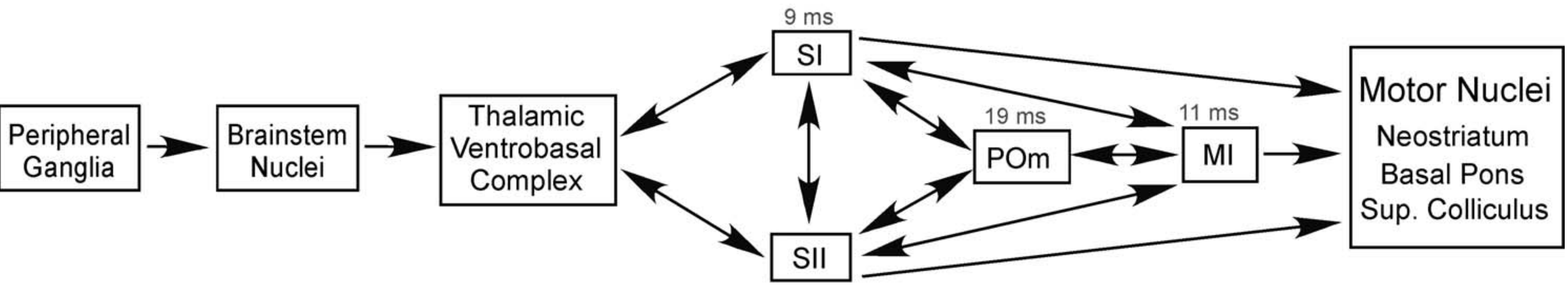
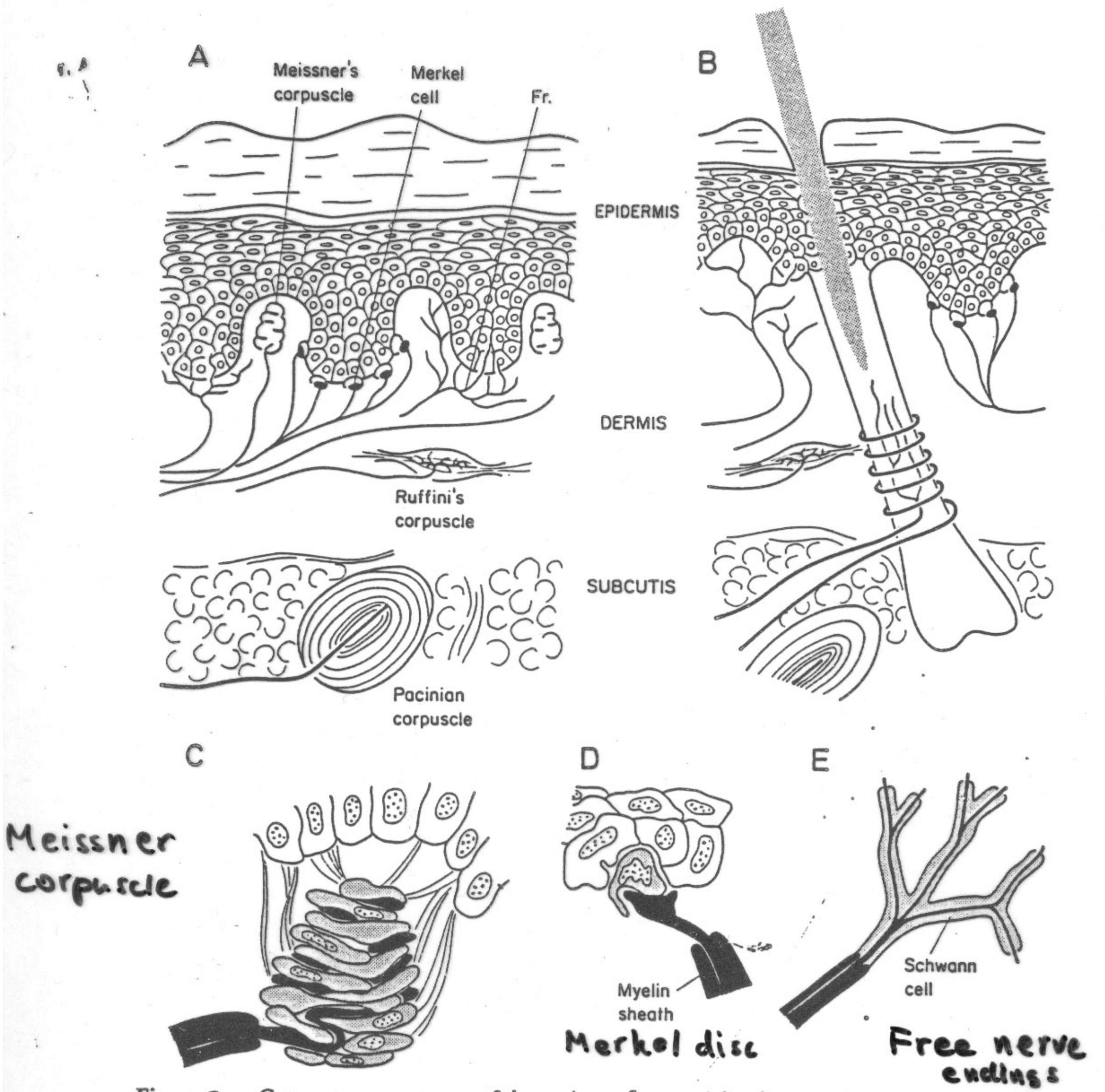
SOMATOSENSORY SYSTEMS



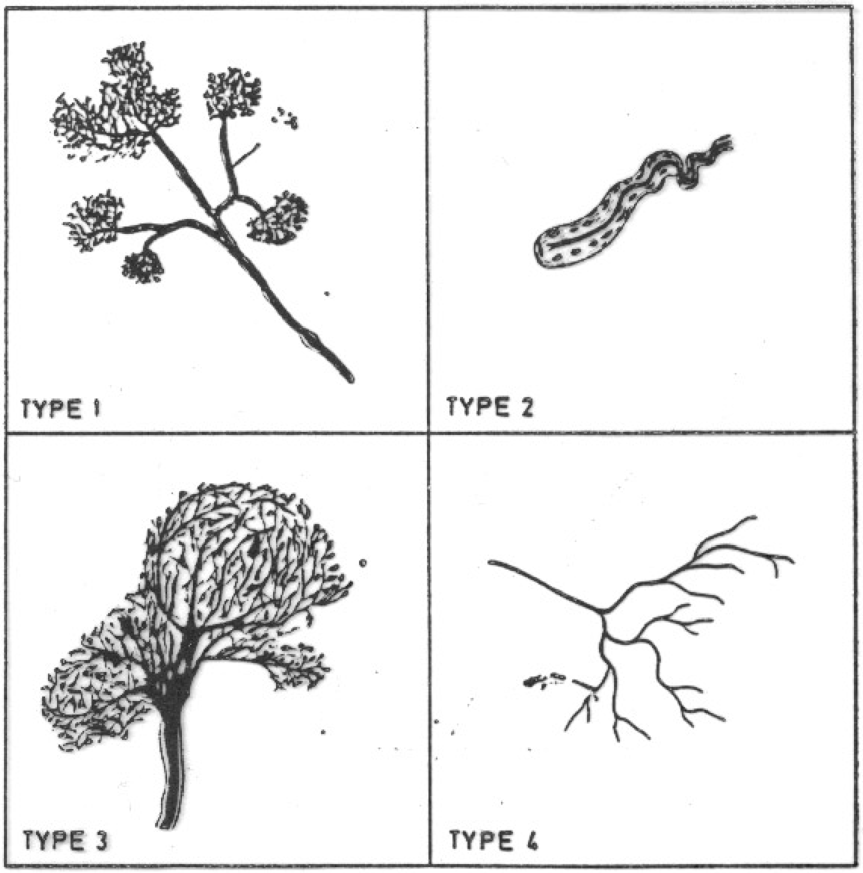
Schematic diagram illustrating the neural pathways that convey somatosensory information to the cortex and, subsequently, to the motor system. Double arrows show reciprocal connections. Numbers next to SI, POm, and MI indicate neuronal response latencies in the cortical and thalamic whisker representations following cutaneous stimulation of the mystacial whisker pad.

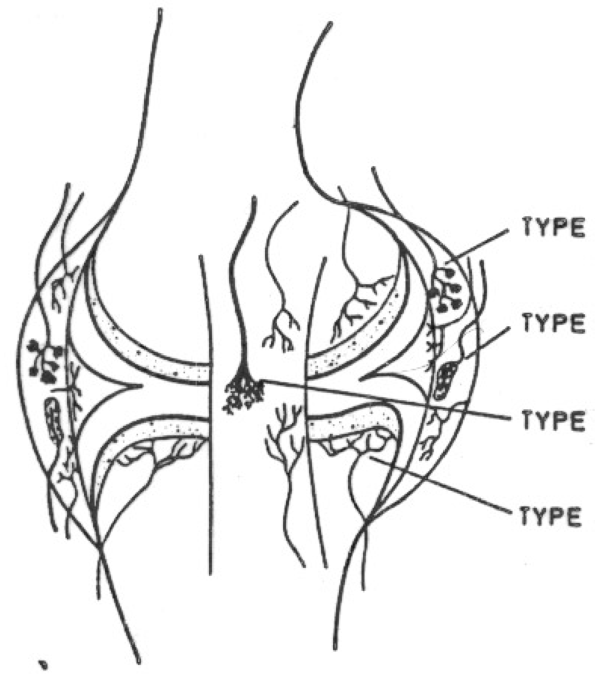
Cutaneous receptors



Schematic drawing of cutaneous receptors in the (A) glabrous skin (palm of the hands and soles of the feet) and (B) hairy skin. Nerve endings in hairy skin wind around the hair follicles and are activated by the slightest bending of the hair. Free nerve endings are covered by Schwann cells except at their tips, where, presumably, the receptor properties reside (Brodal)

