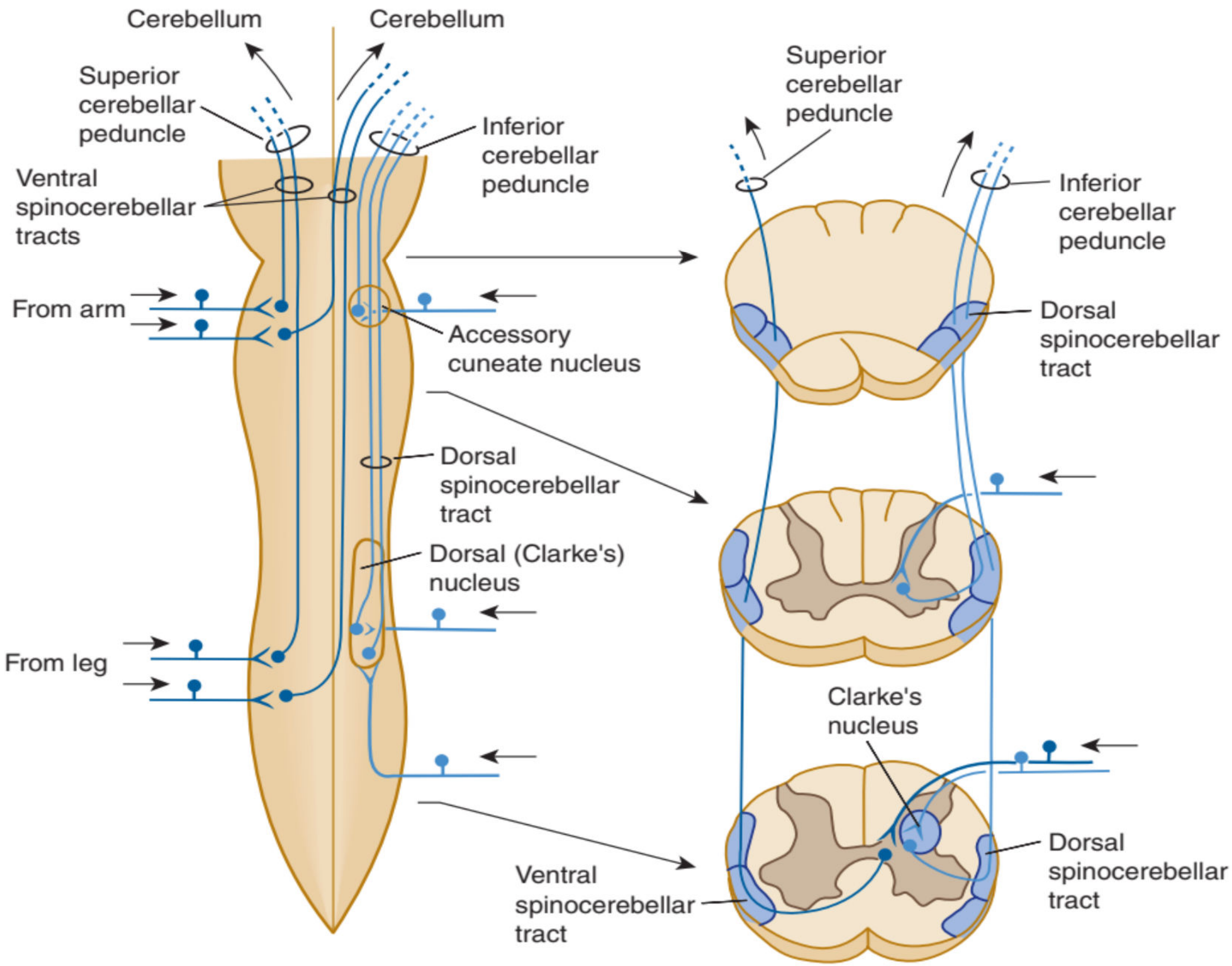


FIGURE 5–17 The spinocerebellar systems in the spinal cord.

REFLEXES

They are subconscious stimulus-response mechanisms.

SIMPLE REFLEX ARC

receptor	✓ (eg, a special sense organ, cutaneous end-organ, or muscle spindle) ✓ Whose stimulation initiates an impulse)
afferent neuron	transmits the impulse through a PN to the CNS.
center	✓ where the nerve synapses with an LMN or an intercalated neuron; one or more intercalated neurons (interneurons), ✓ which for some reflexes relay the impulse to the efferent neuron;
efferent neuron	(usually an LMN), which passes outward in the nerve and delivers the impulse to an effector
effector	(eg, the muscle or gland that produces the response). Interruption of this simple reflex arc at any point abolishes the response.

TYPES OF REFLEXES

The reflexes of importance to the clinical neurologist may be divided into four groups:

I. superficial (skin and mucous membrane) reflexes,
II. deep tendon (myotatic) reflexes,
III. visceral (organic) reflexes, and
IV. pathologic (abnormal) reflexes

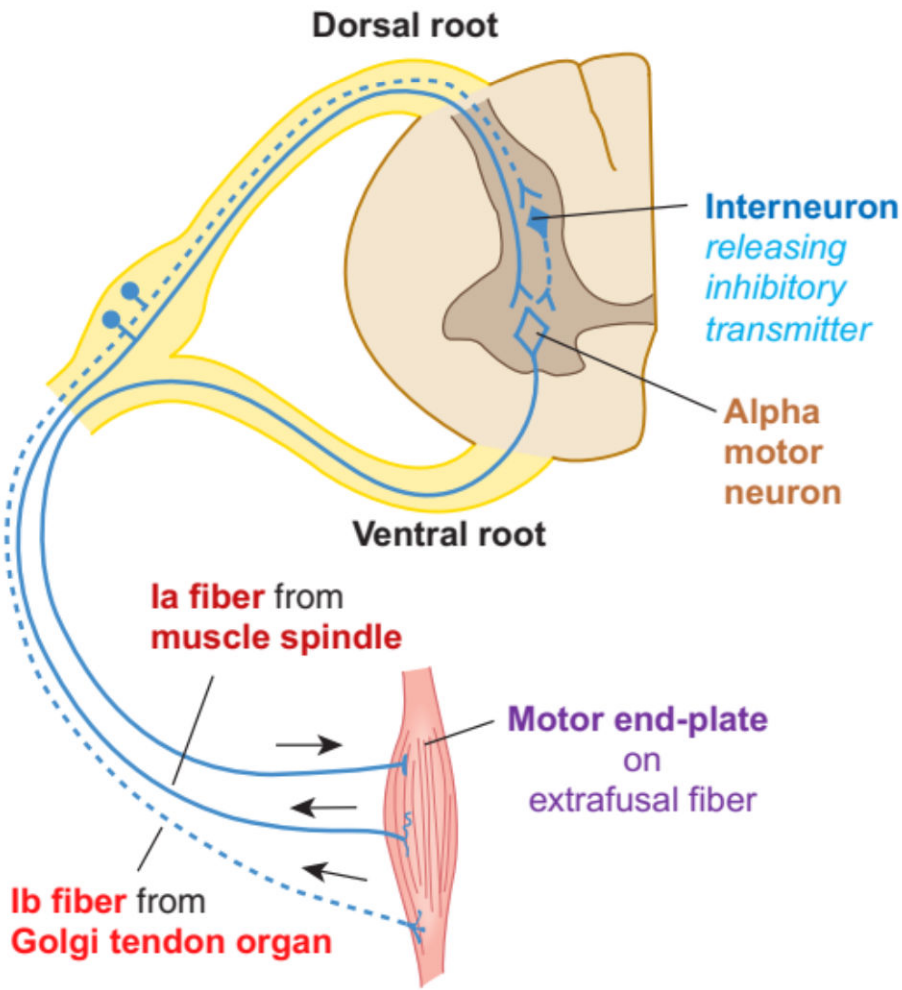
(Table 5–5).

Reflexes can also be classified according to the **level of their central representation**, for example, as spinal, bulbar (postural & righting reflexes), or midbrain.

SPINAL REFLEXES

- The segmental spinal reflex involves the **afferent neuron** and **its axon within a peripheral nerve** + **dorsal root** + **a motor unit at the same level** (see Fig 5–18).
- Simple reflex reactions ***involve specific patterns of muscle contractions.***

FIGURE 5–18 Diagram illustrating the pathways responsible for the stretch reflex and the inverse stretch reflex. Stretch *stimulates the muscle spindle, and impulses pass up the Ia fiber to excite the lower (alpha) motor neuron*. Stretch also *stimulates the Golgi tendon organ, which is arranged in series with the muscle, and impulses pass-ing up the Ib fiber activate the inhibitory neuron*. With strong stretch,the resulting hyperpolarization of the motor neuron is so great that it stops discharging. (Reproduced, with permission, from Ganong WF: *Review of Medical Physiology*, 22nd ed. McGraw-Hill, 2005.)



Reflexes	Afferent Nerve	Center	Efferent Nerve
Superficial reflexes			
Corneal	Cranial V	Pons	Cranial VII
Nasal (sneeze)	Cranial V	Brain stem and upper cord	Cranials V, VII, IX, X, and spinal nerves of expiration
Pharyngeal and uvular	Cranial IX	Medulla	Cranial X
Upper abdominal	T7, 8, 9, 10	T7, 8, 9, 10	T7, 8, 9, 10
Lower abdominal	T10, 11, 12	T10, 11, 12	T10, 11, 12
Cremasteric	Femoral	L1	Genitofemoral
Plantar	**Tibial**	**S1, 2**	**Tibial**
Anal	Pudendal	S4, 5	Pudendal
Tendon reflexes			
Jaw	Cranial V	Pons	Cranial V
Biceps	Musculocutaneous	C5, 6	Musculocutaneous
Triceps	Radial	C7, 8	Radial
Brachioradialis	Radial	C5, 6	Radial
Patellar	Femoral	L3, 4	Femoral
Achilles	Tibial	S1, 2	Tibial
Visceral reflexes			
Light	Cranial II	Midbrain	Cranial III
Accommodation	Cranial II	Occipital cortex	Cranial III
Ciliospinal	A sensory nerve	T1, 2	Cervical sympathetics
Oculocardiac	Cranial V	Medulla	Cranial X
Carotid sinus	Cranial IX	Medulla	Cranial X
Bulbocavernosus	Pudendal	S2, 3, 4	Pelvic autonomic
Bladder and rectal	Pudendal	S2, 3, 4	Pudendal and autonomics
Abnormal reflexes			
Extensor plantar (Babinski)	**Plantar**	**L3–5, S1**	**Extensor hallucis longus**

A. STRETCH REFLEXES AND THEIR ANATOMIC SUBSTRATES

Stretch reflexes (also called **tendon reflexes** or **deep tendon reflexes**)

provide a feedback mechanism for maintaining appropriate muscle tone (see Fig 5–18).

- **The stretch reflex depends on:**

1. **specialized sensory receptors** (muscle spindles),
2. **afferent nerve fibers** (primarily Ia fibers) extending from these receptors via the dorsal roots to the spinal cord,
3. **two types of LMNs** (alpha & gamma motor neurons) that project back to muscle,
4. **specialized inhibitory interneurons** (Renshaw cells).

B. MUSCLE SPINDLES

These **specialized mechanoreceptors** are located within muscles provide information about the **length** and **rate of changes in length** of the muscle.

The muscle spindles *contain specialized intrafusal muscle fibers, which are surrounded by a connective tissue capsule.*

- (**Intrafusal muscle fibers** should not be confused with ***extrafusal fibers*** or ***primary muscle cells***, *which are the regular contractile units that provide the force underlying muscle contraction.*)

- **Two types of intrafusal fibers** (nuclear bag fibers + nuclear chain fibers) are anchored to the connective tissue septae, which run longitudinally within the muscle and are *arranged in parallel with the extrafusal muscle fibers*

B. MUSCLE SPINDLES

types of intrafusal fibers	
nuclear bag fibers	**nuclear chain fibers**
primary(or annulospinal) endings	**secondary (or flower-spray)**
afferent axons, **Ia**	afferent axons, **II**
make **monosynaptic**, excitatory connections with alpha motor neurons.	make **monosynaptic**, excitatory connections with alpha motor neurons.
provide information about **the rate of change in muscle length** **(the dynamic response)**	provide information about **muscle length** **(the static response)**

The muscle spindles are distributed in parallel with the extrafusal muscle fibers

Lengthening or stretching muscle (Fig 5–19) → distorts the **2ry endings** in the spindle → Generates a receptor potential. → afferent axons from the muscle spindle **(Ia afferents)** to fire, *with a frequency that is proportionate to the degree of stretch*

✗

Conversely,
contraction of the muscle shortens the spindles
leads to
decrease in their firing rate.

Deep tendon reflexes are concerned with **resisting inappropriate stretch on muscles** and thus contribute to the **maintenance of body posture**.

Lengthening of a muscle stretches the muscle spindle

I

a discharge of an afferent Ia fiber in the dorsal root via monosynaptically

activates alpha motor neurons running to the muscle

extrafusal muscle fibers to contract so that the muscle will shorten

II

Ia afferents project, via **inhibitory interneurons**, to antagonistic muscle groups.

provides for **reciprocal inhibition**

(flexors are excited and extensors are inhibited (or vice versa) in a coordinated manner.)

