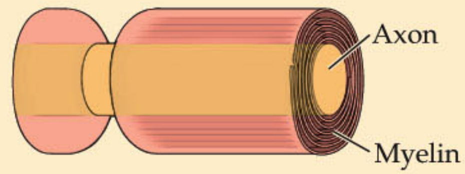
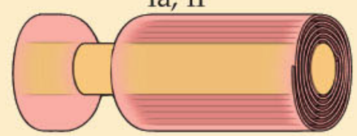
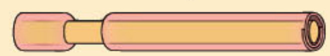
Somatosensory system

(touch and pain)

General, historical

- compelling "Physiology" (vs psychology)
- submodalities (e.g. pain vs hot)
- von Frey (around 1900) punctate sensitivity -
- correlation receptor with sensory experience.
- Muller's (mid-1800's) "doctrine of specific nerve energies"
- the quality comes from the nervous system not the physics of the stimulus.

TABLE 9.1 Somatic Sensory Afferents that Link Receptors to the Central Nervous System

Sensory function	Receptor type	Afferent axon type[a]	Axon diameter	Conduction velocity
Proprioception	Muscle spindle	 Ia, II	13–20 μm	80–120 m/s
Touch	Merkel, Meissner, Pacinian, and Ruffini cells	 Aβ	6–12 μm	35–75 m/s
Pain, temperature	Free nerve endings	 Aδ	1–5 μm	5–30 m/s
Pain, temperature, itch	Free nerve endings	 C	0.2–1.5 μm	0.5–2 m/s

[a]During the 1920s and 1930s, there was a virtual cottage industry classifying axons according to their conduction velocity. Three main categories were discerned, called A, B, and C. A comprises the largest and fastest axons, C the smallest and slowest. Mechanoreceptor axons generally fall into category A. The A group is further broken down into subgroups designated α (the fastest), β, and δ (the slowest). To make matters even more confusing, muscle afferent axons are usually classified into four additional groups—I (the fastest), II, III, and IV (the slowest)—with subgroups designated by lowercase roman letters!

(After Rosenzweig et al., 2005.)

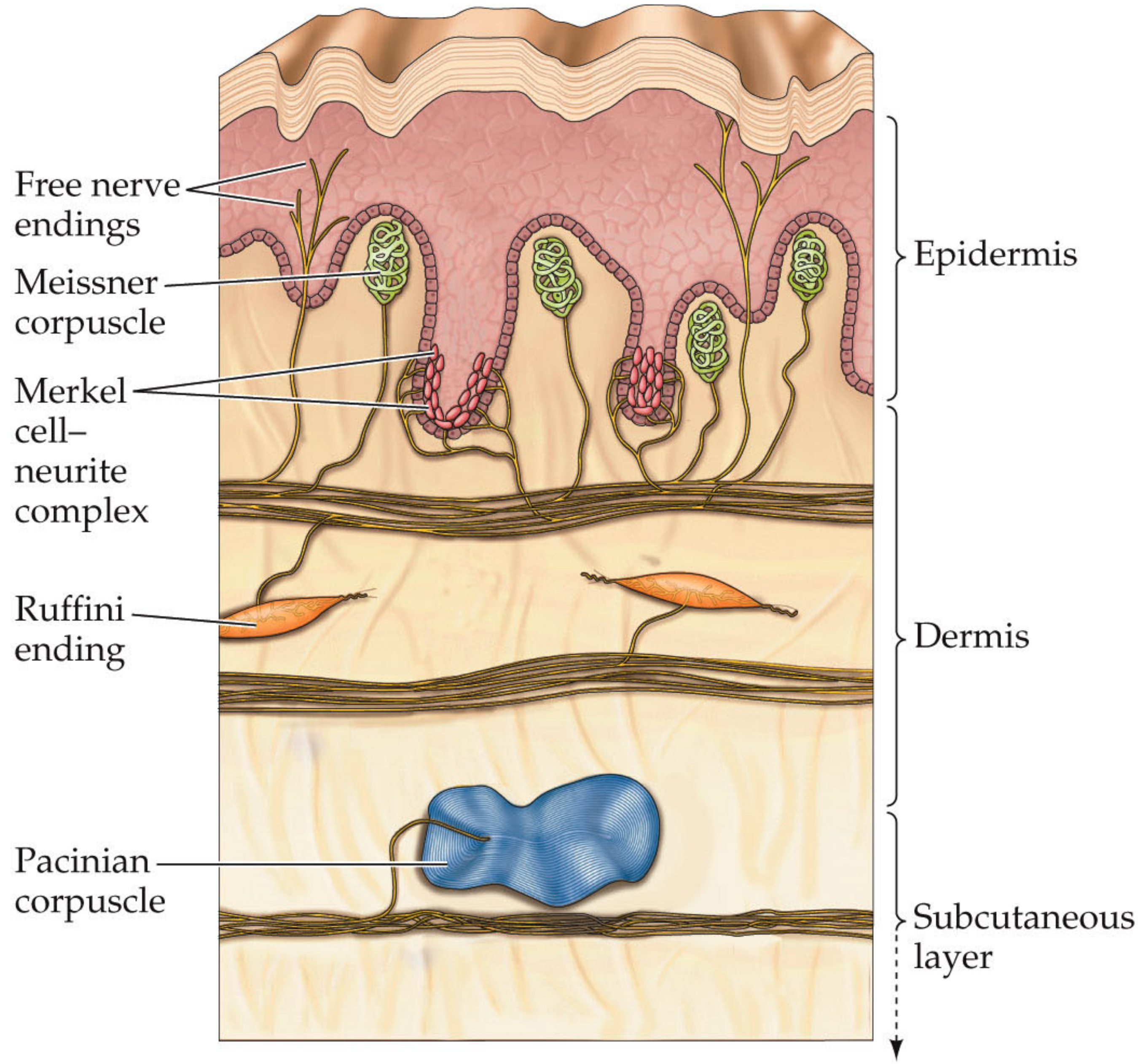
TABLE 9.2 Afferent Systems and Their Properties

	Small receptor field		Large receptor field	
	Merkel	**Meissner**	**Pacinian**	**Ruffini**
Location	Tip of epidermal sweat ridges	Dermal papillae (close to skin surface)	Dermis and deeper tissues	Dermis
Axon diameter	7–11 μm	6–12 μm	6–12 μm	6–12 μm
Conduction velocity	40–65 m/s	35–70 m/s	35–70 m/s	35–70 m/s
Sensory function	Form and texture perception	Motion detection; grip control	Perception of distant events through transmitted vibrations; tool use	Tangential force; hand shape; motion direction
Effective stimuli	Edges, points, corners, curvature	Skin motion	Vibration	Skin stretch
Receptive field area[a]	9 mm^2	22 mm^2	Entire finger or hand	60 mm^2
Innervation density (finger pad)	100/cm^2	150/cm^2	20/cm^2	10/cm^2
Spatial acuity	0.5 mm	3 mm	10+ mm	7+ mm
Response to sustained indentation	Sustained (slow adaptation)	None (rapid adaptation)	None (rapid adaptation)	Sustained (slow adaptation)
Frequency range	0–100 Hz	1–300 Hz	5–1000 Hz	0–? Hz
Peak sensitivity	5 Hz	50 Hz	200 Hz	0.5 Hz
Threshold for rapid indentation or vibration:				
Best	8 μm	2 μm	0.01 μm	40 μm
Mean	30 μm	6 μm	0.08 μm	300 μm

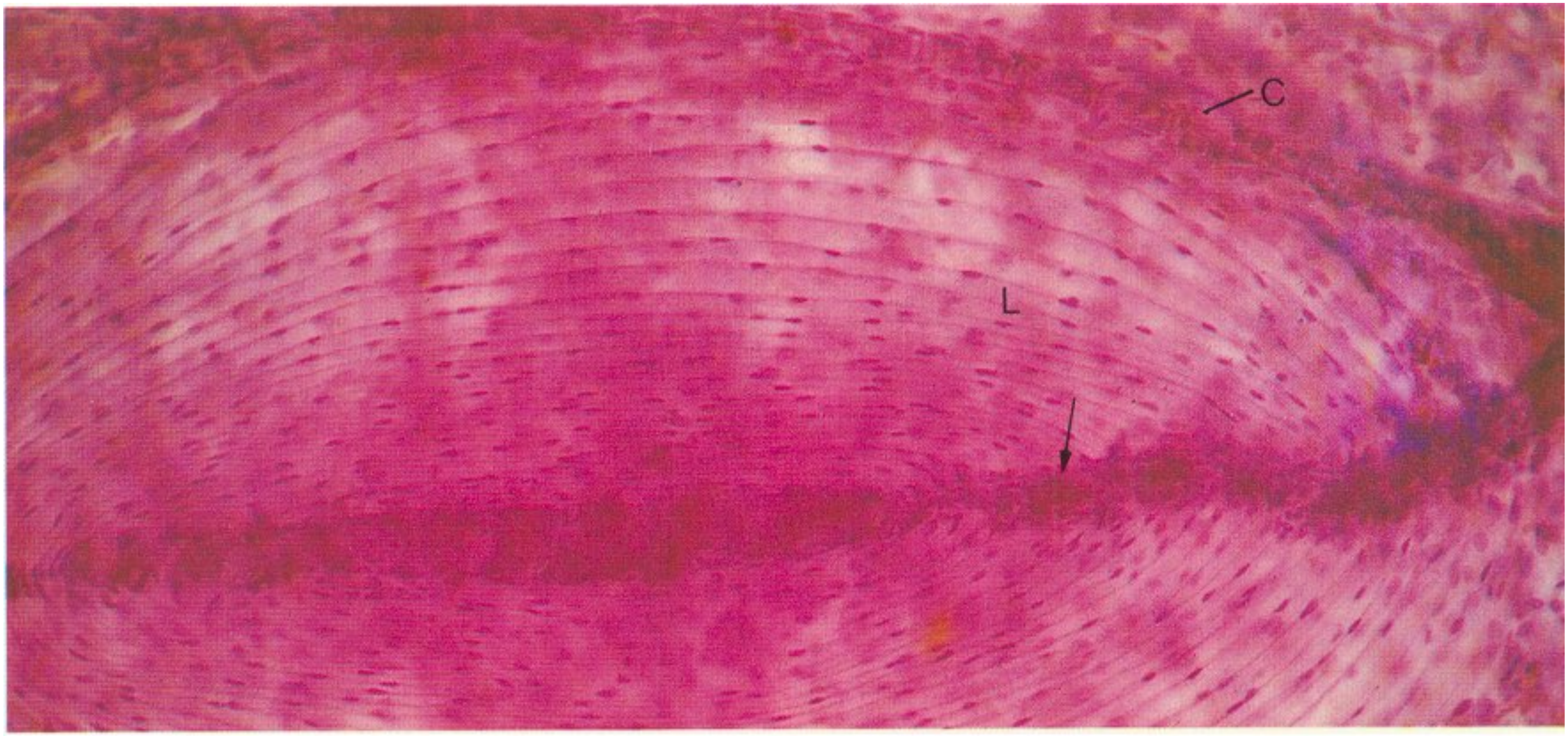
[a]Receptive field areas as measured with rapid 0.5-mm indentation.
(After K. O. Johnson, 2002.)

Current thinking

- conduction velocities
- different sizes of myelinated (A) axons, alpha biggest and delta is smallest,
- unmyelinated (C) axons.
- Skin (glabrous, there is also hairy)
- The different types of receptors
- free nerve endings and encapsulated
- Free nerve endings for pain, temperature and crude touch the axons are C fibers (unmyelinated) and A delta, also slow



NEUROSCIENCE, Fourth Edition, Figure 9.5



Vater-Pacini corpuscle H&E Med
C - peripheral capsule; L - surrounding lamellae; arrow - nerve containing core

Loewenstein

- Pacinian corpuscle is rapidly adapting
- because of the layers surrounding the nerve ending
- dissecting off these layers
- Also, there is an electrical adaptation preventing continued spikes after stimulus onset.

Pacinian corpuscle

- rapid adaptation
- A beta
- very sensitive,
- very large receptive field (area which, if stimulated, will affect the receptor [or higher order sensory nerve])
- vibration - 250 - 300 Hz

Meisner's corpuscles

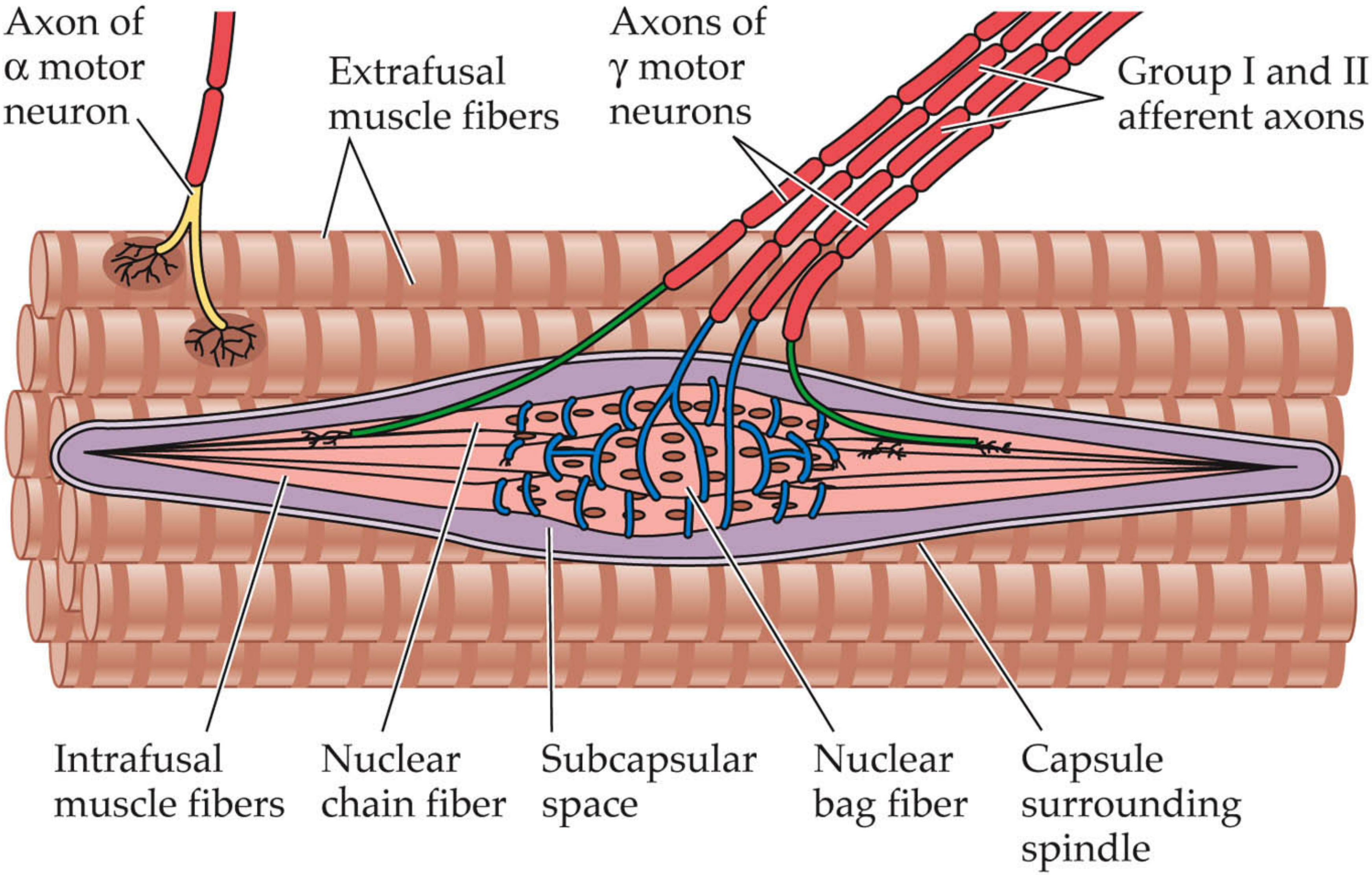
- not as fast as Pacinian
- encapsulation with Schwann cell layers
- most common receptors of fingers, palms and soles
- A beta axons
- smaller receptive field
- "feeling" - active touch - would use fast as finger moves across textured surface

