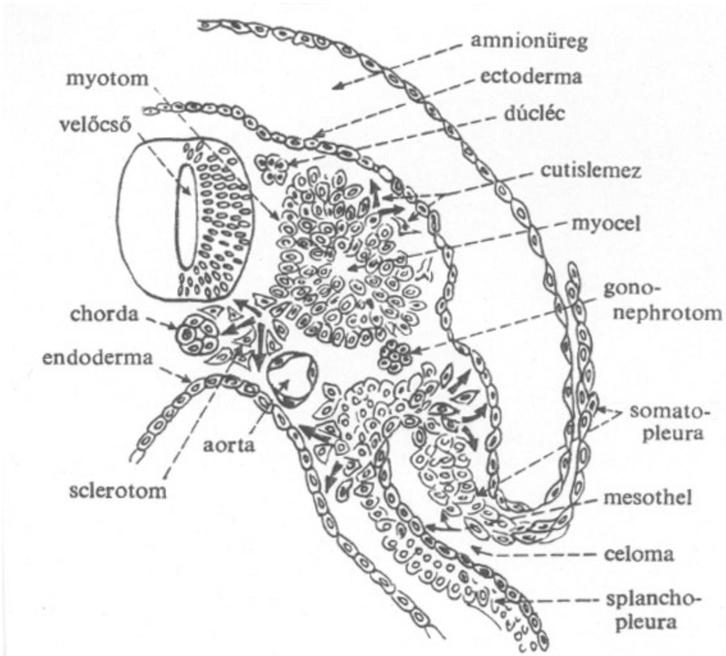
THE SPINAL CORD AND THE SOMATOSENSORY SYSTEMS


amnionüreg
myotom
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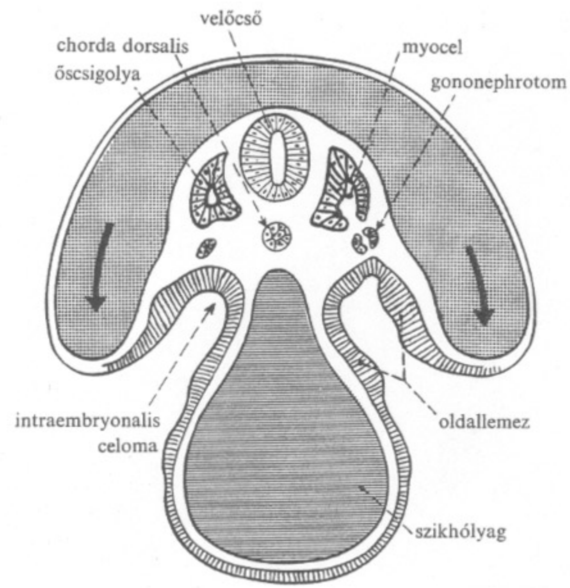
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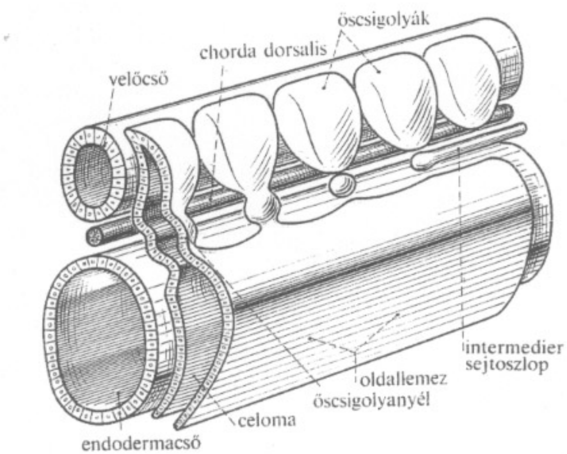
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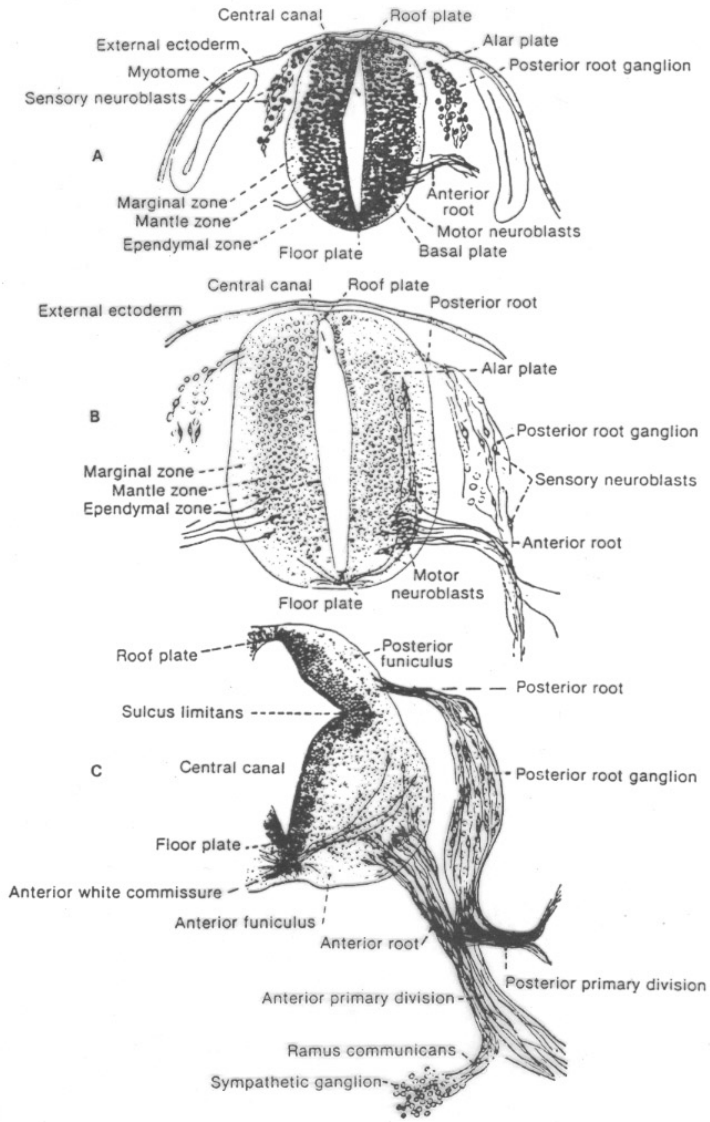
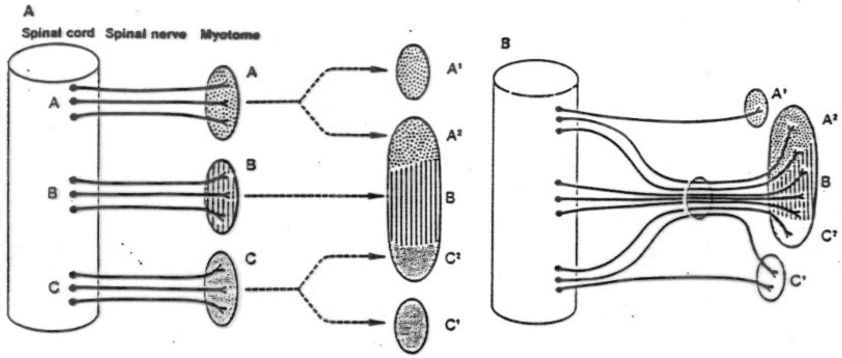
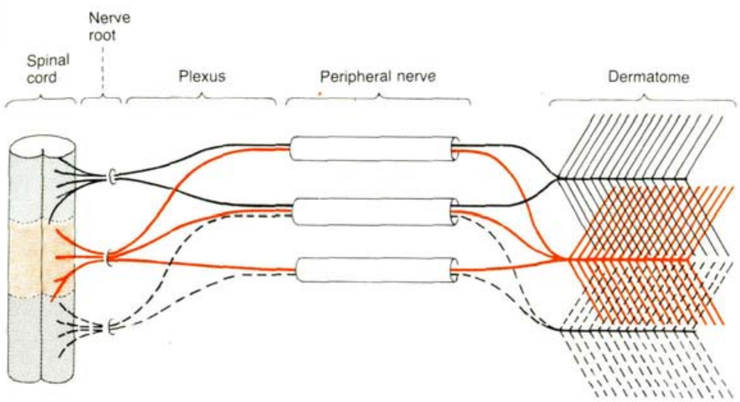