C. ALPHA MOTOR NEURONS (LARGE ANTERIOR HORN NEURONS)

- When alpha motor neurons fire → (via axons in ventral roots & PN,) → motor end-plate → muscle contraction.
- Axon diameters of 12–20 µm
- conduction velocities of 70–120 m/s

D. GAMMA MOTOR NEURONS

- Each muscle spindle contains, within its capsule, 2 to 10 small intrafusal fibers.
- Intrafusal muscle fibers receive their own innervation from **gamma motor neurons**, which are *small, specialized motor neurons whose cell bodies are located in the ventral horn* (Fig 5–20).
- **Gamma motor neurons have:**

✓ ***small axons*** (in the Aγ groups, 3–6 μm in diameter)

✓ ***make up about 25% to 30% of the fibers in the ventral root*.**

Firing in gamma motor neurons excites the intrafusal muscle fibers so that they contract. This action *does not lead directly to detectable muscle contraction, because the intrafusal fibers are small*.

Firing gamma motor neurons, however, does *increase tension on the muscle spindle*, *which increases its sensitivity to overall muscle stretch*. **Thus, the gamma motor neuron/intrafusal muscle fiber system sets the "gain" on the muscle spindle.**

The firing rates of gamma motor neurons are regulated by

***Descending activity from the brain*.**

By

modulating the thresholds for stretch reflexes,

descending influences regulate postural tone.

E. RENSHAW CELLS

- *These interneurons, located in the ventral horn, project to alpha motor neurons and are inhibitory*.

- Renshaw cells **receive excitatory synaptic input via collaterals**, which *branch from alpha motor neurons.*

- These cells are part of local feedback circuits that prevent overactivity in alpha motor neurons.

F. GOLGI TENDON ORGANS

- A second set of receptors, the Golgi tendon organs, is **present within** *muscle tendons*.

- These stretch receptors are **arranged in** *series with extrafusal muscle fibers* and are **activated by** *either stretching* or *contracting the muscle*.

- **Group Ib afferent fibers** run from the tendon organs

via the dorsal roots

to the spinal gray matter.

Here, they **end on interneurons** that **inhibit the alpha motor neuron innervating the agonist muscle**, thus mediating the inverse stretch reflex (see Fig 5–18).

- **This feedback arrangement prevents overactivity of alpha motor neurons.**

G. CLINICAL CORRELATIONS

- If the **alpha motor neuron** fibers in a ventral root or peripheral nerve are cut or injured, The ***muscle*** becomes weak & flaccid and has little tone.

- Examination of deep tendon reflexes can provide valuable diagnostic information. **Loss of all deep tendon reflexes**, for example, can suggest a polyneuropathy (eg, Guillain–Barré syndrome), while

- loss or reduction of one **particular deep tendon reflex** (eg, loss of the knee jerk on one side) suggests injury to the afferent or efferent nerve fibers in the nerves or roots supplying that reflex.

- **The large extensor muscles that support the body are kept constantly active by** *coactivation of alpha + gamma motor neurons*.

G. CLINICAL CORRELATIONS

Transection of the spinal cord acutely reduces muscle tone below the level of the lesion, *indicating that supraspinal descending axons modulate the alpha and gamma motor neurons*.

- **In the chronic phase after transection of the spinal cord,**

✓ there is *hyperactivity of stretch reflexes below the level of the lesion*, producing **spasticity.**

This condition is a result of the *loss of descending, modulatory influences*.

H. POLYSYNAPTIC REFLEXES

- In contrast to the extensor stretch reflex (eg, patellar, Achilles tendon), polysynaptic, ***crossed extensor reflexes*** *are not limited to one muscle; they usually involve many muscles on the same or opposite side of the body* (Fig 5–21).
- These reflexes have several physiologic characteristics:

1) **Reciprocal action of antagonists**—*Flexors are excited and extensors inhibited on one side of the body;* the opposite occurs on the opposite side of the body.
2) **Divergence**—*Stimuli from a few receptors are distributed to many motor neurons in the cord.*
3) **Summation**—Consecutive *or simultaneous subthreshold stimuli may combine to initiate the reflex.*

H. POLYSYNAPTIC REFLEXES

Propriospinal axons

- located on the *periphery of the spinal gray matter*,
- are the *axons of local circuit neurons that convey impulses upward or downward, for several segments*, to coordinate reflexes involving several segments.
- Some researchers refer to these axons as the **propriospinal tract**.

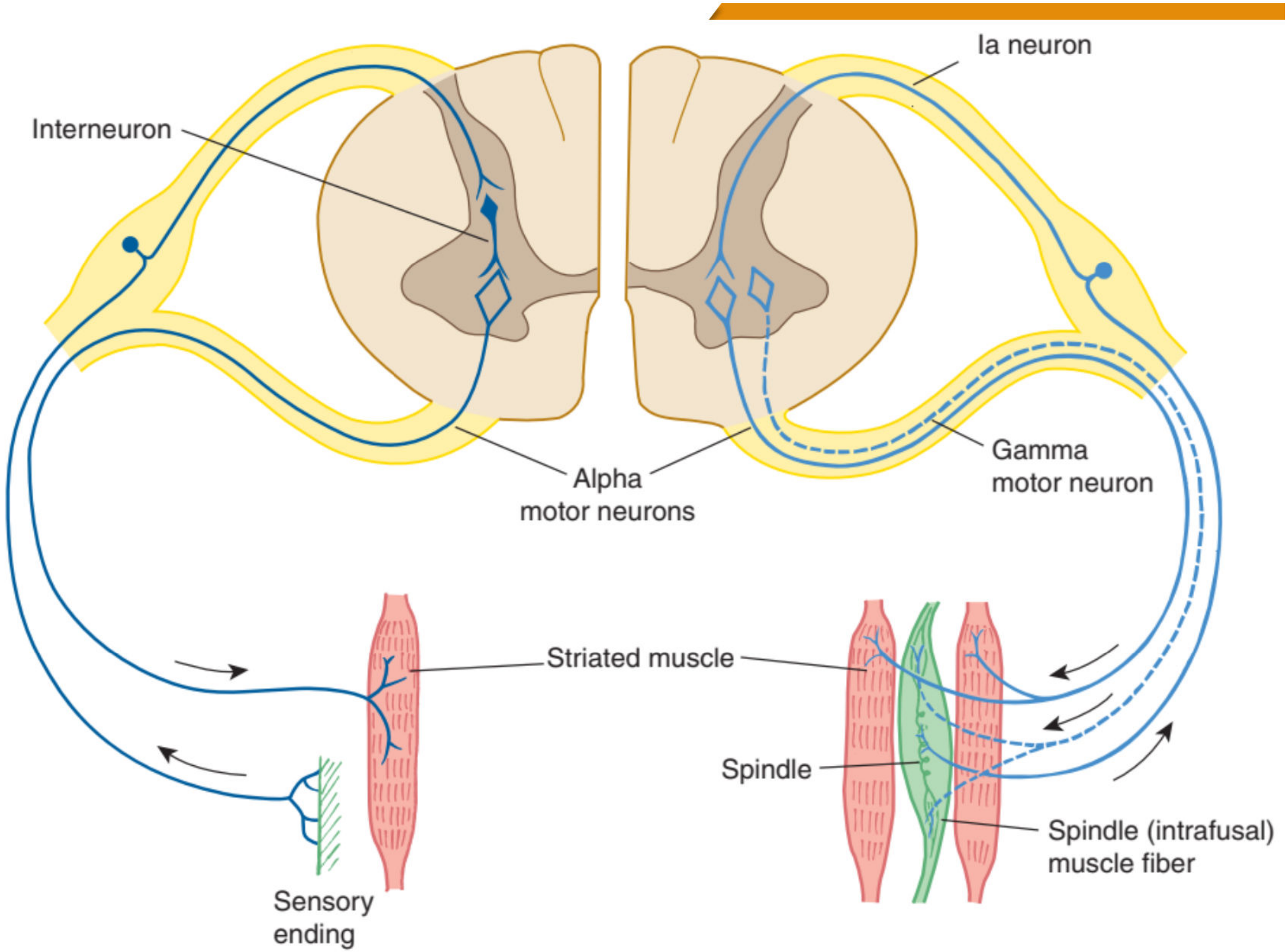


FIGURE 5–20 Schematic illustration of the neurons involved in the **stretch reflex (right half)** showing *innervation of* ***extrafusal (striated muscle)*** *fibers by alpha motor neurons*, and of ***intrafusal fibers (within muscle spindle)*** *by gamma motor neurons.* The left half of the diagram shows an inhibitory reflex arc, which includes an *intercalated inhibitory interneuron.*

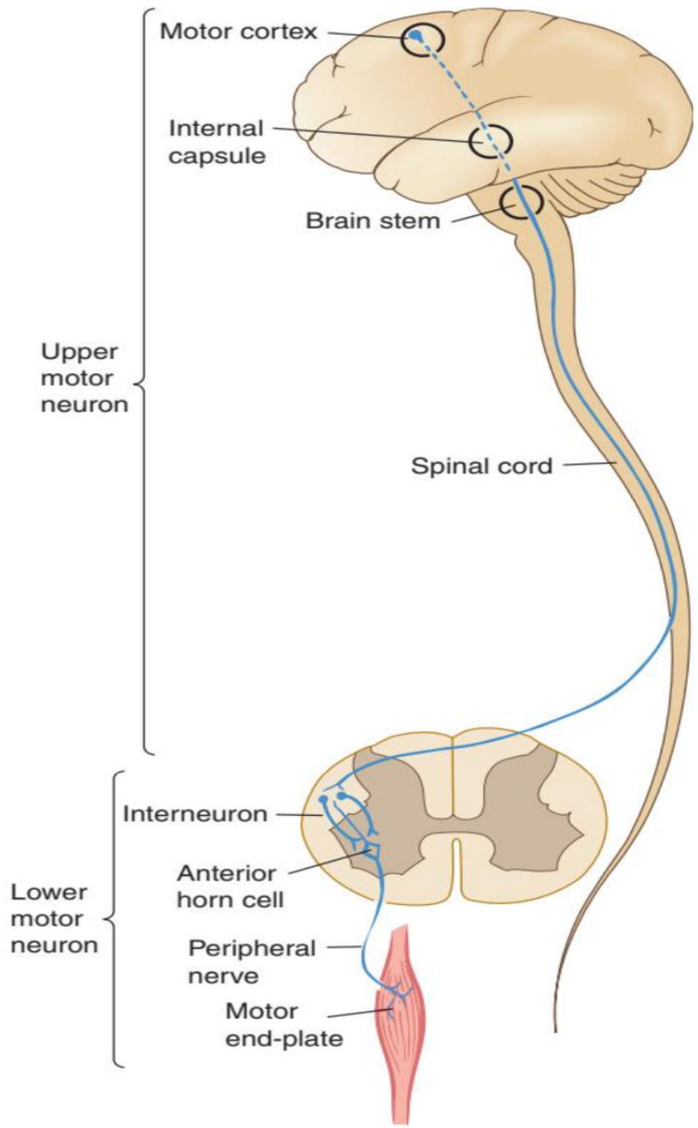


FIGURE 5–22 Motor pathways divided into upper- and lower-motor-neuron regions.

LESIONS IN THE MOTOR PATHWAYS

TABLE 5–6 **Lower- Versus Upper-Motor-Neuron Lesions.**

Variable	Lower-Motor-Neuron Lesion	Upper-Motor-Neuron Lesion
Weakness	Flaccid paralysis	Spastic paralysis
Deep tendon reflexes	Decreased or absent	Increased
Babinski's reflex	Absent	Present
Atrophy	May be marked	Absent or resulting from disuse
Fasciculations and fibrillations	May be present	Absent

- **The cerebral hemispheres make us human. They include:**

1) **the cerebral cortex** (which consists of ***six lobes*** on each side: frontal, parietal, temporal, occipital, insular, and limbic),

1) **the underlying cerebral white matter,**

1) **a complex of deep gray matter masses,** the basal ganglia.

ANATOMY OF THE CEREBRAL HEMISPHERES

- **highly convoluted masses of gray matter** *that are organized into two somewhat symmetrical* (but not totally symmetrical) *folded structures*.
- The crests of the cortical folds (**gyri**) are separated by furrows (**sulci**) or deeper fissures.
- The **folding** of the cortex into gyri and sulci *permits the cranial vault to contain a large area of cortex.*

✓(nearly 21/2 square feet if the cortex were unfolded)+

➢more than 50% of which is hidden within the sulci & fissures.

➢**The lateral cerebral fissure (Sylvian fissure)** *separates the temporal lobe from the frontal & parietal lobes. The insula lies deep within the fissure* (Fig 10–7).