Merkel's disks

- Slow, small receptive field, light touch
- finger tips, lips and genitals
- A beta axons
- static discrimination of shape

Others

- Ruffini slow - large receptive field - sensitive to stretching in deep skin, ligaments and tendons
- A beta axons
- Krauss in lips and genitals (dry vs mucous skin)


Axon of α motor neuron
Extrafusal muscle fibers
Axons of γ motor neurons
Group I and II afferent axons
Intrafusal muscle fibers
Nuclear chain fiber
Subcapsular space
Nuclear bag fiber
Capsule surrounding spindle

Proprioceptors

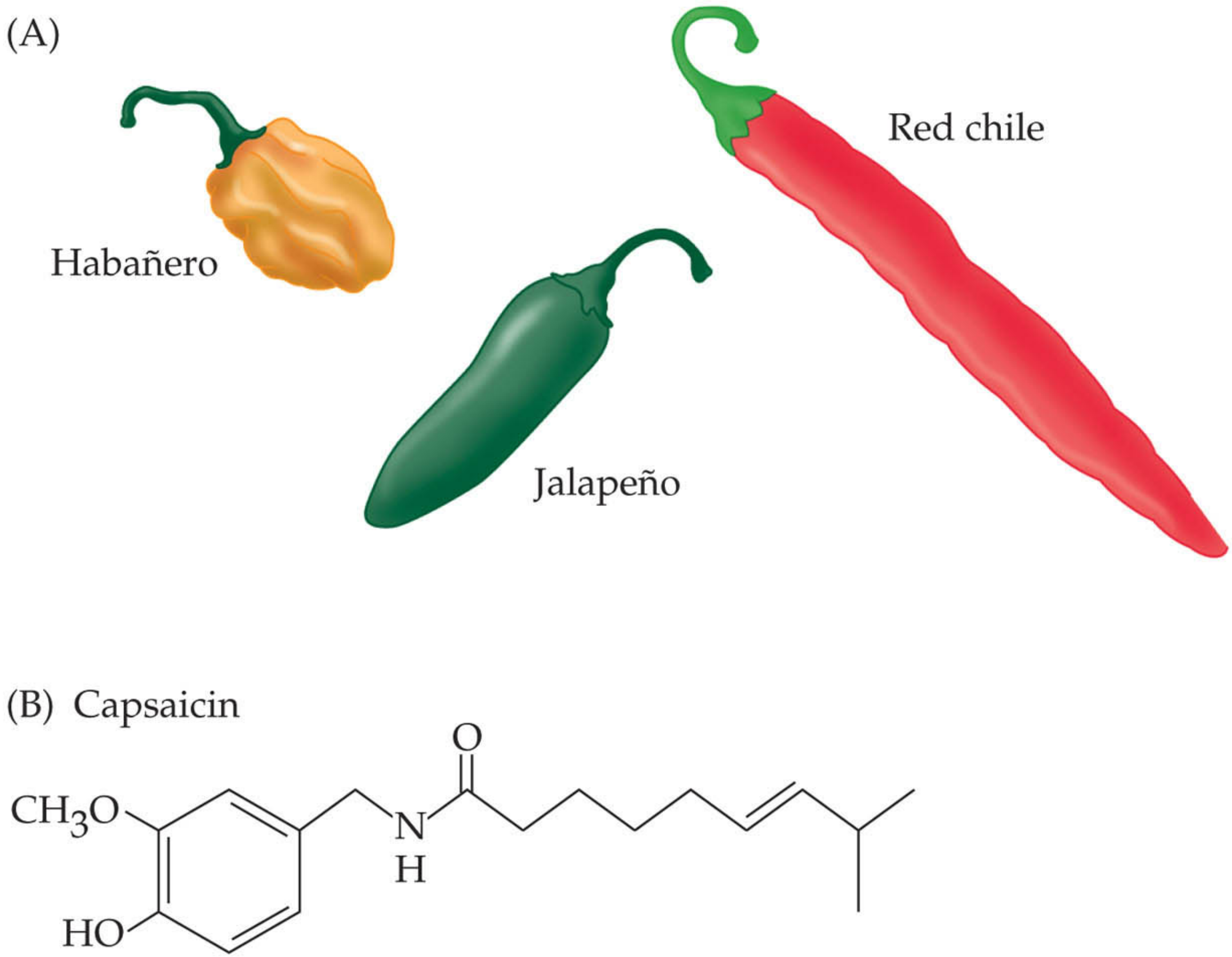
- muscle spindles (nuclear bag fibers)
- muscle spindle tension presets readiness for reflex,
- gamma motor neurons to intrafusal fibers
- Ia sensory axon
- also Golgi tendon organs Ib afferents

warm and cold

- person can feel a difference of 0.01oC
- relation to body temperature
- (cold have additional peak at high temp
- paradoxical cold - "pins and needles"

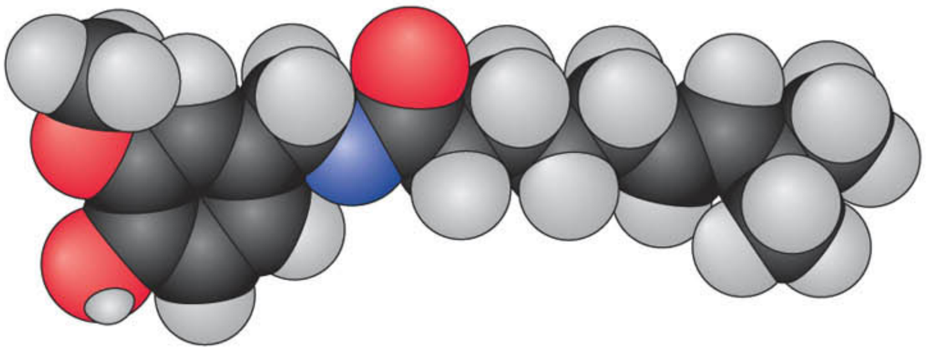
Recent progress

- channel properties
- How neurons know that it's cold outside,
- Hot and cold trp ion channels,
- cold related to menthol
- hot related to capsaicin

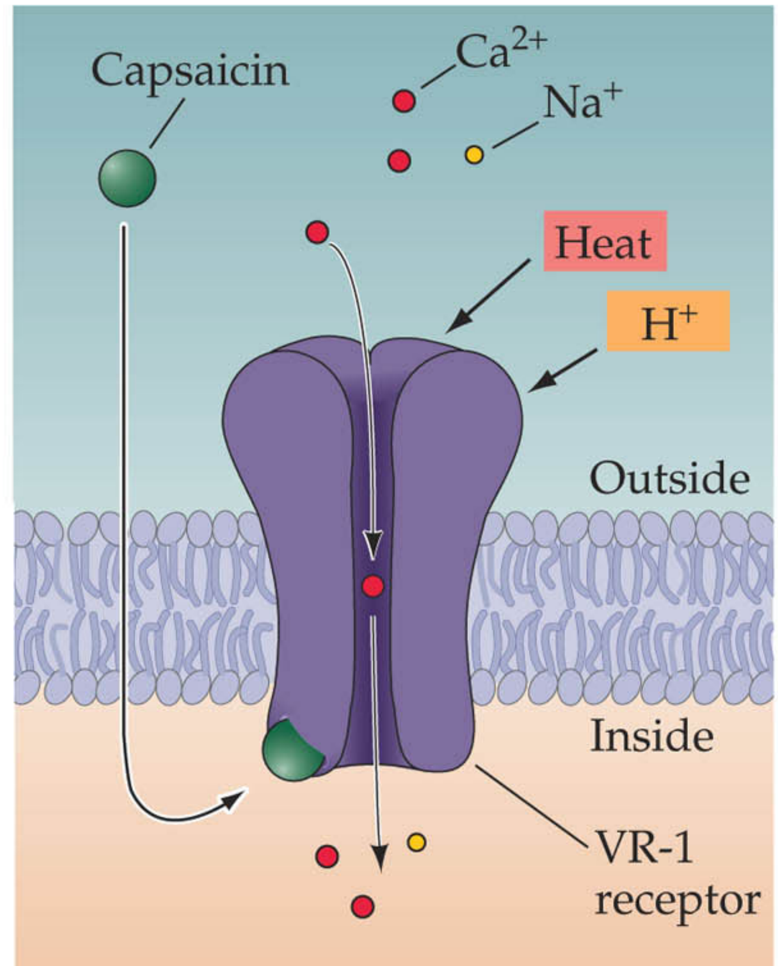


NEUROSCIENCE, Third Edition, **Chapter 9, Box A (Part 1)**

(C)

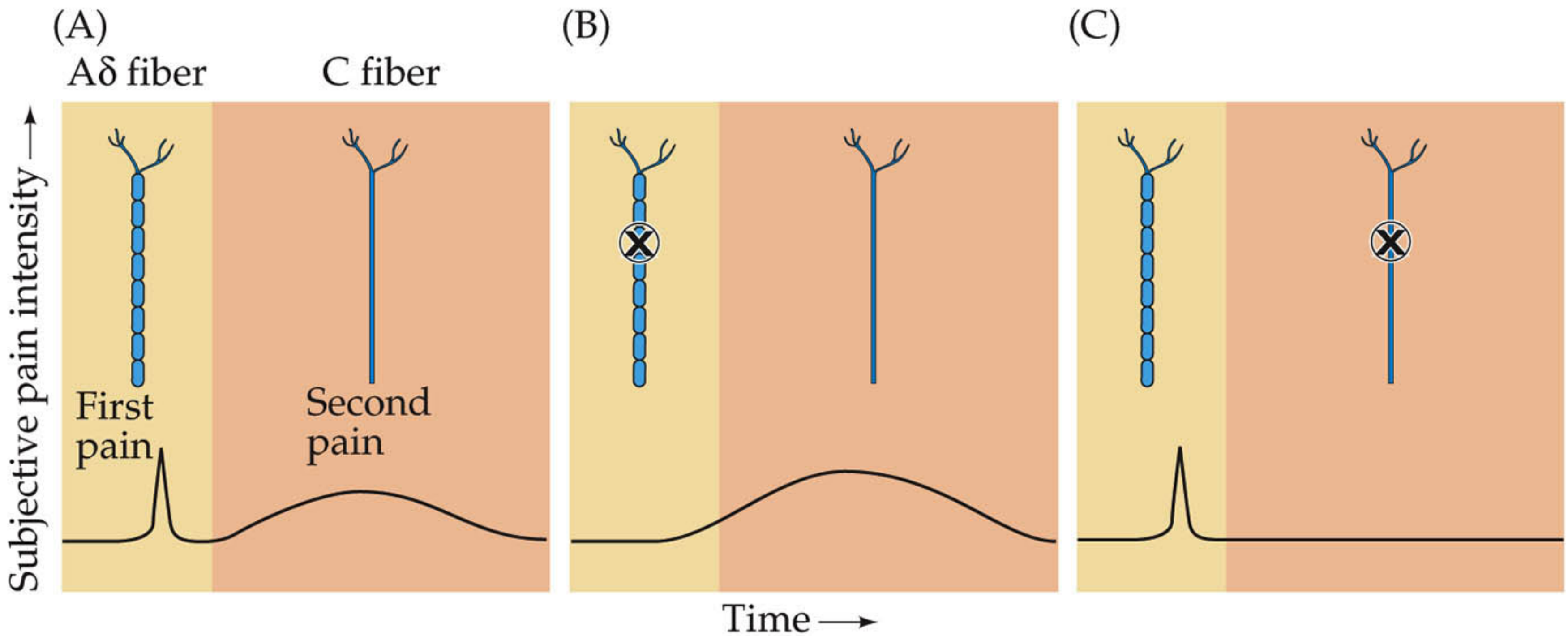


(D)



