Physiology for medical students

Somatic sensations-III

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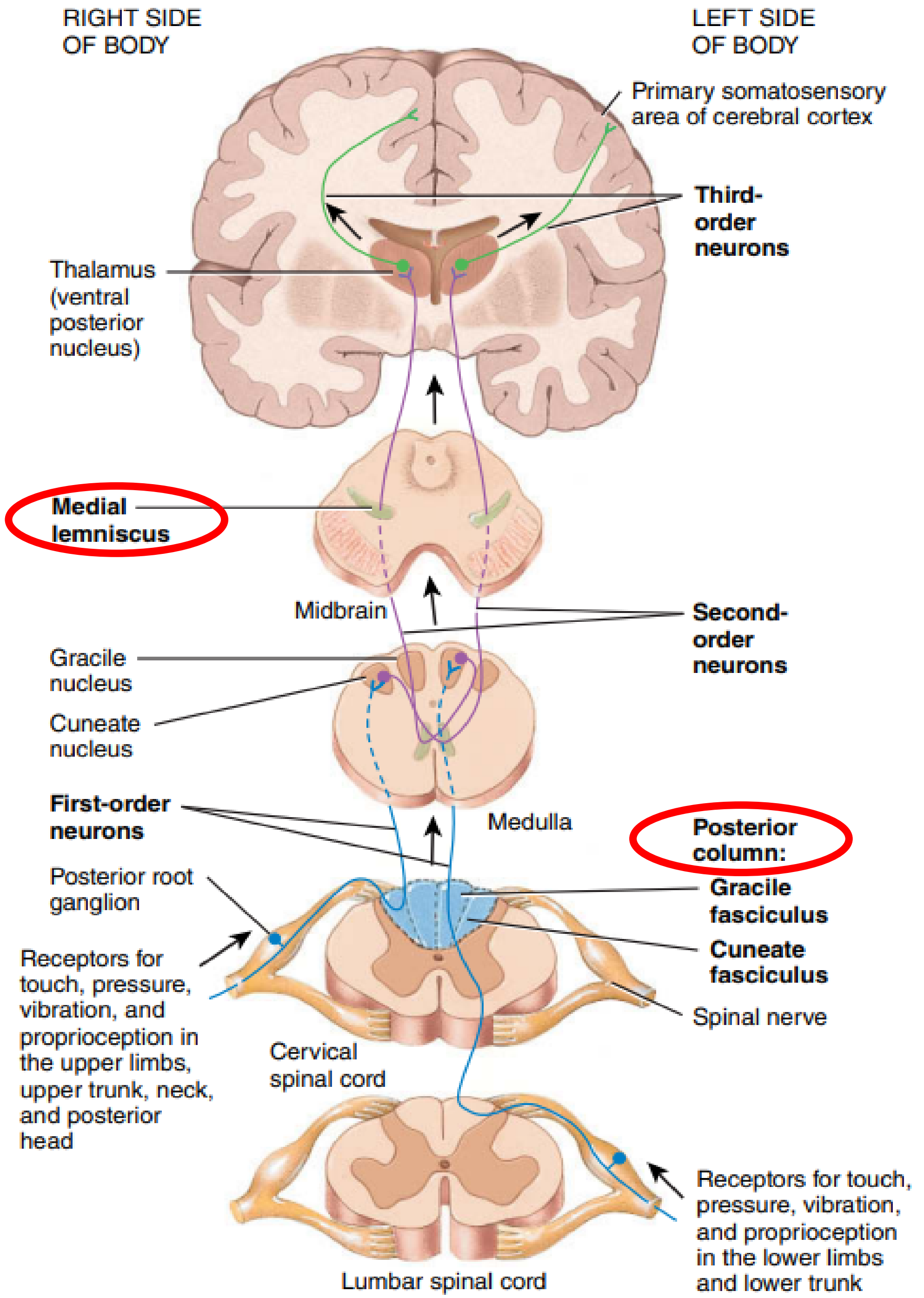
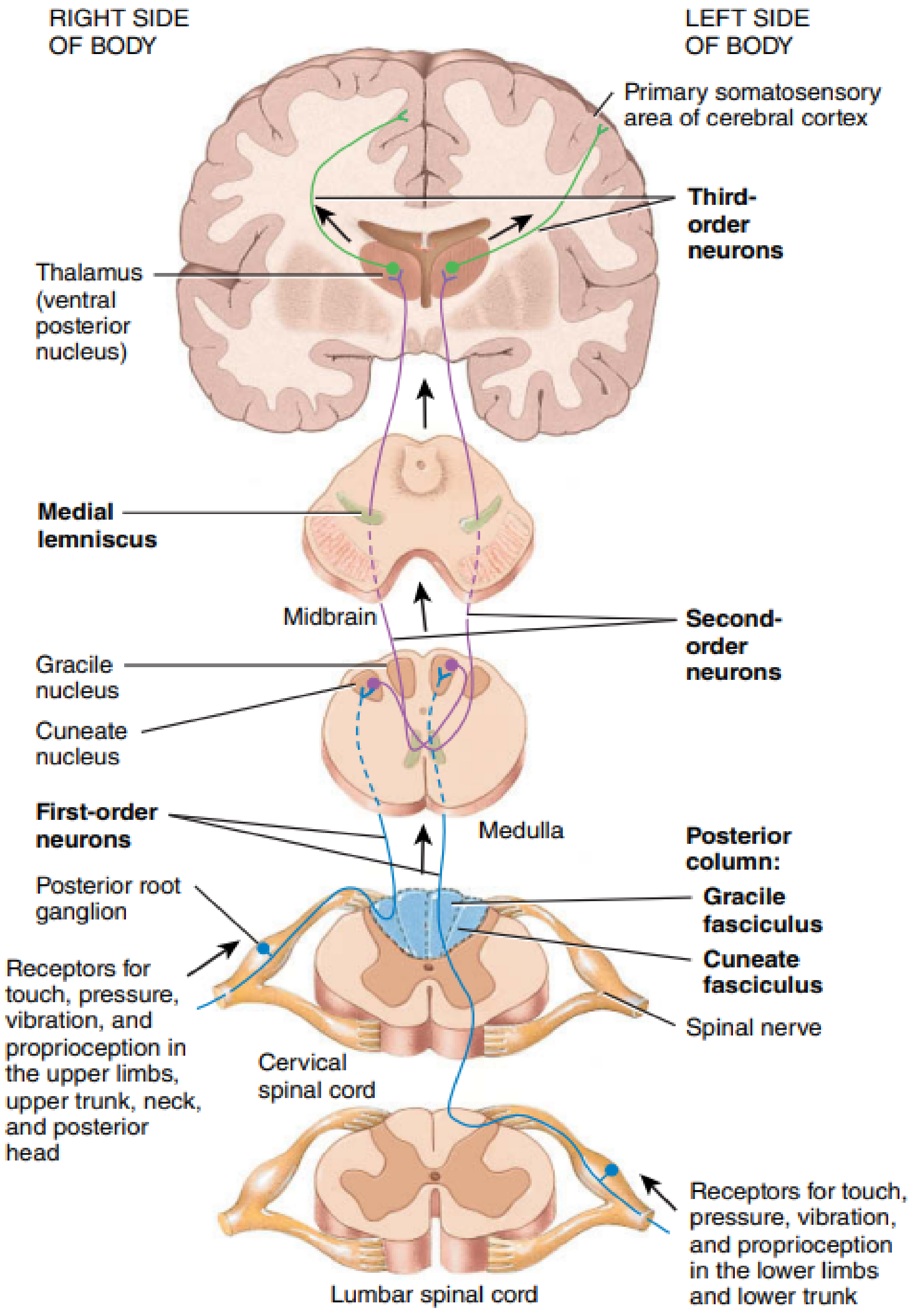
Posterior column - medial lemniscus pathway