➢**The circular sulcus (circuminsular fissure)** surrounds the insula + *separates it from the adjacent frontal, parietal, and temporal lobes.*

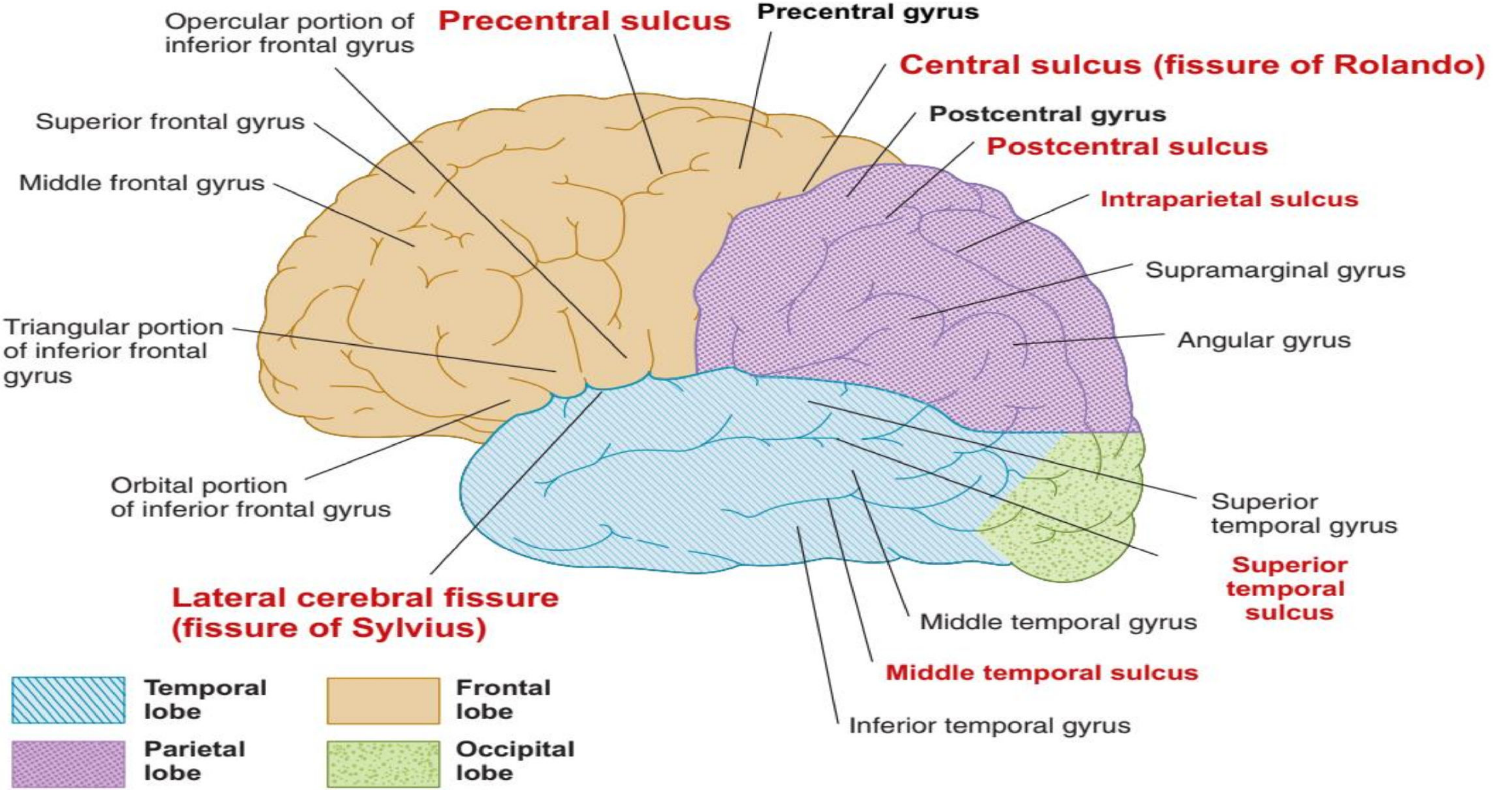


FIGURE 10–5 Lateral view of the left cerebral hemisphere, showing principal gyri and sulci.

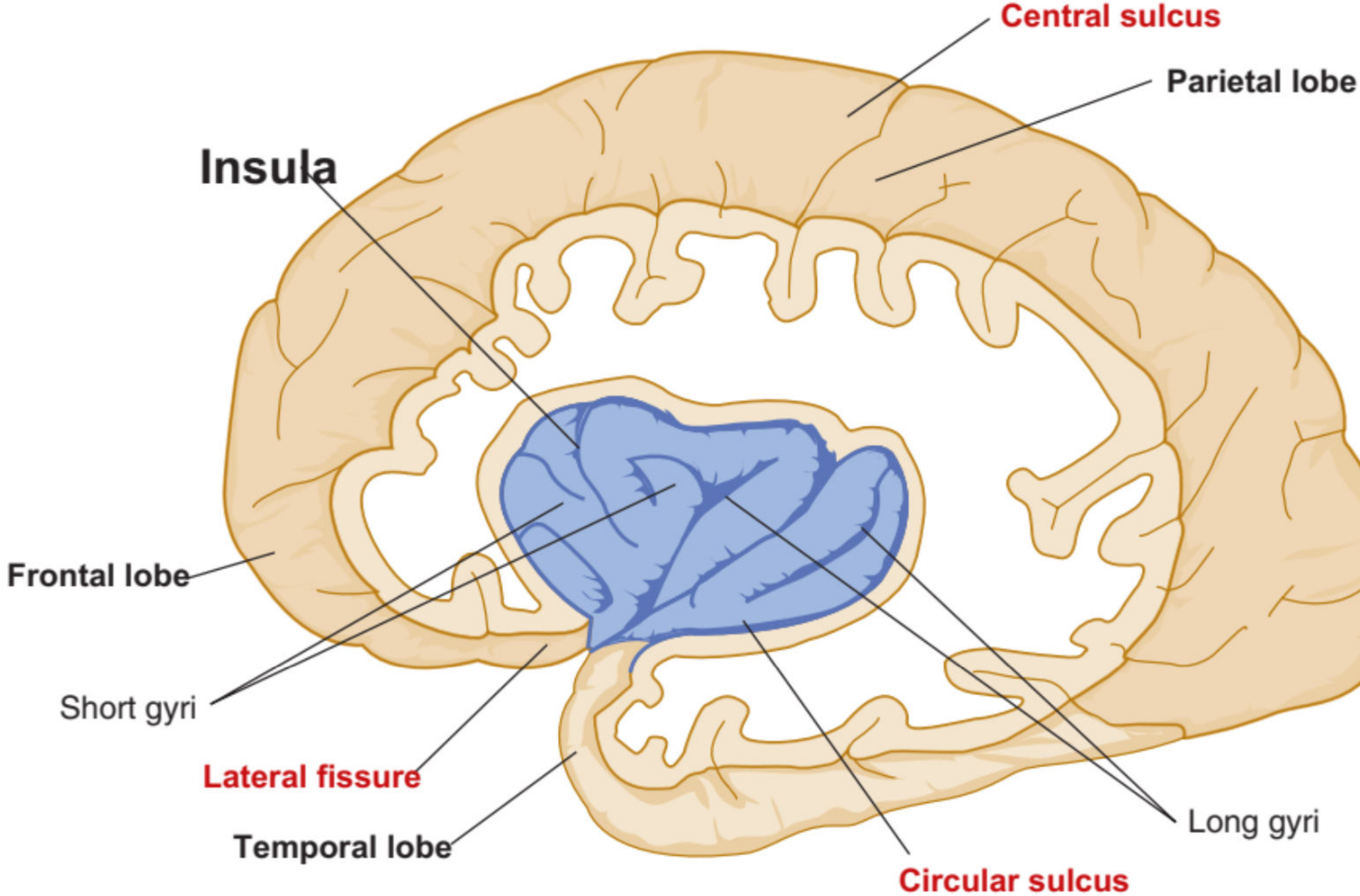


FIGURE 10–7 Dissection of the left hemisphere to show the insula.

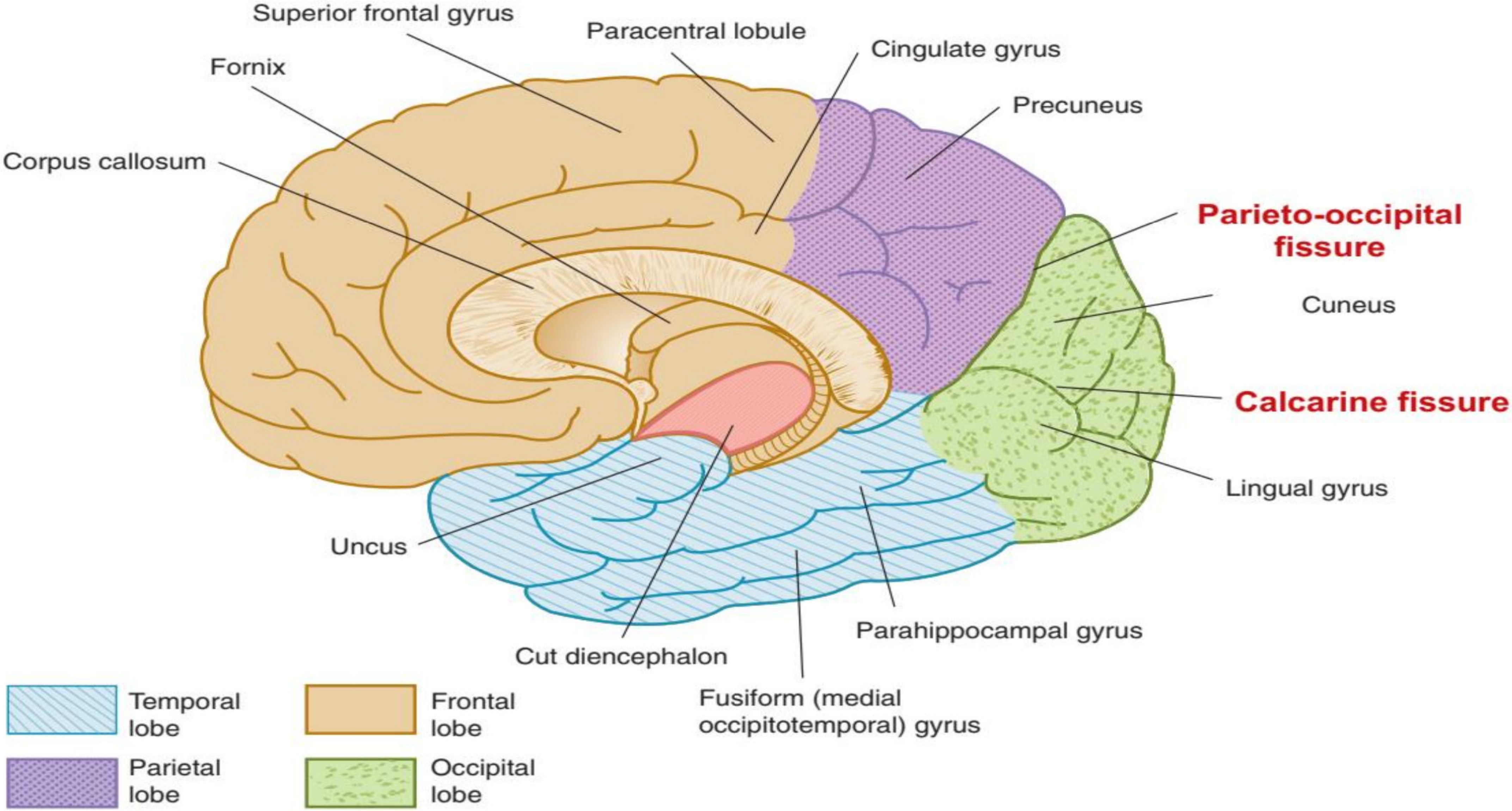


FIGURE 10–6 **Medial view of the right cerebral hemisphere.**

- The hemispheres are separated by a deep median fissure, **the longitudinal cerebral fissure**.
- **The central sulcus (the fissure of Rolando)** arises about the middle of the hemisphere, beginning near the longitudinal cerebral fissure and extending downward and forward to about 2.5 cm above the lateral cerebral fissure (see Fig 10–5). The central sulcus *separates the frontal lobe from the parietal lobe.*
- **The parieto-occipital fissure** passes along the medial surface of the posterior portion of the cerebral hemisphere and then runs downward and forward as a deep cleft (see Fig 10–6). The fissure separates the parietal lobe from the occipital lobe.
- **The calcarine fissure** begins on the medial surface of the hemisphere near the occipital pole and extends forward to an area slightly below the splenium of the corpus callosum (see Fig 10–6).

CORPUS CALLOSUM

- a large bundle of myelinated + nonmyelinated fibers, the great white commissure that crosses the longitudinal cerebral fissure (see Figs 10–4 and 10–6).

✓ **The corpus callosum** ***permits the two hemispheres to communicate with each other.***

✓ **Most parts of the cerebral cortex** *are connected with their counterparts in the opposite hemisphere by axons that run in the corpus callosum*.

✓ The corpus callosum is the largest of the interhemispheric commissures and is largely responsible for **coordinating the activities of the two cerebral hemispheres**.

INSULA

- a sunken portion of the cerebral cortex (see Fig 10–7).
- It lies at the bottom of a deep fold within the lateral cerebral fissure and can be exposed by separating the upper and lower lips (opercula) of the lateral fissure.

LIMBIC SYSTEM COMPONENTS

- **The cortical components of the limbic system include :**

1) Hippocampus,
2) Amygdale,
3) Anterior thalamic nuclei.

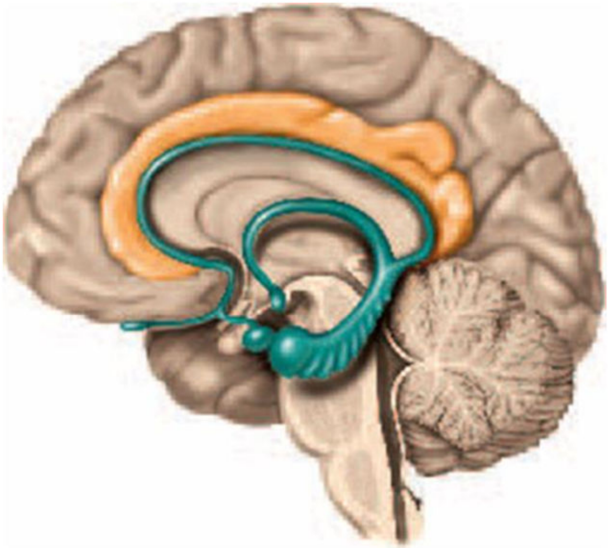
- **Functions**

✓Cognitive, attentional processing

✓Emotion, behavior.

✓Recent and long term memory.

✓Olfaction.