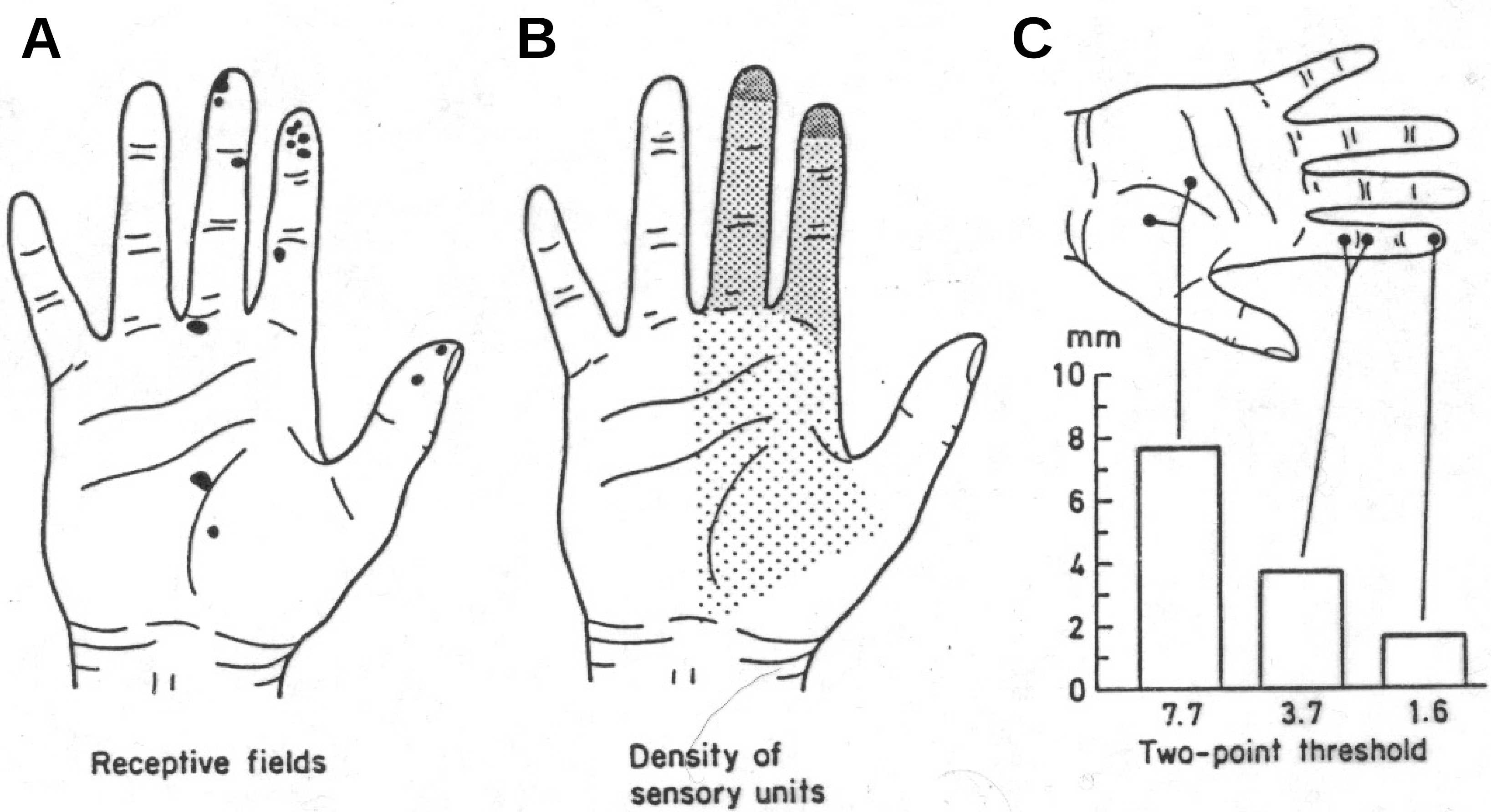
JOINT RECEPTORS





Joint innervation. A knee joint, showing the distribution of the various kinds of joint receptors, to the left shown in more detail (Brodal).

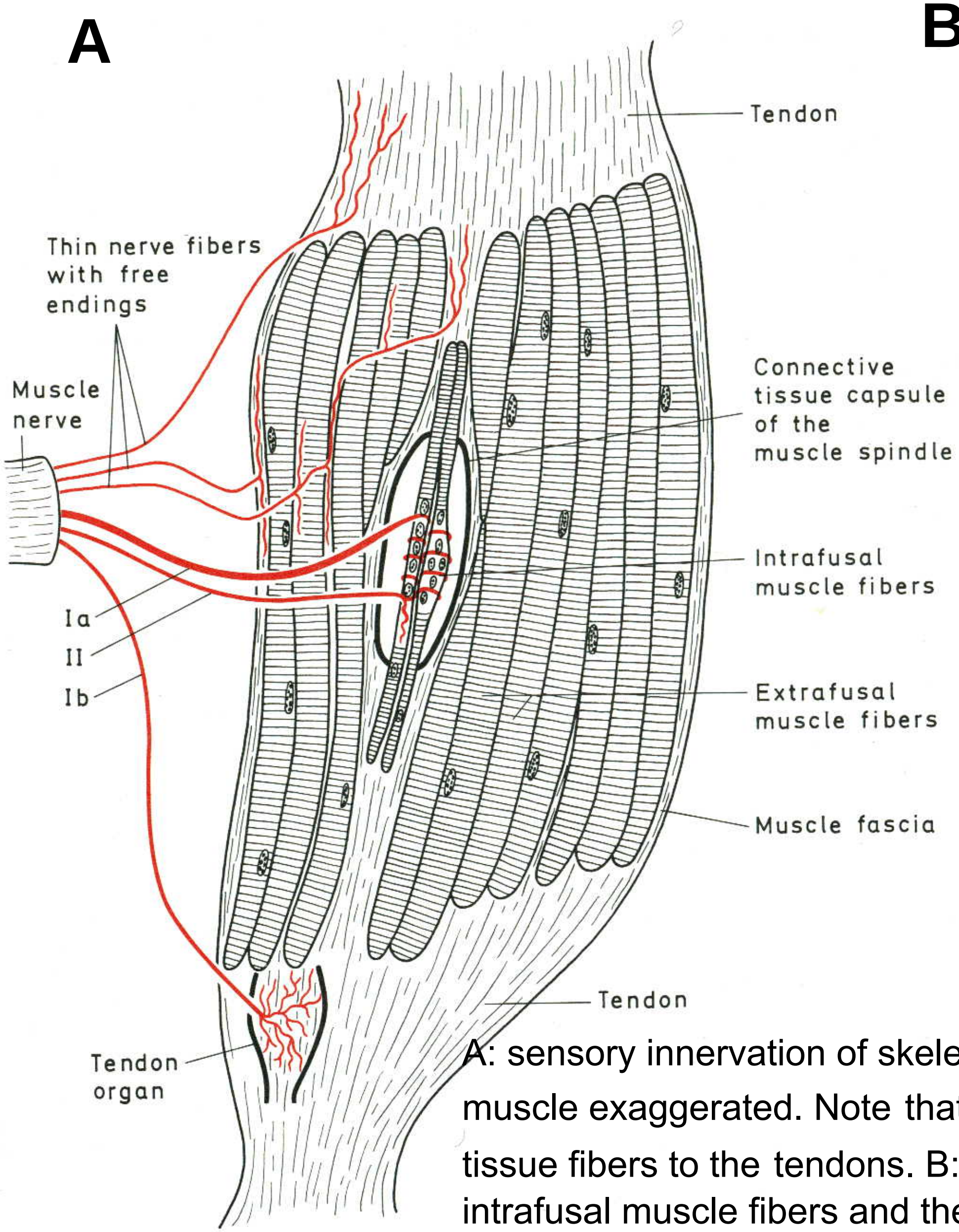
RECEPTIVE FIELD SIZE and DENSITY (Meissner, FA)



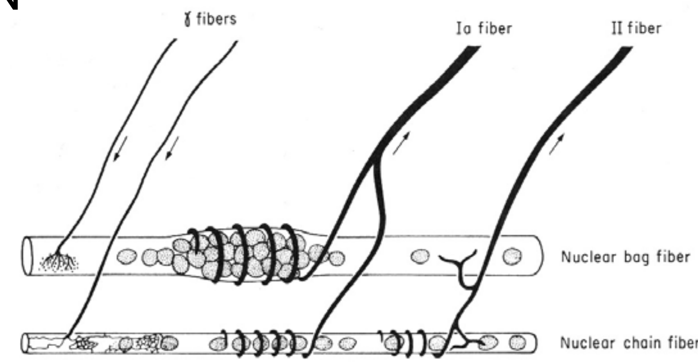
A: Receptive fields. Size and locations of the receptive fields of 15 sensory units, determined by recording from the median nerve. All of these sensory units were rapidly adapting and were most likely conducting from **Meissner-**corpuscles. Within each receptive fields there are many Meissner corpuscles, all supplied by the same axon. **B**: Relative density of sensory units conducting from **Meissner** corpuscles (that is, # of sensory units supplying 1 cm2). Note that the density increases distally and is highest at the volar aspect of the fingertips. **C**: Two-point discrimination. The numbers give the shortest distance between two pointws touching the skin that can be identified by the experimentaql subject as two. Based on 10 subjects (From Brodal).