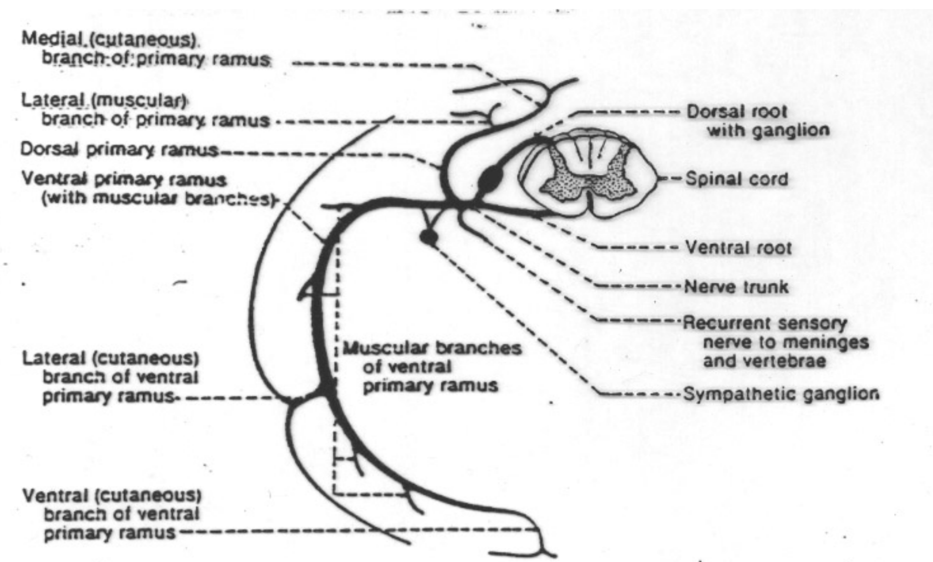
Cross section of the embryonic spinal cord and dorsal root to show the neurogenesis in the ventral horn and dorsal root ganglia



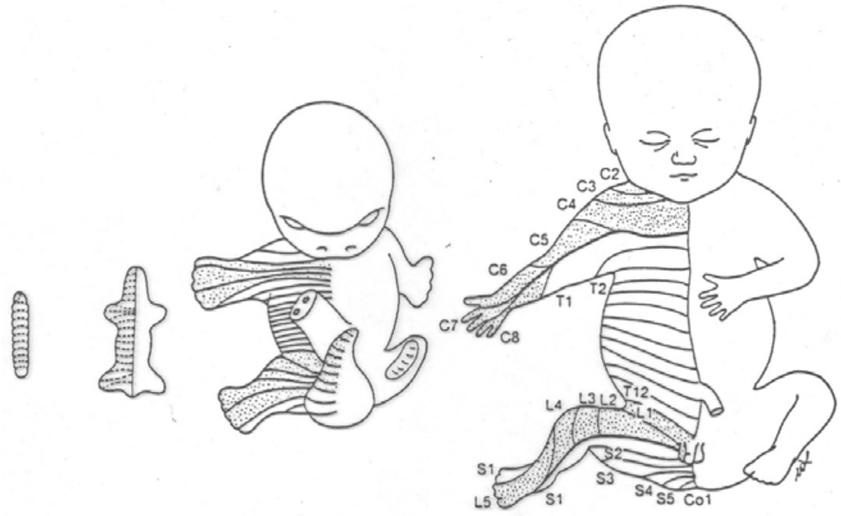
Diagrammatic representation of plexus formation by spinal nerves. (A) Each myotome receives one spinal nerve, but the myotome may split to contribute to a composite muscle. (B) The axons that innervate a composite muscle still reach their original myotome but first run through a plexus to form a common nerve.



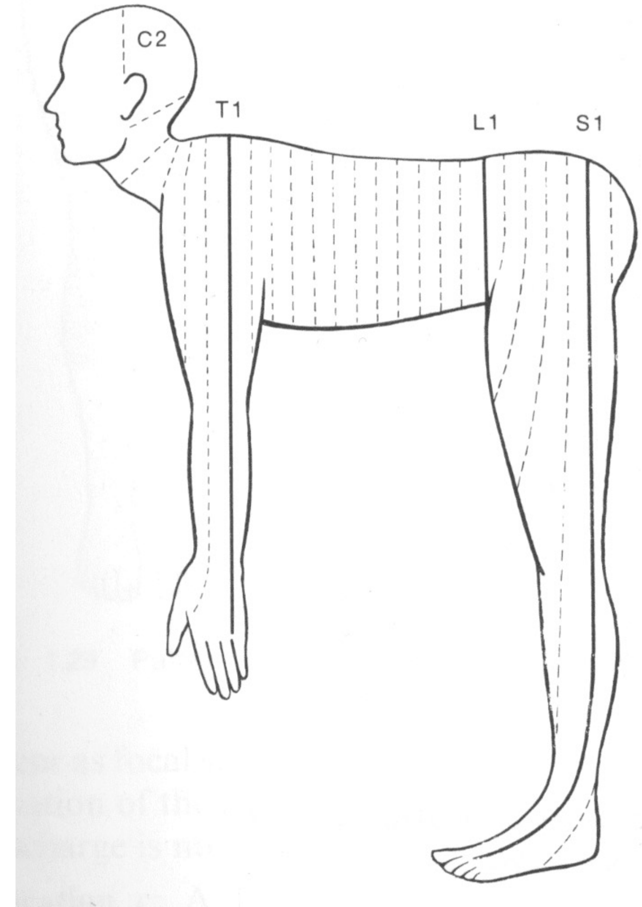
Nerve roots in plexus divide into peripheral nerves having segmental arrangement in the skin (dermatomes). The segments overlap.