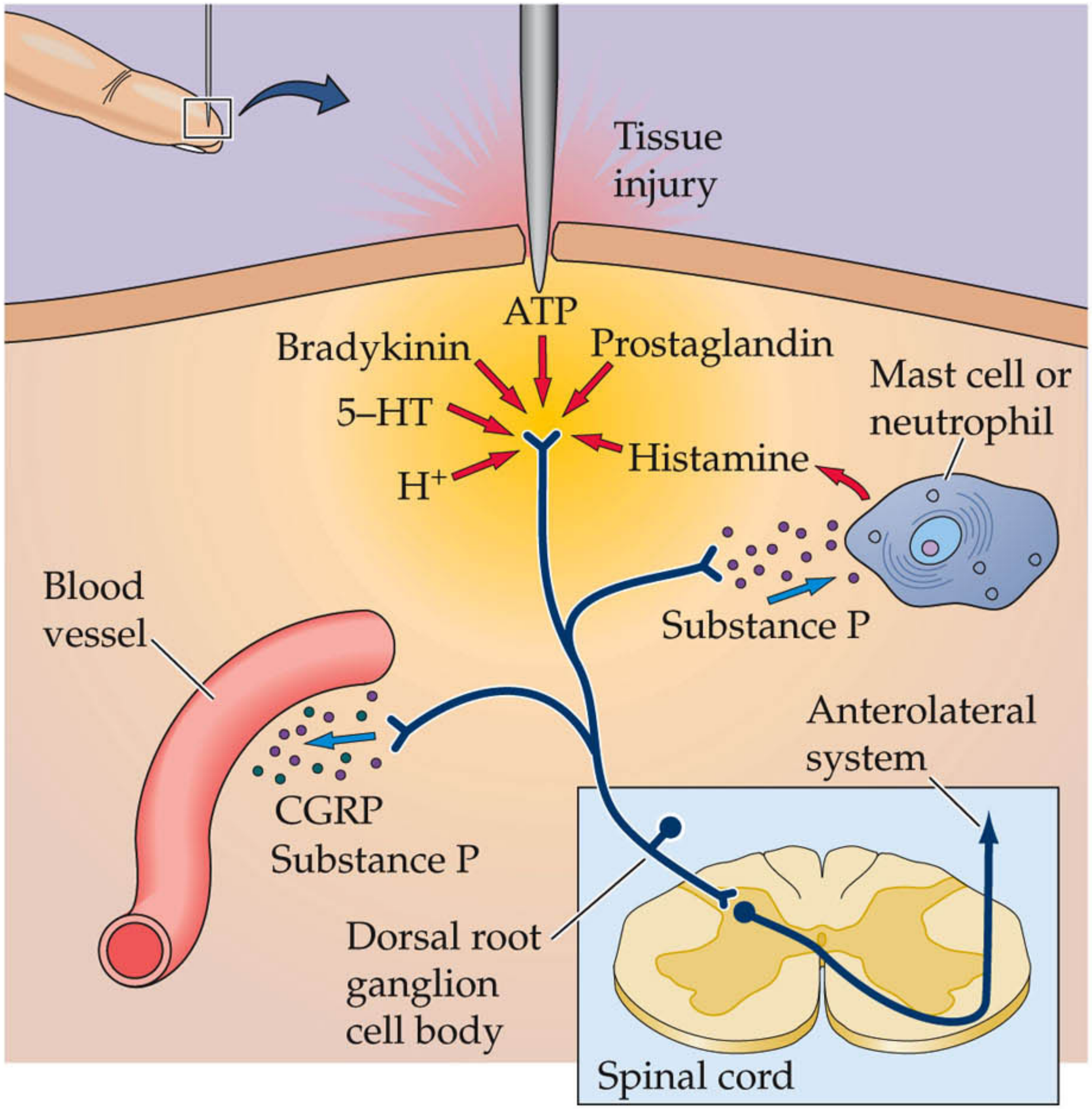
Personal reflection

- Cosens & Manning *Drosophila* mutant
- Cosens - abnormal mating.
- Baruch Minke,
- trp (transient receptor potential)


(A)
Aδ fiber
C fiber
(B)
(C)
Subjective pain intensity →
First pain
Second pain
Time →

Pain axons

- Pain is faster in A delta fibers than in C fibers
- Nociceptors
- A delta mechano and mechano-thermal,
- C fiber polymodal



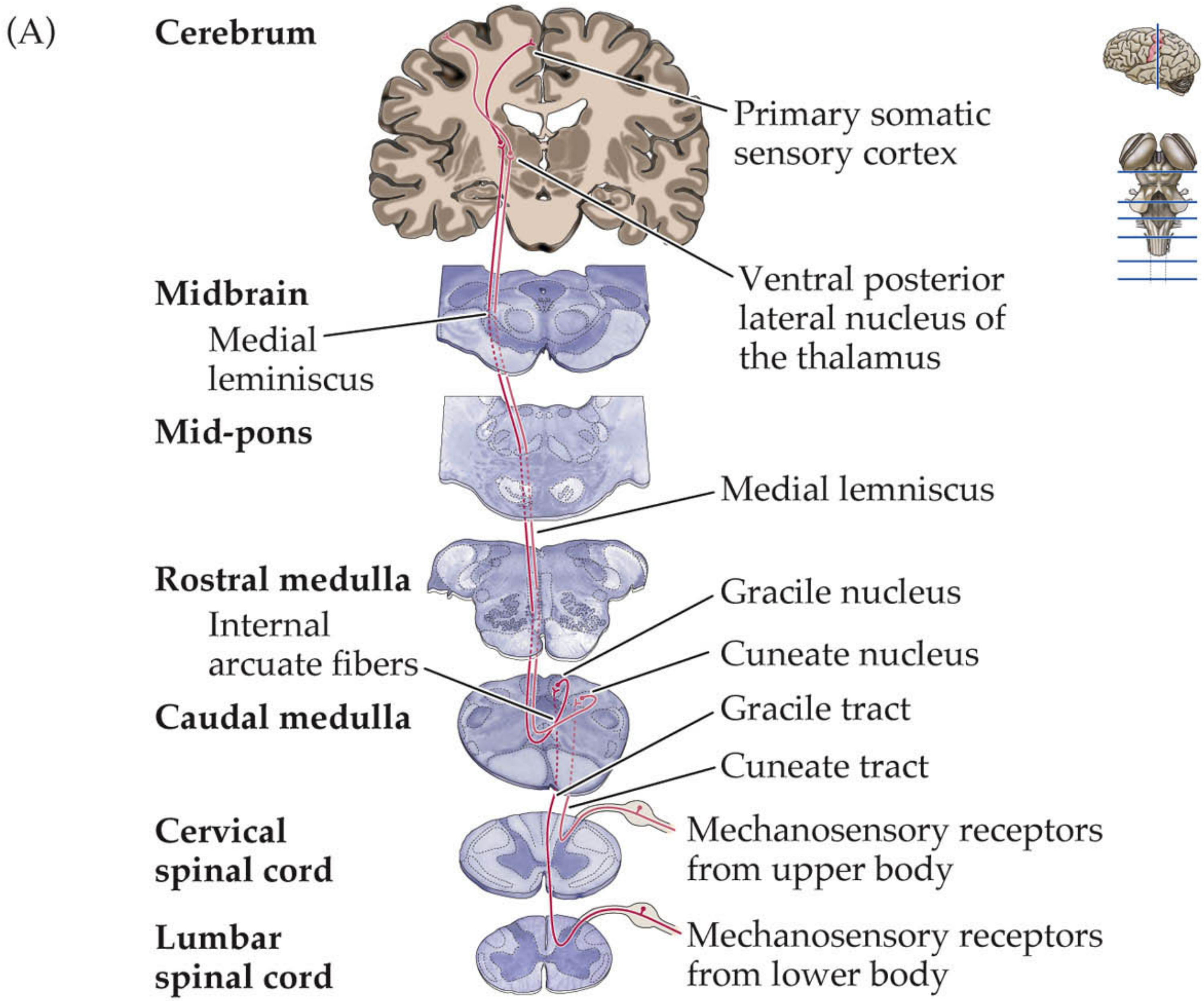
NEUROSCIENCE, Third Edition, **Figure 9.6**

From outline

- sting venoms (serotonin, histamine, acetylcholine).
- Also tissue damage substances
- serotonin (platelets), prostaglandins, leukotrienes, Histamine from mast cells, substance P, Bradykinin from blood borne precursor - enzyme from injury

In summary

- nociceptor is really a chemoreceptor
- Nociceptors are in many places,
- but not in brain,
- hence brain surgery under local anesthesia
- used in mapping studies in humans by Penfield.



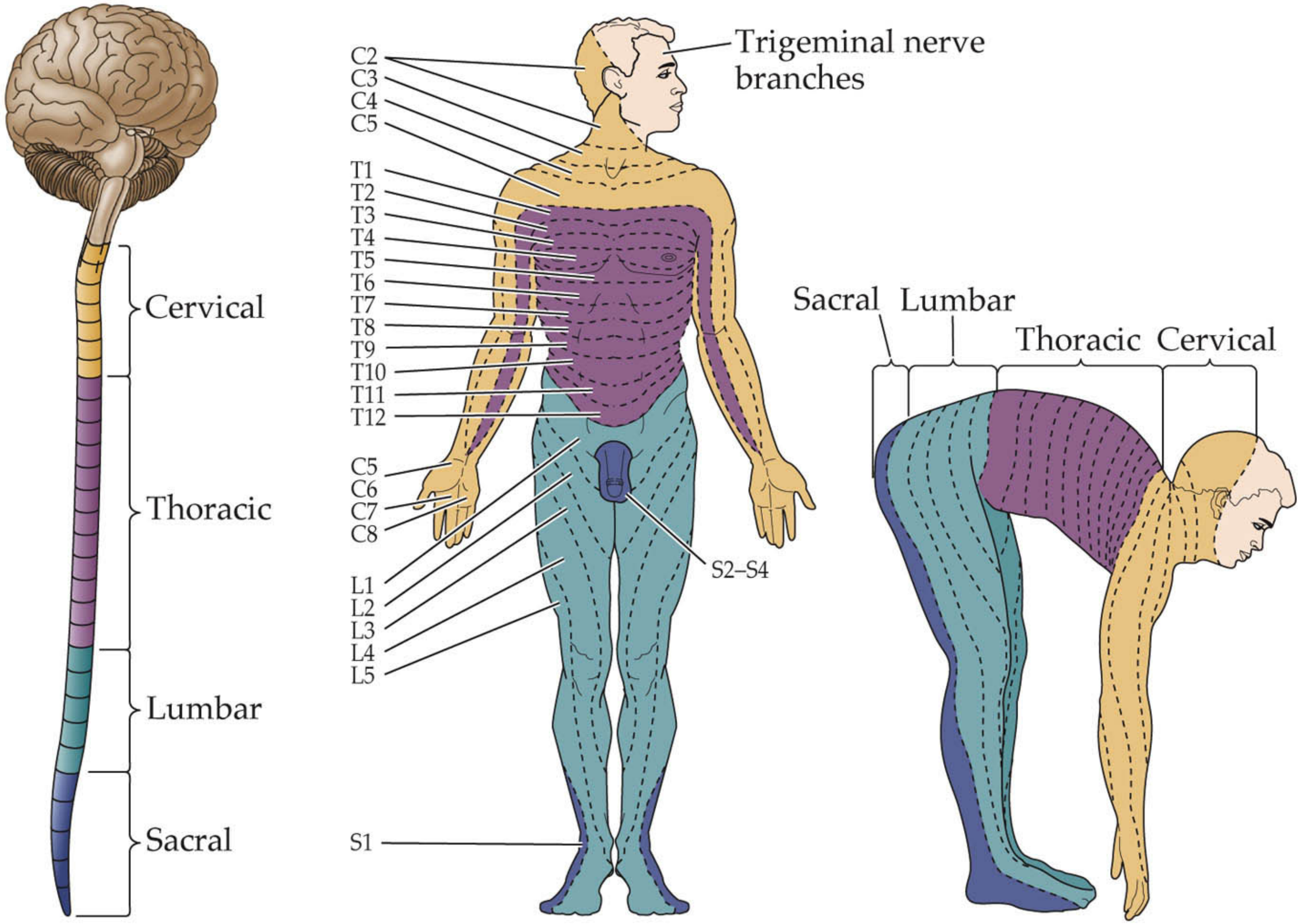
NEUROSCIENCE, Third Edition, **Figure 8.6 (Part 1)**

From outline

- Lower limbs medial in gracile tract.
- Upper limbs lateral in cuneate tract.
- ipsilateral projection
- First nucleus is in lower medulla
- There is a cross-over, and then the next nucleus is in the thalamus.
- This lemnicsal system is evolutionarily "new" (reptiles and above) and is for localized touch.

More

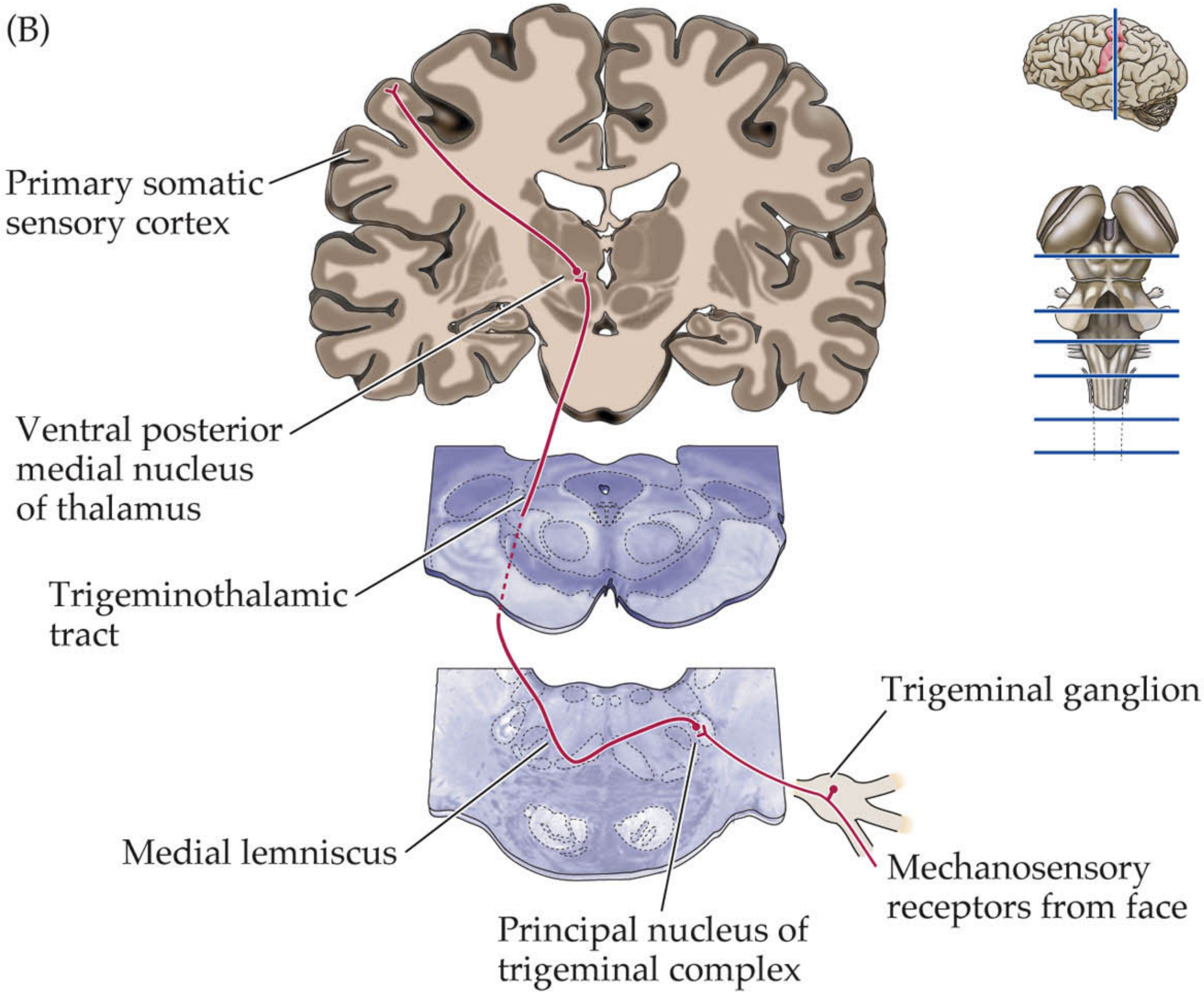
- processing - lateral inhibition to sharpen spatial localization.
- (This is the first mention of lateral inhibition, a fundamental mechanism of sensory processing.)
- If you tap your forearm, there are big waves but you feel localized touch.