CLASSIFICATION OF PRINCIPAL AREAS

- The most commonly used classification system is **Brodmann's**, which is based on cytoarchitectonics (the precise shapes + arrangements of the neurons within a given part of the cortex).
- The Brodmann classification uses numbers *to label individual areas of the cortex* that Brodmann believed differed from others (Figs 10– 11 and 10–12).
- These anatomically defined areas have been used as a reference base for the localization of physiologic and pathologic processes.
- More recently, **functional brain imaging** has been *used to localize various functions to particular cortical areas.*

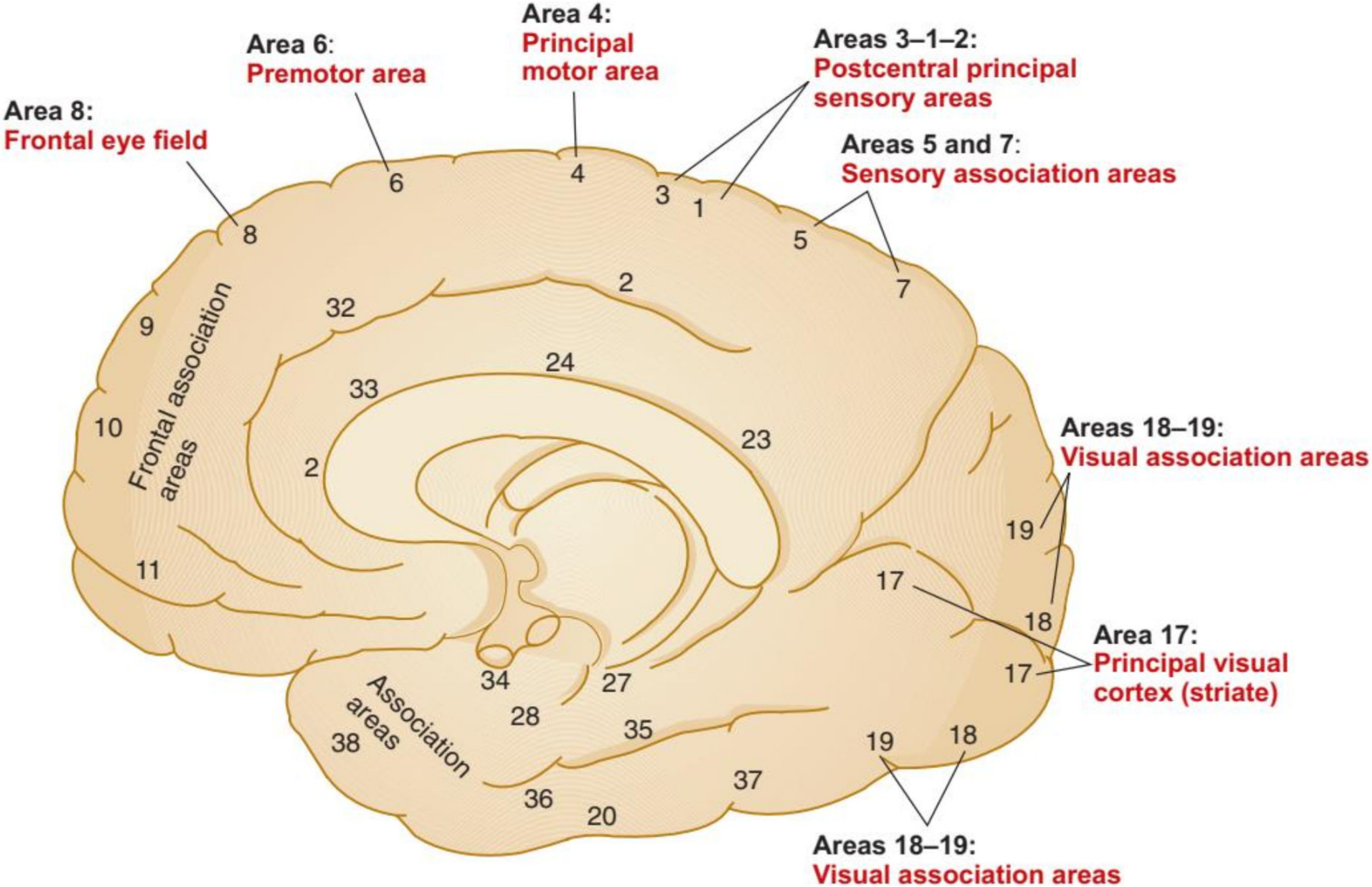


FIGURE 10–12 **Medial aspect of the cerebrum.** The cortical areas are shown according to Brodmann with functional localizations

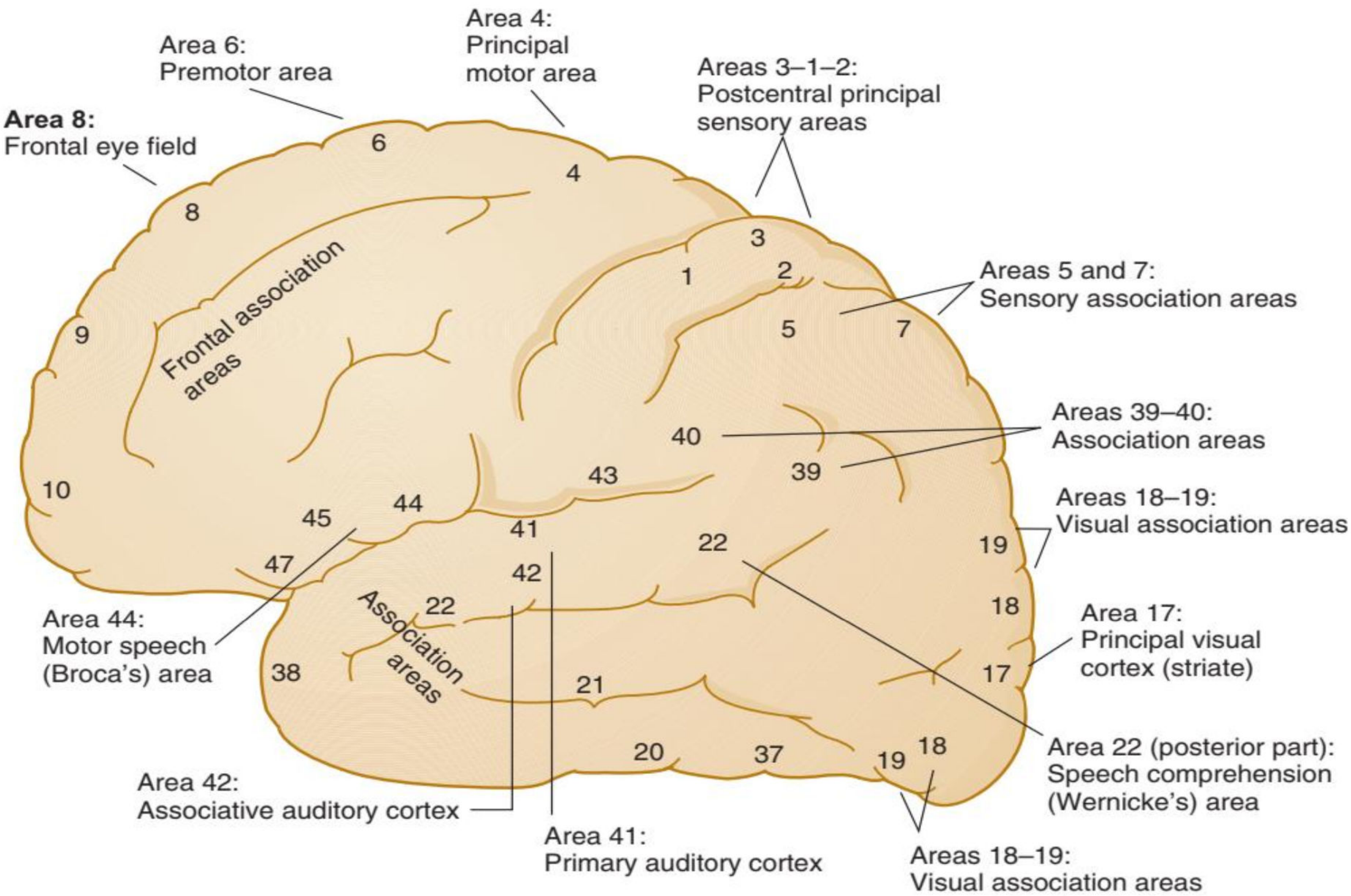
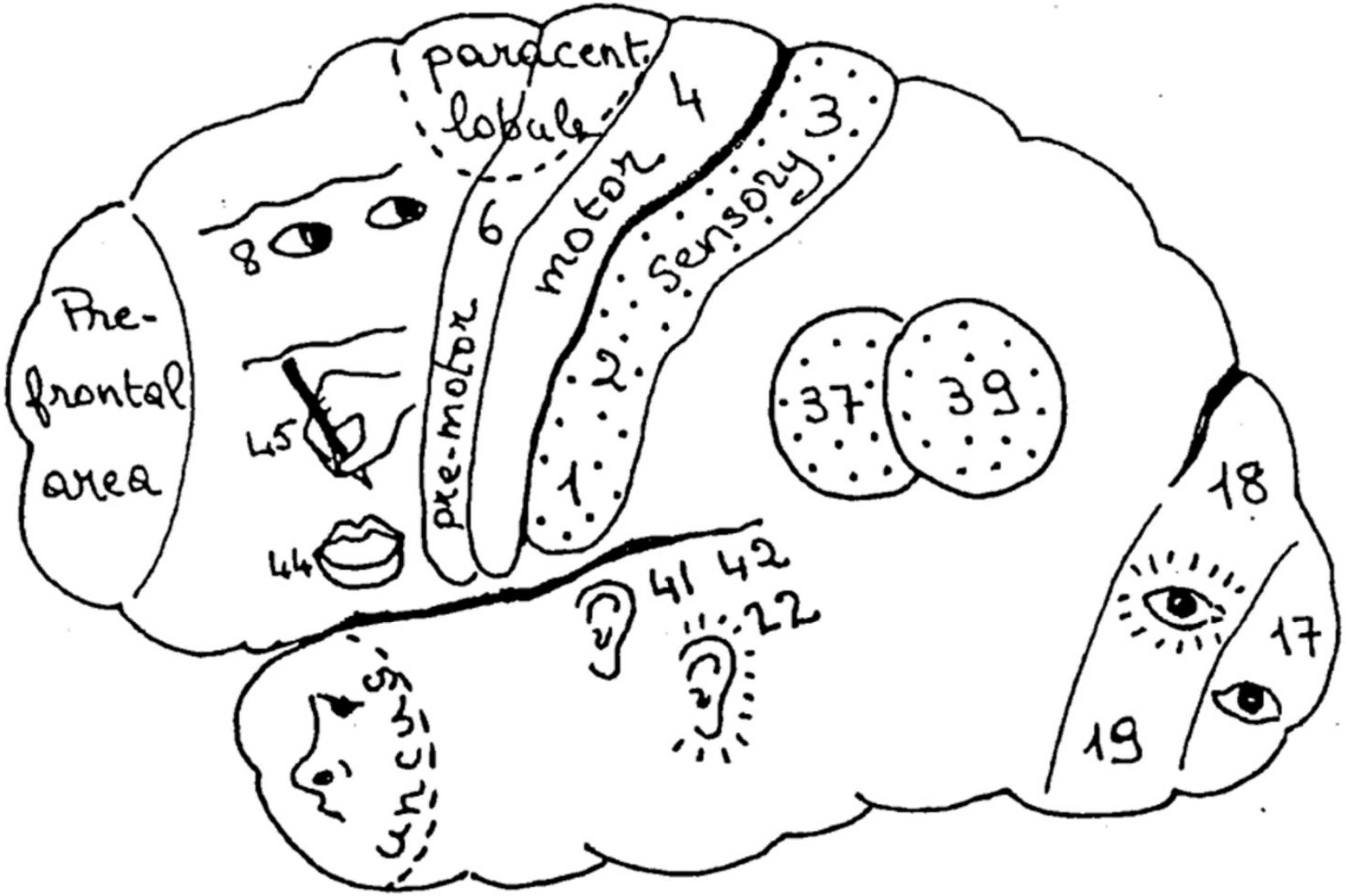


FIGURE 10–11 **Lateral aspect of the cerebrum.** The cortical areas are shown according to Brodmann with functional localizations.

CEREBRAL CORTEX



AREAS OF THE CERBERAL CORTEX

A. FRONTAL LOBE

1) Motor Area (area 4):

- Site: floor of central sulcus & posterior part of precentral gyrus.
- Function: initiation of voluntary motor activity of the opposite $^1/_2$ of the body through the pyramidal (Δ) tract. **In this area the body is represented upside down.** Complex movements involving speech, face & hands are widely represented in the lower part of this area.
- Lesion: – Irritative: contralateral **motor Jacksonian fits**: there are convulsions involving the muscles of one side of the body; the fit has a focal onset either in the thumb, angle of the mouth or big toe (depending on whether the irritative lesion starts in the lower or upper part of the motor area); the fit spreads in a march course e.g. thumb → arm → shoulder → trunk → L.L.
  – Destructive: Contralateral **paralysis** usually affecting one limb (monoplegia).

- Large pyramidal neurons (Betz's cells) and smaller neurons in this *area give rise to many (but not all) axons that descend as the corticospinal tract*.
- The motor cortex is organized somatotopically: The lips, tongue, face, and hands are represented in order within a map-like homunculus on the lower part of the convexity of the hemisphere.