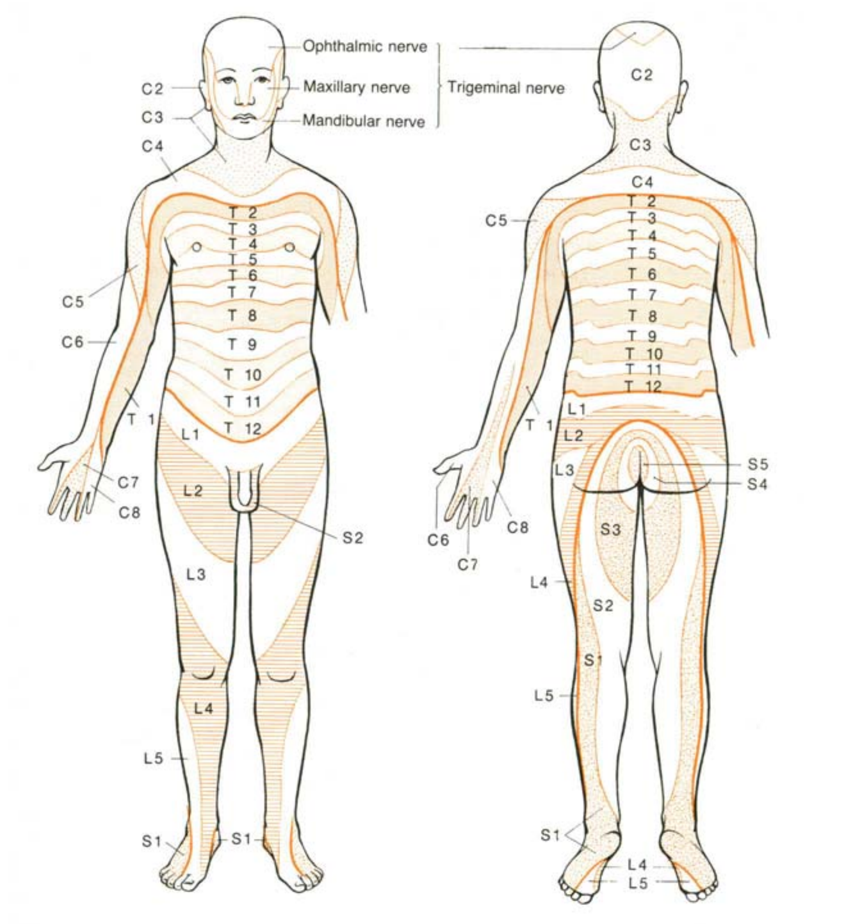
Gross components of a prototypical peripheral nerve (thoracic level).



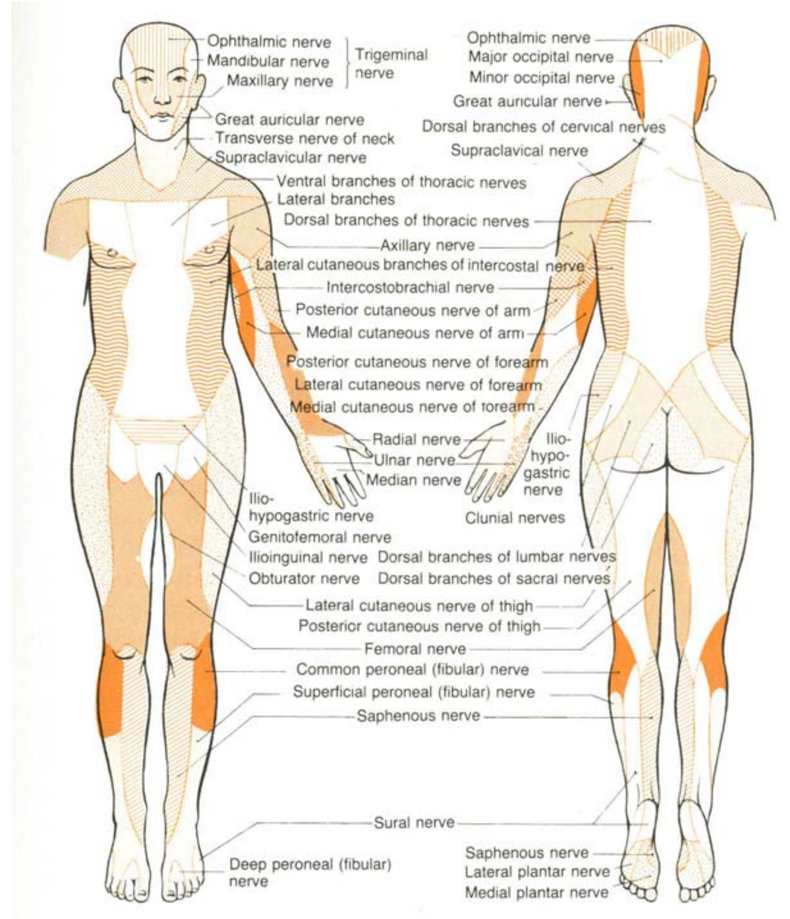
Transformation of dermatomes during the outgrowth of the limb buds. C- cervical; T-thoracal; L-lumbar; S-sacral.



Simplified diagram of segmental borders (Duus)