MUSCLE SPINDLE AND GOLGI TENDON ORGAN

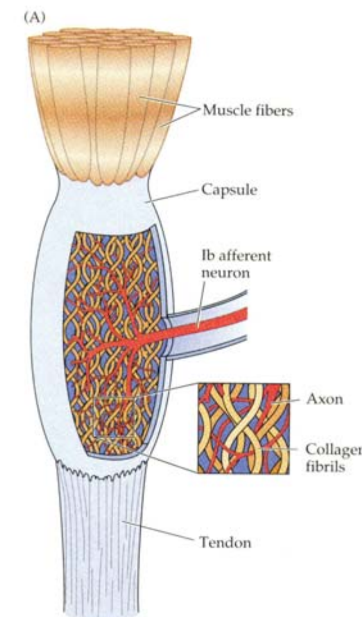
A



B

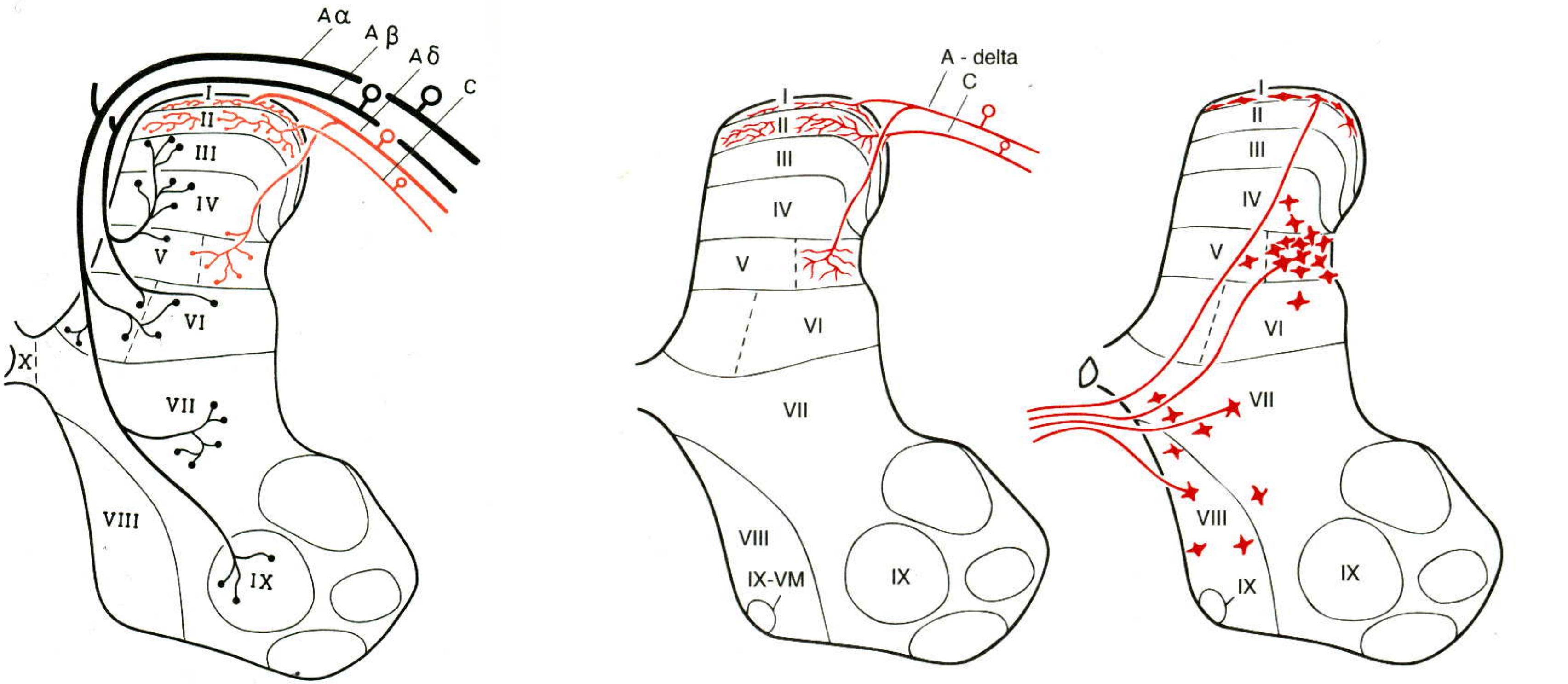


c



A: sensory innervation of skeletal muscles. The size of the receptors to the muscle exaggerated. Note that the muscle spindle is attached via connective tissue fibers to the tendons. B: Schematic representation of the two kinds of intrafusal muscle fibers and their innervation (Brodal). C: Golgi tendon organ

PRIMARY SENSORY FIBERS



The terminal regions of the dorsal root fibers in the cord. The thickest myelinated fibers (Aα form muscle spindles and tendon organs) end in the deep parts of the dorsal horn and partly also in the ventral horn. Thick myelinated fibers from cutaneous mechanoreceptors (AB) end in laminae III-VI. The thinnest myelinated and unmyelinated dorsal root fibers (Adelta and C)- many of them leading from nociceptors end in laminae I, II, and parts of V. (Brodal)

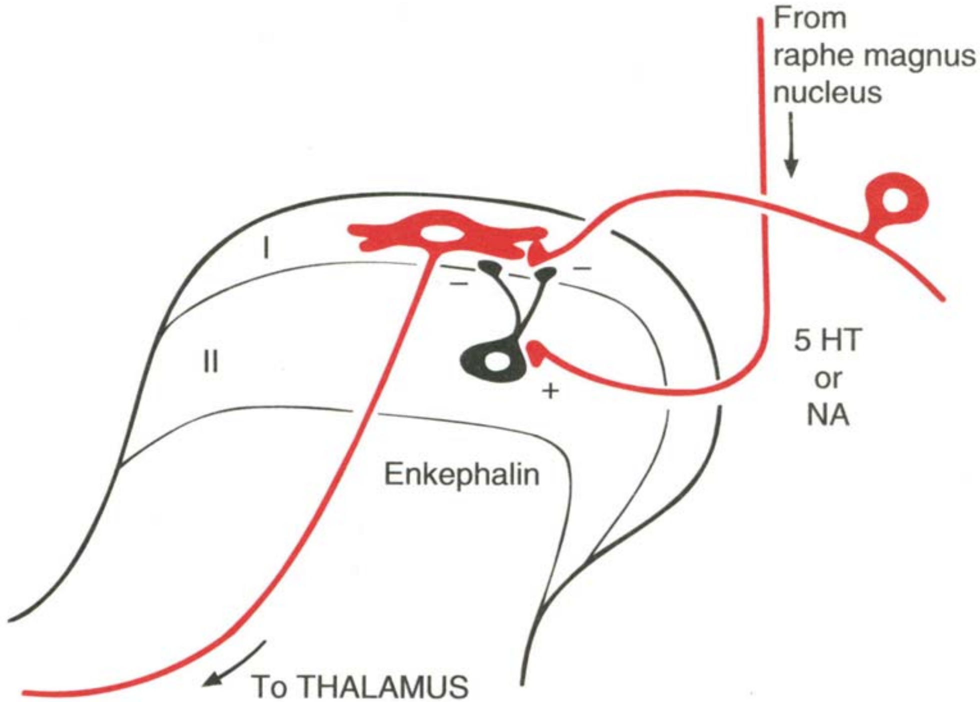
Location of spinothalamic cells (Brodal)

Table 9-3 Classification of Peripheral Nerve Fibers

Roman numeral classification	Diameter (μm)	Letter classification	Conduction velocity (m/sec)	Myelinated?	Types of structures innervated
Ia*	12–20	—	70–120	Yes	Muscle spindle primary endings
Ib*	12–20	—	70–120	Yes	Golgi tendon organs
—	12–20	α	70–120	Yes	Efferents to extrafusal muscle fibers
II	6–12+	$A\beta$†	30–70	Yes	Other encapsulated endings and endings with accessory structures: Meissner corpuscles, Merkel endings, muscle spindle secondary endings, etc.
—	2–10	γ	10–50	Yes	Efferents to intrafusal muscle fibers
III	1–6	$A\delta$	5–30	Yes	Some nociceptors (sharp pain) Cold receptors Most hair receptors Some visceral receptors
—	<3	B	3–15	Yes	Preganglionic autonomic efferents
IV	<1.5	C	0.5–2	No	Most nociceptors (dull, aching pain) Warmth receptors Itch receptors Some (few) mechanoreceptors Some visceral receptors Postganglionic autonomic efferents

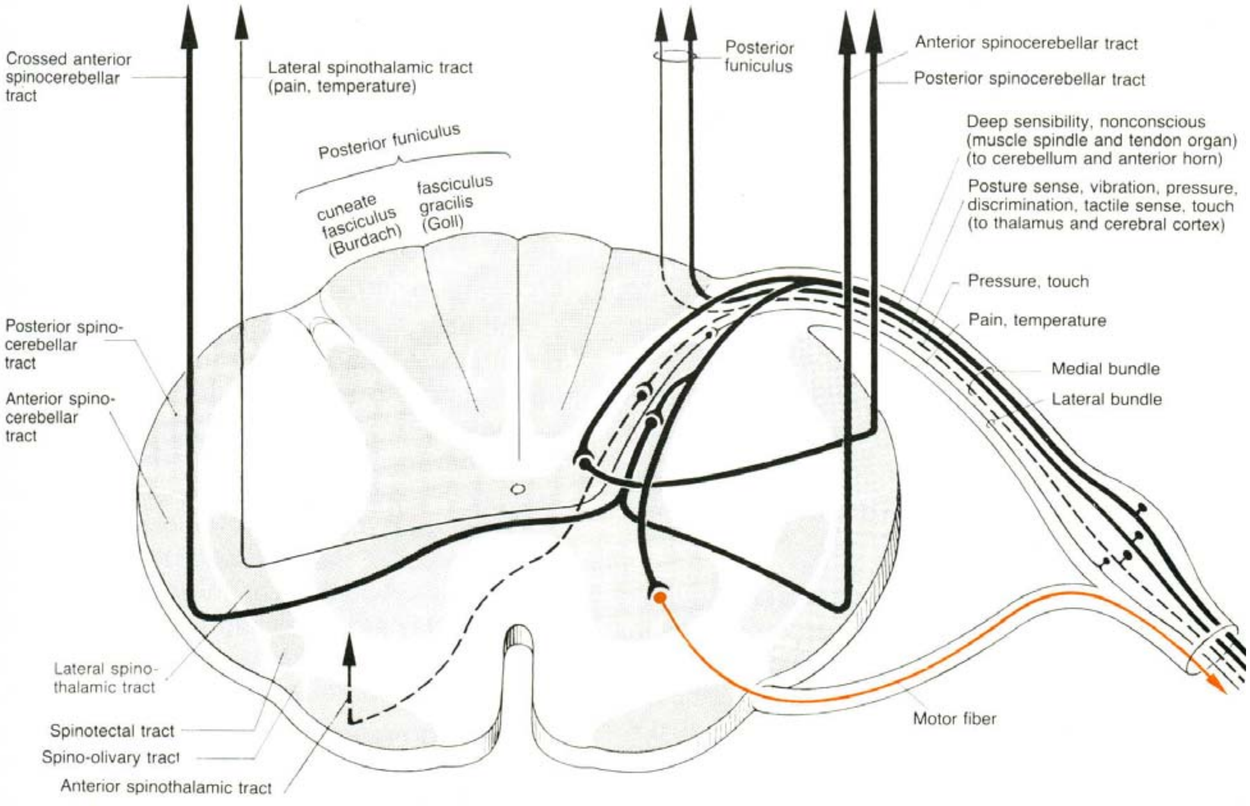
*Data from carefully studied peripheral nerves of cats. Muscle afferents in primates, including humans, probably conduct more slowly, up to only about 80 m/sec.