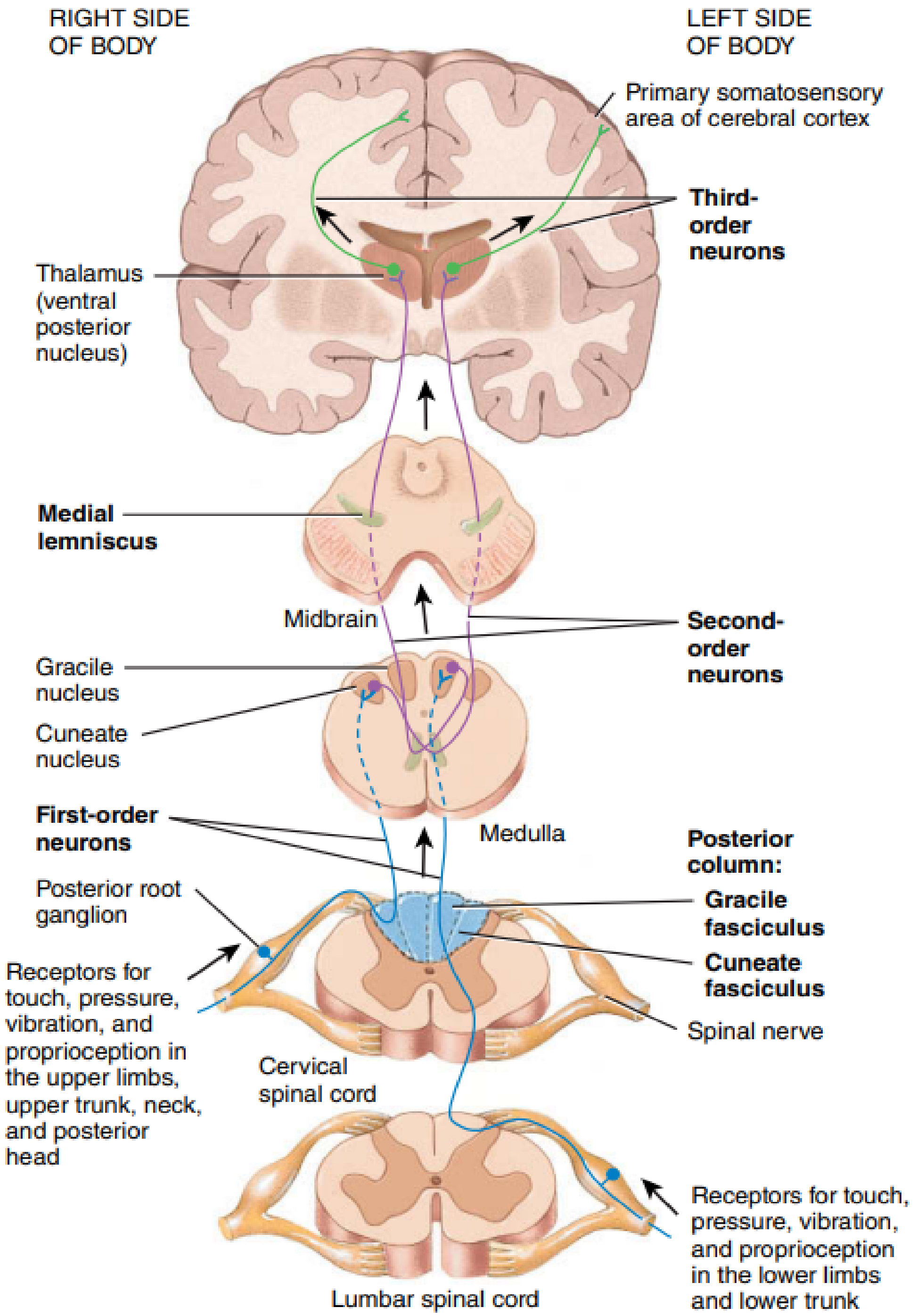


Posterior column - medial lemniscus pathway

Touch
Vibration
Pressure
Proprioception

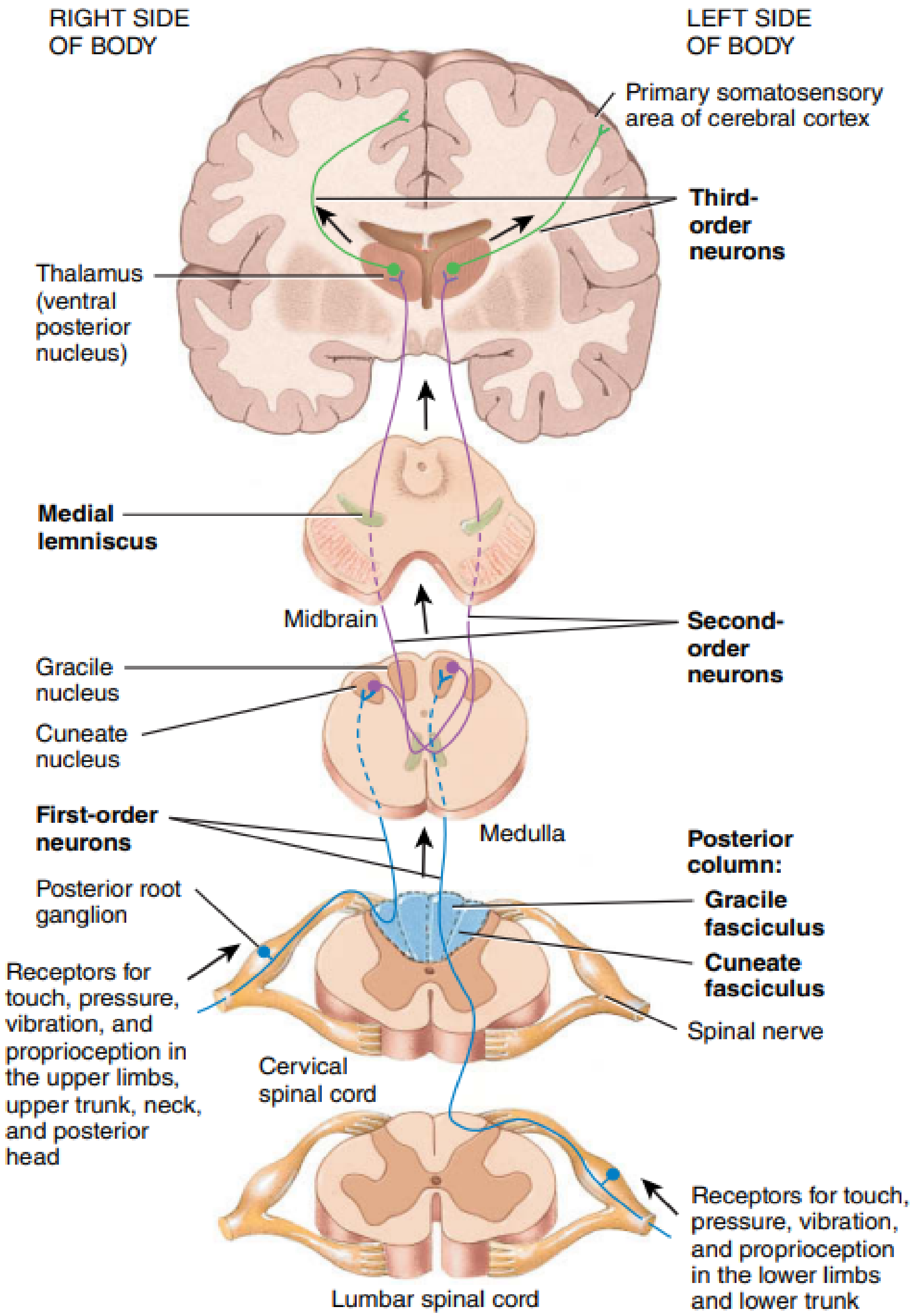


Posterior column - medial lemniscus pathway

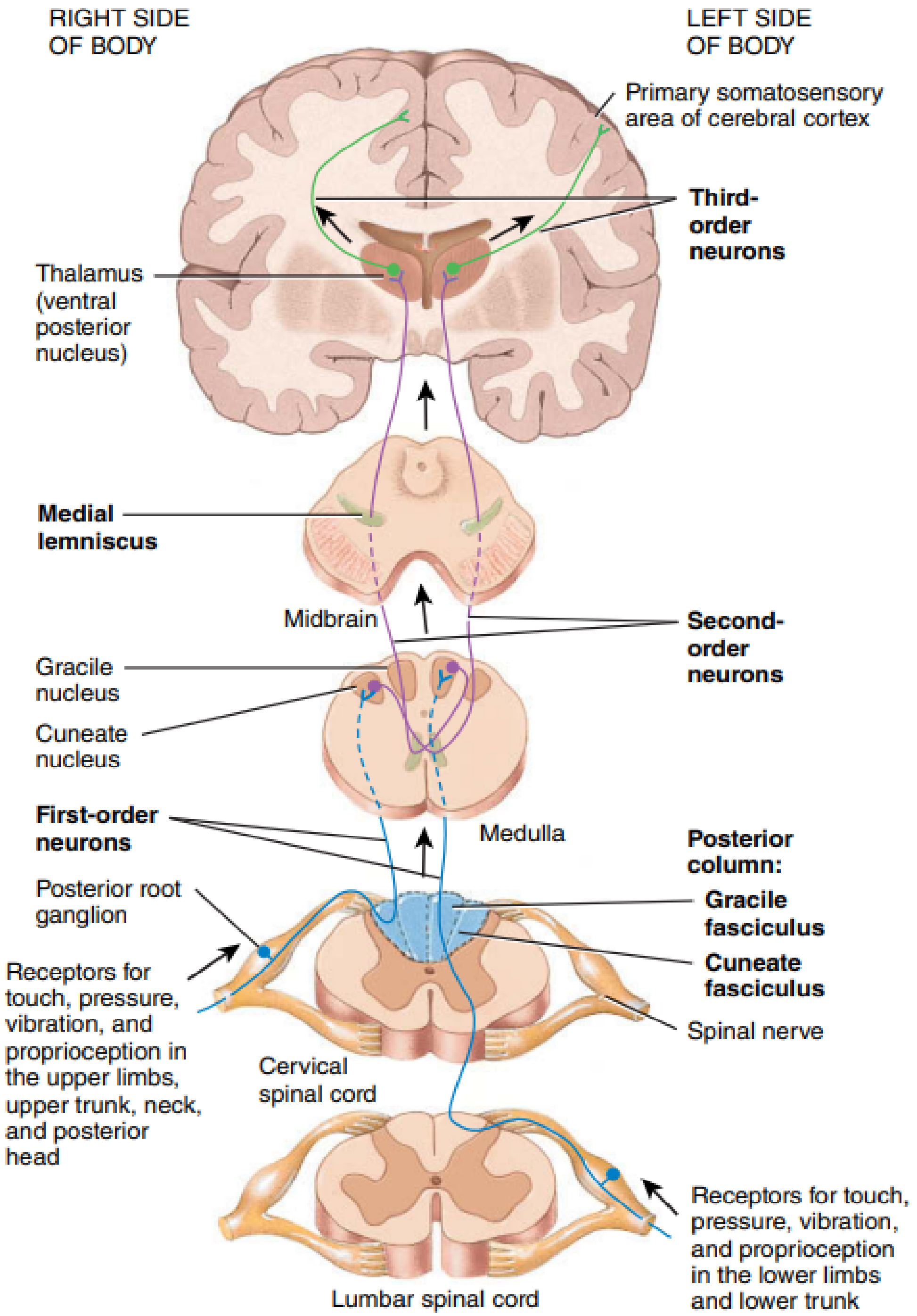


Posterior column - medial lemniscus pathway

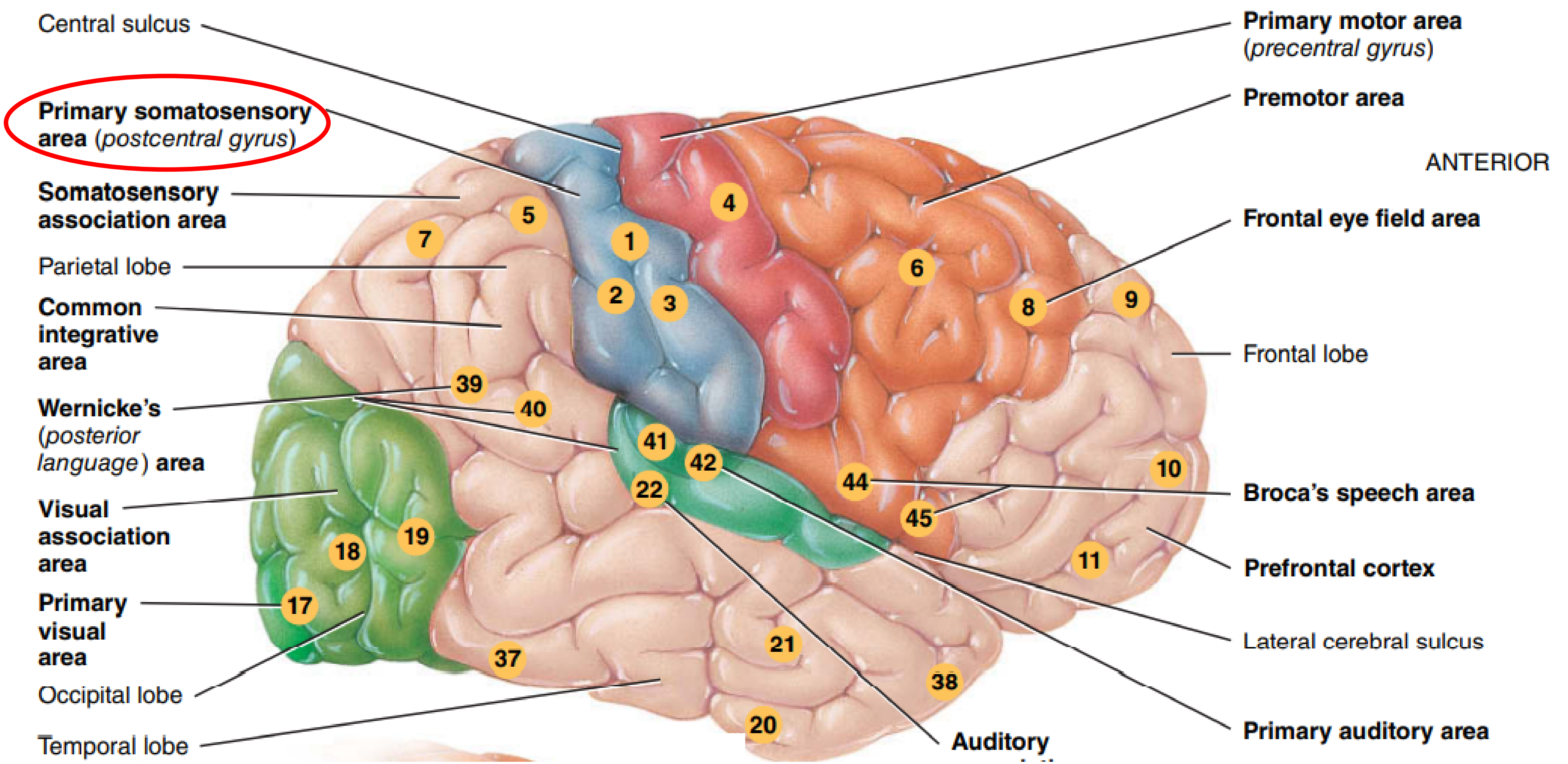
Decussation