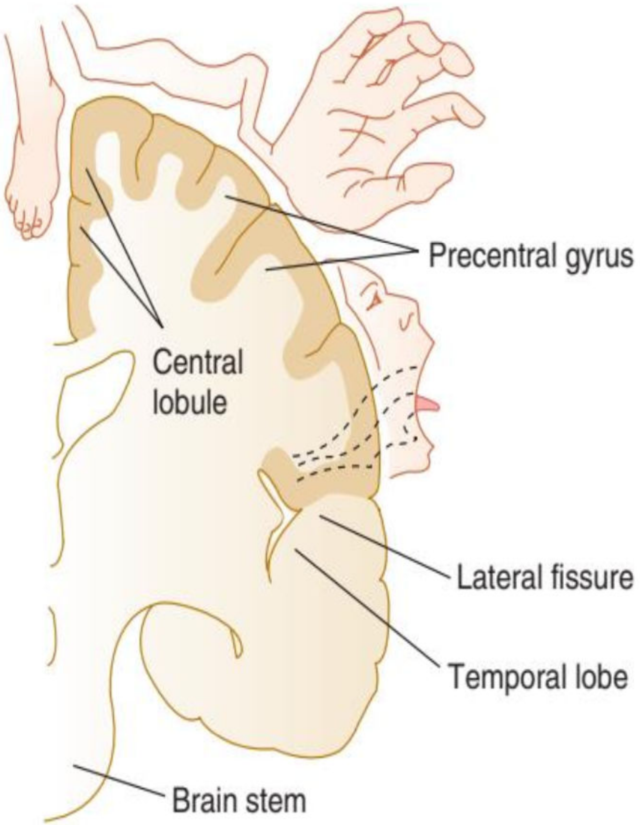


FIGURE 10–14 Motor homunculus drawn on a coronal section through the precentral gyrus. The location of cortical control of various body parts is shown.

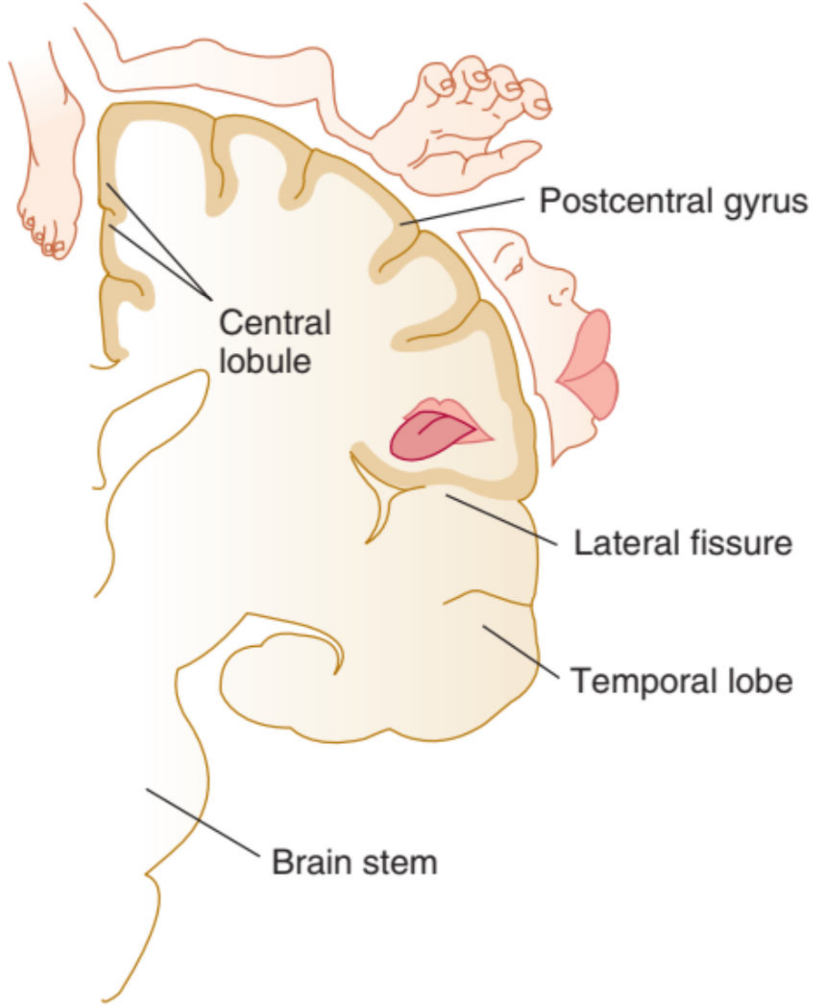


FIGURE 10–15 Sensory homunculus drawn overlying a coronal section through the postcentral gyrus. The location of the cortical representation of various body parts is shown.

2) Premotor Area (area 6):

- Site: anterior part of the precentral gyrus.
- Function: 1- partly supplies Δ tract & 2- gives extra Δ fibres.

  This area inhibits the muscle tone & the deep reflexes on the opposite side of the body.
- Lesion: 1- contralateral **hypertonia & exaggerated deep reflexes.**

  2- contralateral **fanning** of the lateral 4 toes on eliciting the Plantar reflex.

- **contains a second motor map.**
- **Several other motor zones,** ***including*** ***the supplementary motor area*** (located on the medial aspect of the hemisphere), are clustered nearby.

3) Area of Voluntary Conjugate Eye Movements (area 8):

- Site: posterior part of middle frontal gyrus.
- Function: voluntary conjugate eye movement to the opposite side e.g. while reading the action of passing from the end of one line to the beginning of the next line; this movement is usually rapid & is termed "**saccadic**."
- Lesion:
  - Irritative: attacks of conjugate eye deviation to the opposite side of the lesion.
  - Destructive: paralysis of conjugate eye movement to the opposite side of the lesion.

4) Broca's Area (area 44):

- Site: posterior part of inferior frontal gyrus of **DOMINANT** hemisphere.
- Function: motor centre for speech.
- Lesion: **motor** (expressive) **aphasia**; the patient cannot express his ideas in spoken words. (see p 37).

5) Exner's Area (area 45):

- Site: adjacent to area 44 in the **DOMINANT** hemisphere.
- Function: centre for writing.
- Lesion: **agraphia**; the patient cannot express his ideas in written words.

6- Pre-frontal area:

-Anterior part of frontal lobe

-Center for mentality, personality & behavior

- Inhibit primitive reflex as grasp reflex

Lesion:

1- mentality & behavior changes: lack of attention & personal hygiene

2-Dementia (loss of thinking abilities & problem solving).

3-Reappearance of primitive reflex

- **has extensive reciprocal connections with** the **dorsomedial** and **ventral anterior thalamus** and with **the limbic system**.
- **This association area receives inputs from multiple sensory modalities and integrates them.**
- The prefrontal cortex serves **"executive" functions**, planning and initiating adaptive actions and inhibiting maladaptive ones; prioritizing & sequencing actions; and weaving elementary motor and sensory functions into a coherent, goal-directed stream of behavior.

7) Paracentral Lobule:

- Site: medial surface of the superior frontal gyrus, adjacent to the foot & leg area.
- Function: cortical inhibition (control) of bladder & bowel voiding
- Lesion: incontinence of urine & faeces.

B. PARIETAL LOBE

1) Cortical Sensory Area (areas 1, 2, 3):

- Site: post-central gyrus.
- Function: Perception of cortical sensations from the opposite $^1/_2$ of the body; like in the motor area, the body is represented upside down.
- Lesion: – Irritative: contralateral **sensory Jacksonian fits** in the form of numbness or tingling with focal onset & a march course; it may be followed by a motor fit if the irritation extends to the adjacent motor area.
  – Destructive: contralateral **cortical sensory loss**.

- ❑ **This area receives somatosensory input from: (VPL)** + **ventral posteromedial (VPM) nuclei in the thalamus**.
- ❑ **The remaining areas** are sensory or multimodal association areas.

2) Angular Gyrus (area 39):

- Site: in the postero-inferior part of the parietal lobe.
- Function: in the **DOMINANT** hemisphere, it is concerned with reading i.e. the recognition & recall of letters & numbers.
- Lesion: **Alexia**; the patient who could read before the lesion, becomes unable to do so, because he cannot understand the letters & numbers which he sees.

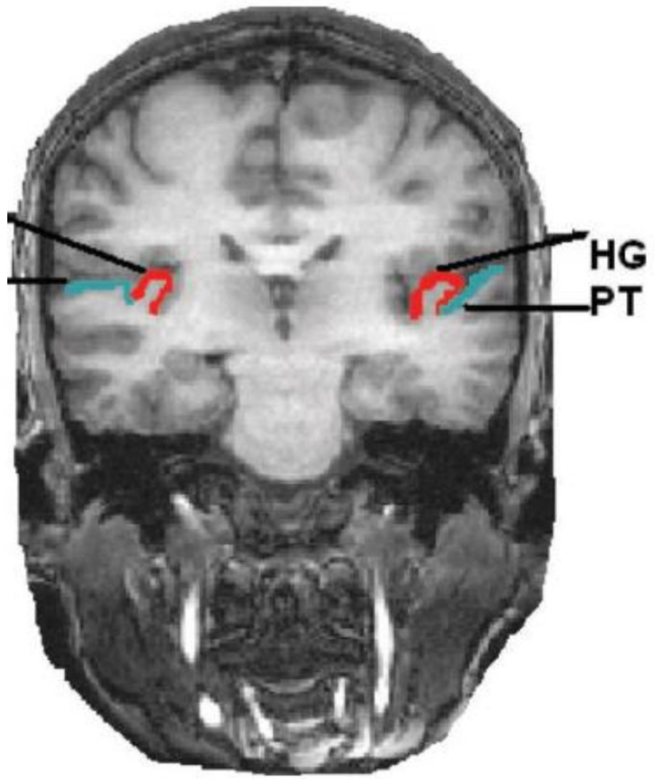
3) Supramarginal Gyrus (area 37):

- Site: anterior to the angular gyrus.
- Function: in the dominant hemisphere it is concerned with storage & recall of:
  - IDEAS of speech.
  - IDEAS of complex voluntary motor activity.
- Lesion:
  1- **Jargon's aphasia** (word salad).
  2- **Apraxia**: inability to perform complex voluntary motor activity in absence of paralysis, incoordination or sensory loss.

C. TEMPORAL LOBE

1) <u>Auditory Sensory Area (area 41, 42)</u>:

- <u>Site</u>: superior temporal gyrus.
- <u>Function</u>: auditory sensory area.
- <u>Lesion</u>:
  - Irritative: auditory hallucinations.
  - Destructive: Slight hearing impairment, **never deafness** as hearing is bilaterally represented.



- **Area 41** is the primary auditory cortex;
- **area 42** is the associative (secondary) auditory cortex.
- Together, these areas are referred to as **Heschl's gyrus**. Immediately adjacent to Heschl's gyrus lies the **planum temporale**, which is located on the superior surface of the tempural lobe (Fig 10–16), which is *larger on the left in right-handed individuals, and is involved in **language** and **music***.

FIGURE 10–16 Magnetic resonance image showing Heschl's gyrus (HG, red) and planum temporal (PT, blue) within the upper part of the temporal lobe. (Reproduced, with permission, from Oertel-Knöchel V,

C. TEMPORAL LOBE

2) Auditory Associative Area (area 22):

- Site: adjacent to areas 41 & 42.
- Function: recognition & recall of sounds.
- Lesion: **Auditory agnosia**: the patient hears but does not understand (recognize) what he hears.

- **In the posterior part of area 22** (in the posterior third of the superior temporal gyrus) is **Wernicke's area**, which *plays an important role in the comprehension of language*.
- **The remaining temporal areas** *are multimodal association areas*.

3) Limbic System:

- Site: uncus & hippocampus in the medial & inferior surfaces of the temporal lobe.
- Function: concerned with smell (uncus), mood & memory.
- Lesion:
  1. **Uncinate fits** with olfactory hallucinations, usually unpleasant.
  2. **Temporal lobe seizures** (see epilepsy).
  3. **Anterograde amnesia** (loss of memory for recent events).

D. OCCIPITAL LOBE

1) **Visual Sensory Area (area 17):** for the reception of visual images.

the striate—the primary visual cortex.

- ✓ *Upper parts of the retina (lower parts of the visual field)* are represented in **upper parts of area 17**, and
- ✓ *lower parts of the retina (upper parts of the visual field)* are represented in **lower parts of area 17**.

D. OCCIPITAL LOBE

2) Visual Associative Area (area 18, 19): anterior to area 17.

- Function: 1- recognition & recall of images.
  2- centre for reflex conjugate eye movement to the opposite side **e.g.** while reading, following the words of a line, one after the other; this movement is usually slow & is termed "**pursuit**."
- Lesion to the visual areas results in:
  - Irritative: **Unformed visual hallucinations** e.g. sparks, lines, flashes ...; this occurs e.g. in the aura of classic migraine or in epilepsy when the occipital lobe is involved.
  - Destructive: 1- **Homonymous hemianopia** with or without macular sparing.
    2- **Visual Agnosia**: the patient sees (e.g. a familiar face) but does not recognize what he sees.
    3- **Paralysis of reflex conjugate eye movements**.

- There are also visual maps within the **temporal** and **parietal lobes.**
- Each of these maps represents the entire visual world, **but** *extracts information about a particular aspect of it (forms, colors, movements) from the incoming visual signals*.

E. MULTIMODAL ASSOCIATION AREAS

As noted earlier, for each sensory modality, there is a primary sensory cortex as well as modality-specific association areas. A number of multimodal association areas also receive converging projections from different modality-specific association areas.

- **Site:**

1) the temporoparietal area within the inferior parietal lobule and the area around the superior temporal sulcus.
2) the prefrontal region.