†Some afferents in nonmuscle nerves, particularly joint afferents, range up to 17 μm in diameter. Some investigators refer to these larger fibers, in the 12-17 μm range, as $A\alpha$ and call those in the 6-12 μm range $A\beta$. Others refer to all nonmuscle afferents larger than 6 μm as $A\beta$.

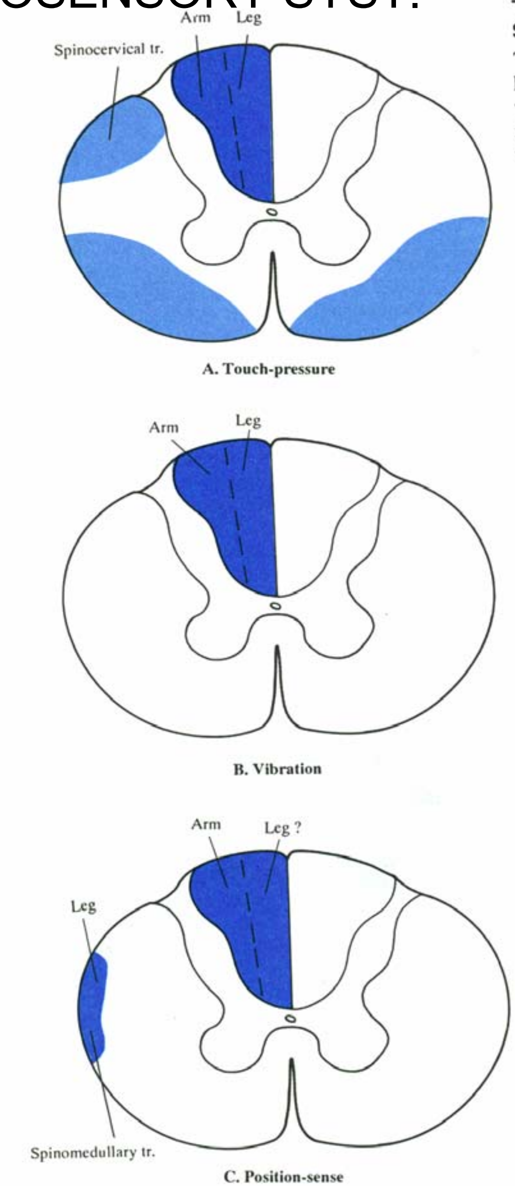


Central control of transmission from nociceptors. Brodal

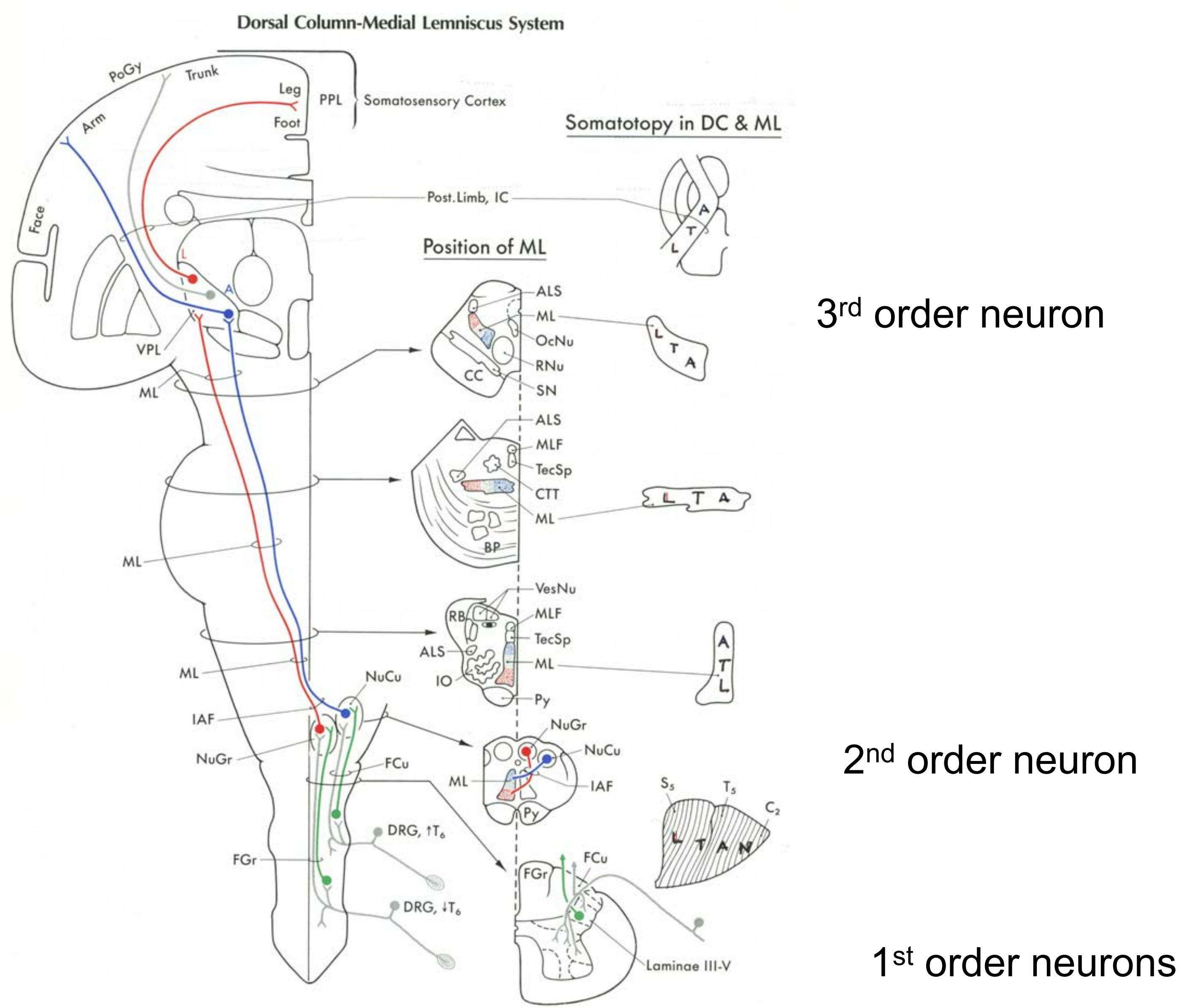
COURSE OF POSTERIOR ROOT FIBERS AND SOMATOSENSORY SYST.



(Duus)

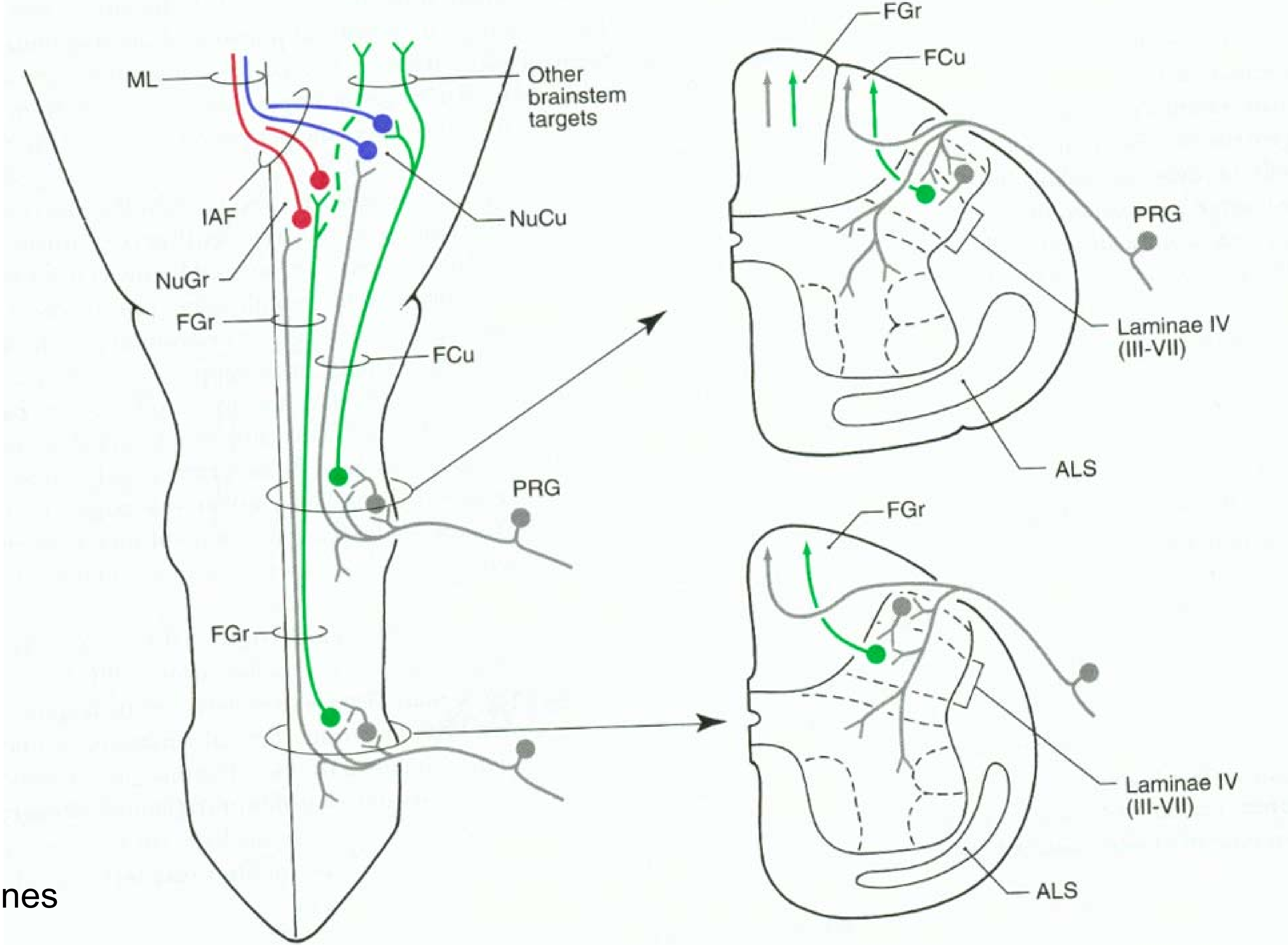


Somatosensory pathways (Heimer)