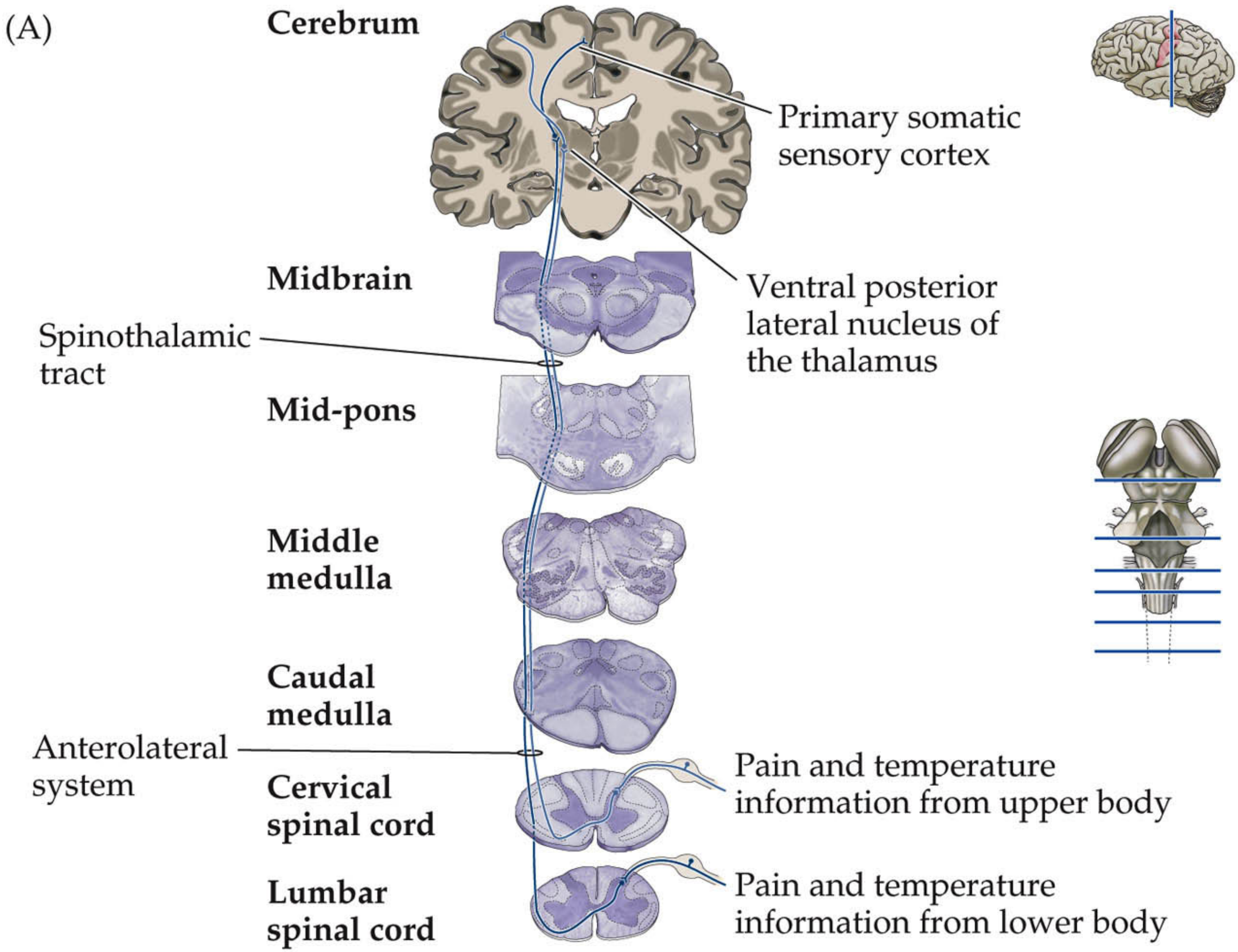


Cervical
Thoracic
Lumbar
Sacral
C2
C3
C4
C5
T1
T2
T3
T4
T5
T6
T7
T8
T9
T10
T11
T12
C5
C6
C7
C8
L1
L2
L3
L4
L5
S1
Trigeminal nerve branches
S2–S4
Sacral
Lumbar
Thoracic
Cervical

Dermatomes

- segmental organization of spinal cord -
- the dorsal root ganglion where input is translates into dermatomes -
- which place is innervated
- herpes zoster "shingles" reactivated virus - localized to one sensory ganglion


(B)
Primary somatic sensory cortex
Ventral posterior medial nucleus of thalamus
Trigeminothalamic tract
Trigeminal ganglion
Medial lemniscus
Mechanosensory receptors from face
Principal nucleus of trigeminal complex



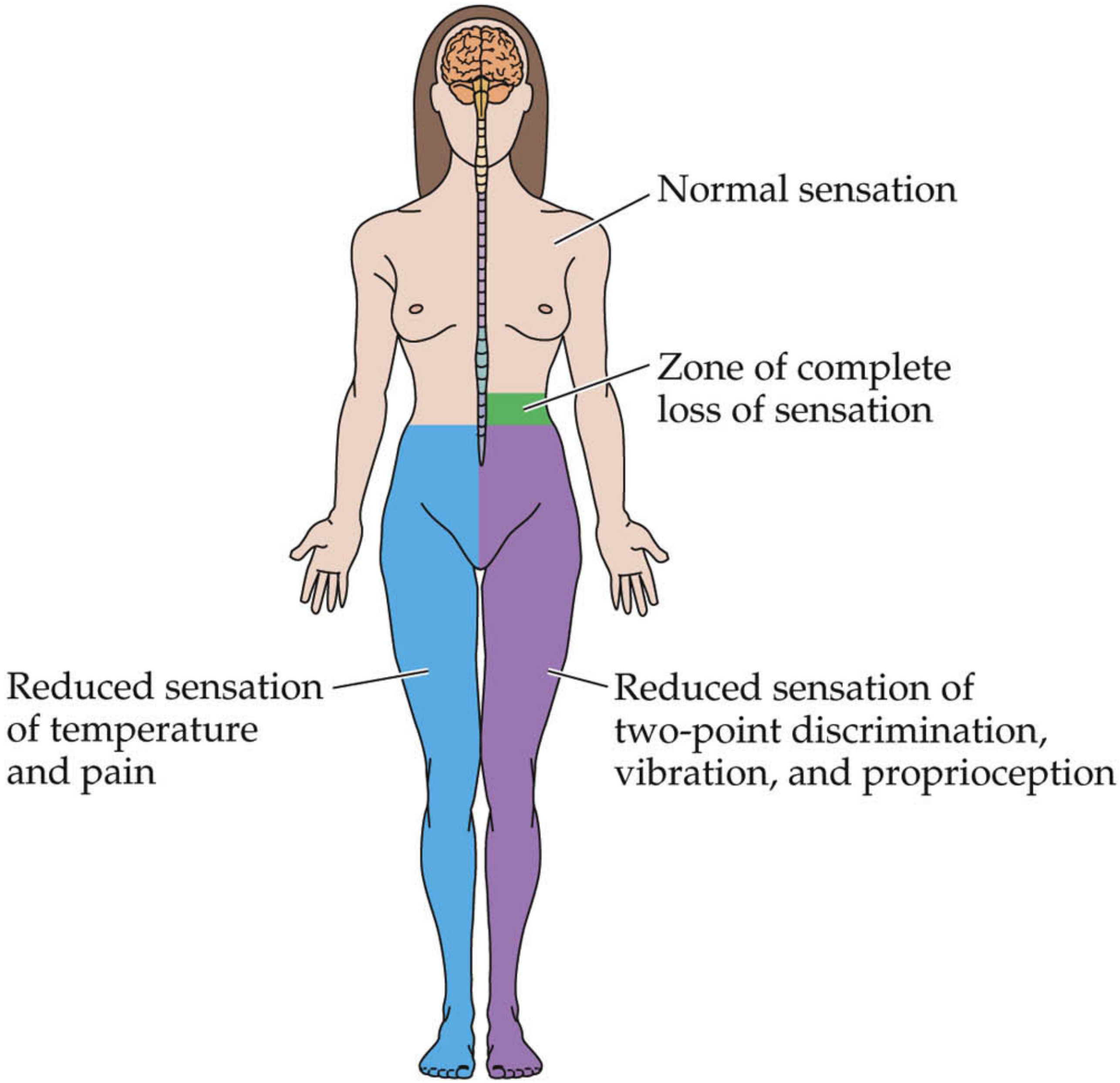
NEUROSCIENCE, Third Edition, **Figure 9.3 (Part 1)**

From outline

- spinothalamic snapse and decussation at entry point.
- There are separate tracts in spinal cord.
- lateral portion is for pain and temperature.
- ventral (anterior) part is for gross tactile sense.
- Hence the nomenclature "anterolateral.”

More

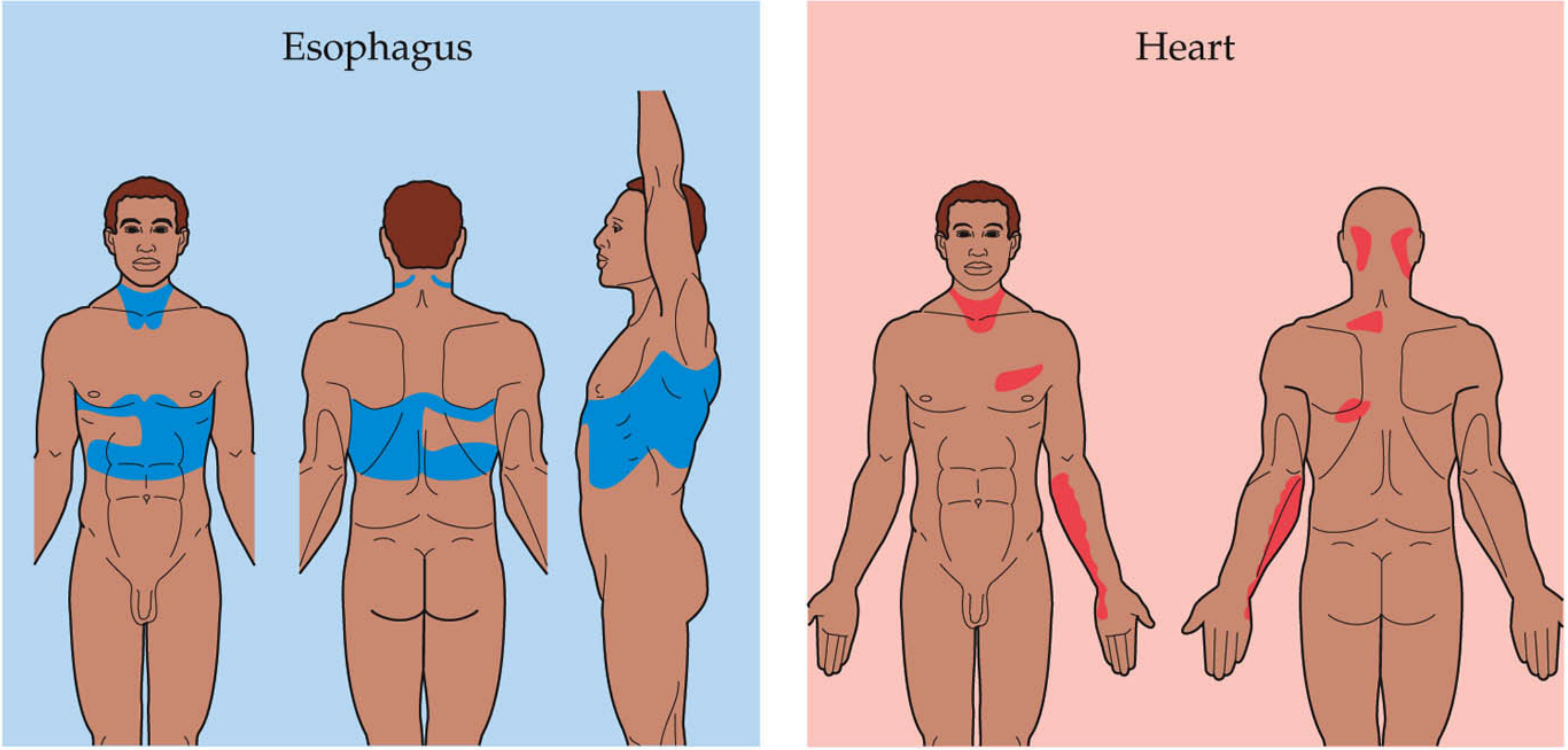
- Sharp pain inhibits worse pain
- (example: a hard touch to a door knob makes an electric shock less annoying)
- "neospinothalamic" (more recently evolved) A-delta
- "paleospinothalamic" (more ancient) C fibers
- injury to the former intractable pain,
- "psychosurgery" can be helpful.
- Dull pain diffuse less localized.