- **receive converging projections from** different modality-specific association areas.
- **Within these multimodal association areas,** information about different attributes of a stimulus (eg, the visual image of a dog, the sound of its bark, and the feel of its fur) all appear to converge, so that higher order information processing can take place.
- **project, in turn, to the limbic cortex.**

CONTROL OF MOVEMENT

CONTROL OF MOVEMENT

- **The motor system includes:**

I. **cortical & subcortical areas of gray matter**;

✓ corticobulbar, corticospinal, corticopontine, rubrospinal, reticulospinal, vestibulospinal, and tectospinal **descending tracts**;

II. **gray matter of the spinal cord; efferent nerves**;

III. **cerebellum** + **basal ganglia** (Figs 13–1 and 13–2).

IV. Feedback from **sensory systems** and **cerebellar afferents** further influences the motor system.

CONTROL OF MOVEMENT

Movement is organized in increasingly complex and hierarchical levels.

I. **Reflexes** are controlled at the ***spinal or higher levels***.

II. **Stereotypic repetitious movements,** such as walking or swimming, are governed by neural networks that include the spinal cord, brain stem, and cerebellum. Walking movements can be elicited in experimental animals after transection of the upper brain stem, probably as a result of the presence of central pattern generators, or local circuits of neurons that can ***trigger simple repetitive motor activities, in the lower brain stem or spinal cord***.

III. **Specific, goal-directed movements** are initiated at the ***level of the cerebral cortex.***

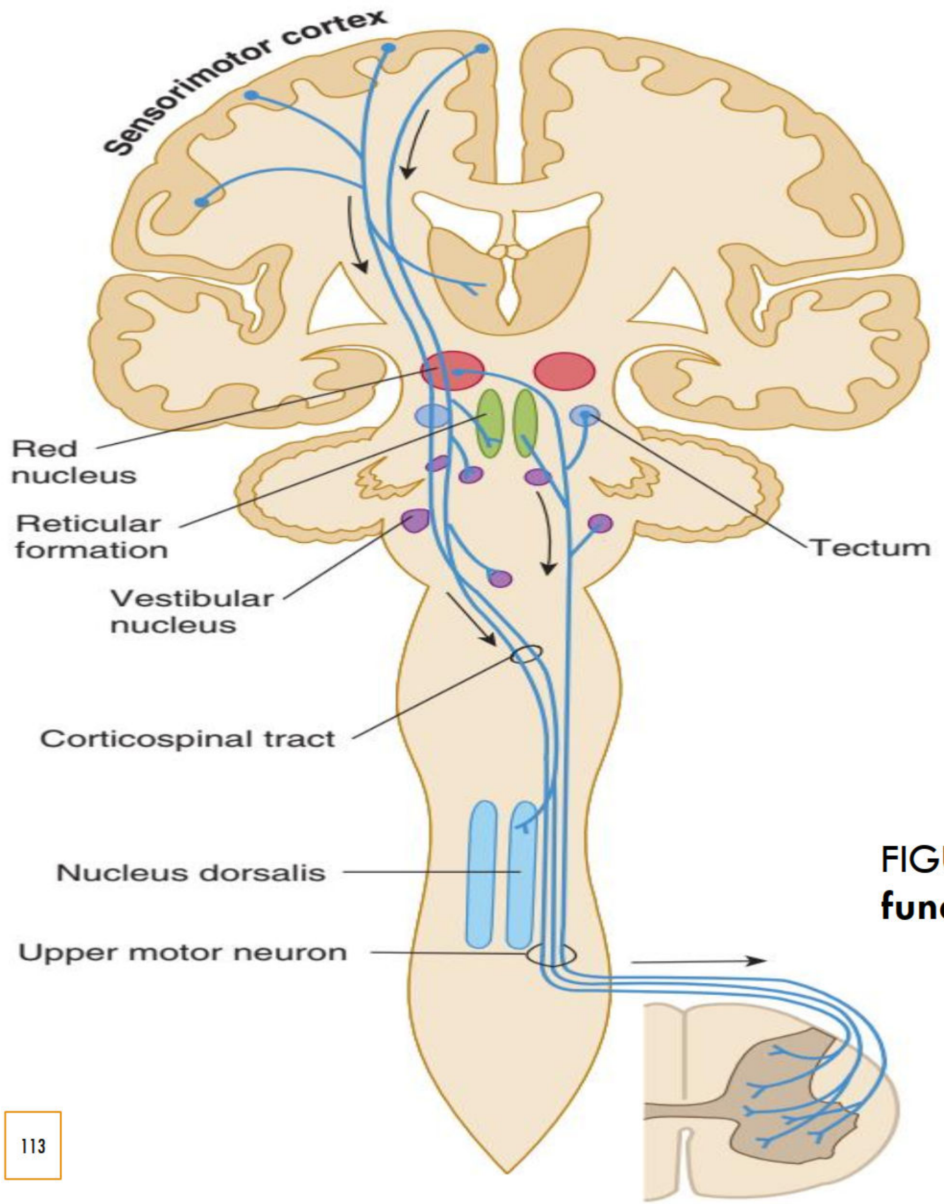


FIGURE 13–1 Schematic illustration of **some pathways controlling motor functions.** Arrows denote descending pathways.

MAJOR MOTOR SYSTEMS

I- Corticospinal and Corticobulbar Tracts

A. Origin and Composition

- **arise from** the sensorimotor cortex around the central sulcus (see Fig 13–1);
- ✓ **about 55%** originate in the **frontal lobe (areas 4 and 6),** and
- ✓ **about 35%** arise from **areas 3, 1, and 2** in the postcentral gyrus of the **parietal lobe** (see Fig 10–11).
- ✓ **About 10%** of the fibers originate in other frontal or parietal areas.
- ✓ The axons arising from the large pyramidal cells in layer V (Betz's cells) of area 4 contribute only **about 5% of** the fibers of the corticospinal tract and its pyramidal portion.
- ➢ **The portion of the pyramidal tract that arises from the frontal lobe** is concerned with **motor function**;
- ➢ **the portion from the parietal lobe** deals more with **modulation of the ascending systems**.

MAJOR MOTOR SYSTEMS

I- Corticospinal and Corticobulbar Tracts

- ❑ **The tracts have endings or collaterals that synapse in**
- ✓ **the thalamus** (ventral nuclei),
- ✓ **the brain stem** (pontine nuclei, reticular formation, and nuclei of cranial nerves),
- ✓ the **spinal cord** (anterior horn motor neurons and interneurons; Fig 13–3).
- ❑ **A direct pathway to spinal cord motor neurons exists only** for *the musculature of the distal extremity, such as the fingers that require rapid and precise control.*

MAJOR MOTOR SYSTEMS

I- The corticobulbar (corticonuclear) fibers

B. Pathways

- **originate in the region of the sensorimotor cortex**, *where the face is represented* (see Figs 10–13 and 10–14).
- **They pass through** the **posterior limb of the internal capsule** + **middle portion of the crus cerebri to their targets**, the **somatic and brachial efferent nuclei in the brain stem.**

MAJOR MOTOR SYSTEMS

I- The corticospinal tract

B. Pathways

- **originates in** the **remainder of the sensorimotor cortex** and **other cortical areas**.
- **It follows**

✓ a similar trajectory through the **brain stem** and

✓ then passes through the **pyramids of the medulla** (hence, the name pyramidal tract),

✓ decussates, and

✓ descends in the **lateral column of the spinal cord** (see Figs 5–13, 13–1, and 13–3).

About 10% of the pyramidal tract does not cross in the pyramidal decussation
but
descends in the anterior column of the spinal cord;
these fibers decussate at lower cord levels, close to their destination.

In addition, up to 3% of the descending fibers in the lateral corticospinal tract are uncrossed.
These ipsilateral descending projections control musculature of the trunk and proximal limbs
thus
participate in the maintenance of an upright stance and in gross positioning of the limbs.

MAJOR MOTOR SYSTEMS

II- The Extrapyramidal Motor System

- a set of subcortical circuits and pathways, phylogenetically older than the corticospinal system, which includes

1) **the corpus striatum** (caudate nucleus, putamen, and globus pallidus)
2) **subthalamic nucleus,**
3) **substantia nigra,**
4) **red nucleus,** and
5) **brain stem reticular formation** (Figs 13–2A, 13–4, and 13–5).
6) Some authorities include **descending spinal cord tracts other than the corticospinal tracts** (such as the vestibulospinal, rubrospinal, tectospinal, and reticulospinal tracts) in the extrapyramidal motor system.

1- Basal Ganglia

- **The striatum (caudate and putamen)** is the *major site of input to the basal ganglia* (see Fig 13–2B).
- **The globus pallidus, GPi (internal part)** is one of the two major output nuclei of the basal ganglia.
- **Substantia nigra is** the second major outflow nucleus of the basal ganglia(which is reciprocally connected with the putamen and caudate nucleus).

- **The striatum receives afferents via :**

Excitatory corticostriate projections :

1) the sensorimotor cortex (areas 4, 1, 2, 3)
2) premotor cortex (area 6), and the
3) frontal eye fields (area 8)

receives inputs from

1) the intralaminar thalamic nuclei,
2) substantia nigra,
3) amygdala,
4) hippocampus
5) midbrain raphe nuclei

1- Basal Ganglia

feedback circuit

Cortex → **caudate & putamen** —(**inhibitory**)→ **inner part of globus pallidus (Gpi)** —(**inhibitory**)→ **(VA &VL) thalamus** → **cortex**

cerebellum, **subthalamic nucleus**, **substantia nigra** → **(VA &VL) thalamus**

Cortex → striatum → substantia nigra —(**inhibitory** / **facilitatory**)→ **striatum** —(**inhibitory**)→ thalamus (VA & VL) → **cortex**

- substantia nigra also sends modulatory projections to **the limbic system & cortex**. This pathway involves the following circuit: Cortex → striatum → substantia nigra → thalamus → cortex

- The pars reticulata of the substantia nigra (SNr) receives input from the striatum, and sends axons outside the basal ganglia to **modulate head + eye movements**.

Basal Ganglia

- **The subthalamic nucleus** (also called the nucleus of Luys) also receives inhibitory inputs from the globus pallidus and from the cortex; Thus, the subthalamic nucleus participates in the feedback loop:

  Cortex → globus pallidus → subthalamic nuclei → globus pallidus → cortex

- Another loop involves the cerebellum.

Portions of the thalamus project by way of the **central tegmental tract** to the **inferior olivary nucleus**; this nucleus, in turn, sends fibers to the **contralateral cerebellar cortex**. From the cerebellum, the loop to the thalamus is closed via the **dentate & contralateral red nuclei (important relay and modifying station).**

- ✓ Projections from the globus pallidus to the red nucleus converge with inputs from the motor cortex and the deep cerebellar nuclei. Efferent fibers from the red nucleus descend in the spinal cord as the rubrospinal tract, which *modulates the tone of flexor muscles*

1- Subcortical Descending Systems

- Additional pathways—important for certain types of movement—include the

I. rubrospinal,

II. vestibulospinal,

III. tectospinal, and

IV. reticulospinal systems (see Fig 13–1

originate in

✓ the red nucleus & tectum of the midbrain,

✓ in the reticular formation, and

✓ in the vestibular nuclei of the brain stem.

rubrospinal tract arises in the red nucleus.

Motor cortex **bilaterally** → red nucleus

contralateral deep cerebellar nuclei → red nucleus

red nucleus
in
crossed rubrospinal tract
within
lateral column

→ synapse on interneurons in the spinal cord.

- **play a role in control of flexor muscle tone.**
- The **corticospinal** and **rubrospinal systems** appear to *cooperate to control hand and finger movement.*

reticulospinal systems

sensorimotor cortex

several nuclei in the reticular formation

reticulospinal tract
in
lateral column

interneurons in the spinal cord

gamma motor neurons.

vestibulospinal tract arises in the vestibular nuclei, located in the floor of the 4th ventricle

vestibular nerve → lateral vestibular nucleus + medial vestibular nucleus

cerebellum → lateral vestibular nucleus + medial vestibular nucleus

↓

both crossed and uncrossed fibers

↓

alpha + gamma motor neurons;
extensor muscle motor neurons
may be supplied directly

The tectospinal tract arises from

cells in the superior colliculus

↓

crosses in the midbrain at the level of the red nuclei.

Medial ongitudinal fasciculus
in the medulla

Other tectospinal fibers
descend in the anterior funiculus of the spinal cord

interneurons that project to motor neurons
terminate at cervical levels,

control reflex movements of <u>upper trunk</u>, <u>neck</u>, and <u>eyes</u> in response to visual stimuli.

- The **reticulospinal**, **vestibulospinal**, and **tectospinal** systems play a limited role in movements of the extremities; their **main influence is on the musculature of the trunk.**

brain stem is transected

(posterior part of the brain stem and spinal cord are isolated from the rest of the brain by injury at the superior border of the pons)

inhibitory influences

from the **cortex** & **basal ganglia** can no longer reach the spinal cord,

facilitatory influences,

which descend in the **vestibulospinal**& **reticulospinal** tracts, **dominate.**

↓

increased gamma motor neuron discharge

↓

Increased activity of alpha motor neurons innervating extensor muscles

(see Fig 5–20).