in the medulla



Posterior column - medial lemniscus pathway

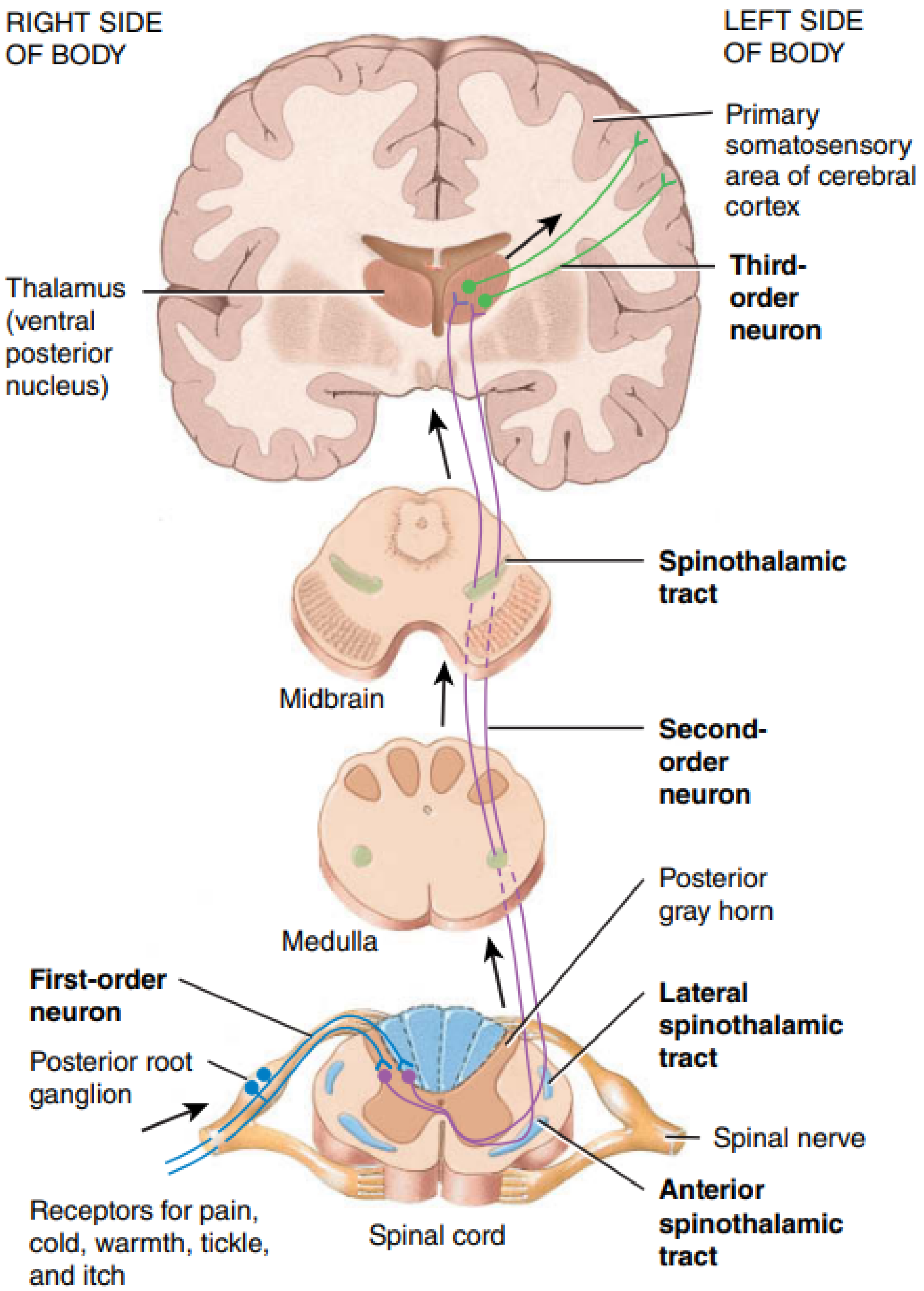


Cerebral cortex



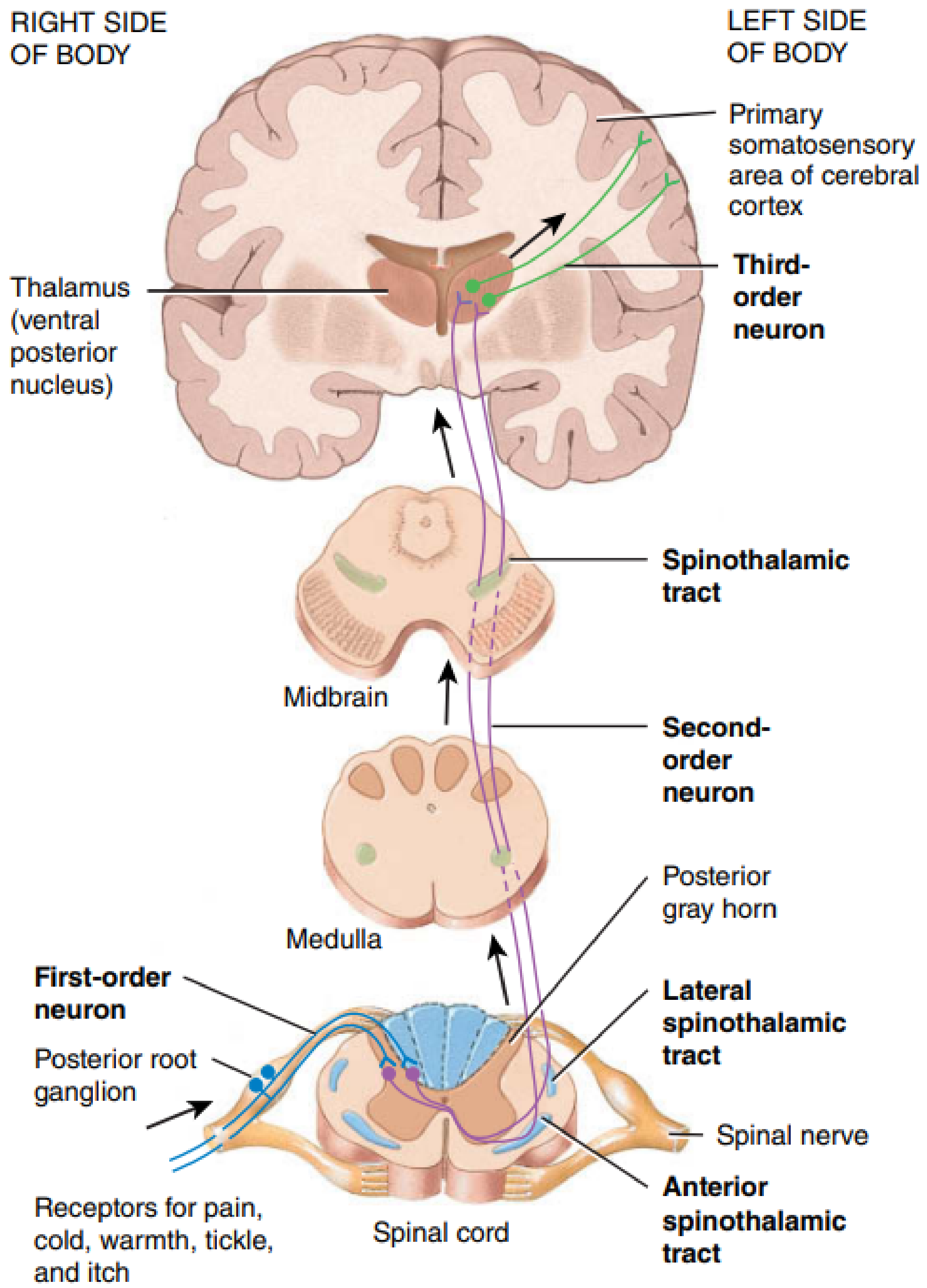
Anterolateral spinothalamic pathway

Pain (crude pressure)
Temperature
Itch
Tickle (crude touch)



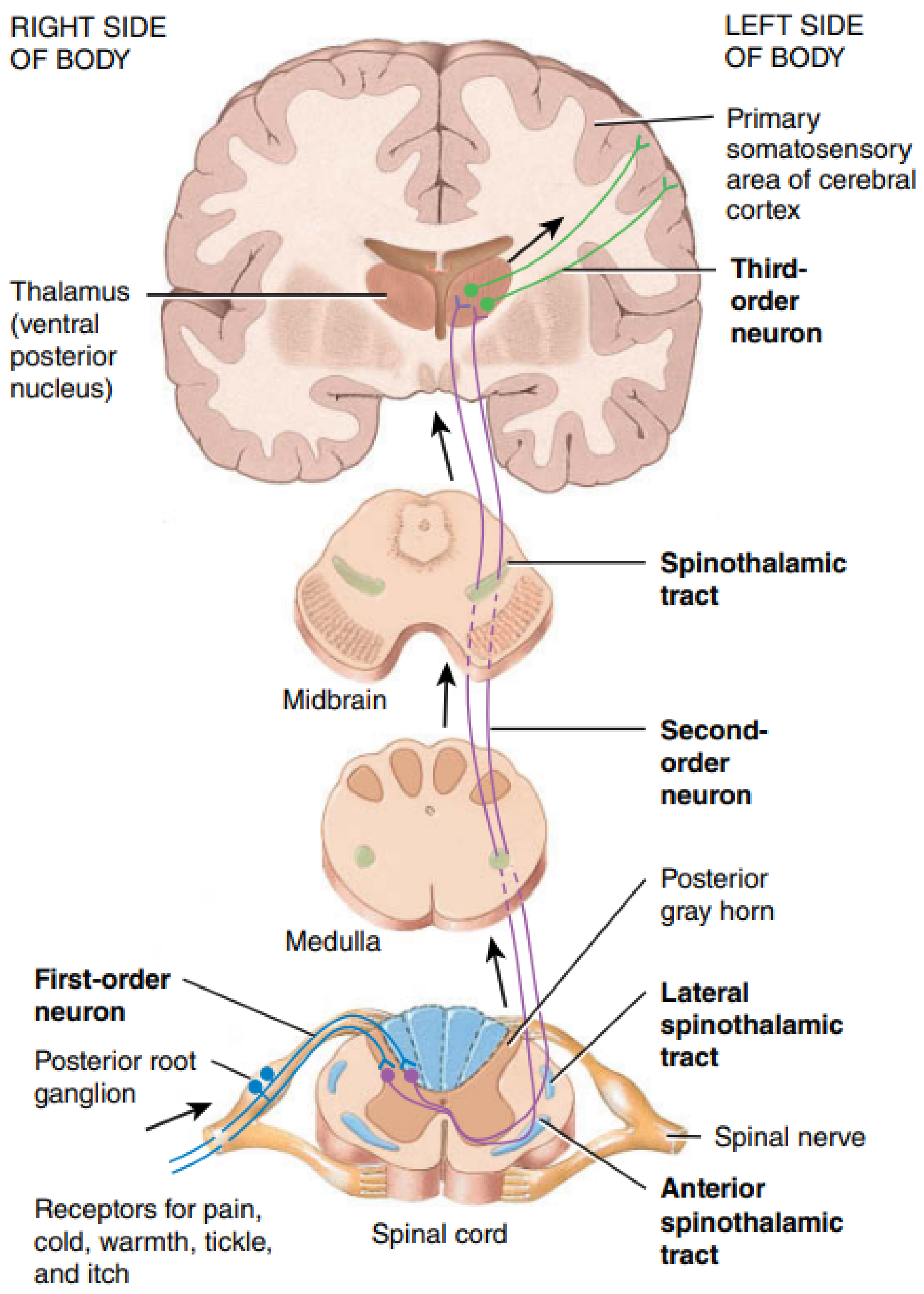
Anterolateral spinothalamic pathway