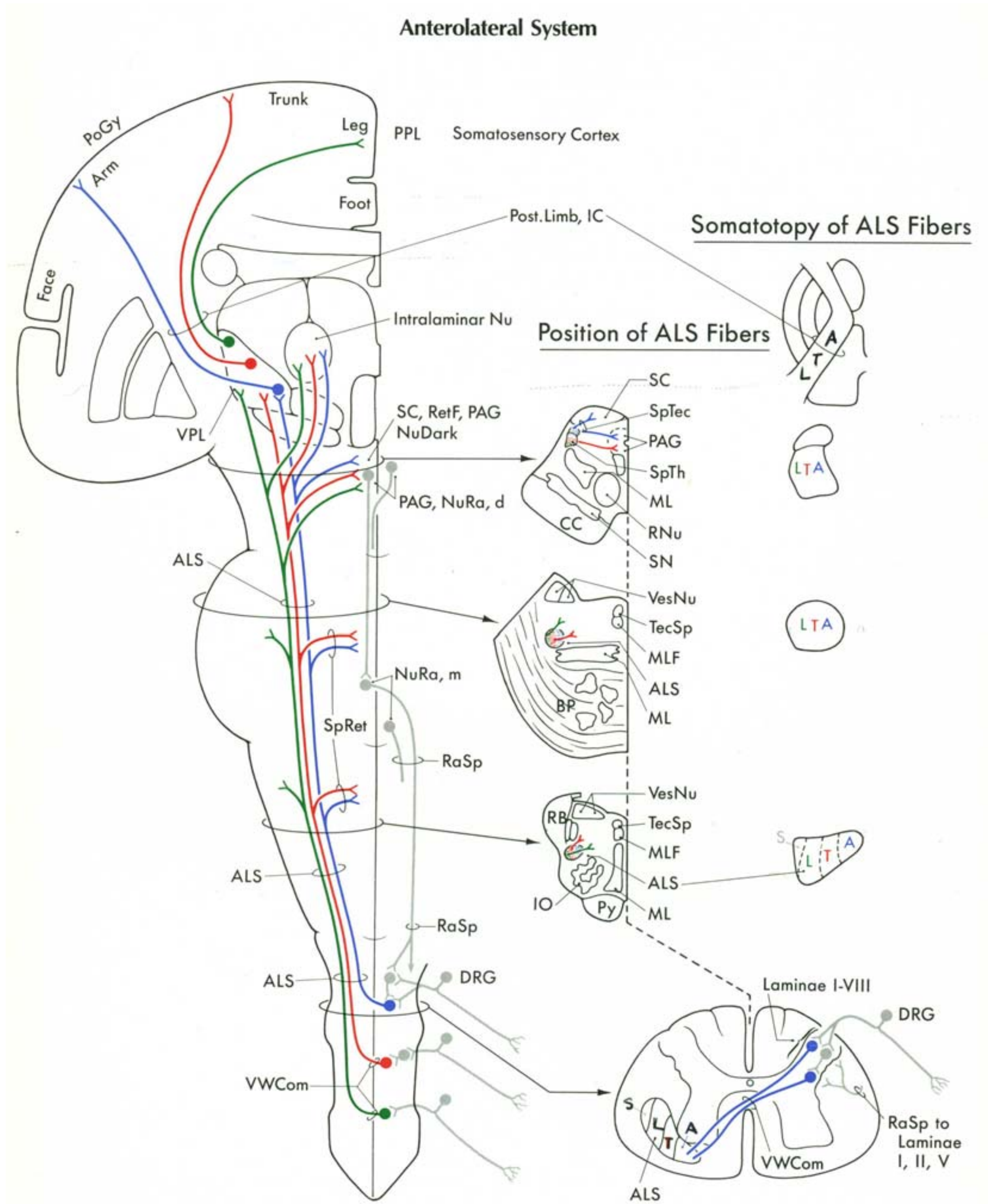


The origin, course and distribution of the dorsal column-medial lemniscus system for tactile, vibratory and proprioceptive impulses (Haines).

THE DORSAL COLUMN –MEDIAL LEMNISCUS SYST 2.

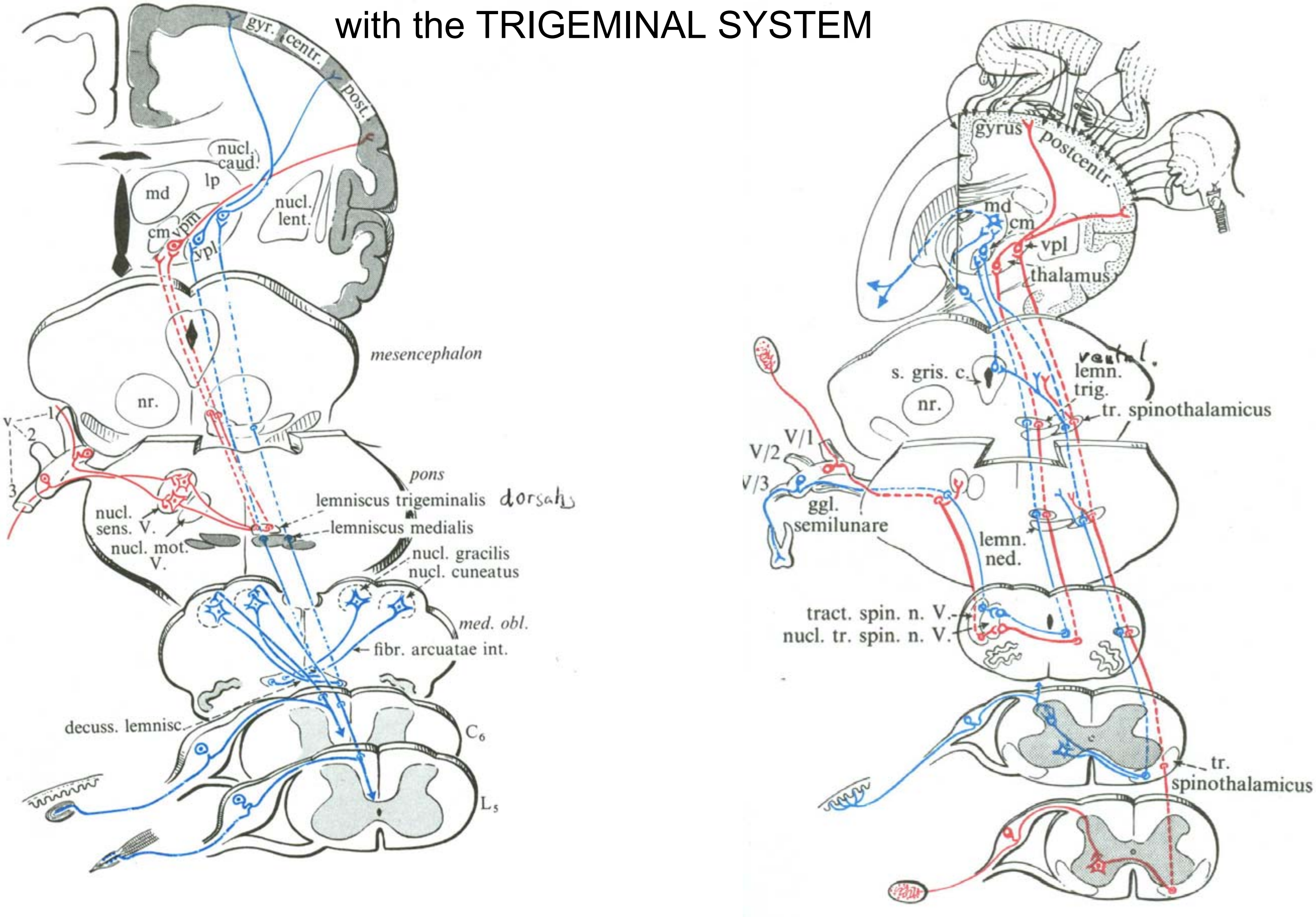


Haines



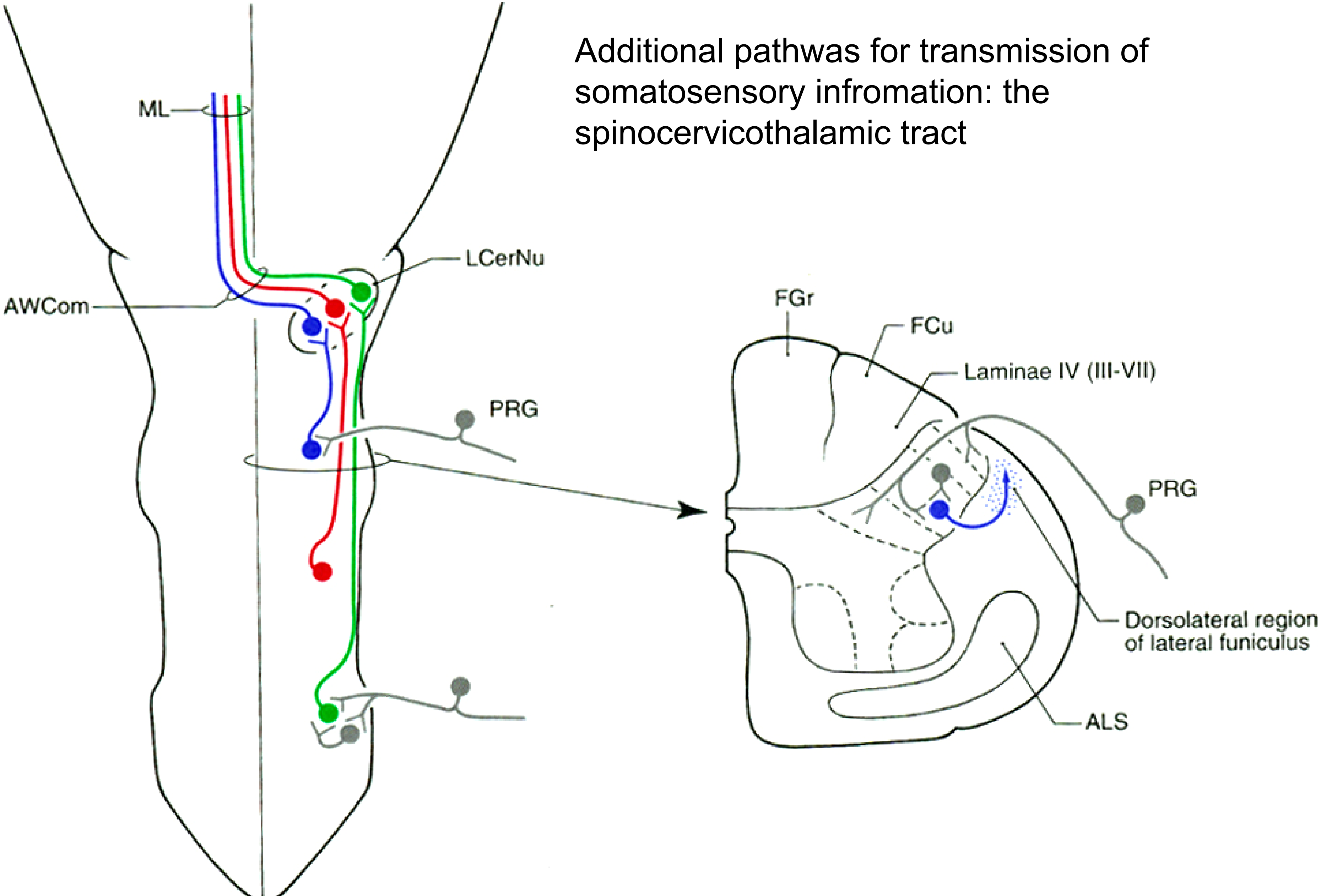
The origin, course and distribution of the anterolateral system, carrying pain and temperature information (Haines)