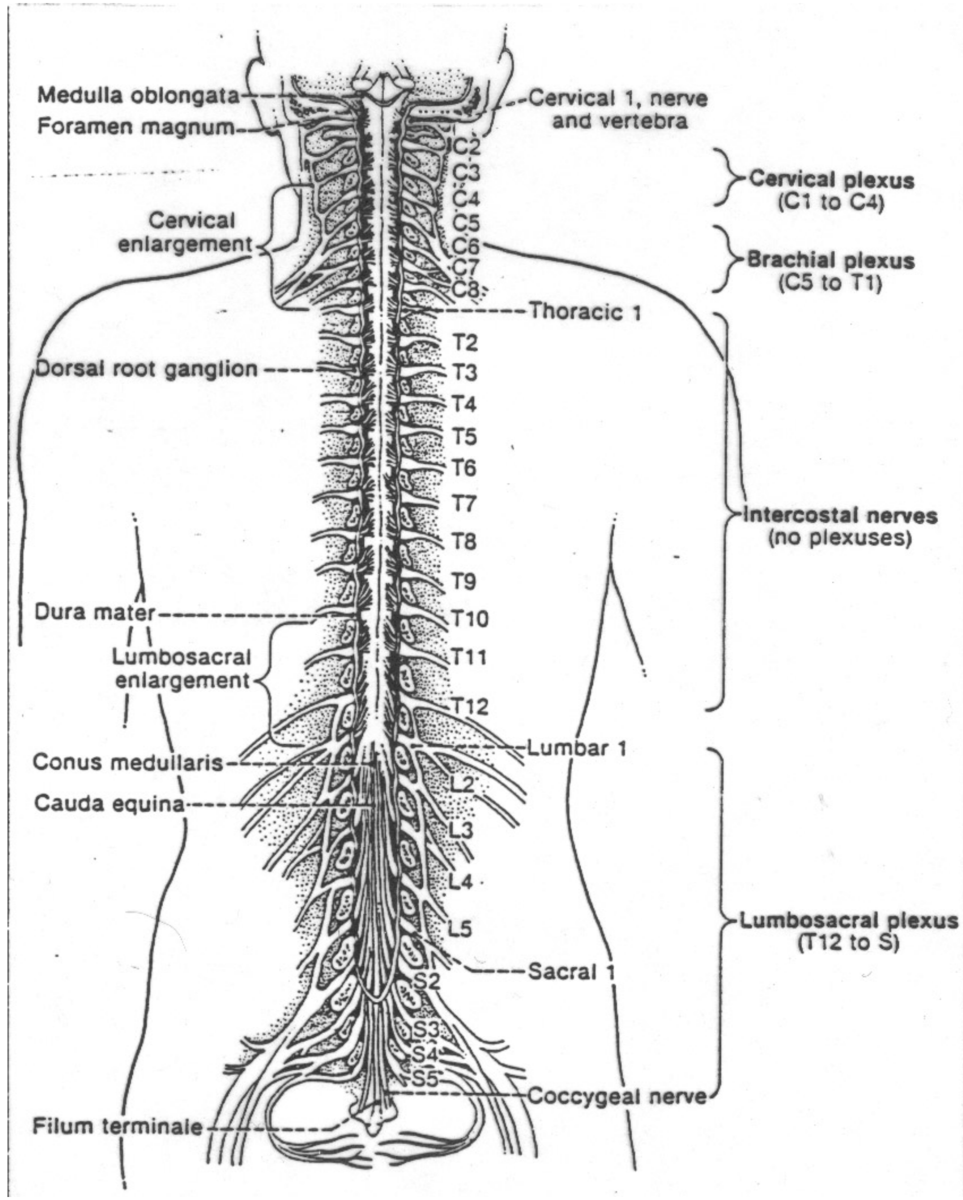


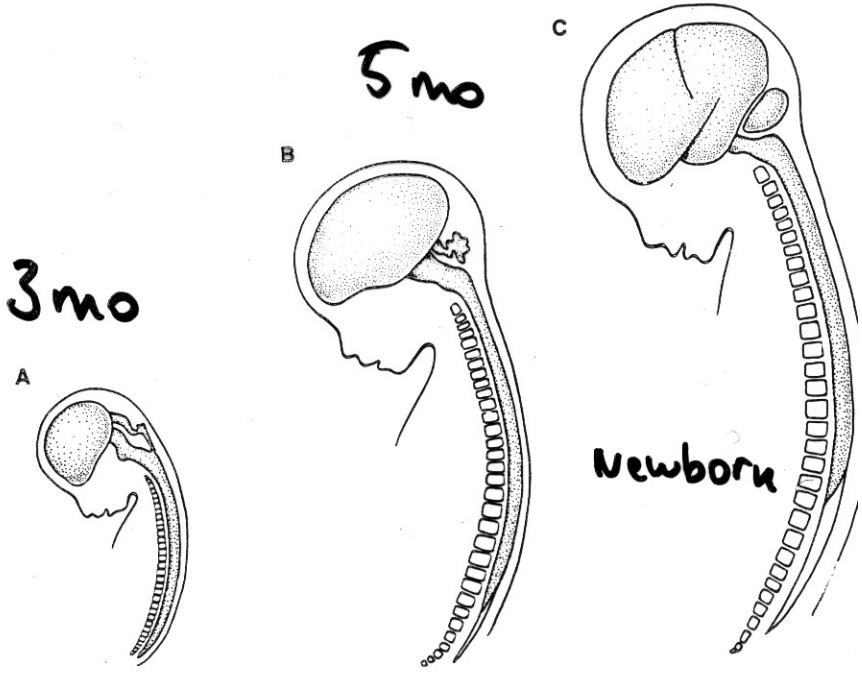
The segmental innervation of the skin (Duus)

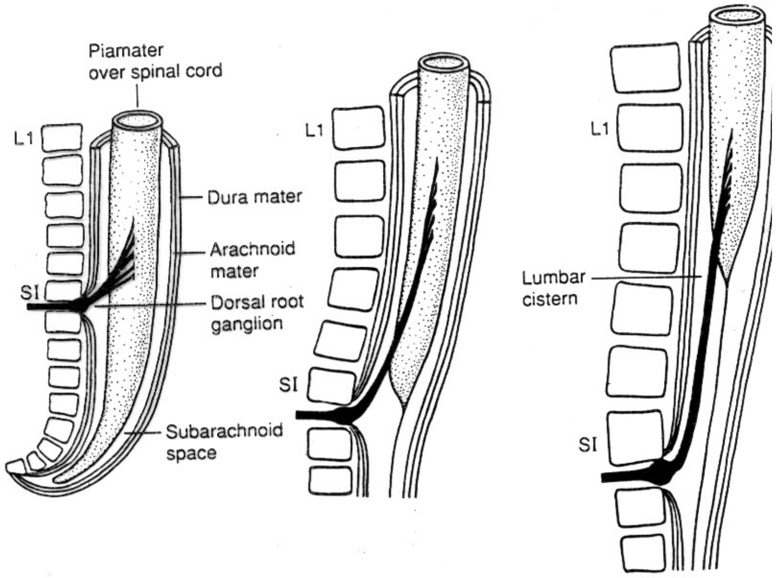


Pattern of innervation of skin by peripheral nerves (Duus)

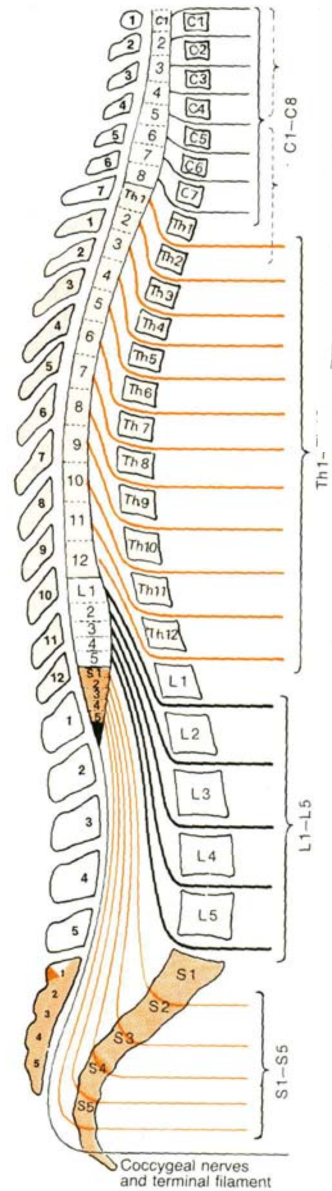
Dorsal view of the spinal cord and dorsal nerve roots in situ, after removal of the neural arches of the vertebrae.



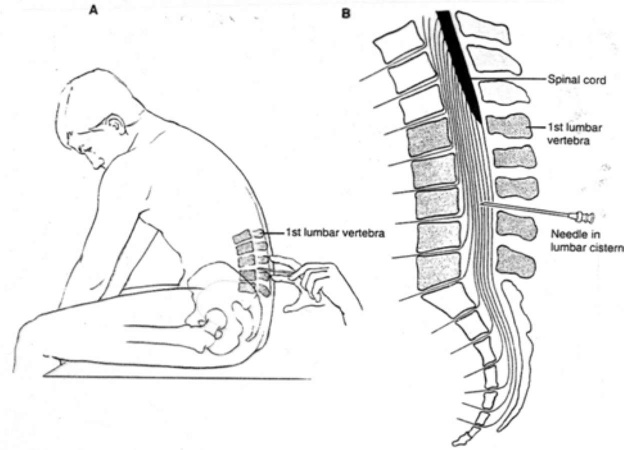




Schematic drawings showing the relationship between the spinal cord and the vertebral column at various stages of development.