Synapse at posterior gray horn of spinal cord

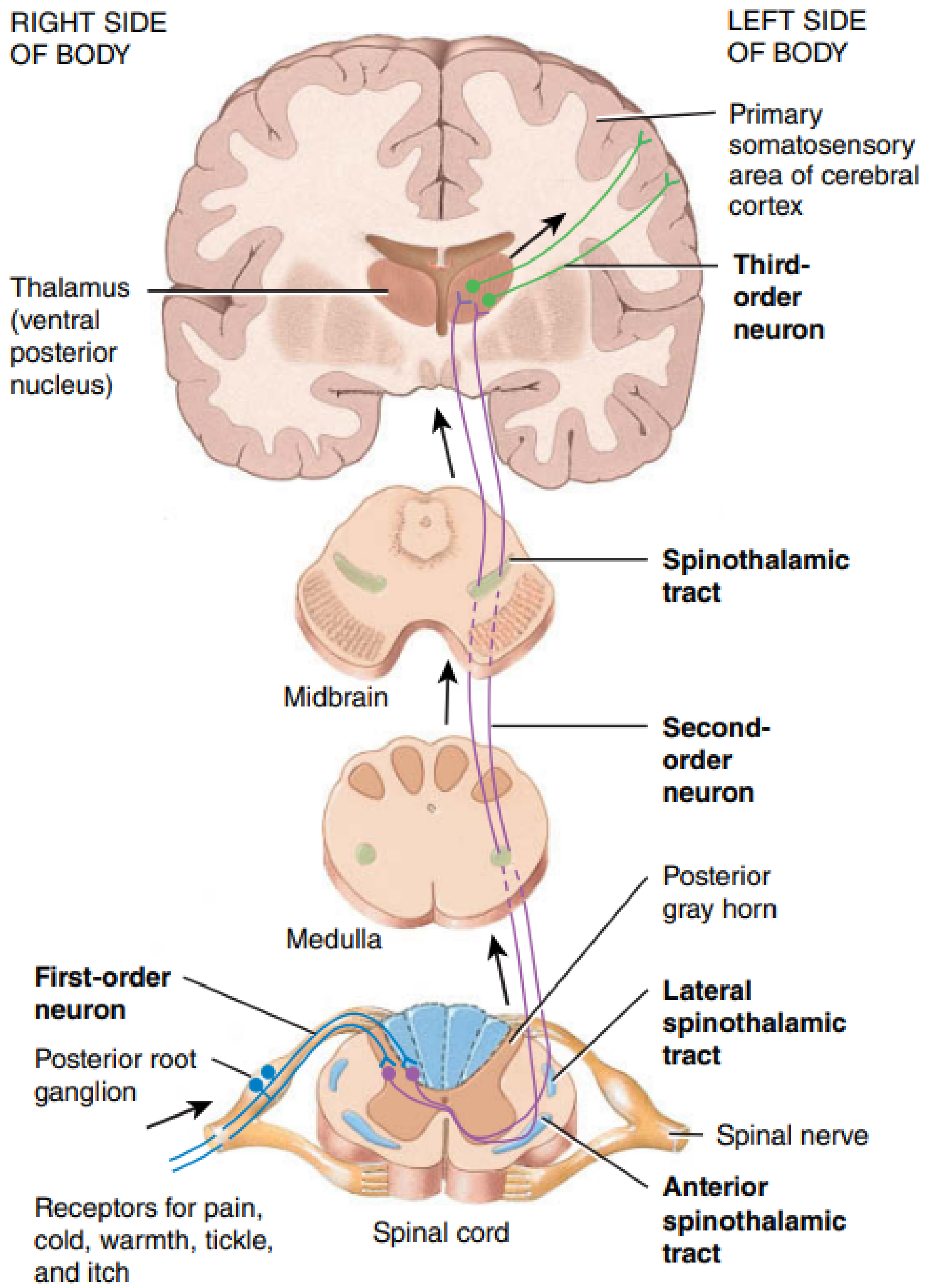


Anterolateral spinothalamic pathway

Decussation in spinal cord



Anterolateral spinothalamic pathway



Somatosensory pathways

- The dorsal column–medial lemniscal system is composed of large myelinated nerve fibers, whereas the anterolateral system is composed of smaller myelinated fibers.