POST COLUMN-MEDIAL LEMNISCUS ----- THE ANETROLATERAL SYSTEM with the TRIGEMINAL SYSTEM

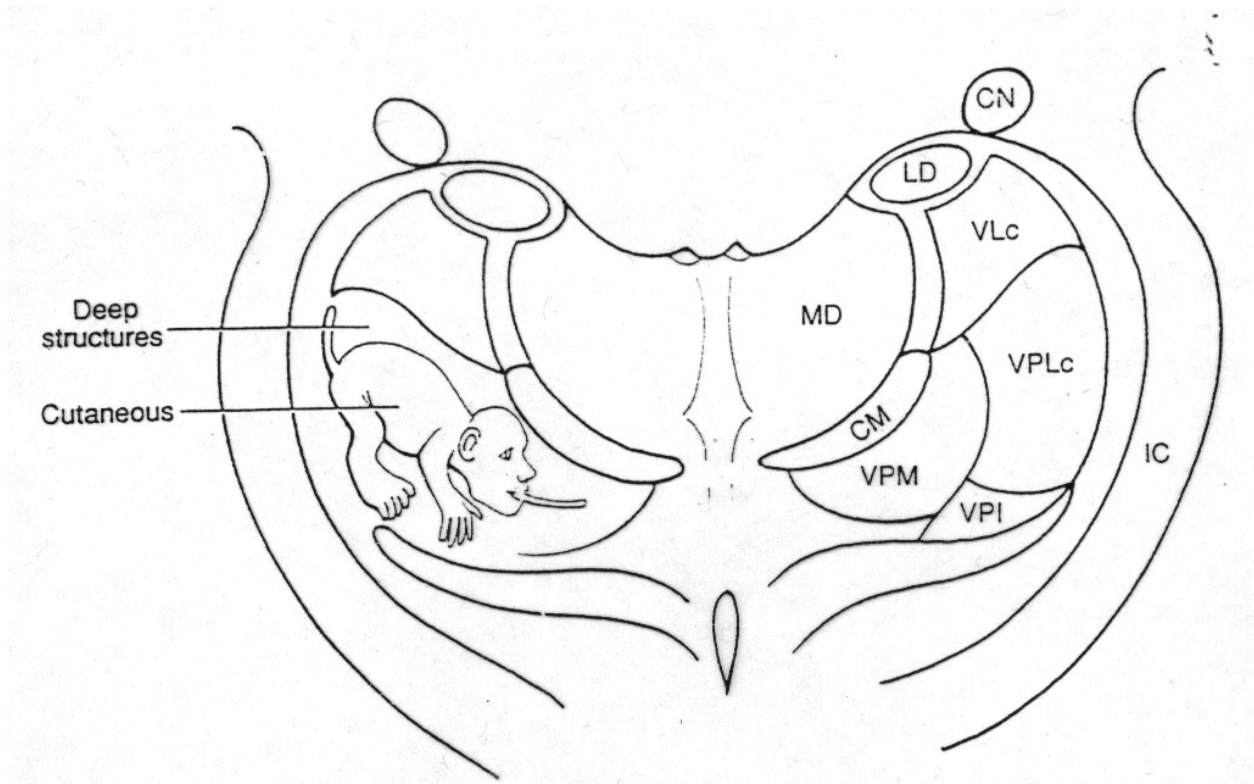


The dorsal column-medial lemniscus (left) and the spinothalamic systems (right). In the left figure the temperature sensitive axons are in blue, the pain-conducting fibers and the trigeminal system in red (Szentagothai)

Additional pathwas for transmission of somatosensory infromation: the spinocervicothalamic tract

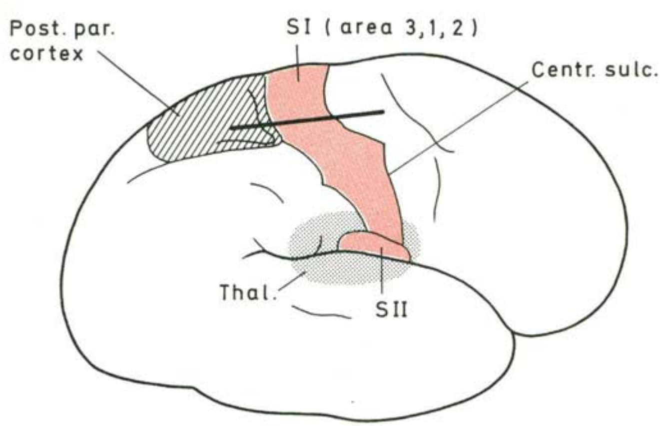


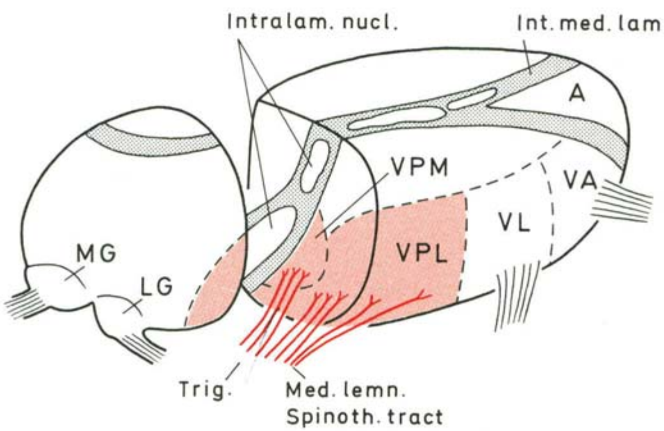
CUTANEOUS REPRESENTATION IN THE VENTROBASAL COMPLEX

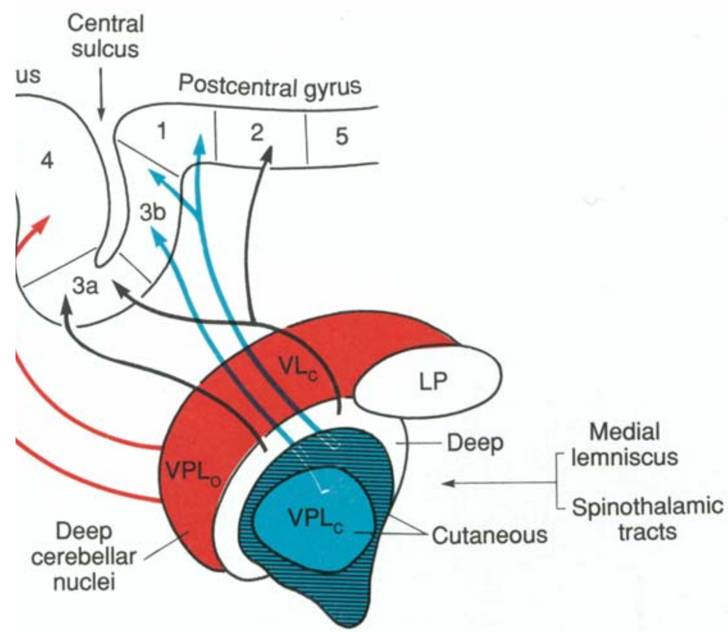


Schematic diagram of the ventrobasal complex in the monkey, indicating the cutaneous somatotopic representation of the body surface on the left. Neurons responsive to stimulation of deep receptors lie in a dorsal shell. Areas representing the head, face and tongue lie in the ventral posteromedial (VPM) nucleus. The body is represented in the ventral posterolateral n. (VPLc) with the trunk dorsal and the extremities ventral (Carpenter).