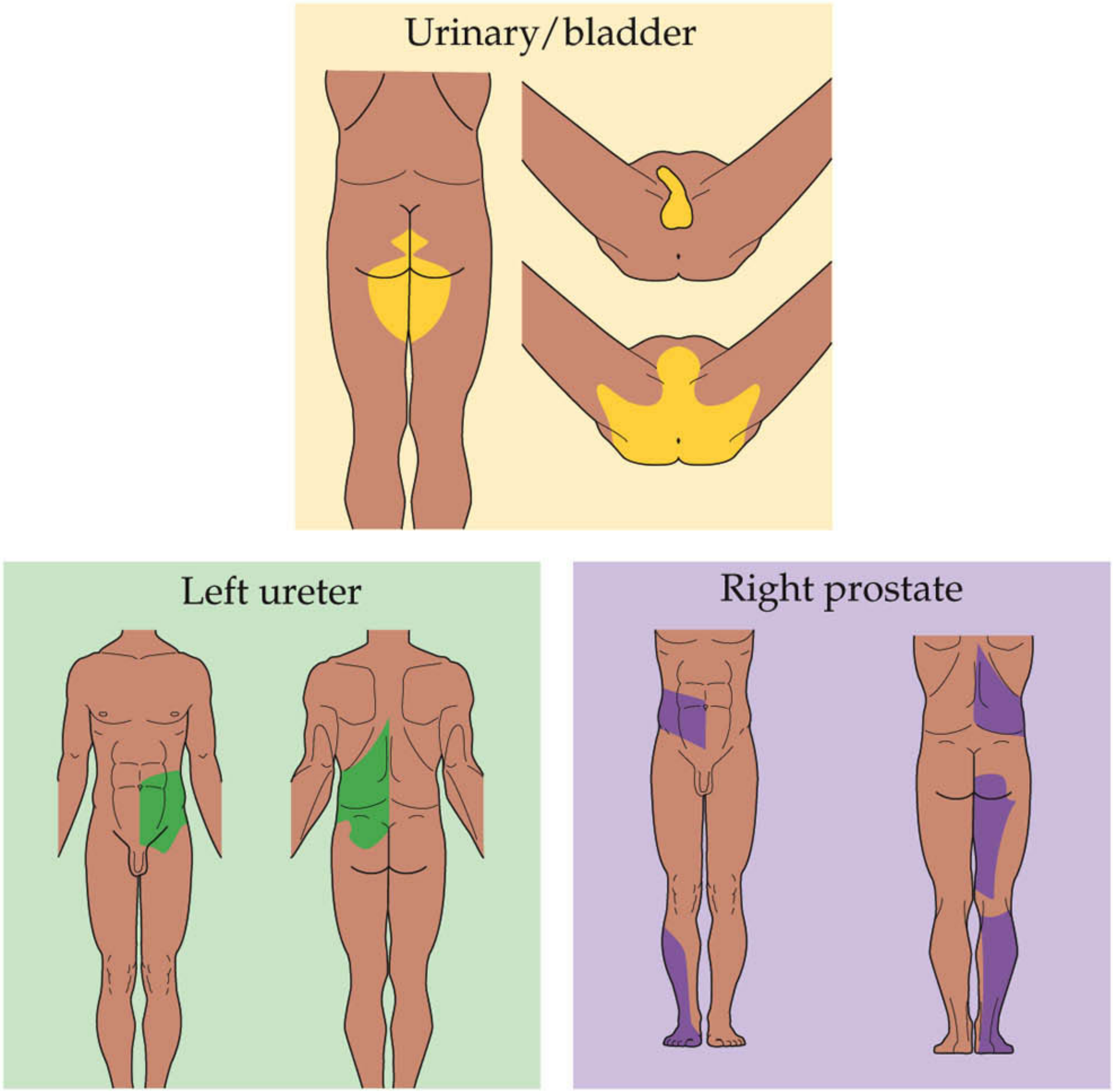


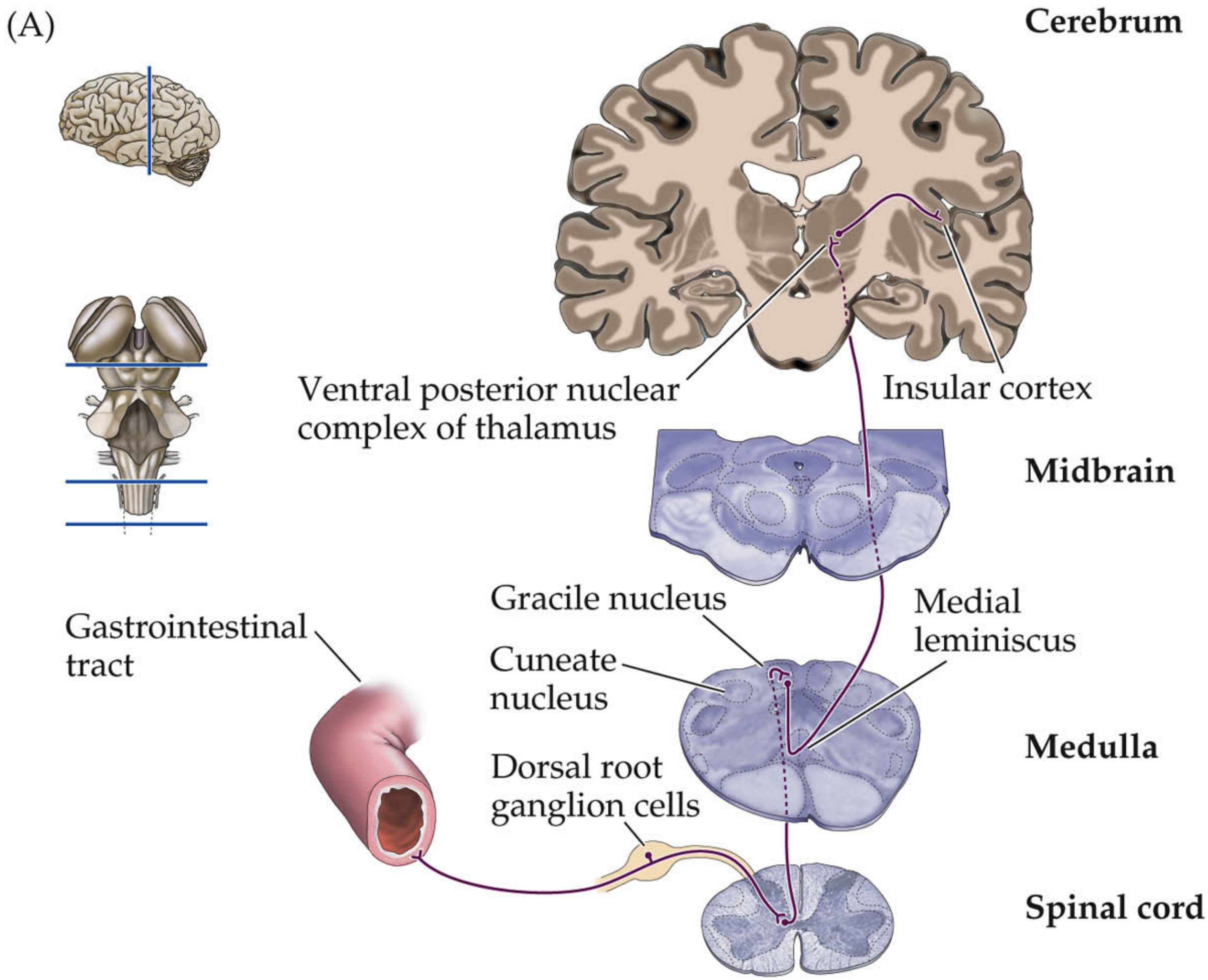
NEUROSCIENCE, Third Edition, **Figure 9.4**

Loss from hemisection

- A half spinal cord injury:
- contralateral loss of spinothalamic below injury
- ipsilateral loss of lemniscal.
- Brown-Sequard syndrome include motor (ipsilateral impairment)