Somatosensory pathways

- The anterolateral system has a special capability that the dorsal system does not have—the ability to transmit a broad spectrum of sensory modalities, such as pain, warmth, cold, and crude tactile sensations.

- The dorsal system is limited to discrete types of mechanoreceptive sensations.

Somatosensory pathways

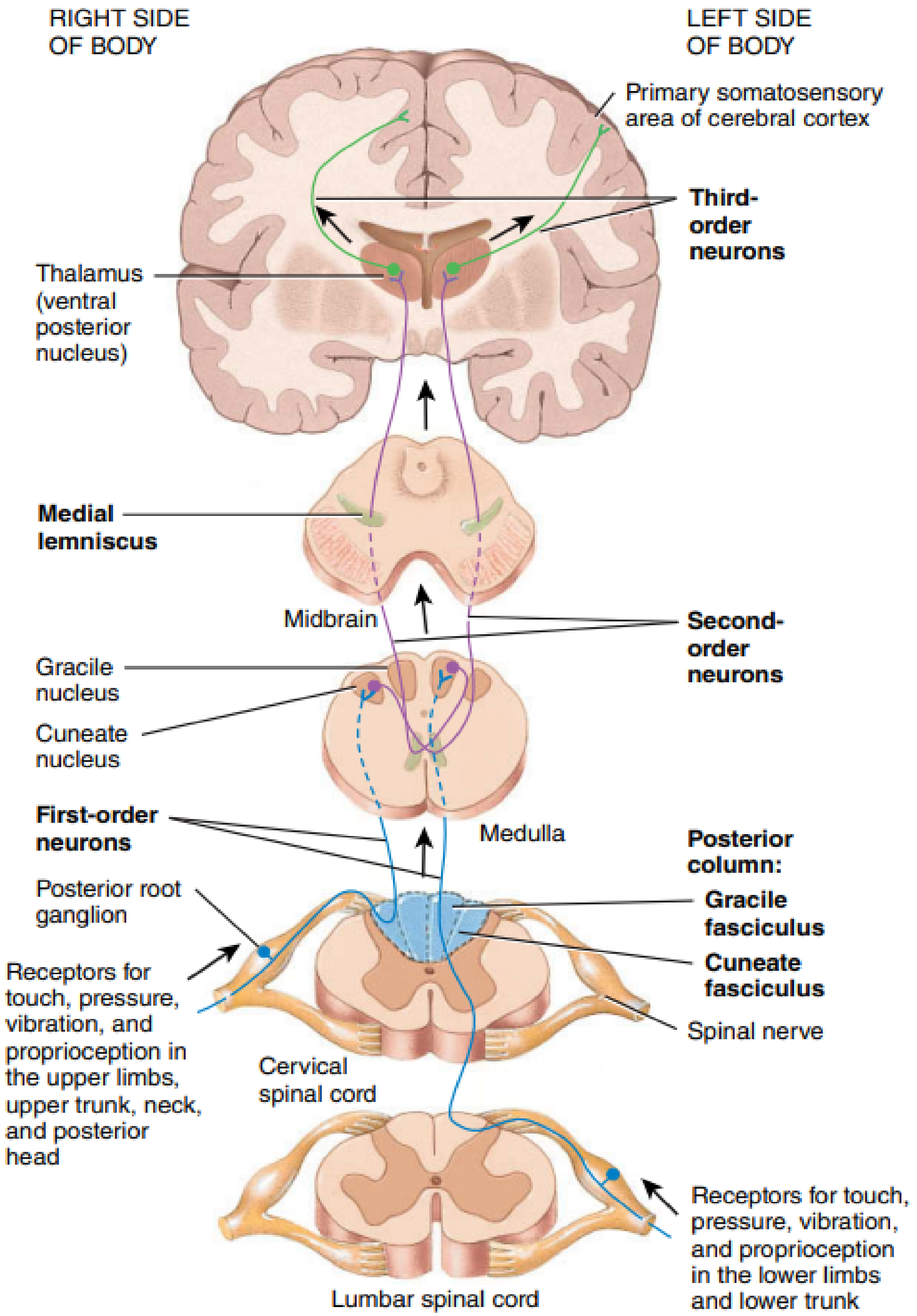
- Sensory information that must be transmitted rapidly with temporal and spatial fidelity is transmitted mainly in the dorsal column–medial lemniscal system.

- That which does not need to be transmitted rapidly or with great spatial fidelity is transmitted mainly in the anterolateral system.

Posterior column - medial lemniscus pathway

Lower limbs and trunk:
Gracile fasiculus (medial)

Cuneate fasiculus (lateral):
Upper limbs and trunk.



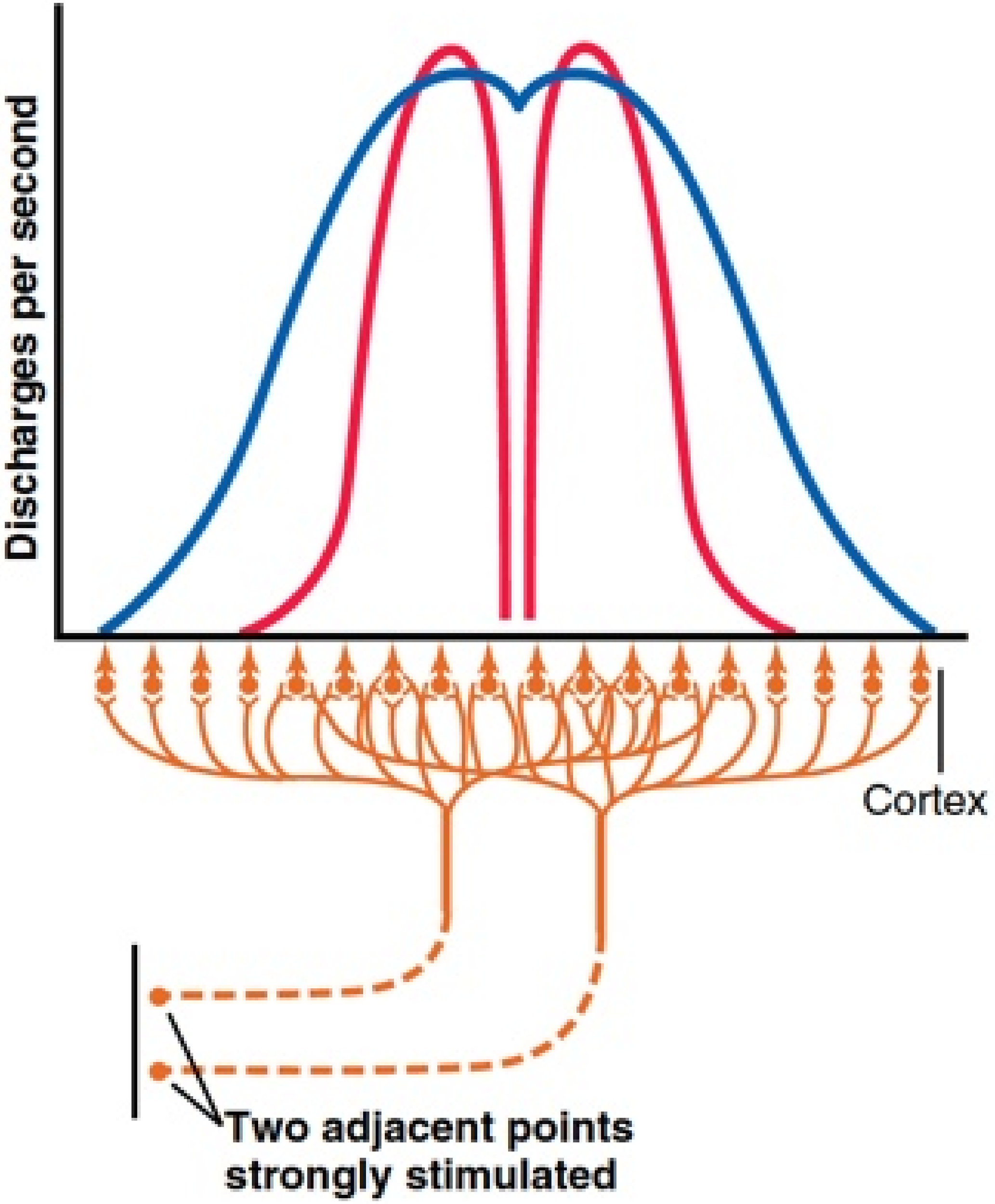
Somatosensory pathways

- One of the distinguishing features of the dorsal column– medial lemniscal system is a distinct spatial orientation of nerve fibers from the individual parts of the body that is maintained throughout.

- columns of the spinal cord, the fibers from the lower parts of the body lie toward the center of the cord, whereas those that enter the cord at progressively higher segmental levels form successive layers laterally.

Two point discrimination

- On the tips of the fingers, a person can normally distinguish two separate points, even when the needles are as close together as 1 to 2 millimeters. However, on someone’s back, the needles usually must be as far apart as 30 to 70 millimeters before two separate points can be detected.
- The reason for this difference is the different numbers of specialized tactile receptors in the two areas.


Discharges per second
Cortex
Two adjacent points
strongly stimulated

Lateral inhibition

- virtually every sensory pathway, when excited, gives rise simultaneously to lateral inhibitory signals; these inhibitory signals spread to the sides of the excitatory signal and inhibit adjacent neurons.