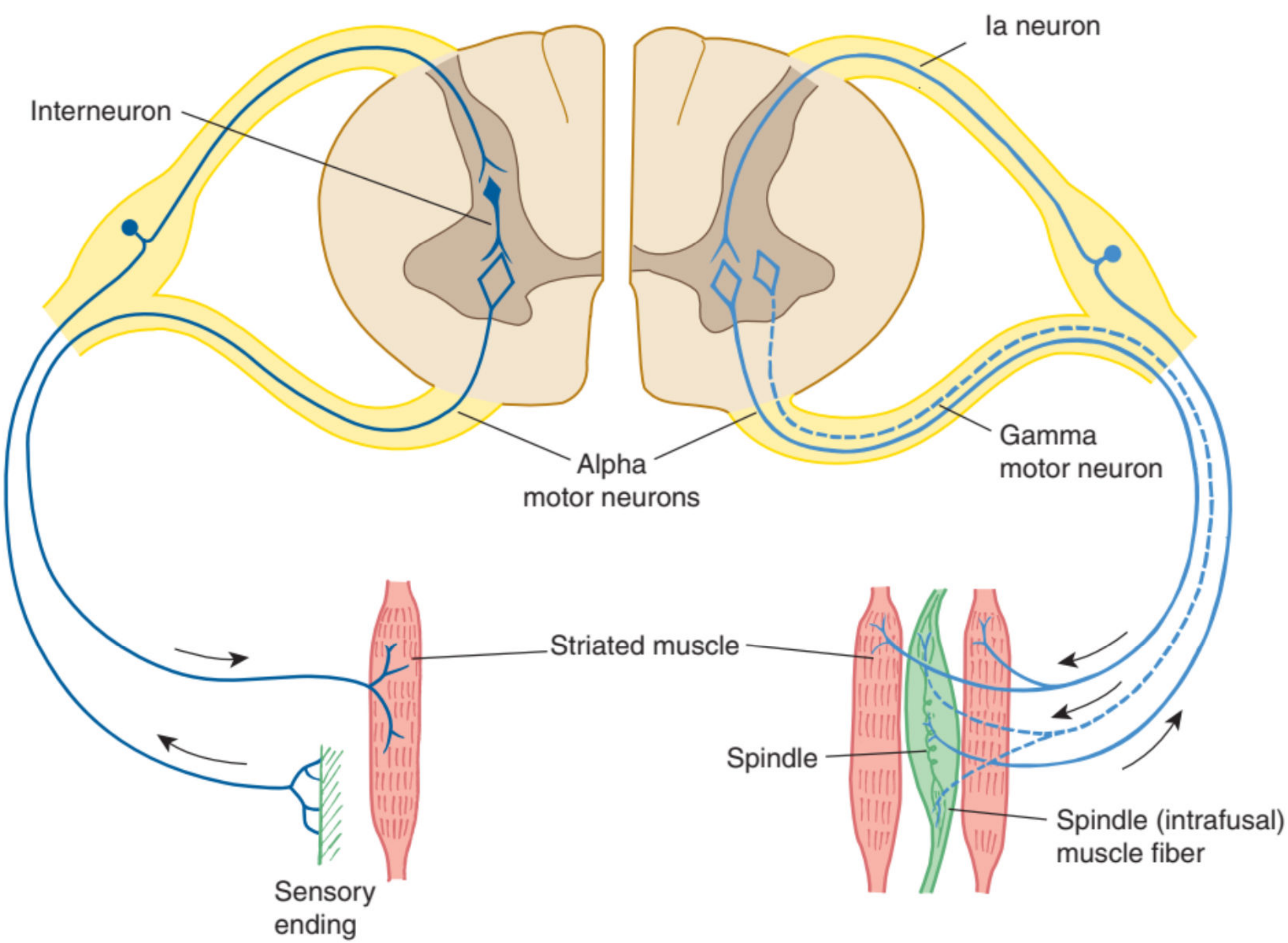


FIGURE 5–20 Schematic illustration of the neurons involved in the **stretch reflex (right half)** showing *innervation of* ***extrafusal (striated muscle)*** *fibers by alpha motor neurons*, and of ***intrafusal fibers (within muscle spindle)*** *by gamma motor neurons.* The left half of the diagram shows an inhibitory reflex arc, which includes an *intercalated inhibitory interneuron.*

Cerebellum

- ➢ The cerebellum is interconnected with several regions of CNS (Fig 13–7).

❑ **They are the ascending tracts from :**

✓ the spinal cord and brain stem,

✓ corticopontocerebellar fibers from the opposite cerebral cortex and

❑ **cerebellar efferent systems to :**

✓ the contralateral red nucleus,

✓ the reticular formation, and

✓ the ventral nuclei of the contralateral thalamus (which connects to the cerebral cortex).

Cerebellum

- The cerebellum has two major functions:

I. **coordination of voluntary motor activity** (fine, skilled movements and gross, propulsive movements, such as walking and swimming)

II. **control of equilibrium and muscle tone.**

Experimental work suggests that the cerebellum is essential in **motor learning** (the acquisition or learning of stereotyped movements) and me**mory mechanisms** (the retention of such learned movements).

LESIONS OF THE HUMAN MOTOR SYSTEM (MOTOR DISTURBANCES)

1) Muscles

- A muscle may be unable to react normally to stimuli conveyed to it by LMN , which results in weakness, paralysis, or tetanic contraction.
- **Muscle tone** may be decreased (hypotonia), and deep tendon reflexes may be reduced (hyporeflexia) or abolished (areflexia) as a result of muscle weakness.

The cause of these disturbances

- muscle itself
  - **progressive muscular dystrophies**
  - **Myotonia congenita**
  - muscle dysfunction in the presence of apparently normal neural tissue.
- myoneural junction
  - **Myasthenia gravis**
  - **decreased efficacy of acetylcholine receptors, that results in weakness and fatigue.**

2) LMNL

A. Description

- **anterior gray column of the spinal cord** or **brain stem** *have axons that pass by way of the **cranial** or **PN** to the motor end-plates of the muscles* (see Fig 5–22).
- **called the "final common pathway" for two reasons.**

I. It is under the influence of the corticospinal, rubrospinal, olivospinal, vestibulospinal, reticulospinal, and tectospinal tracts as well as the segmental or intersegmental reflex neurons,

II. it is the ultimate pathway through which neural impulses reach the muscle.

LMNL

- **located in**

I. the cells of the anterior gray column of the spinal cord(AHC) or brain stem (MOTOR NEUCLUI OF CRANIAL N) or

II. in their axons, which constitute the ventral roots of the spinal or cranial nerves.

- **Signs of lower-motor-neuron lesions**

✓ weakness, flaccid paralysis of the involved muscles, decreased muscle tone, muscle atrophy with fasciculations and degeneration of muscle fibers over time, and histologic-reaction degeneration (10–14 days after injury).

✓ Reflexes of the involved muscle are diminished or absent, and no abnormal reflexes are obtainable.

LMNL

❑ **seen in**

- **poliomyelitis** (*a viral disorder that results in death of motor neurons*) and
- **motor neuron disease** (including forms called amyotrophic lateral sclerosis and spinal muscular atrophy, in which *motor neurons degenerate*).
- **Mass lesions such as tumors** involving the spinal cord can also *damage lower motor neurons.*

Upper Motor Neurons

A. Description

- **a complex of descending systems conveying impulses** from the motor areas of the cerebrum and subcortical brain stem to the AHC of the spinal cord.
- **It is essential for the initiation of voluntary muscular activity.**
- One major component, the **corticospinal tract**, arises in the motor cortex, passes through the internal capsule and brain stem, and projects within the spinal cord to LMNs of cord.
- Another component, the **corticobulbar tract**, projects to the brain stem nuclei of the cranial nerves that innervate striated muscles.
- **UMNs control voluntary activation (but not necessarily reflex activation) of LMNs.**

Upper Motor Neurons

b) LESION

the cerebral cortex, internal capsule, cerebral peduncles, brain stem, or spinal cord (see Table 13–1).

- **Signs of UMNLs in the spinal cord include :**

✓ **paralysis or paresis (weakness) of the involved muscles**,

✓ increased muscle tone (hypertonia) and spasticity,

✓ **hyperactive deep reflexes**,

✓ no or little muscle atrophy (atrophy of disuse),

✓ **diminished or absent superficial abdominal reflexes**, and

✓ abnormal reflexes (eg, Babinski's response).

Upper Motor Neurons

C. Patterns of Paralysis and Weakness

- **Hemiplegia** is a spastic or flaccid paralysis of one side of the body and extremities; it is delimited by the median line of the body.
- **Monoplegia** is paralysis of one extremity only, and **diplegia** is paralysis of any two corresponding extremities, usually both lower extremities (but can be both upper).
- **Paraplegia** is a symmetric paralysis of both lower extremities. **Quadriplegia**, or tetraplegia, is paralysis of all four extremities.
- **Hemiplegia** alternans **(crossed paralysis)** is paralysis of one or more cranial nerves and contralateral paralysis of the arm and leg.

- The term **paresis** refers to **weakness**, ***rather than total paralysis***, and is used with the same prefixes.

Basal Ganglia

Defects in function of the basal ganglia (sometimes termed extrapyramidal lesions)

- **characterized by**

1) **changes in muscle tone**,
2) *poverty of voluntary movement* **(akinesia)** or *abnormally slow movements* **(bradykinesia),** or *involuntary, abnormal movement* **(dyskinesia).**
3) **A variety of abnormal movements can occur: tremors** (resting tremor at rest and postural tremor when the body is held in a particular posture), **athetosis** (characterized by slow, writhing movements of the extremities and neck musculature), and **chorea** (quick, repeated, involuntary movements of the distal extremity muscles, face, and tongue, often associated with lesions of the corpus striatum)

SOME PARTICULARLY NOTABLE DISEASES OF THE BASAL GANGLIA

A. Huntington's Disease

- This autosomal-dominant disorder is characterized by debilitating abnormal movements (most often **chorea**; **rigidity** in early-onset cases) and **cognitive** and **psychiatric** dysfunction.
- **Depression** is common.
- The disorder progresses relentlessly to incapacitation and death.
- Onset usually occurs between the ages of 35 and 45 years, although a childhood form is sometimes present.
- loss of bulk of the caudate nucleus
- Loss of GABA-ergic (inhibitory) neurons in the striatum results in chorea

B. Hemiballismus

- one extremity or the arm and leg on one side engage in large, flailing movement.
- Hemiballismus usually results from damage to contralateral subthalamic nucleus, commonly as a result of infarction.
- For reasons that are poorly understood, hemiballismus often resolves spontaneously after several weeks.

C. Parkinson's Disease

- This progressive disorder is associated with loss of pigmented (dopaminergic) neurons in the substantia nigra.
- Most causes of Parkinson's disease, are idiopathic, Some toxic agents (carbon
- monoxide, manganese) can damage the basal ganglia, some neuroleptics (eg, phenothiazines)
- onset usually between the ages of 50 and 65 years, is characterized by a triad of symptoms: **tremor**, **rigidity**, and **akinesia**.
- There are often accompanying abnormalities of **equilibrium**, **posture**, and **autonomic function**. Characteristic signs include **slow**, **monotonous speech**; diminutive writing (**micrographia**); and loss of facial expression (**masked face**)

Cerebellum

- characterized by reduced muscle tone and a loss of coordination of smooth movements (see Table 13–1).
- Lesions in each of the three cerebellum subdivisions exhibit characteristic signs:

A. Vestibulocerebellum (Archicerebellum)

Loss of equilibrium, often with nystagmus, is typical.

B. Spinocerebellum (Paleocerebellum)

Truncal ataxia and “drunken” gait are characteristic

C. Neocerebellum

Ataxia of extremities and asynergy (loss of coordination) are prominent. Decomposition of movement, jerky, discrete motions, Dysmetria (past-point in phenomenon), Dysdiadochokinesia (the inability to perform rapidly alternating movements), intention tremor, and rebound phenomenon (loss of interaction between agonist and antagonist smooth muscles) are also typical. *If there is a unilateral lesion of the cerebellum, these abnormalities present on the same side as the lesion*.

TABLE 13–1 Signs of Lesions of the Human Motor System.

Location of Lesion	Voluntary Strength	Atrophy	Muscle Stretch Reflexes	Tone	Abnormal Movements
Muscle (myopathy)	Weak (paretic)	Can be severe	Hypoactive	Hypotonic	None
Motor end-plate	Weak	Slight	Hypoactive	Hypotonic	None
Lower motor neuron (includes peripheral nerve, neuropathy)	Weak (paretic or paralyzed)	May be present	Hypoactive or absent	Hypotonic (flaccid)	Fasciculations*
Upper motor neuron	Weak or paralyzed	Mild (atrophy of disuse)	Hyperactive (spastic). After a massive upper-motor-neuron lesion (as in stroke), reflexes may be absent at first, with hypotonia and spinal shock	Hypertonic (claspknife) or spastic	Withdrawal spasms, abnormal reflexes (eg, Babinski's extensor plantar response)
Cerebellar systems	Normal	None	Hypotonic (pendulous)	Hypotonic	Ataxia, dysmetria, dysdiadochokinesia, gait
Basal ganglia	Normal	None	Normal	Rigid (cogwheel)	Dyskinesias (eg, chorea, athetosis, dystonia, tremors, hemiballismus)

* Fasciculations are spontaneous, grossly visible contractions (twitches) of entire motor units.

SOMATOSENSORY SYSTEM

Sensation can be divided into four types:

I. **Superficial sensation** is concerned with touch, pain, temperature, and two-point discrimination.

II. **Deep sensation** includes muscle and joint position sense (proprioception), deep muscle pain, and vibration sense.

III. **Visceral sensations** are relayed by autonomic afferent fibers and include hunger, nausea, and visceral pain.

IV. **The special senses**—smell, vision, hearing, taste, and equilibrium—are conveyed by cranial nerves

RECEPTORS

specialized cells for detecting particular changes in the environment.

- **Exteroceptors** include *receptors affected mainly by the external environment*: Meissner's corpuscles, Merkel's corpuscles, and hair cells **for touch**; Krause's end-bulbs **for cold**; Ruffini's corpuscles **for warmth**; and free nerve endings **for pain** (Fig 14–1).