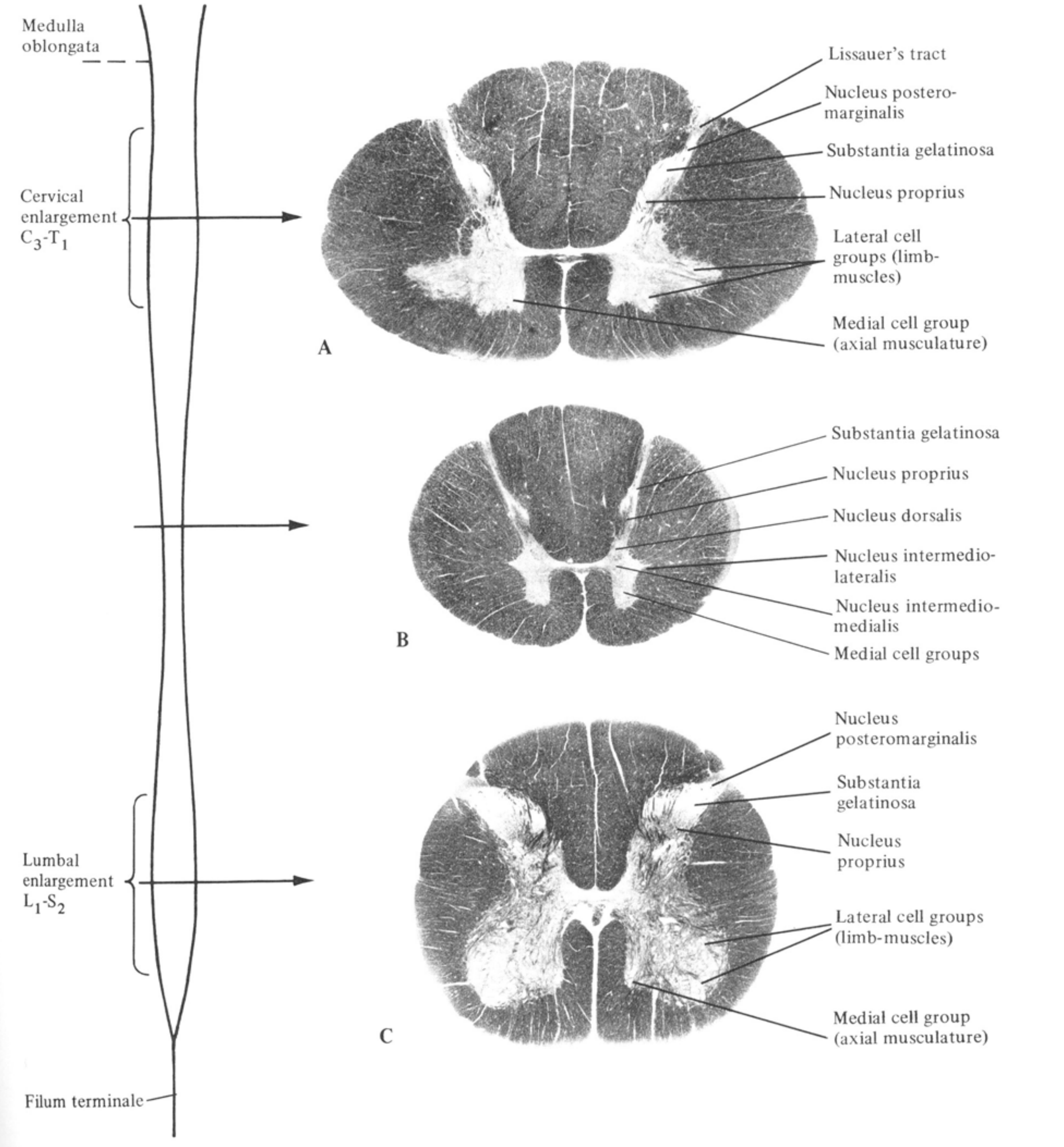


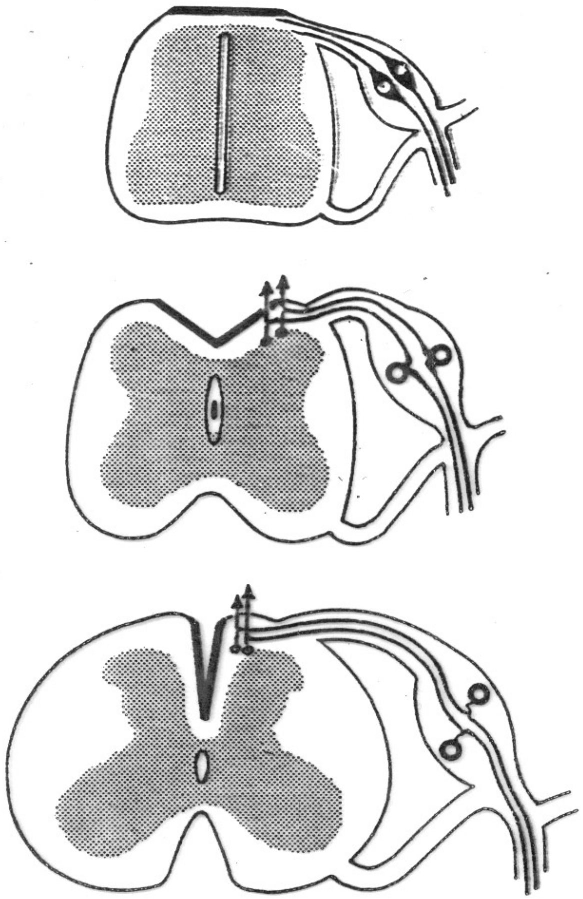
adult

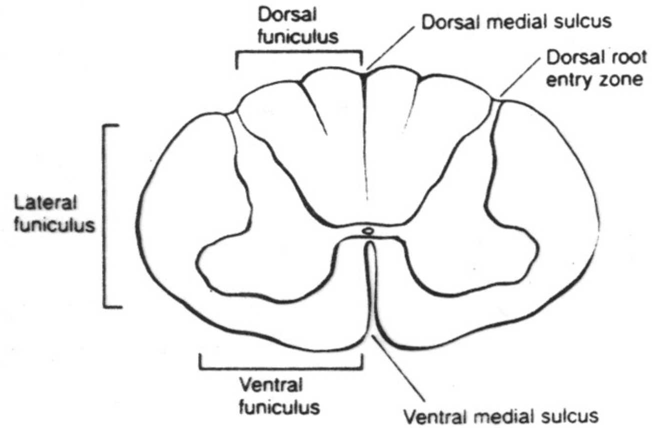


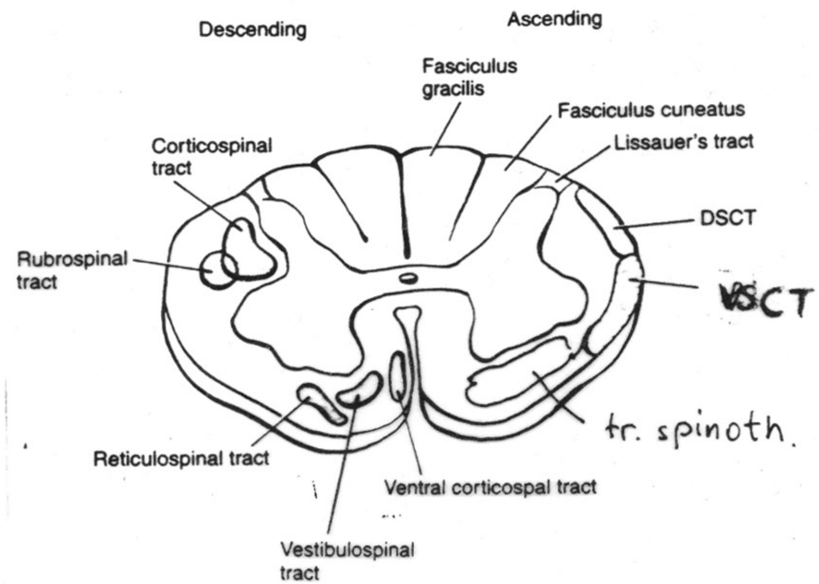
CSF is obtained by inserting a Needle into the lumbar cistern between the 3rd and 4th or 4th and 5th lumbar spinal processes.