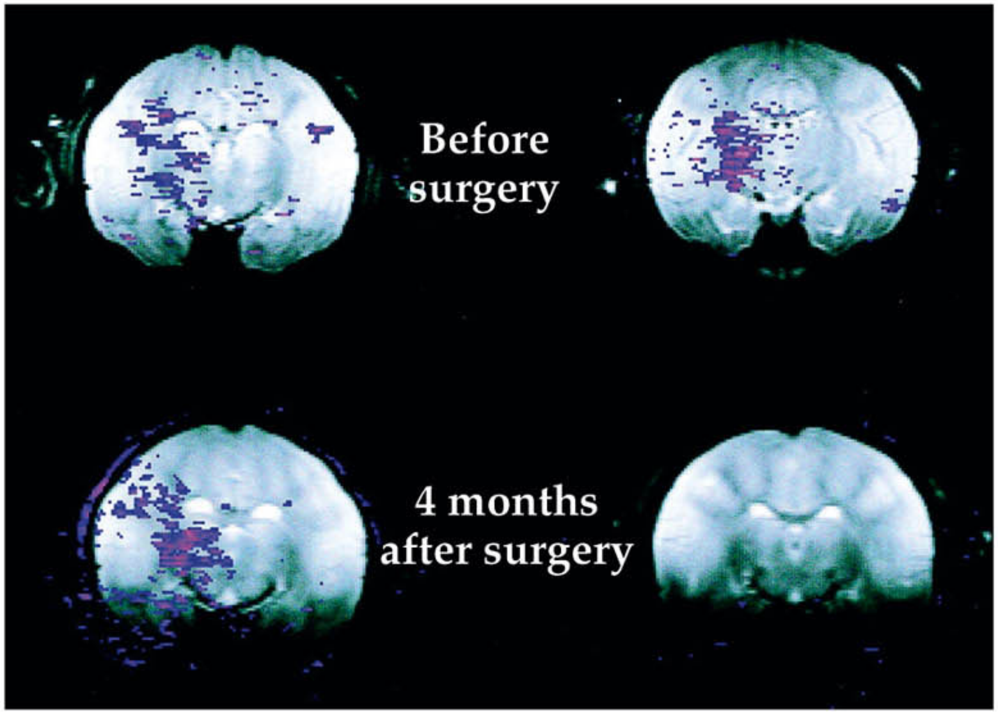

Esophagus
Heart


Urinary/bladder
Left ureter
Right prostate

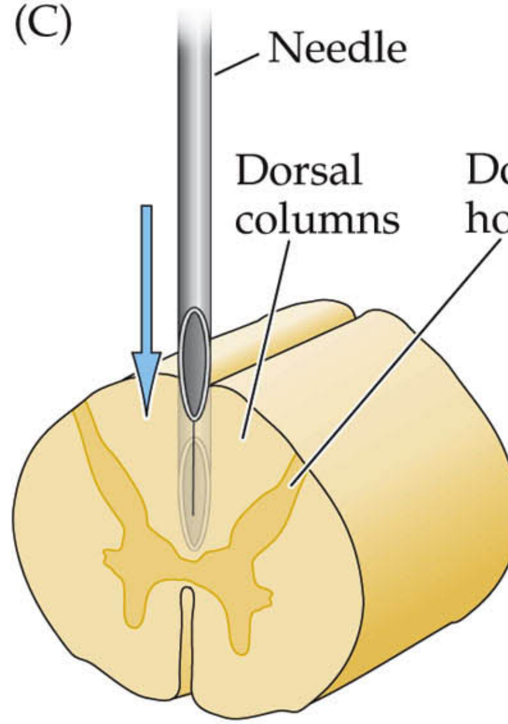


NEUROSCIENCE, Third Edition, **Chapter 9, Box C (Part 1)**

(B) Sham lesion Dorsal column lesion

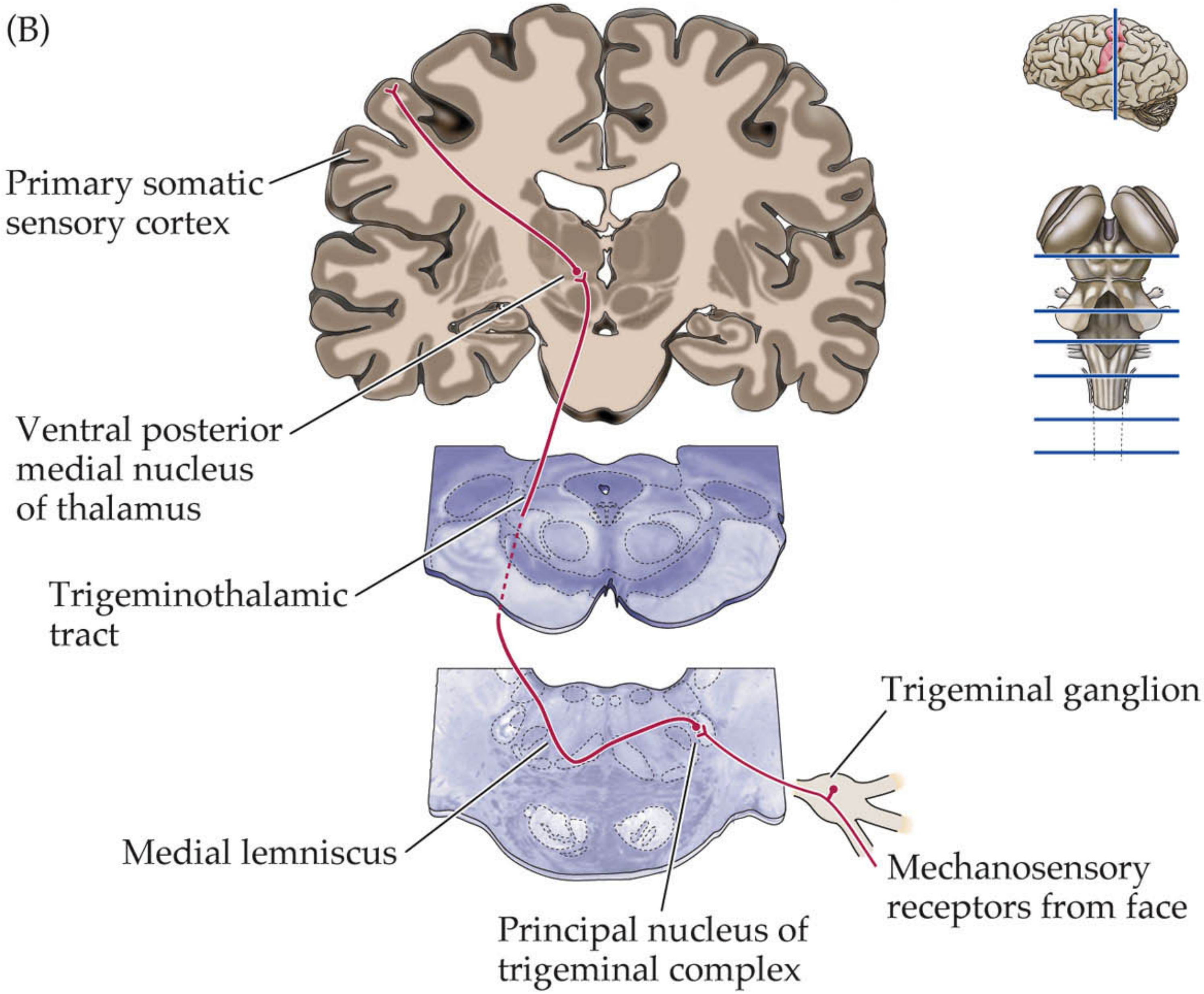


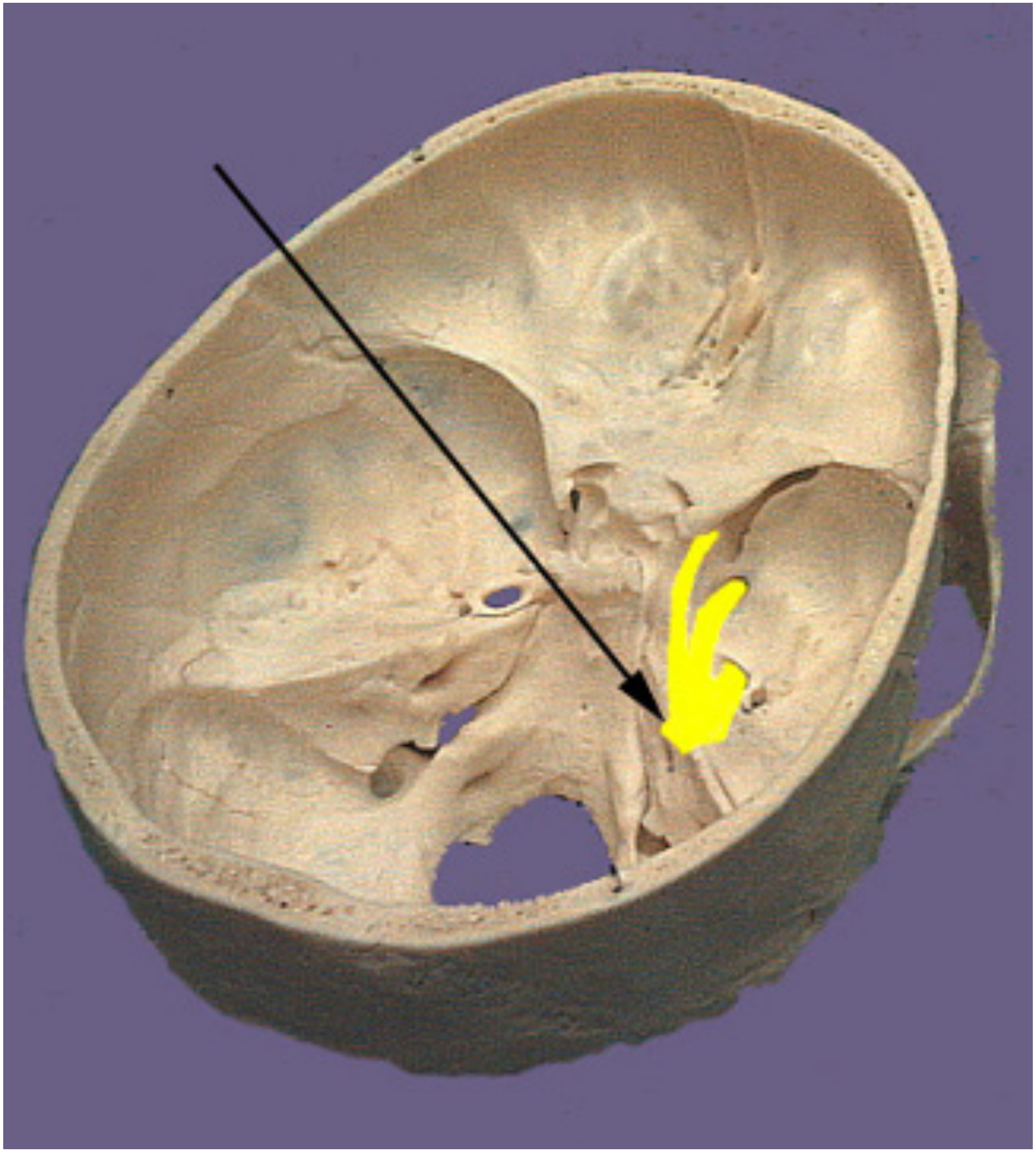
(C)

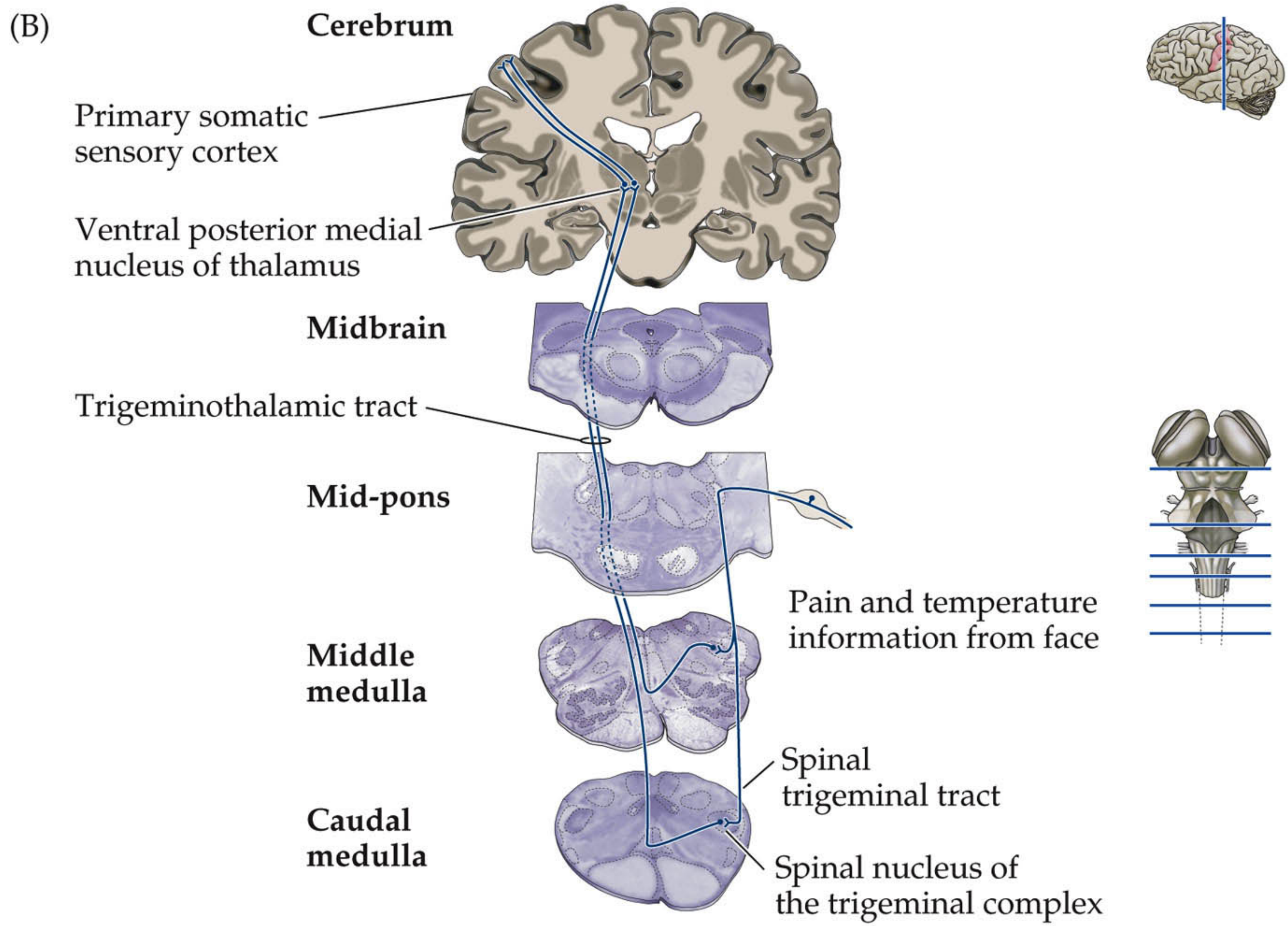


visceral pain

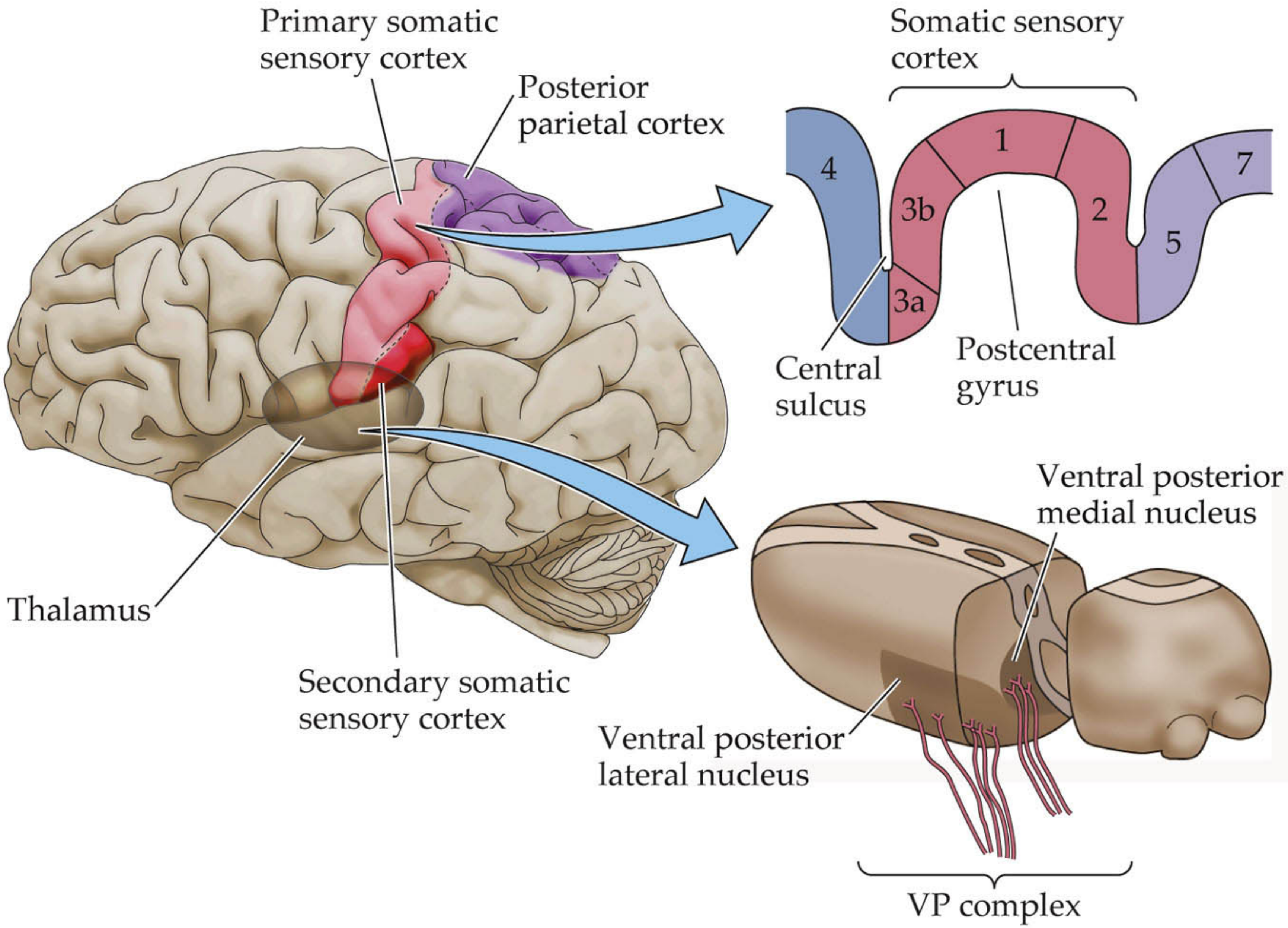
- Interestingly, visceral pain goes in dorsal columns.
- Very useful since midline myelotomy for palliative treatment in terminal and painful cancer.


(B)
Primary somatic sensory cortex
Ventral posterior medial nucleus of thalamus
Trigeminothalamic tract
Medial lemniscus
Principal nucleus of trigeminal complex
Trigeminal ganglion
Mechanosensory receptors from face





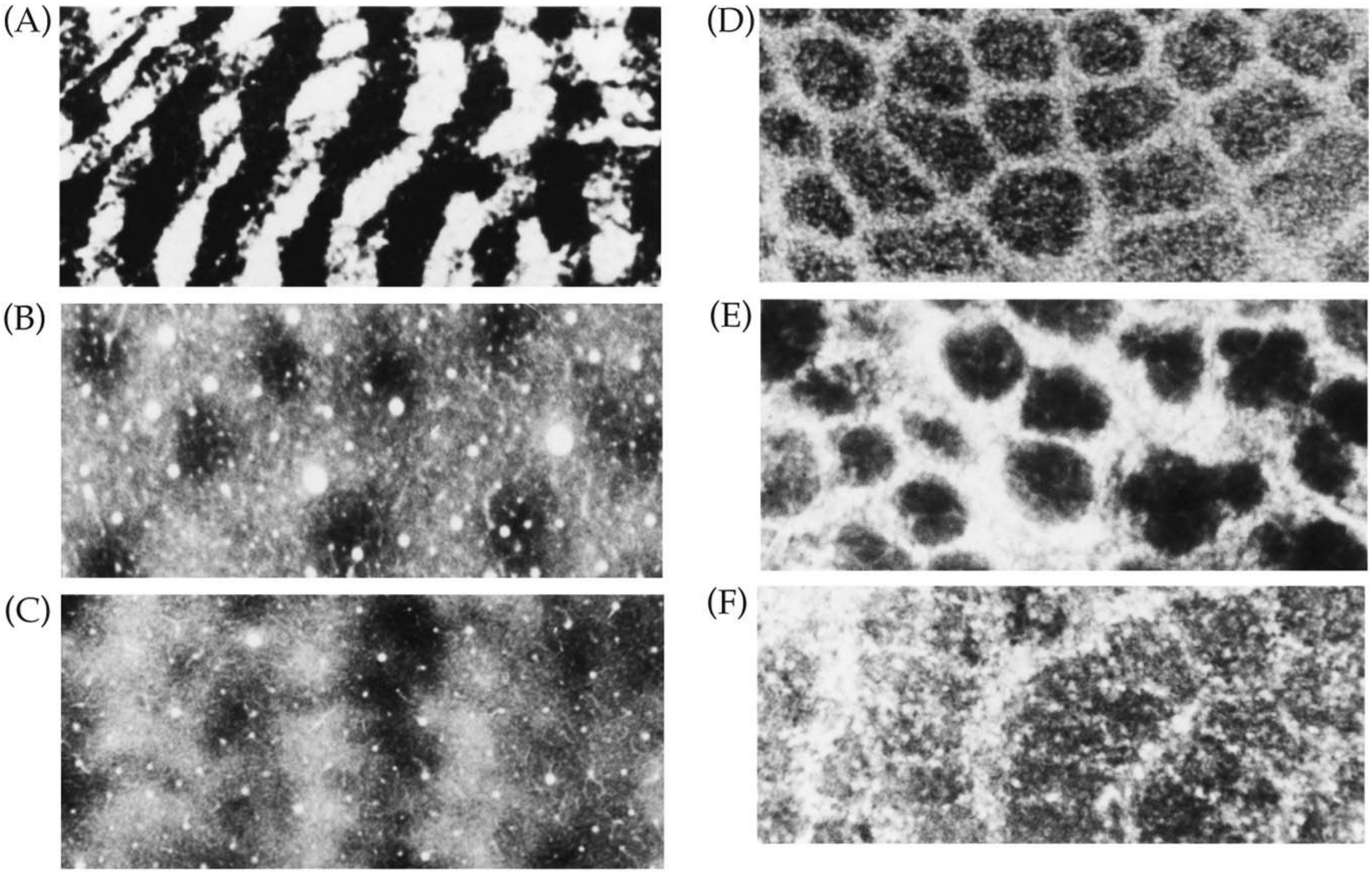
NEUROSCIENCE, Third Edition, **Figure 9.3 (Part 2)**