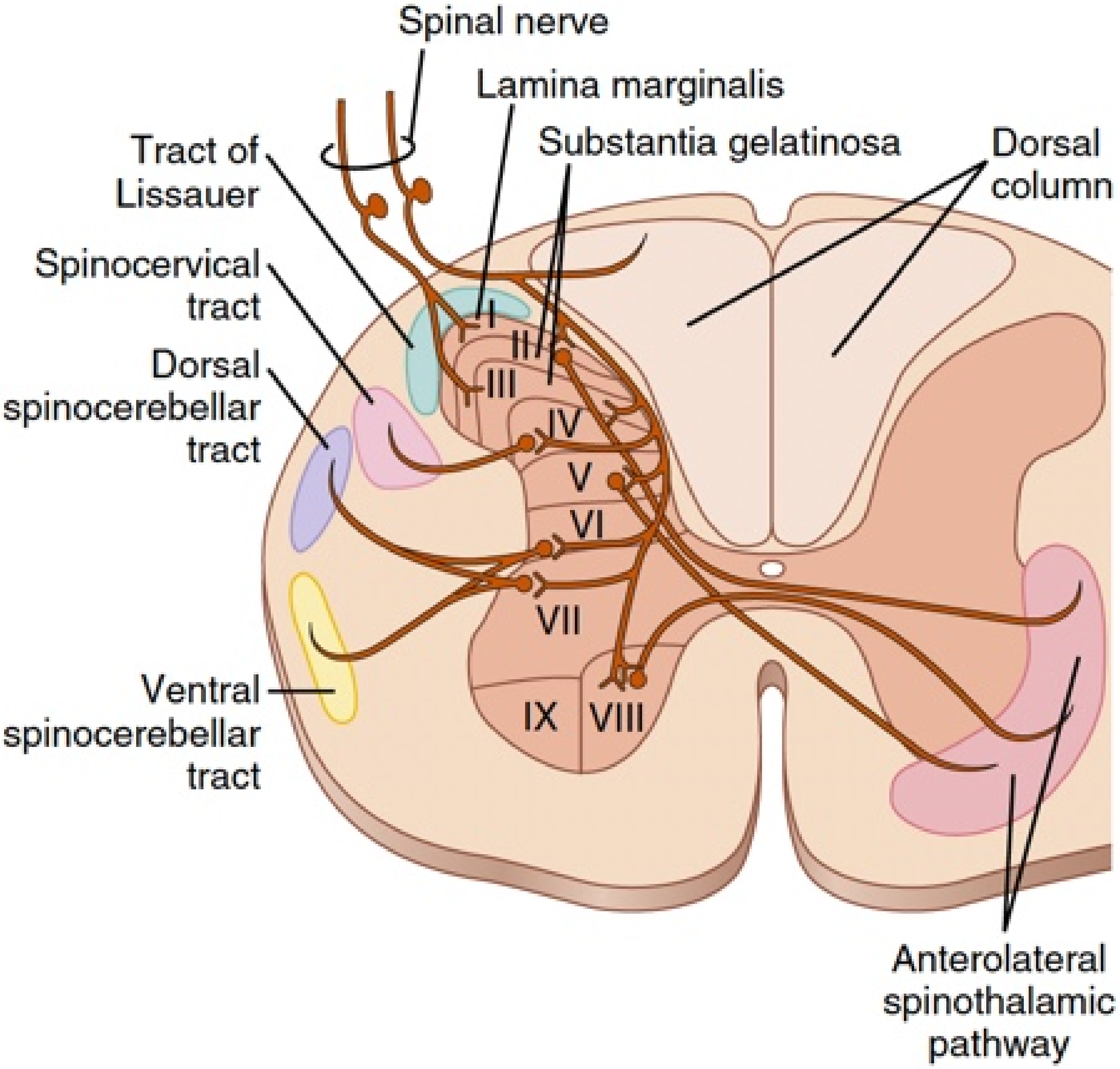
- The importance of lateral inhibition, also called surround inhibition, is that it blocks lateral spread of the excitatory signals and, therefore, increases the degree of contrast in the sensory pattern perceived in the cerebral cortex.

Lateral inhibition

- In the case of the dorsal column system, lateral inhibitory signals occur at each synaptic level.

- for example, in the following: (1) the dorsal column nuclei of the medulla; (2) the ventrobasal nuclei of the thalamus; and (3) the cortex itself.

- At each of these levels, the lateral inhibition helps to block lateral spread of the excitatory signal. As a result, the peaks of excitation stand out, and much of the surrounding diffuse stimulation is blocked.


Spinal nerve
Lamina marginalis
Substantia gelatinosa
Tract of Lissauer
Dorsal column
Spinocervical tract
Dorsal spinocerebellar tract
Ventral spinocerebellar tract
Anterolateral spinothalamic pathway
I
II
III
IV
V
VI
VII
VIII
IX

- On entering the spinal cord through the spinal nerve dorsal roots, the large myelinated fibers from the specialized mechanoreceptors divide almost immediately to form a medial branch and a lateral branch.

- The lateral branch enters the dorsal horn of the cord gray matter and then divides many times to provide terminals that synapse with local neurons in the intermediate and anterior portions of the cord gray matter.

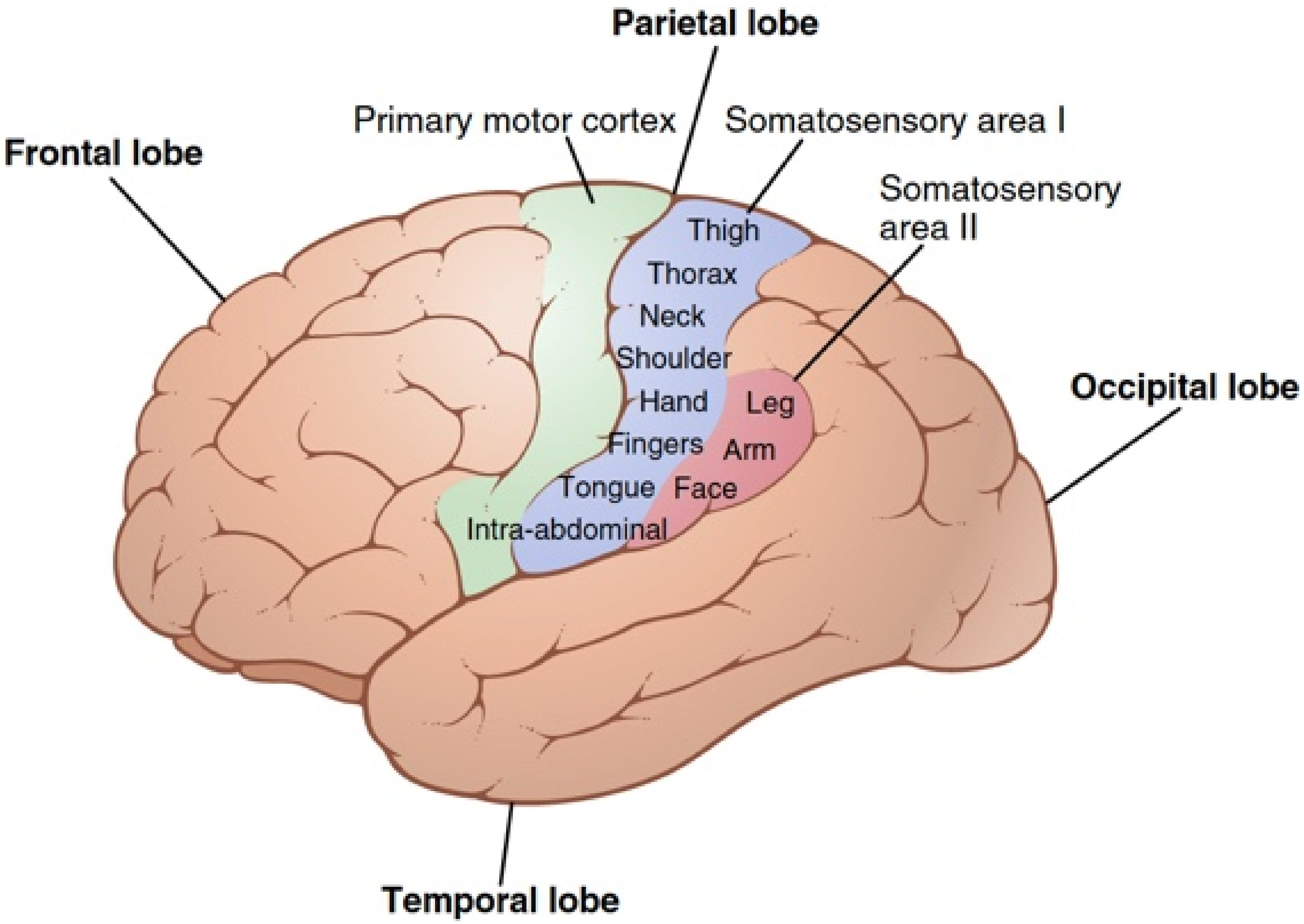
- These local neurons in turn serve three functions:
- 1. A major share of them give off fibers that enter the dorsal columns of the cord and then travel upward to the brain.
- 2. Many of the fibers are very short and terminate locally in the spinal cord gray matter to elicit local spinal cord reflexes.
- 3. Others give rise to the spinocerebellar tracts.

Anterolateral pathway vs dorsal column pathway

- (1) the velocities of transmission are less than the dorsal column–medial lemniscal system.
- (2) the degree of spatial localization of signals is poor.
- (3) the gradations of intensities are also far less accurate.
- (4) the ability to transmit rapidly changing or rapidly repetitive signals is poor.

Corticofugal signals

- In addition to somatosensory signals transmitted from the periphery to the brain, corticofugal signals are transmitted in the backward direction from the cerebral cortex to the lower sensory relay stations of the thalamus, medulla, and spinal cord.
- They control the intensity of sensitivity of the sensory input.
- Corticofugal signals are almost entirely inhibitory, so when sensory input intensity becomes too great, the corticofugal signals automatically decrease transmission in the relay nuclei. This action does two things:
- First, it decreases lateral spread of the sensory signals into adjacent neurons and, therefore, increases the degree of sharpness in the signal pattern.
- Second, it keeps the sensory system operating in a range of sensitivity that is not so low that the signals are ineffectual nor so high that the system is swamped beyond its capacity to differentiate sensory patterns.