The cross-sections of the spinal cord are wider at the level of the cervical and lumbar enlargements than elsewhere. Note that relative amount of gray and white matter is also different at different levels. The amount of white matter decreases gradually in caudal direction, since the long ascending and descending fiber tracts contain fewer axons at successively more caudal levels of the spinal cord. The main nuclear groups of the gray matter have been indicated in the right halves (Heimer)

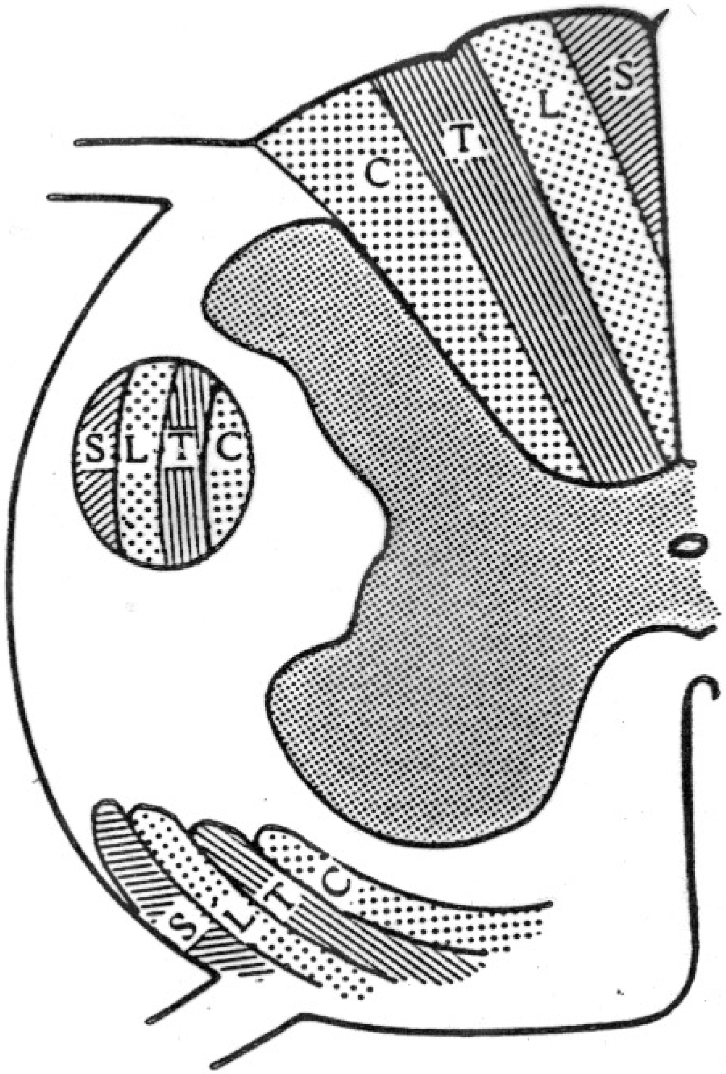




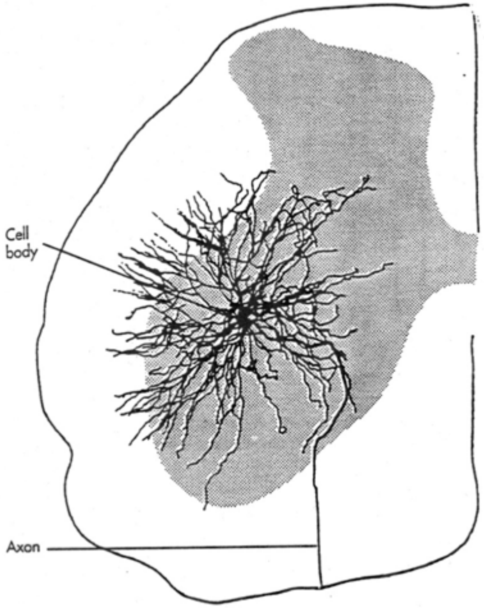




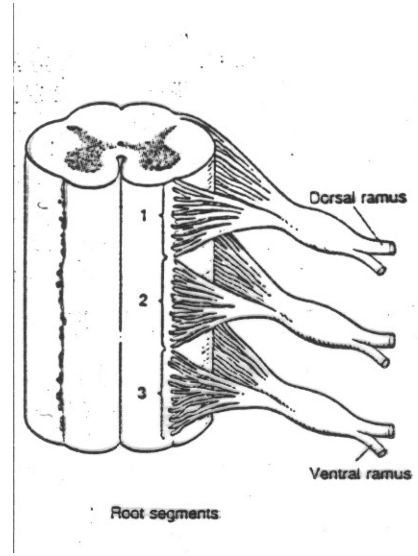
The development of the septum medianum posterior and the dorsal columns (Szentagothai)



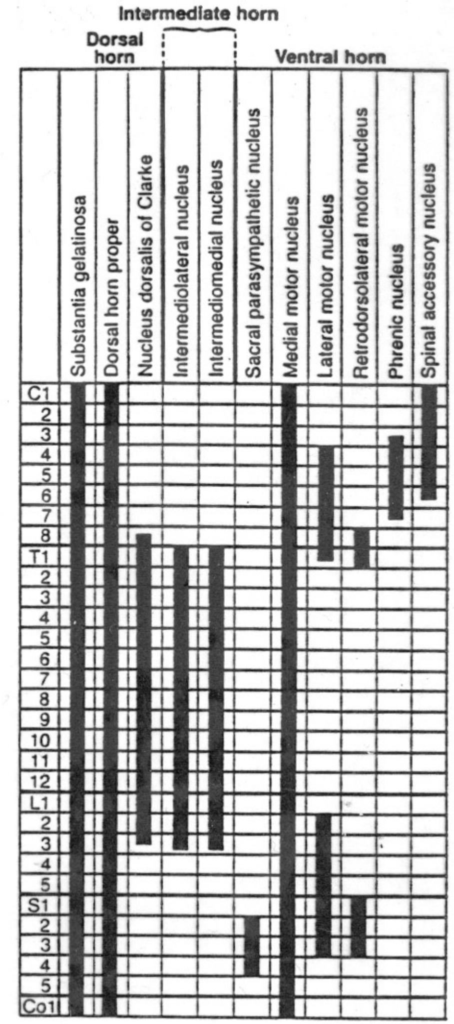
Laminar arrangement of the white matter of the spinal cord. S-sacral, L-lumbar, T-thoracal, C, cervical (Szentahothai)