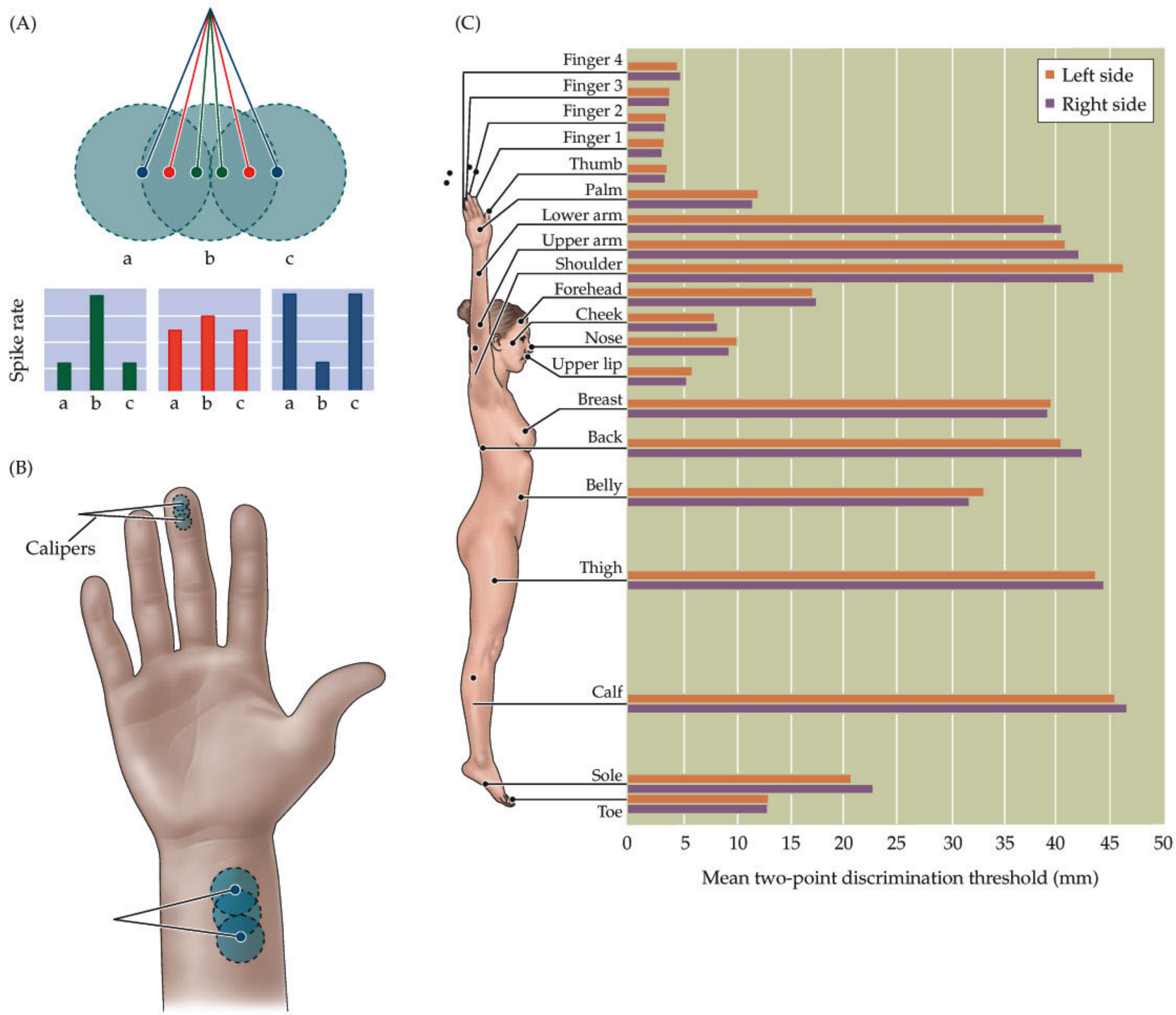


NEUROSCIENCE, Third Edition, **Figure 8.7**

Thalamus and cortex

- VPL of thalamus to Postcentral gyrus-
- S1 = areas 1, 2, 3a & 3b
- arranged in columns
- - a vertical electrode penetration same submodality
- each S1 nerve responds to only one receptor type

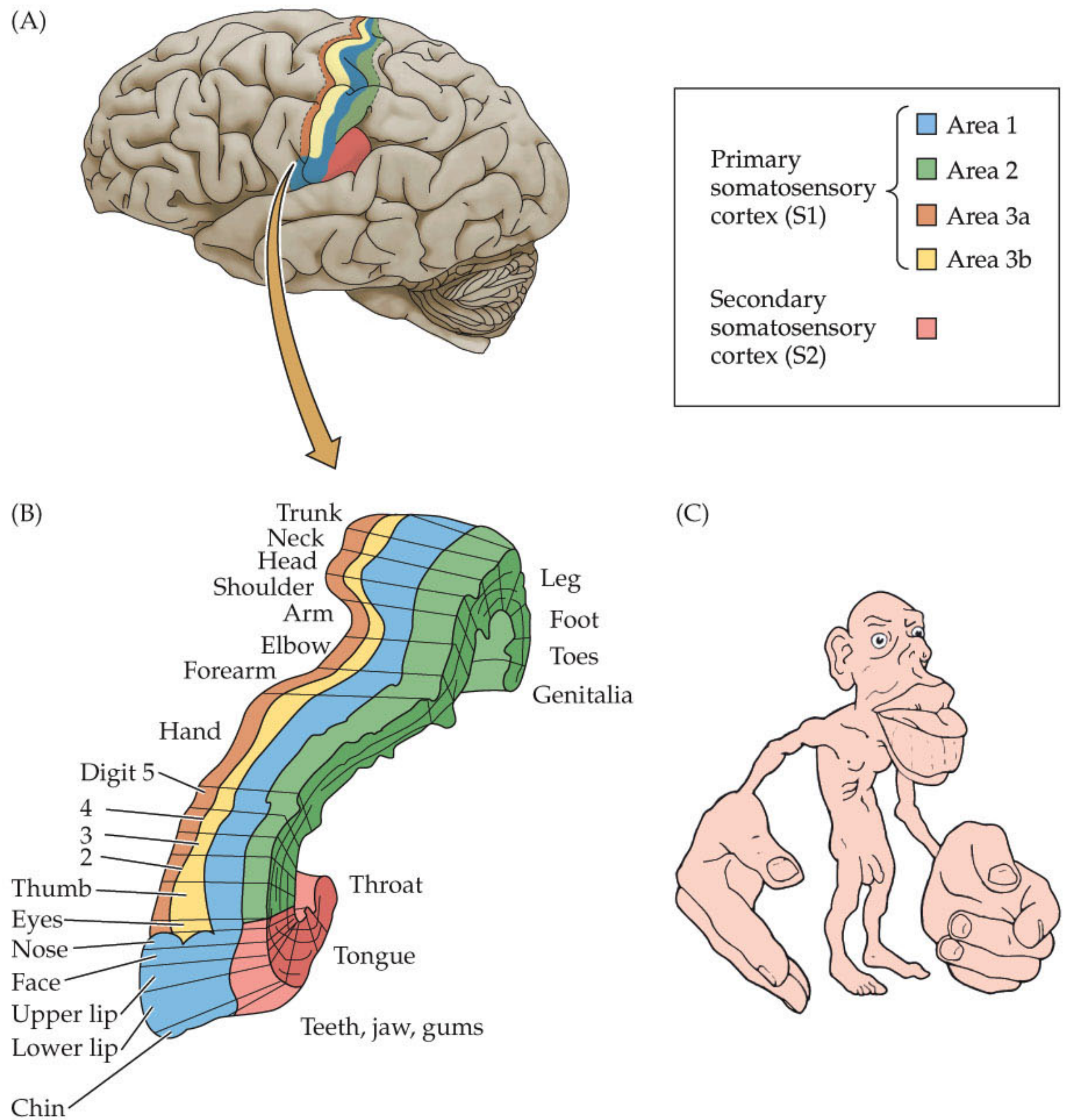

(A)
(B)
(C)
(D)
(E)
(F)



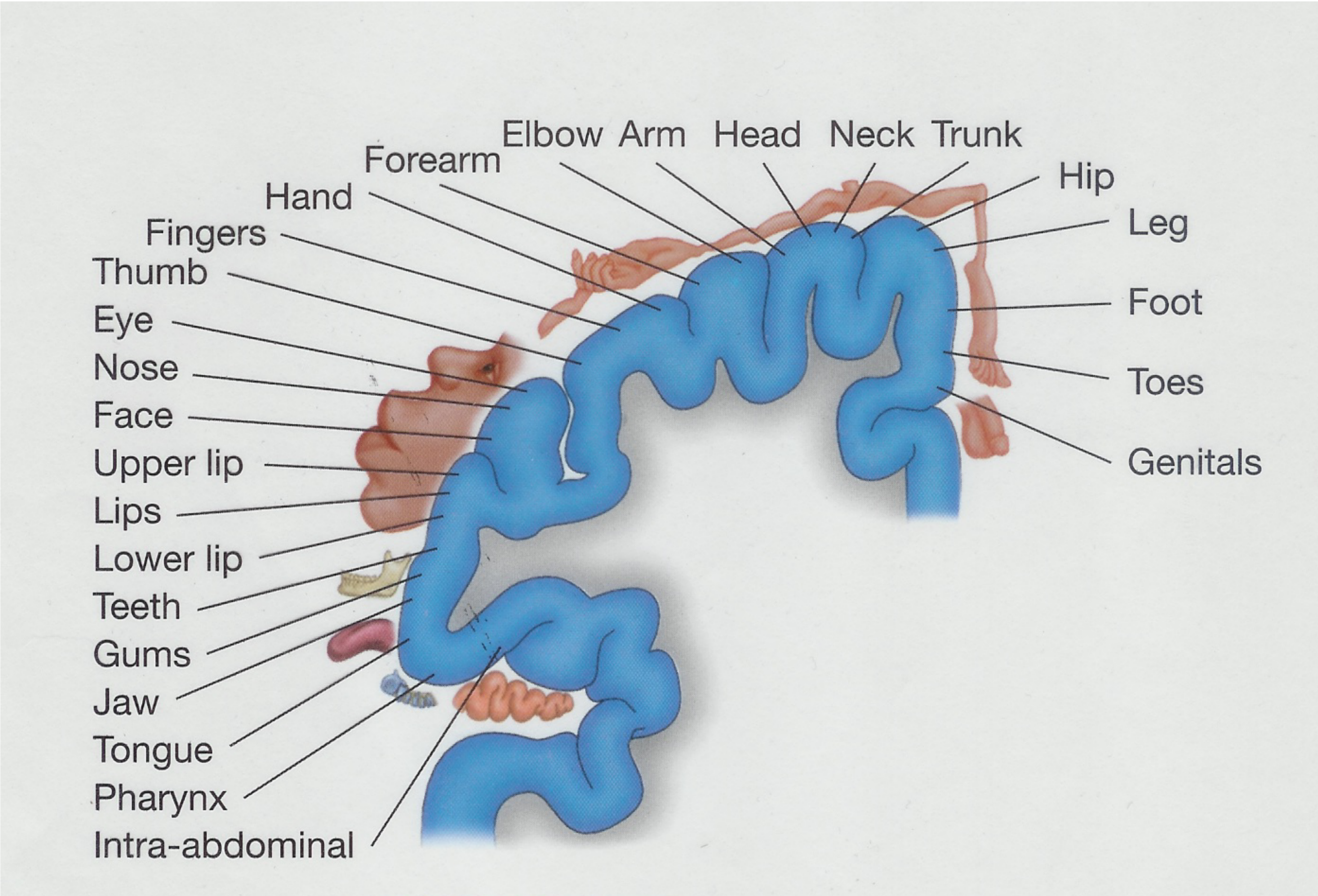
***NEUROSCIENCE*, *Fourth Edition*, Figure 9.3**

Sensory mapping

- In sensory map of cortex, all cells as electrode penetrates vertically are from one area (Mountcastle)
- (a) Ocular dominance coumns for vision (Hubel and Wiesel) Nobel 1981
- (d) Woolsey - (box) "barrels" from vibrissae (whiskers)