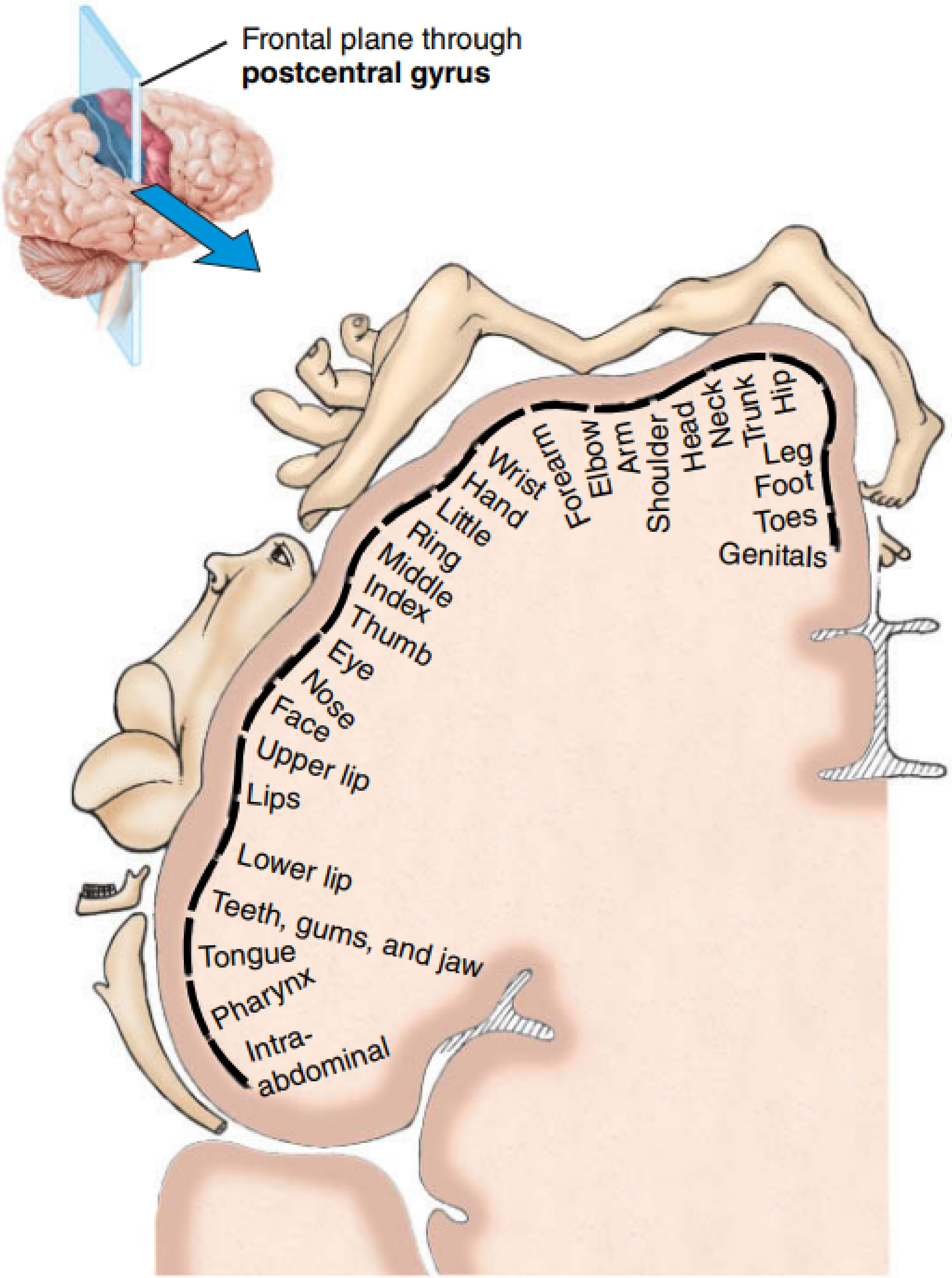


Parietal lobe
Primary motor cortex
Somatosensory area I
Frontal lobe
Somatosensory area II
Thigh
Thorax
Neck
Shoulder
Hand
Leg
Fingers
Arm
Tongue
Face
Intra-abdominal
Occipital lobe
Temporal lobe

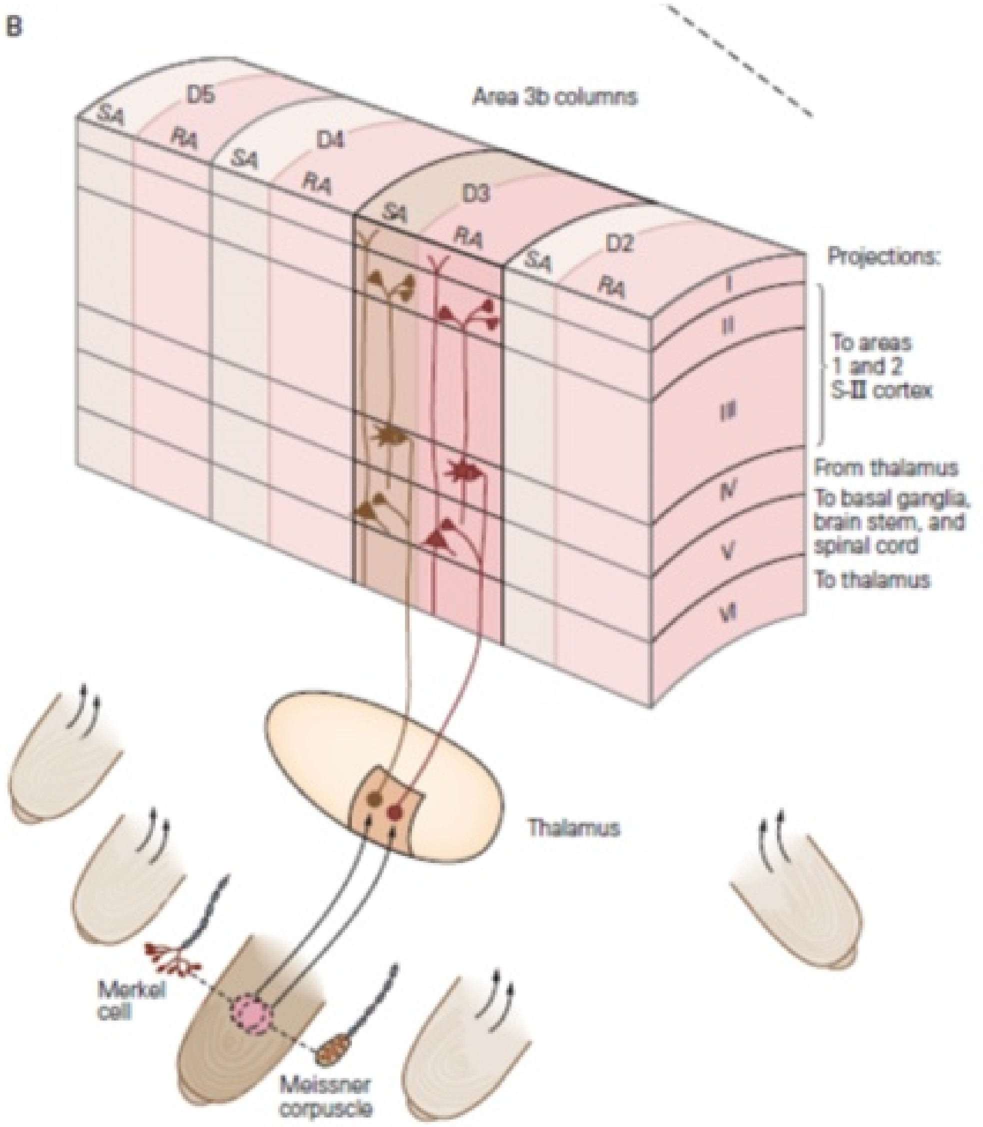
Somatosensory cortex

- Two separate sensory areas in the anterior parietal lobe called somatosensory area I and somatosensory area II.
- The reason for this division into two areas is that a distinct and separate spatial orientation of the different parts of the body is found in each of these two areas.
- However, somatosensory area I is so much more extensive and so much more important than somatosensory area II that in popular usage, the term “somatosensory cortex” almost always means area I.