Cell body
Axon



Dorsal ramus
1
2
3
Ventral ramus
Root segments



Intermediate horn
Dorsal horn
Ventral horn
Substantia gelatinosa
Dorsal horn proper
Nucleus dorsalis of Clarke
Intermediolateral nucleus
Intermediomedial nucleus
Sacral parasympathetic nucleus
Medial motor nucleus
Lateral motor nucleus
Retrodorsolateral motor nucleus
Phrenic nucleus
Spinal accessory nucleus
C1
2
3
4
5
6
7
8
T1
2
3
4
5
6
7
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9
10
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L1
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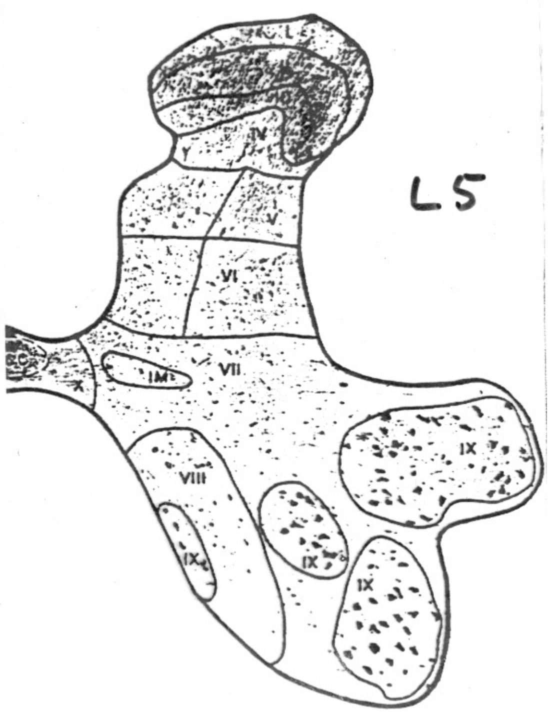
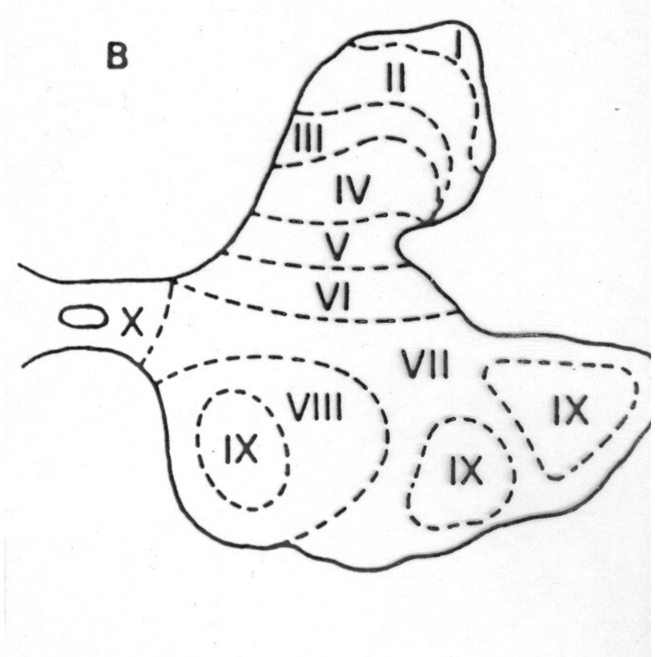
S1
2
3
4
5
Co1