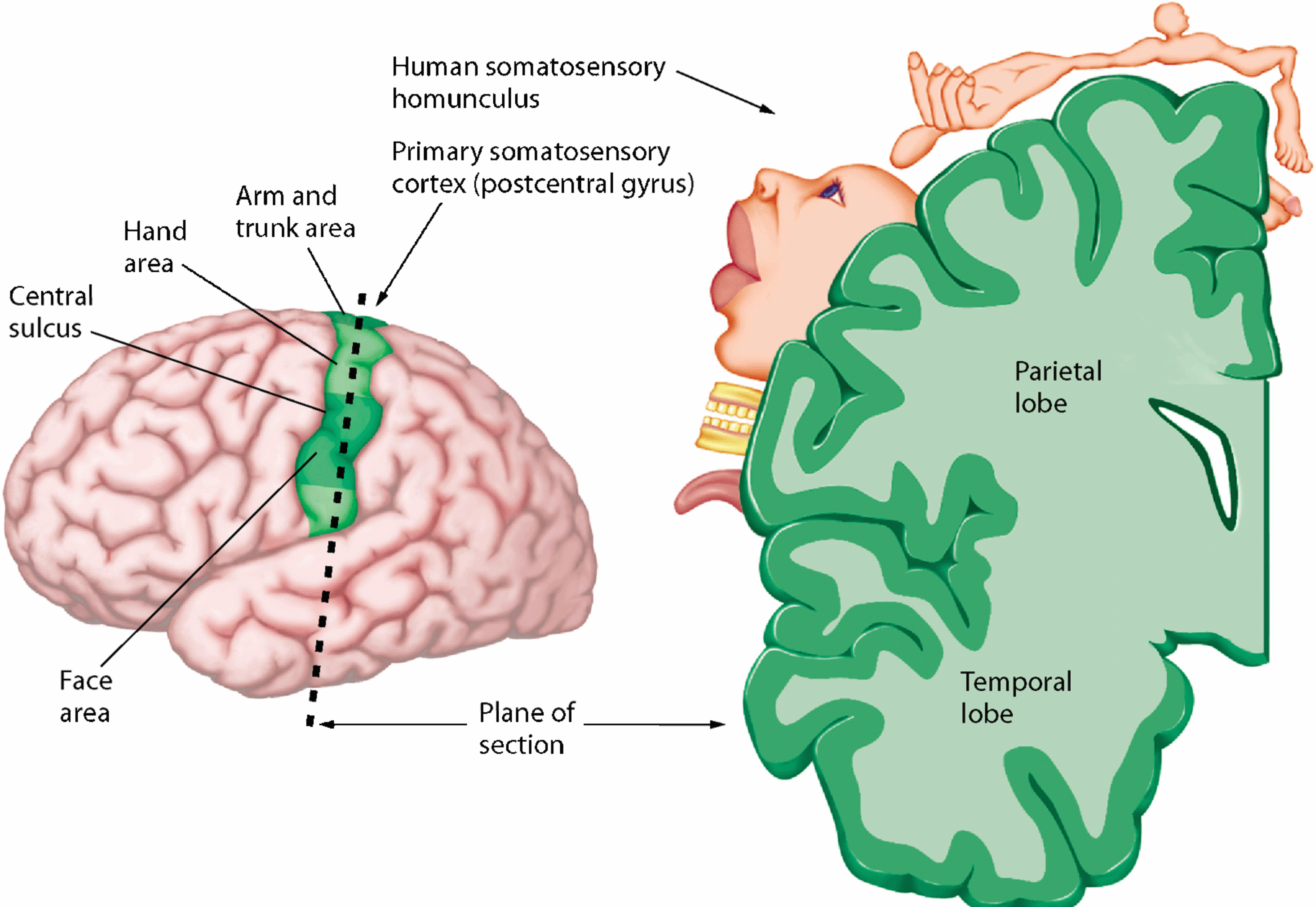
THE SOMATOSENSORY CORTEX AND ITS THALAMIC AFFERENT CONENCTIONS



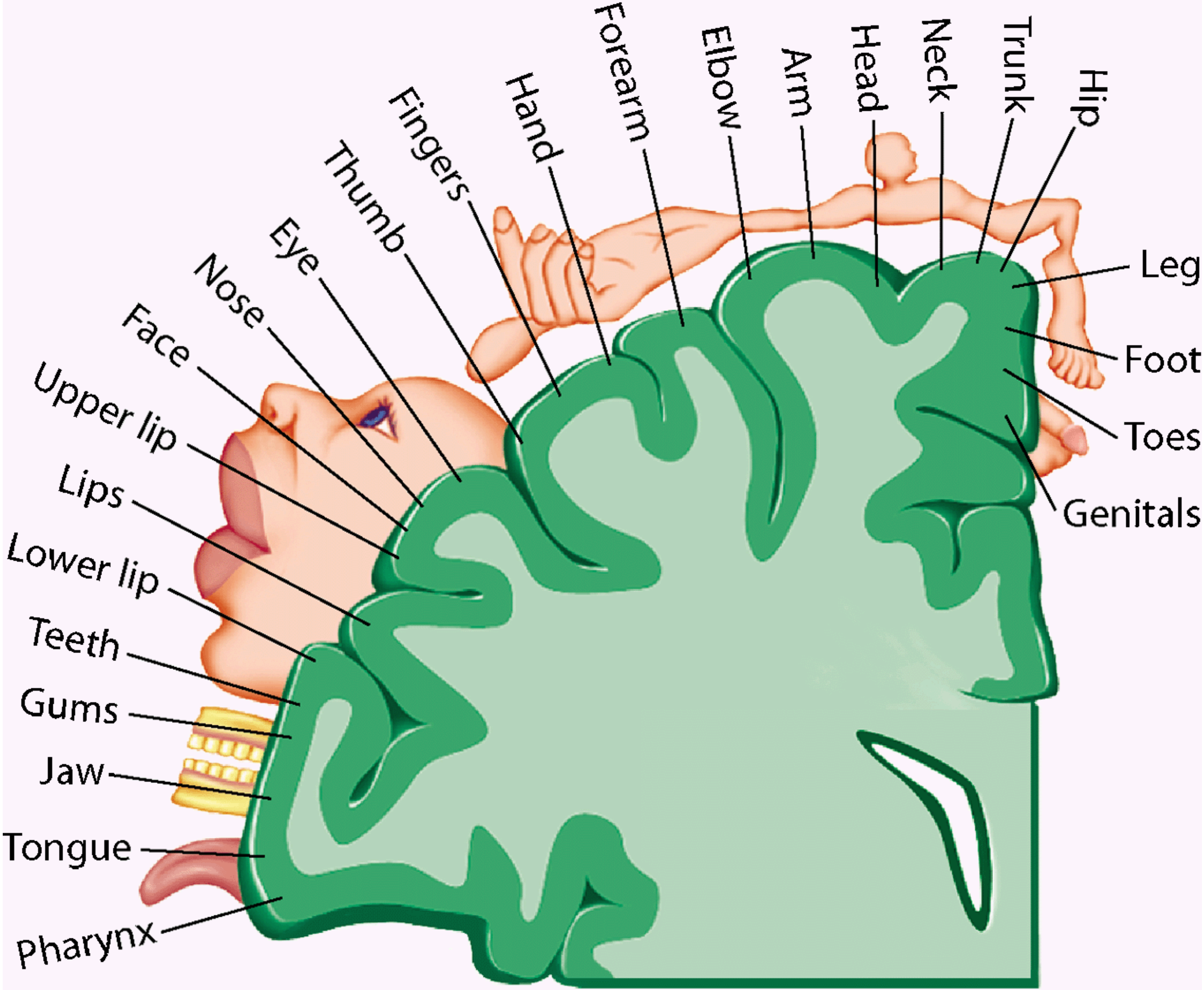




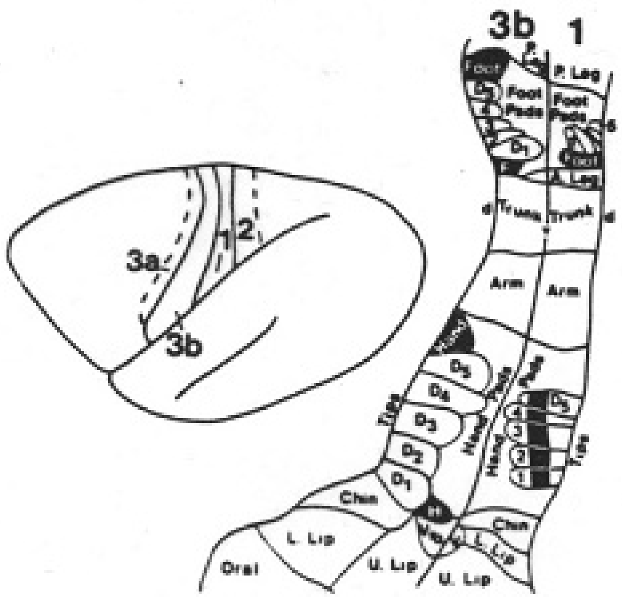
Schematic diagram in a sagittal plane showing projections of thalamic subdivisons to the sensorimotor cortex. Neurons in the ventral posterolateral (VPLc) and ventral poteromedial (VPM) nuclei form a central core (blue) consisting of two parts (one represented by solid blue and another by lined blue) responsive to cutaneous stimuli and an outer shell (white) composed of neurons responsive to deep stimuli. Inputs to VPLc is via the medial lemniscus and the spinothalamic tracts. Cell in the outer shell project to cortical area 3a (muscle spindle) and to area 2 (deep receptors). Cells in the central core (blue) project to area 3b (cutaneous). These projections are somatotopic (Carpenter).



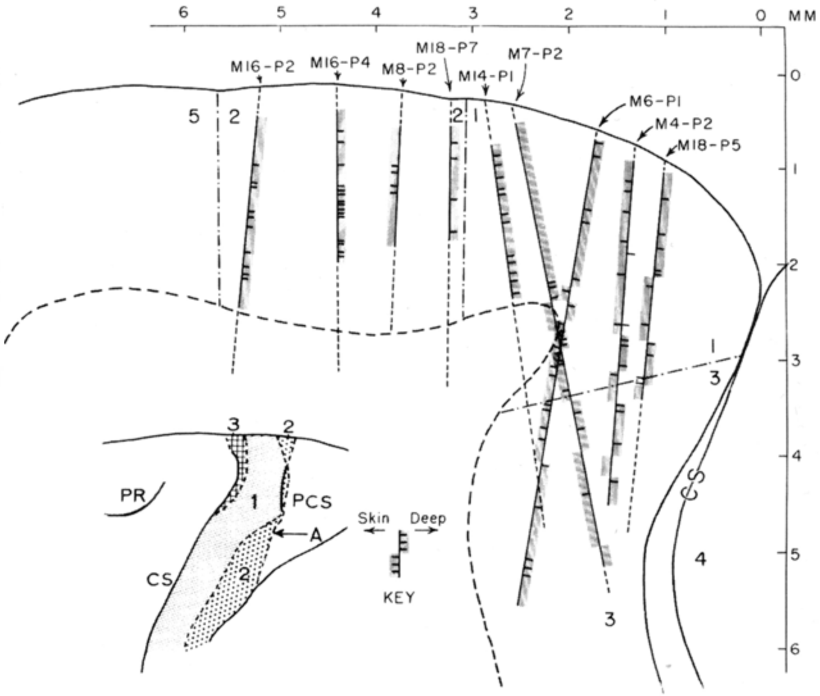
Human somatosensory homunculus
Primary somatosensory cortex (postcentral gyrus)
Arm and trunk area
Hand area
Central sulcus
Face area
Plane of section
Parietal lobe
Temporal lobe