- **Receptors are not absolutely specific for a given sensation; strong stimuli can cause various sensations, even pain**,

- **Proprioceptors** receive impulses mainly from pacinian corpuscles, joint receptors, muscle spindles, and Golgi tendon organs. Painful stimuli are detected at the free endings of nerve fibers.

- **Each individual receptor fires either completely or not at all when stimulated.**

→ The greater the intensity of a stimulus, the more end-organs that are stimulated,

→ *the higher the rate of discharge is*, and *the longer the duration of effect is*.

- **Adaptation** denotes *the diminution in rate of discharge of some receptors on repeated or continuous stimulation of constant intensity*; the sensation of sitting in a chair or walking on even ground is suppressed.

A chain of three long neurons and a number of interneurons conducts stimuli from the receptor or free ending to the somatosensory cortex.

- **First-Order Neuron**

The cell body of a first-order neuron lies in a dorsal root ganglion or a somatic afferent ganglion (eg, trigeminal ganglion) of cranial nerves.

- **Second-Order Neuron**

The cell body of a second-order neuron lies within the neuraxis (spinal cord or brain stem; examples are provided by the dorsal column nuclei, ie, the gracile & cuneate nuclei, and by neurons within the dorsal horn of the spinal cord).

- ✓ Axons of these cells usually decussate and terminate in the thalamus.

- **Third-Order Neuron**

The cell body of a third-order neuron, which lies in the thalamus, projects rostrally to the sensory cortex. The networks of neurons within the cortex, in turn, process information relayed by this type of neuron; they **interpret** its location, quality, and intensity and make appropriate responses.

The lemniscal (dorsal column) system

carries **touch, joint sensation, two-point discrimination**, and **vibratory** sense from receptors to the cortex.

the ventrolateral system

relays impulses concerning **nociceptive stimuli** (pain, crude touch) or **changes in skin temperature**

- Significant anatomic and functional differences characterize these two pathways: the size of the receptive field, nerve fiber diameter, course in the spinal cord, and function (Table 14–1).
- *Each system is characterized by **somatotopic distribution***, + *convergence in the **thalamus** (ventroposterior complex) & **cerebral cortex** (the sensory projection areas*; see Figs 10–13 and 10–15), where there is a map-like representation of the body surface.
- **The sensory trigeminal fibers** *contribute to both the lemniscal and the ventrolateral systems* and *provide the input from the face and mucosal membranes* (see Figs 7–8 and 8–11).

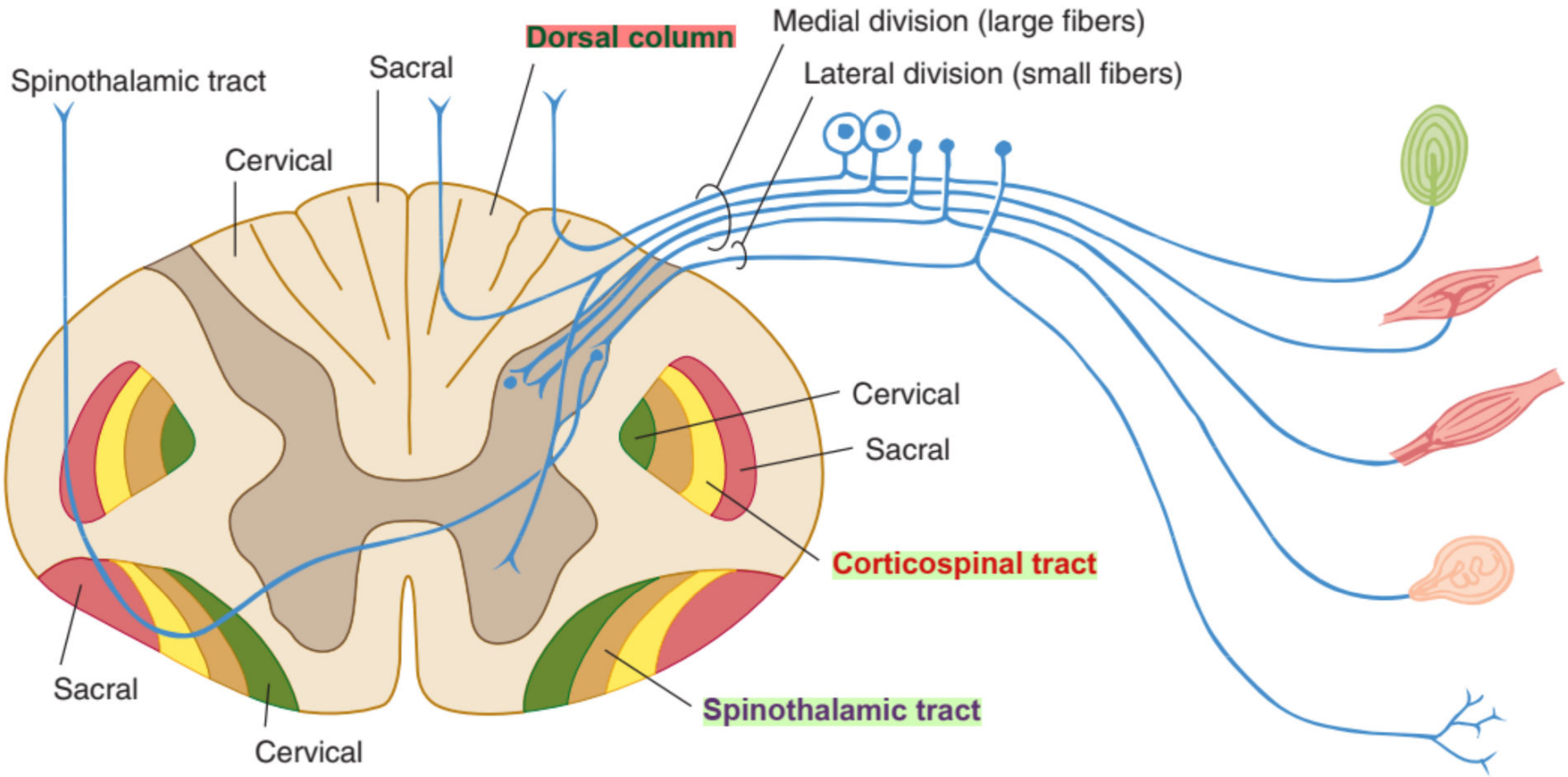


FIGURE 14–1 Schematic illustration of **a spinal cord segment** with its **dorsal root**, **ganglion cells**, and **sensory organs.**

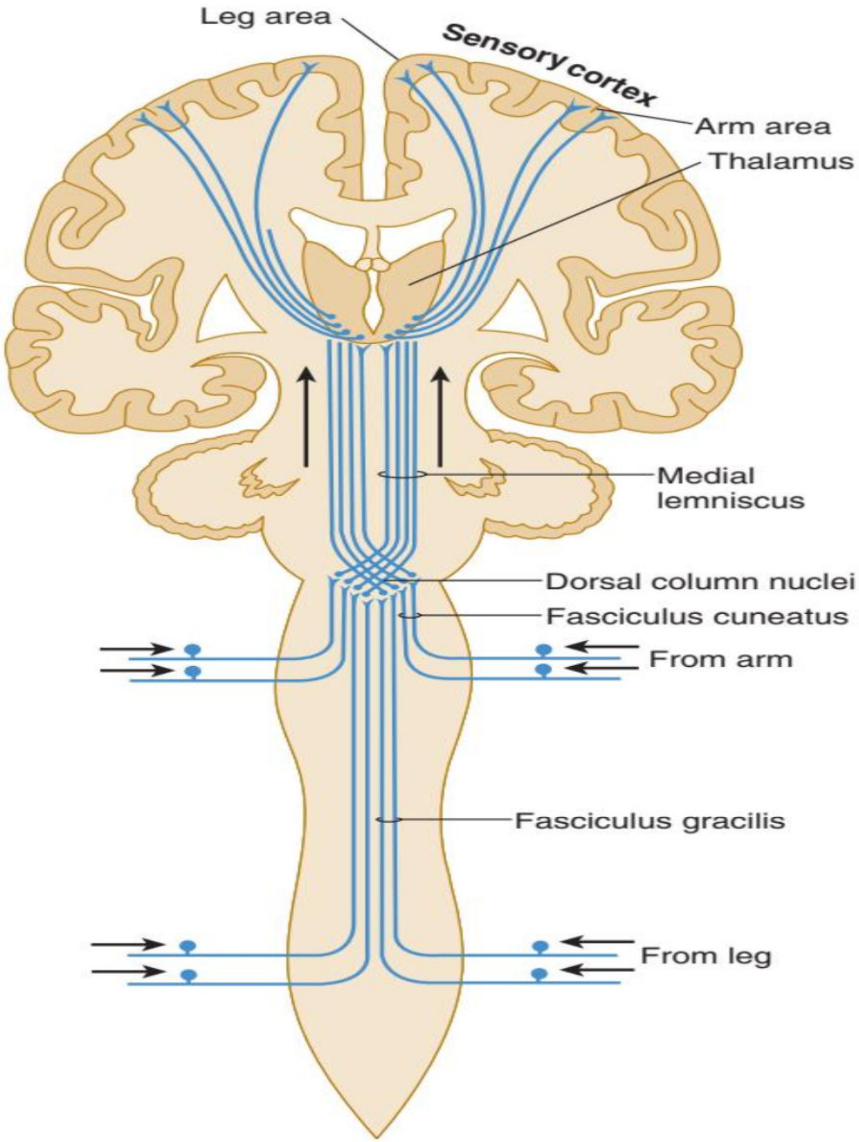


FIGURE 14–2 Dorsal column system for discriminative touch and position sense (lemniscus system).

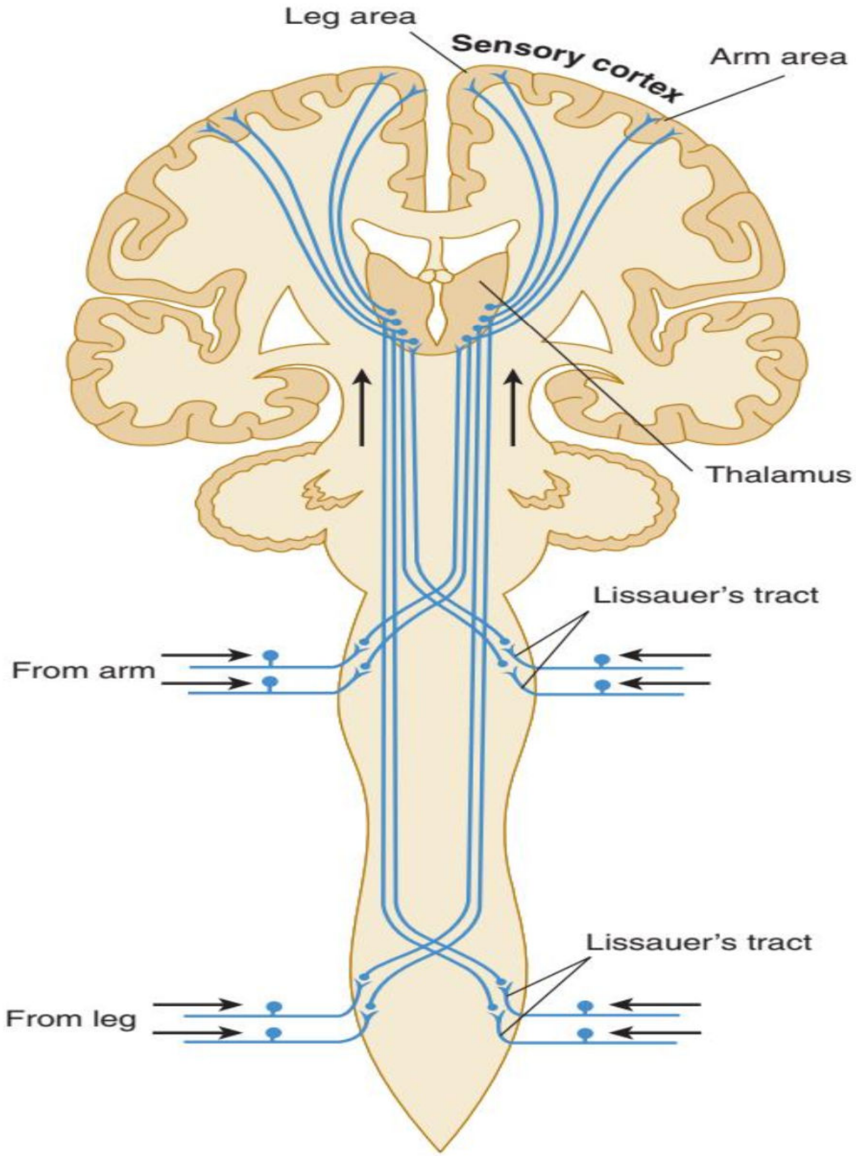


FIGURE 14–3 Spinothalamic tracts for pain and temperature (ventrolateral system).

TABLE 14–1 Differences between Lemniscal and Ventrolateral Systems.

Variable	Lemniscal (Dorsal Column) Pathway	Ventrolateral Pathway
Course in spinal cord	Dorsal and dorsolateral funiculi	Ventral and ventrolateral funiculi
Size of receptive fields	Small	Small & large
Specificity of signal conveyed	Each sensation carried separately; precise localization of sensation	Multimodal (several sensations carried in one fiber system)
Diameter of nerve fiber	Large-diameter primary afferents	Small-diameter primary afferents
Sensation transmitted	Fine touch, joint sensation, vibration	Pain, temperature, crude touch, visceral
Synaptic chain	Two or three synapses to cortex	pain Multisynaptic
Speed of transmission	Fast	Slow
Tests for function	Vibration, two-point discrimination, stereognosis	Pinprick, heat & cold testing