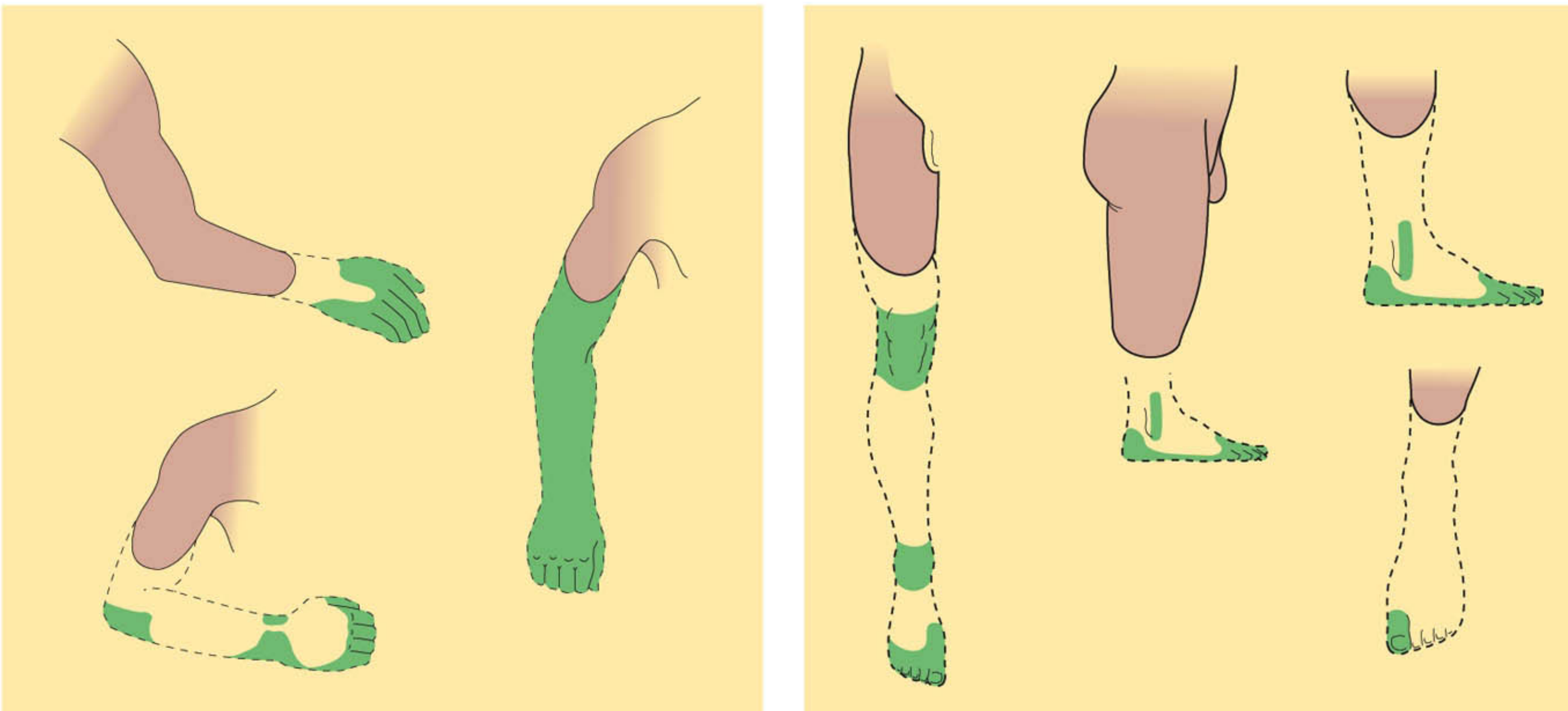


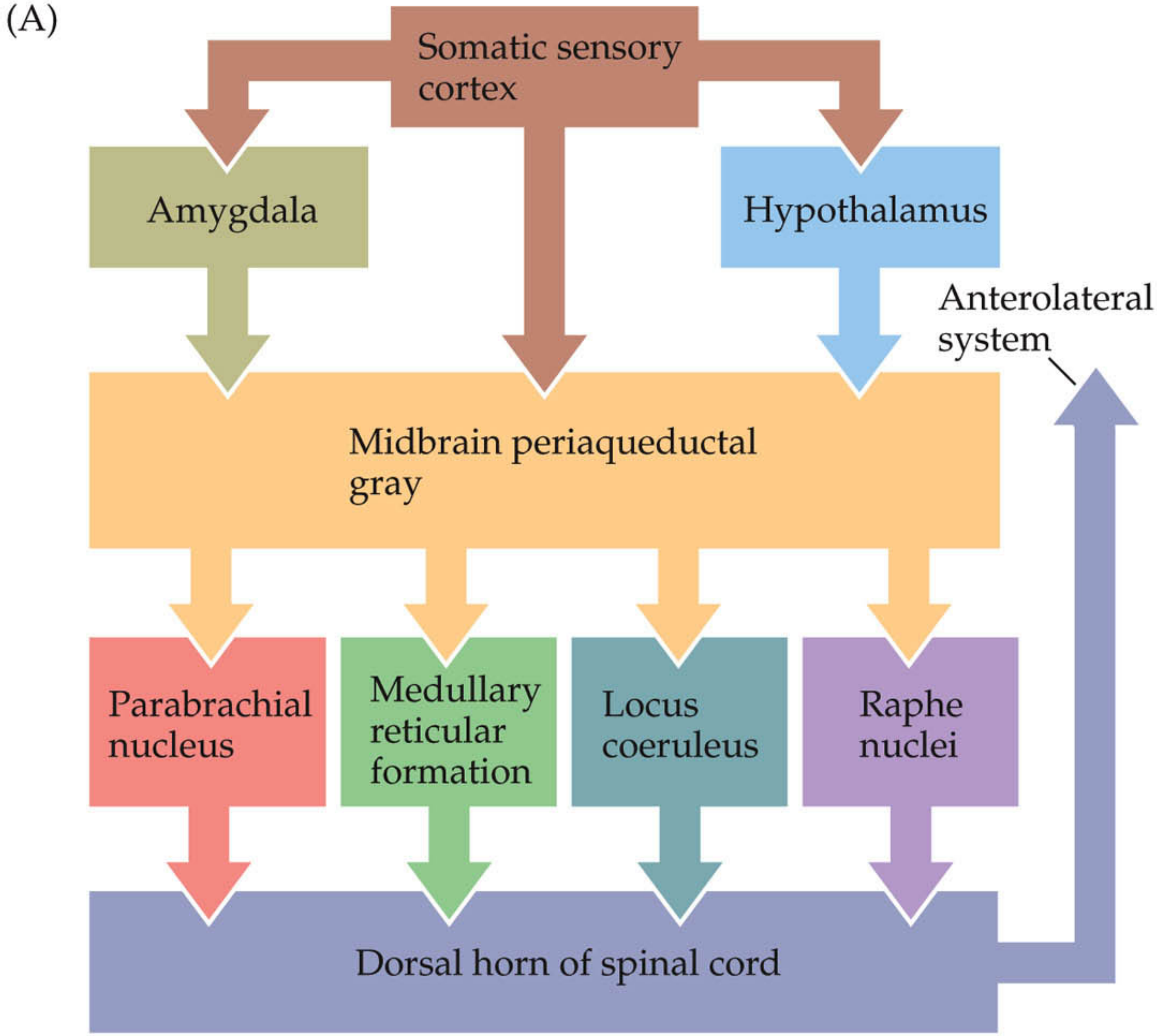
NEUROSCIENCE, *Fourth Edition,* Figure 9.11


Elbow
Arm
Head
Neck
Trunk
Forearm
Hip
Hand
Leg
Fingers
Thumb
Foot
Eye
Nose
Toes
Face
Genitals
Upper lip
Lips
Lower lip
Teeth
Gums
Jaw
Tongue
Pharynx
Intra-abdominal

From outline

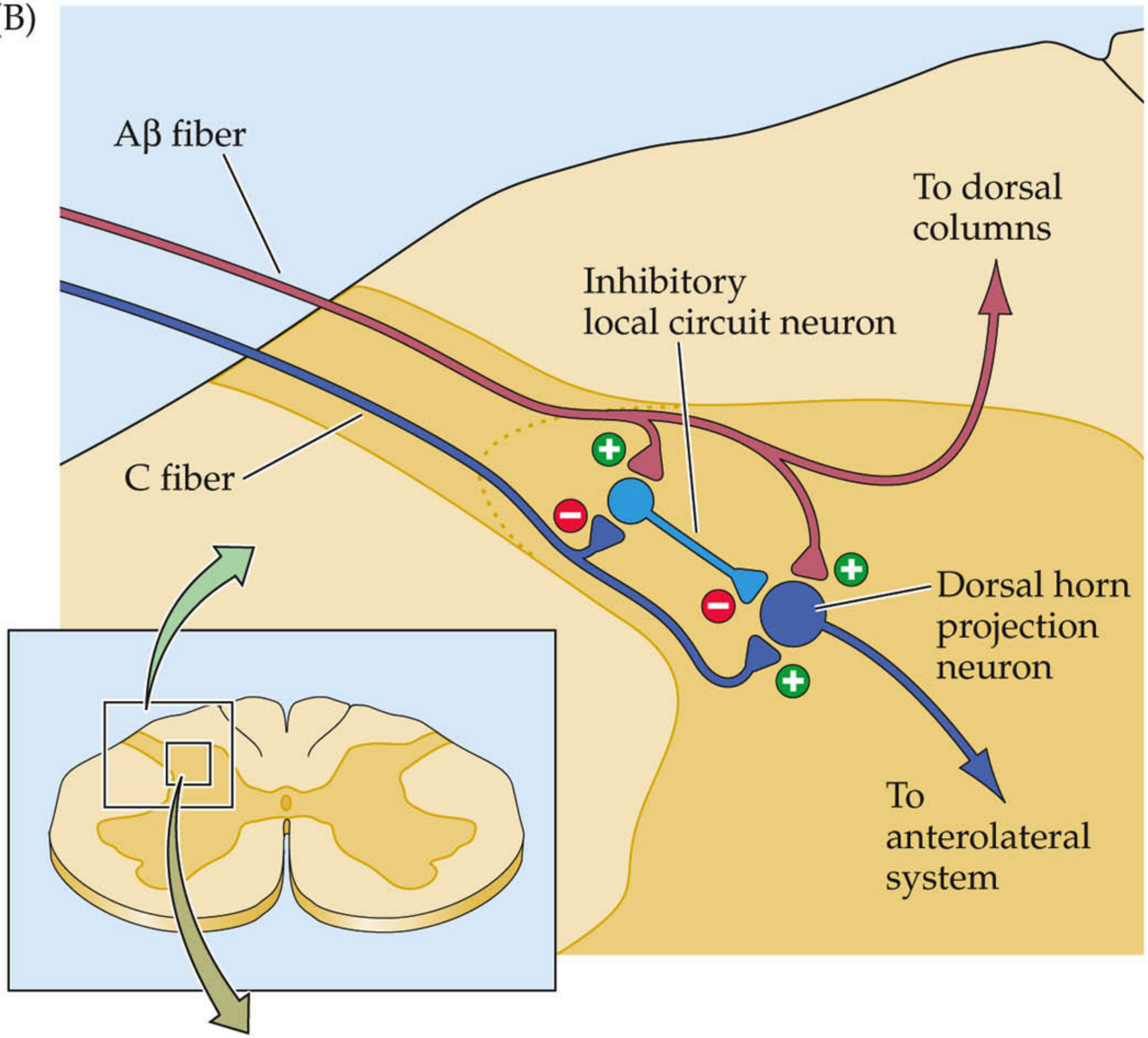
- two point threshold
- 2 mm fingertips, 30 arm, 70 back
- this relates to the cortical projection
- sensory magnifications
- Penfield - homunculus



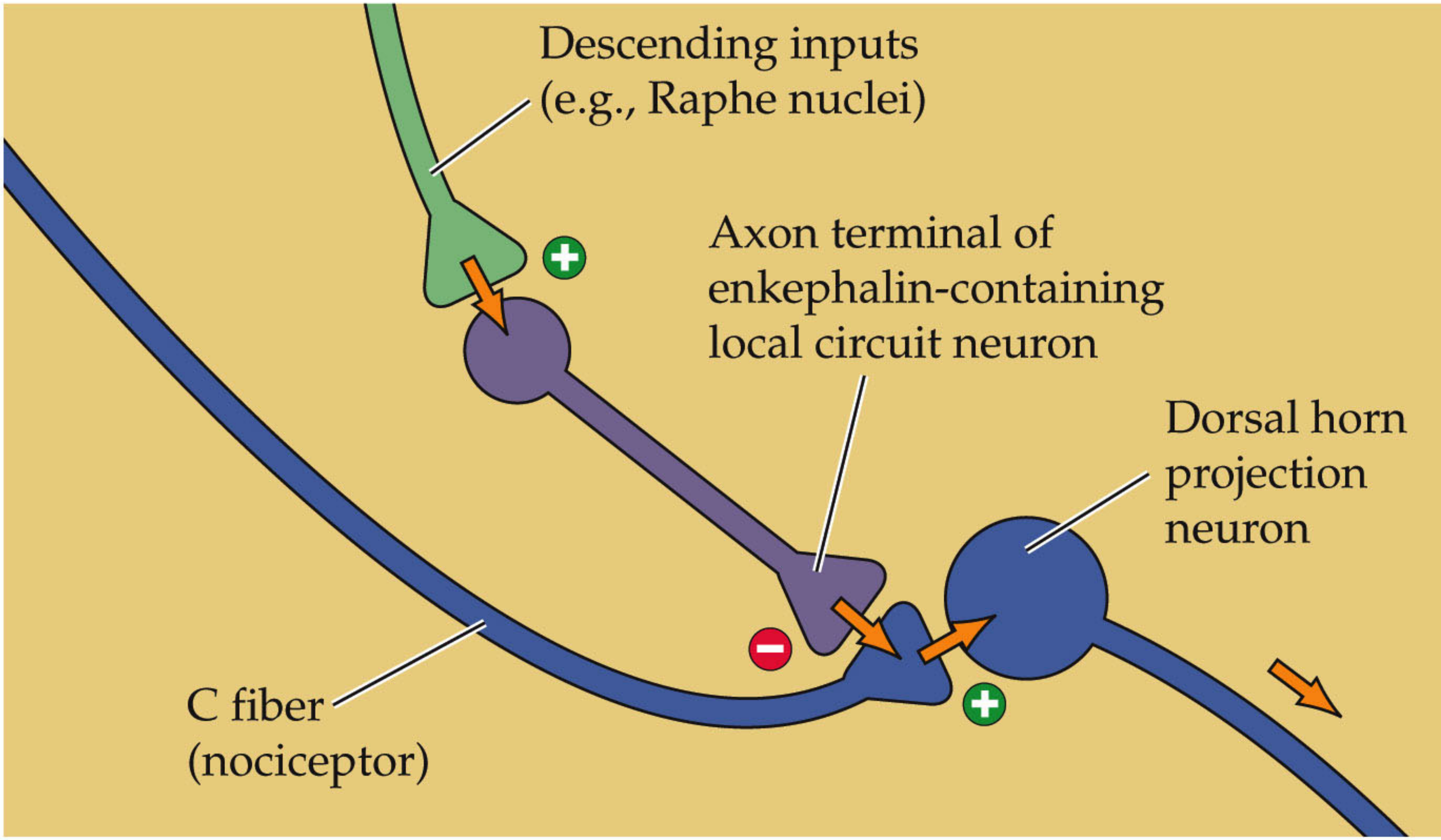


NEUROSCIENCE, Third Edition, Figure 9.7 (Part 1)

(B)


Aβ fiber
To dorsal columns
Inhibitory local circuit neuron
C fiber
Dorsal horn projection neuron
To anterolateral system

(C)



NEUROSCIENCE, Fourth Edition, **Figure 10.8 (Part 3)**

From outline

- "microcircuits" in dorsal (posterior) horn
- all sensory input uses glutamate
- pain also uses substance P
- capsaicin causes release of substance P
- enkephalin from Substantia Gelatinosa interneuron - presynaptic
- (opiates are narcotic analgesics) stimulate - cause analgesia
- connect to Raphe
- Itch: only skin, mucous - opiates not suppress