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

ORGANIZATION OF THE POSTCENTRAL GYRUS IN MONKEYS



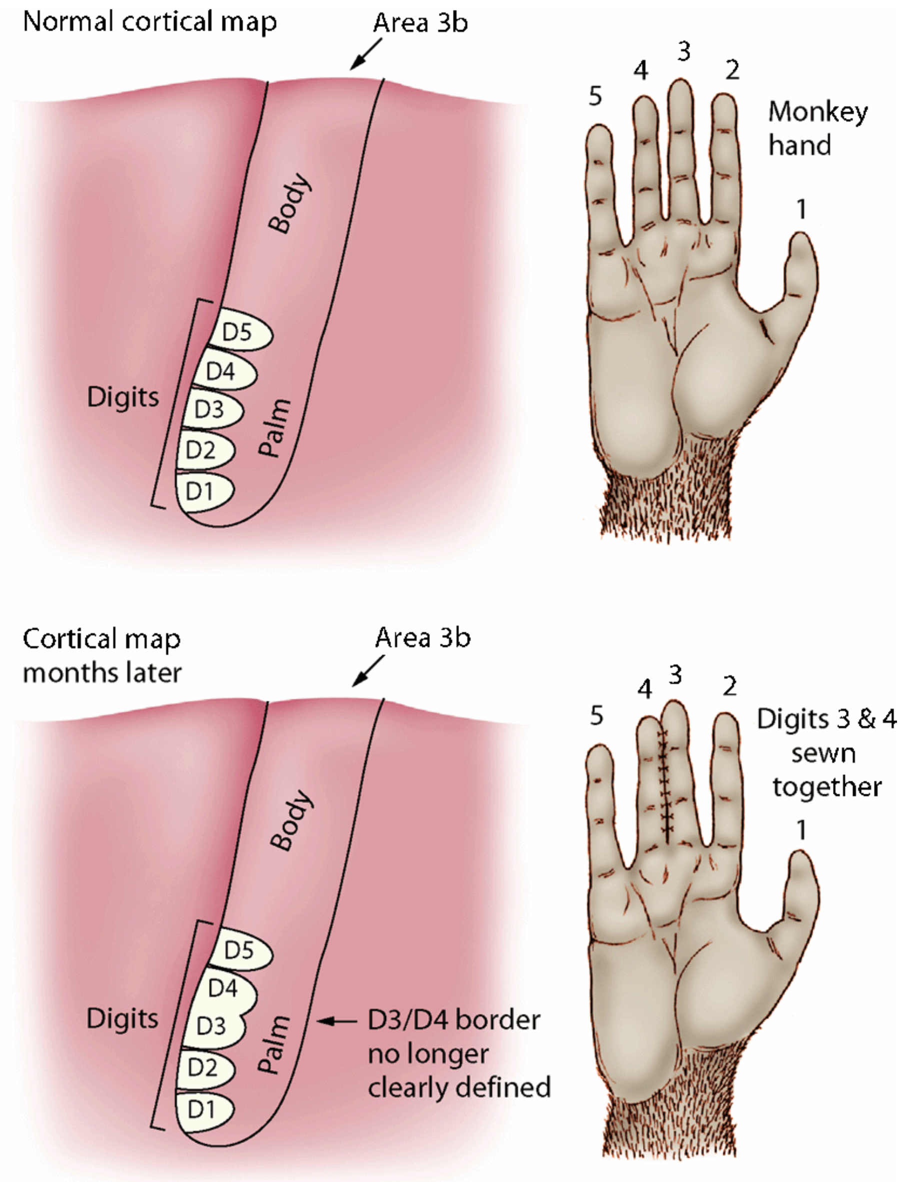
multiple representations of the skin surface in the postcentarl gyrus of Owl moneky (Merzenich and Kaas, 1980).



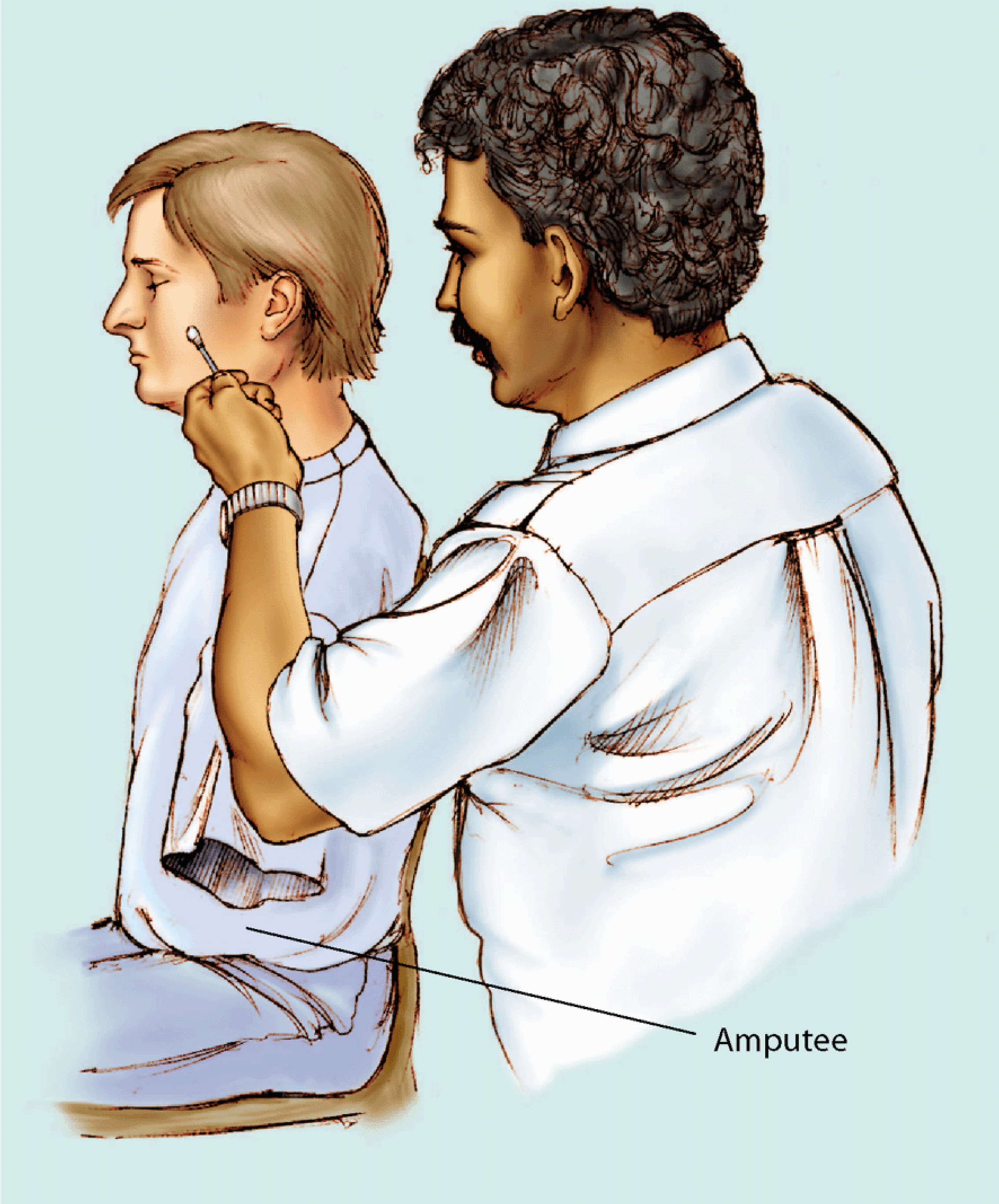
Microelectrode reconstructions in the postcentral gyrus of anesthetized monkeys. All were placed within 1 mm of the plane marked A on the inset drawing, which show the cytoarchitectonic areas. Penetrations perpendicular to the cortical surface and passing down parallel to its radial axis encountered neurons all of the same modality (Powell and Mountcastle, 1957)

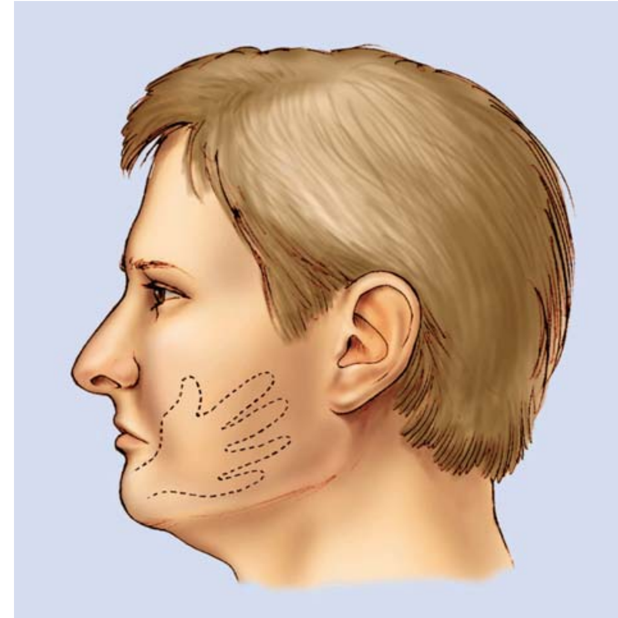
REORGANIZATION OF SENSORY MAPS IN THE PRIMATE CORTEX

Top: Mapping of the somatosensory hand area in a normal monkey cortex. The individual digit representation can be revealed using single unit recording. If the two fingers of one hand are sewn together, months later the cortical maps change such that the sharp border once present between the sewn fingers is now blurred. (Gazzaniga, 2002)



FUNCTIONAL PLASTICITY IN HUMAN SS CORTEX





Rhamachandran has tested the ability of persons to discriminate sensory stimuli. During stroke of a cotton swab the man reported sensation in his arm. However, the person lost his arm in an accident some time earlier. This is not simple the phantom sensation since the sensation was induced by stimulating the face.

From Gazzaniga, 2002