Mapping of the primary somatosensory area in the cerebral cortex

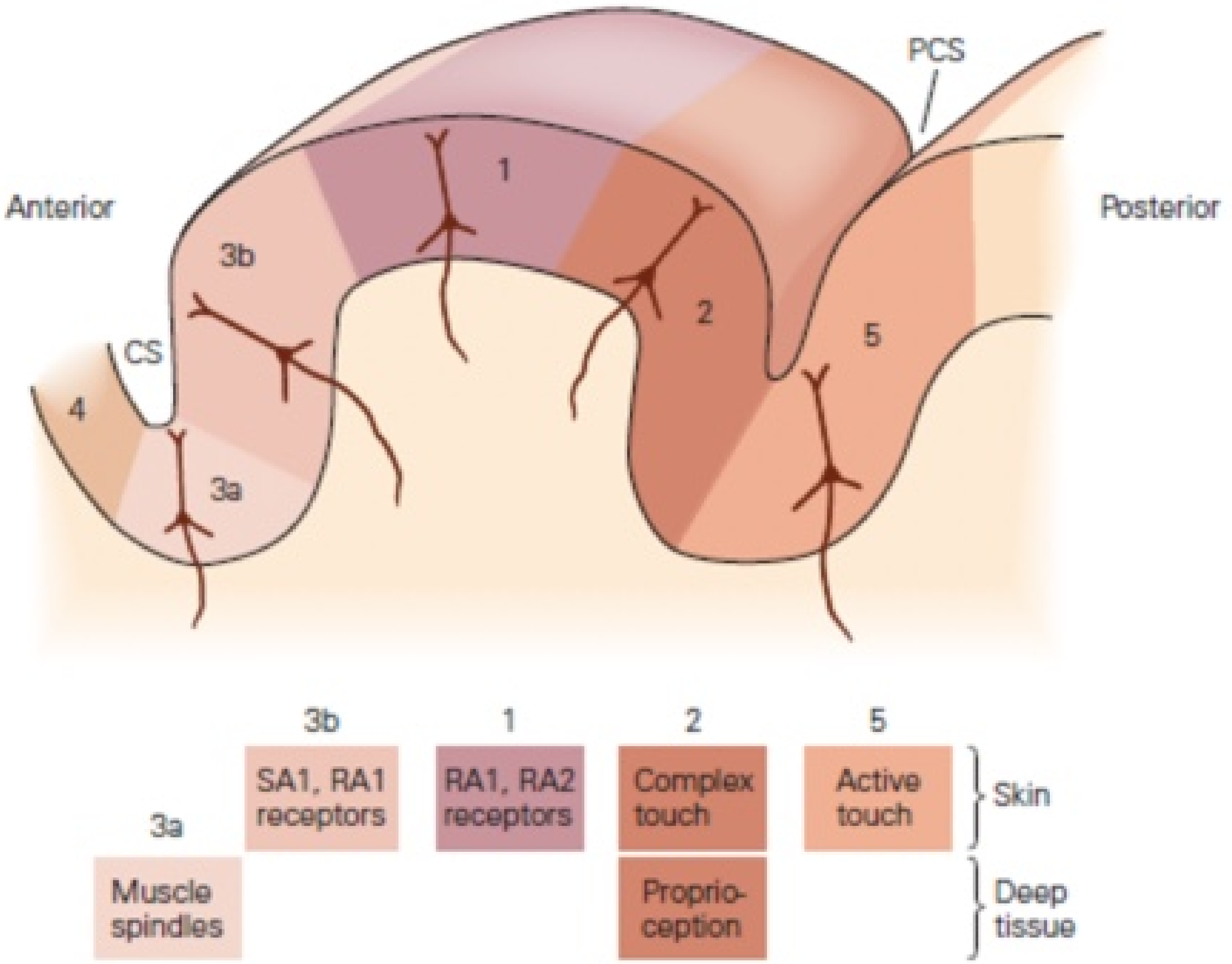


B



Area 3b columns
D5
SA
RA
D4
SA
RA
D3
SA
RA
D2
SA
RA
Projections:
I
II
III
IV
V
VI
To areas
1 and 2
S-II cortex
From thalamus
To basal ganglia,
brain stem, and
spinal cord
To thalamus
Thalamus
Merkel
cell
Meissner
corpuscle

A Inputs to areas of primary somatic sensory cortex



Somatosensory area I damage

- Widespread bilateral excision of somatosensory area I causes loss of the following types of sensory judgment:

- 1. The person is unable to localize discretely the different sensations in the different parts of the body. However, he or she can localize these sensations crudely, such as to a particular hand, to a major level of the body trunk, or to one of the legs. Thus, it is clear that the brain stem, thalamus, or parts of the cerebral cortex not normally considered to be concerned with somatic sensations can perform some degree of localization.

Somatosensory area I damage

- 2. The person is unable to judge critical degrees of pressure against the body.
- 3. The person is unable to judge the weights of objects.
- 4. The person is unable to judge shapes or forms of objects. This condition is called astereognosis.
- 5. The person is unable to judge texture of materials because this type of judgment depends on highly critical sensations caused by movement of the fingers over the surface to be judged.

Somatosensory area I damage

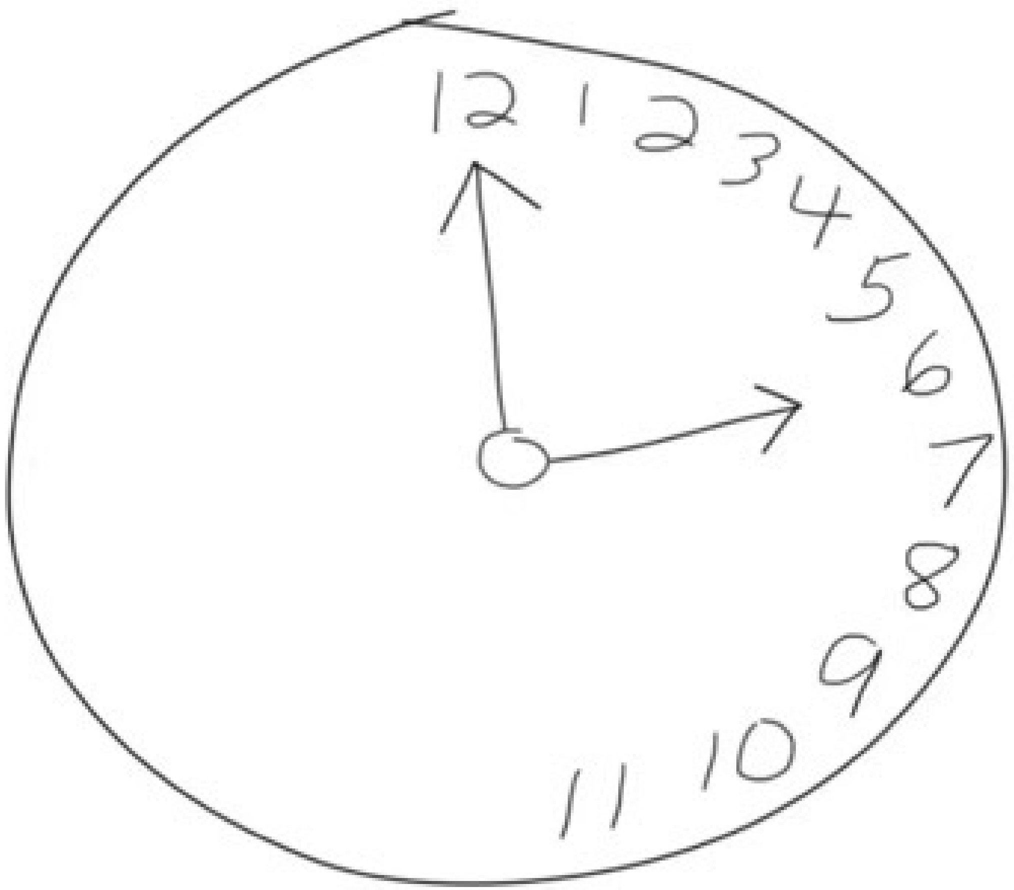
- In the specific absence of only somatosensory area I, appreciation of pain and temperature senses is still preserved both in quality and intensity.
- However, the sensations are poorly localized, indicating that pain and temperature localization depend greatly on the topographic map of the body in somatosensory area I to localize the source.

Somatosensory association area

- Electrical stimulation in a somatosensory association area can occasionally cause an awake person to experience a complex body sensation, sometimes even the “feeling” of an object such as a knife or a ball.
- Therefore, it seems clear that the somatosensory association area combines information arriving from multiple points in the primary somatosensory area to decipher its meaning.
- This occurrence also fits with the anatomical arrangement of the neuronal tracts that enter the somatosensory association area because it receives signals from the following:
- (1) somatosensory area I; (2) the ventrobasal nuclei of the thalamus; (3) other areas of the thalamus; (4) the visual cortex; and (5) the auditory cortex.

- When the somatosensory association area is removed on one side of the brain, the person loses the ability to recognize complex objects and complex forms felt on the opposite side of the body.
- In addition, the person loses most of the sense of form of his or her own body or body parts on the opposite side.
- In fact, the person is mainly oblivious to the opposite side of the body—that is, forgets that it is there. Therefore, the person also often forgets to use the other side for motor functions as well. Likewise, when feeling objects, the person tends to recognize only one side of the object and forgets that the other side even exists. This complex sensory deficit is called amorphosynthesis.

Contralateral neglect or amorphosynthesis (posterior parietal damage)



- Generally, the anterior half of the parietal lobe is concerned almost entirely with reception and interpretation of somatosensory signals, but the posterior half of the parietal lobe provides still higher levels of interpretation.

Sensory coding

- Stimulus **modality** is often encoded by **labeled lines**, which consist of pathways of sensory neurons dedicated to that modality.

- Stimulus **location** is encoded by the **receptive field** of sensory neurons and may be enhanced by lateral inhibition.

- **Threshold** is the minimum stimulus that can be detected. Threshold is best appreciated in the context of the receptor potential.

Sensory coding

- Stimulus information also is encoded in **neural map**s formed by arrays of neurons receiving information from different locations on the body (i.e., somatotopic maps), from different locations on the retina (i.e., retinotopic maps), or from different sound frequencies (i.e., tonotopic maps).

Sensory coding

- Stimulus **duration** is encoded by the duration of firing of sensory neurons.
- However, during a prolonged stimulus, receptors “adapt” to the stimulus and change their firing rates.

Sensory coding

- Other stimulus information is encoded in **the pattern of nerve impulses.**
- Some of these codes are based on mean discharge frequency, others are based on the duration of firing, while others are based on a temporal firing pattern.
- The frequency of the stimulus may be encoded directly in the intervals between discharges of sensory neurons.

Sensory coding

- Stimulus **intensity** is encoded in three ways.
- (1) Intensity can be encoded by the **number of receptors** that are activated.
- (2) Intensity can be encoded by differences in **firing rates** of sensory neurons in the pathway.
- (3) Intensity even may be encoded by **activating different types of receptors.** Thus a light touch of the skin may activate only mechanoreceptors, whereas an intense damaging stimulus to the skin may activate mechanoreceptors and nociceptors.

Thank you