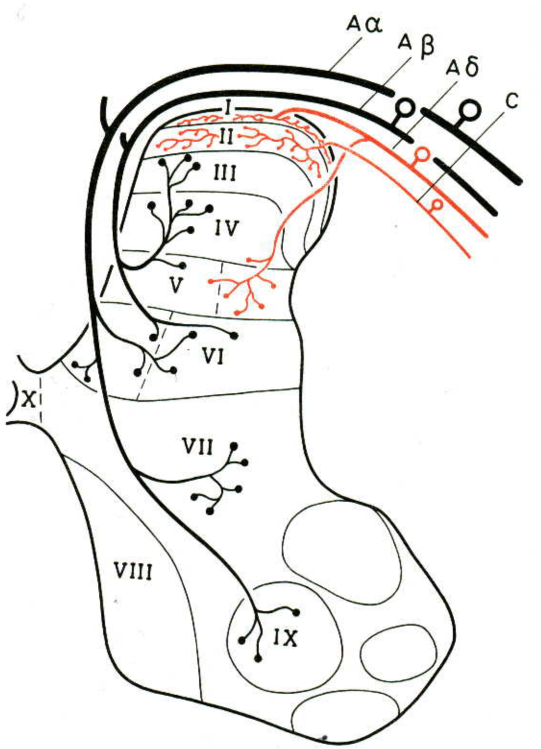


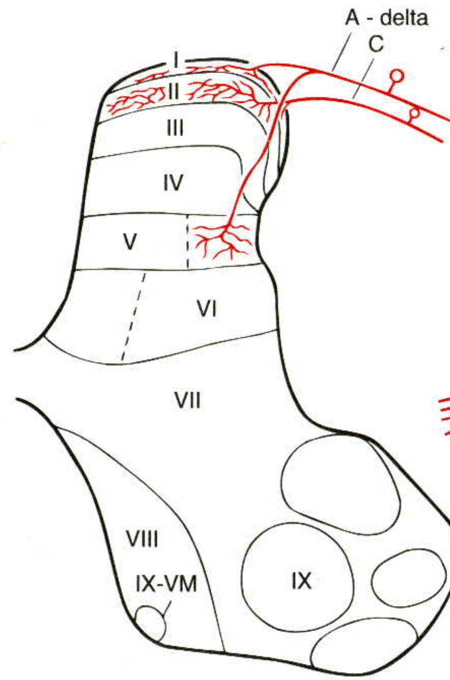
L5
IV
V
VI
VII
IM
VIII
IX
IX
IX
IX

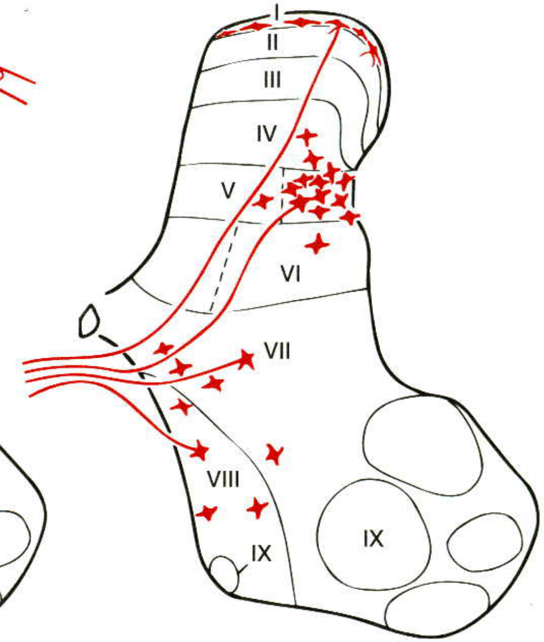
B



I
II
III
IV
V
VI
X
VII
VIII
IX
IX
IX



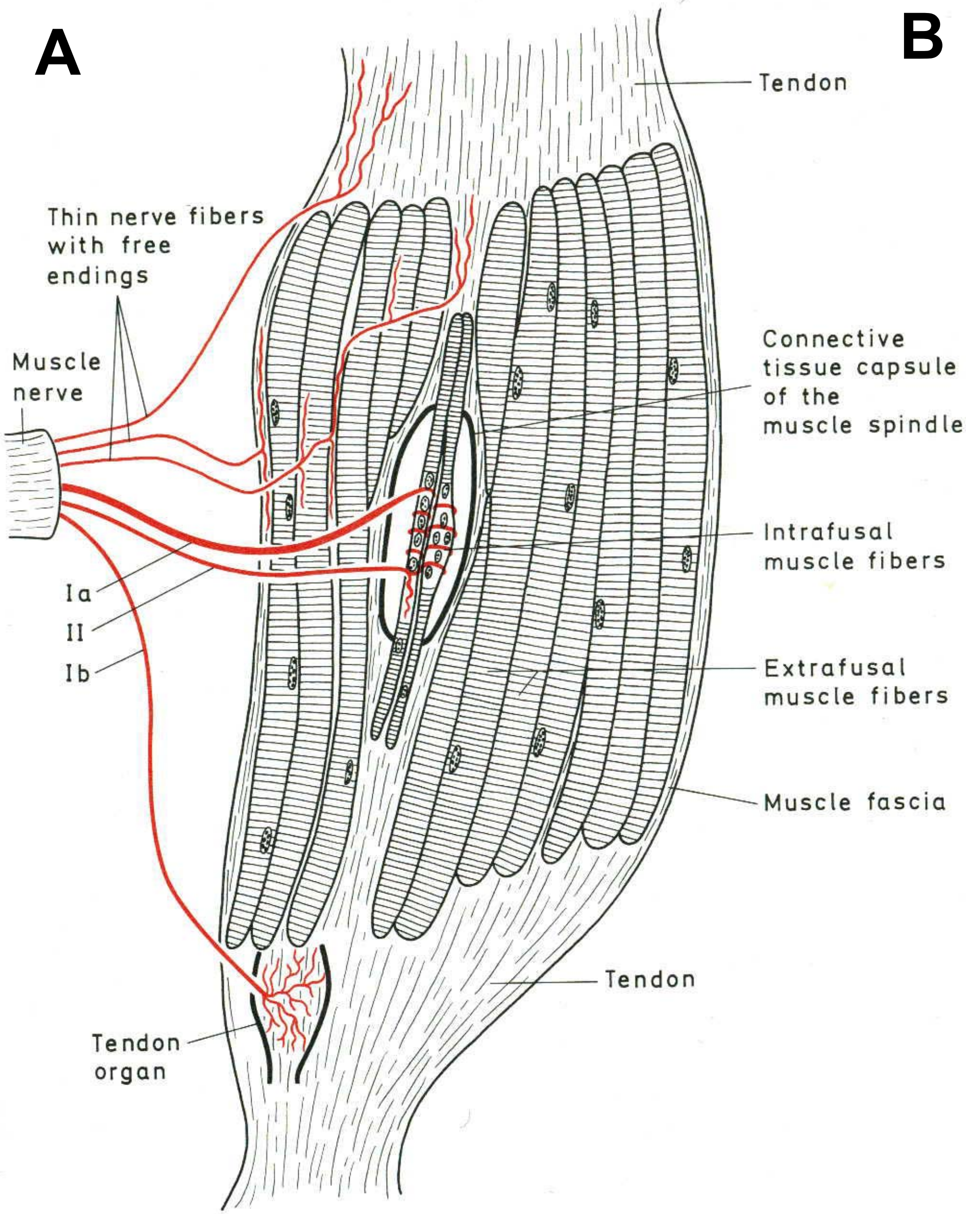




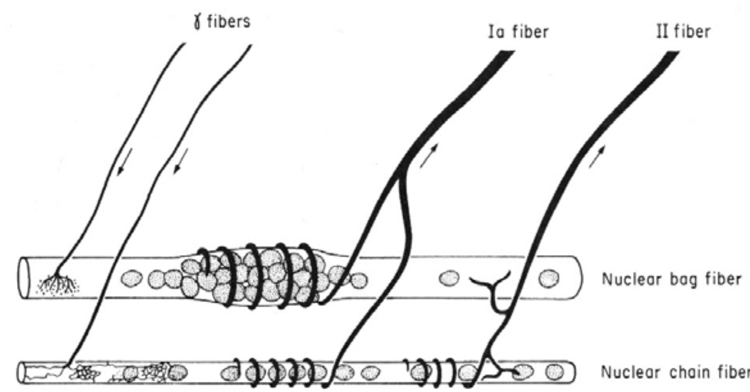
The terminal regions of the dorsal root fibers in the cord. The thickest myelinated fibers (Aα form muscle spindles and tendon organs) end in the deep parts of the dorsal horn and partly also in the ventral horn. Thick myelinated fibers from cutaneous mechanoreceptors (AB) end in laminae III-VI. The 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)

A

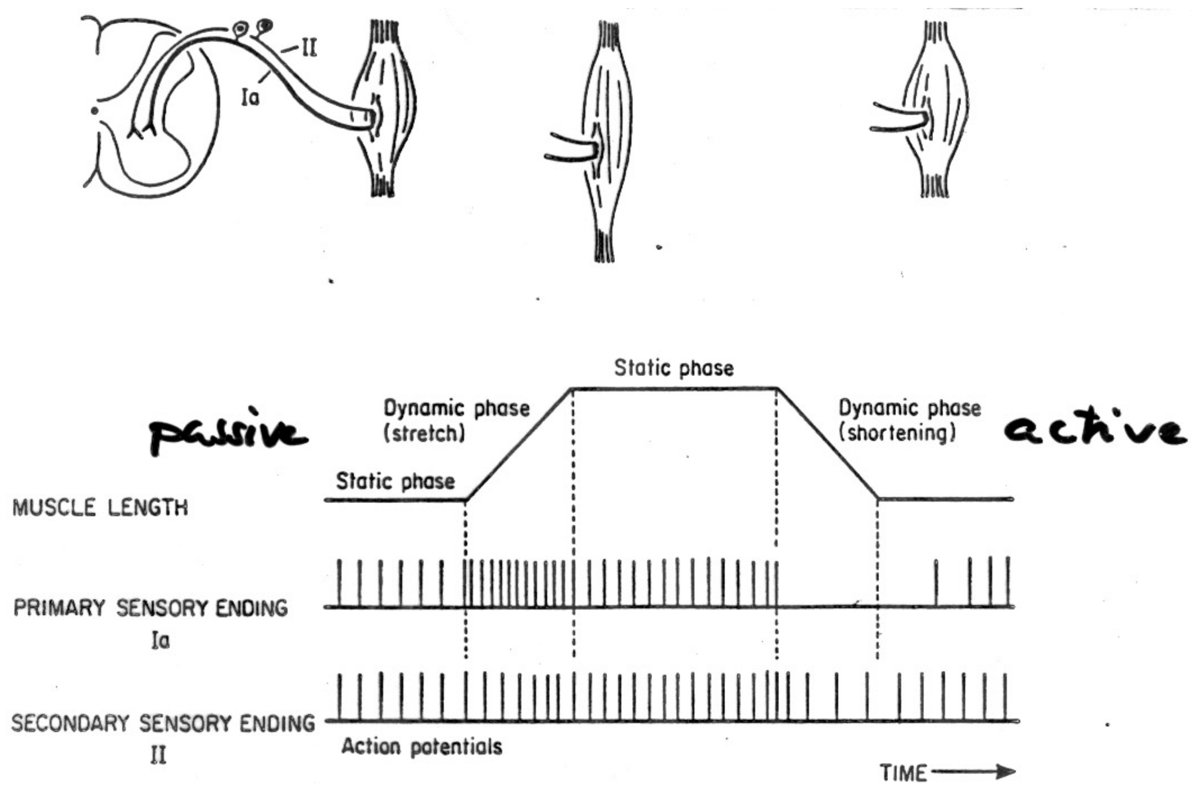


B



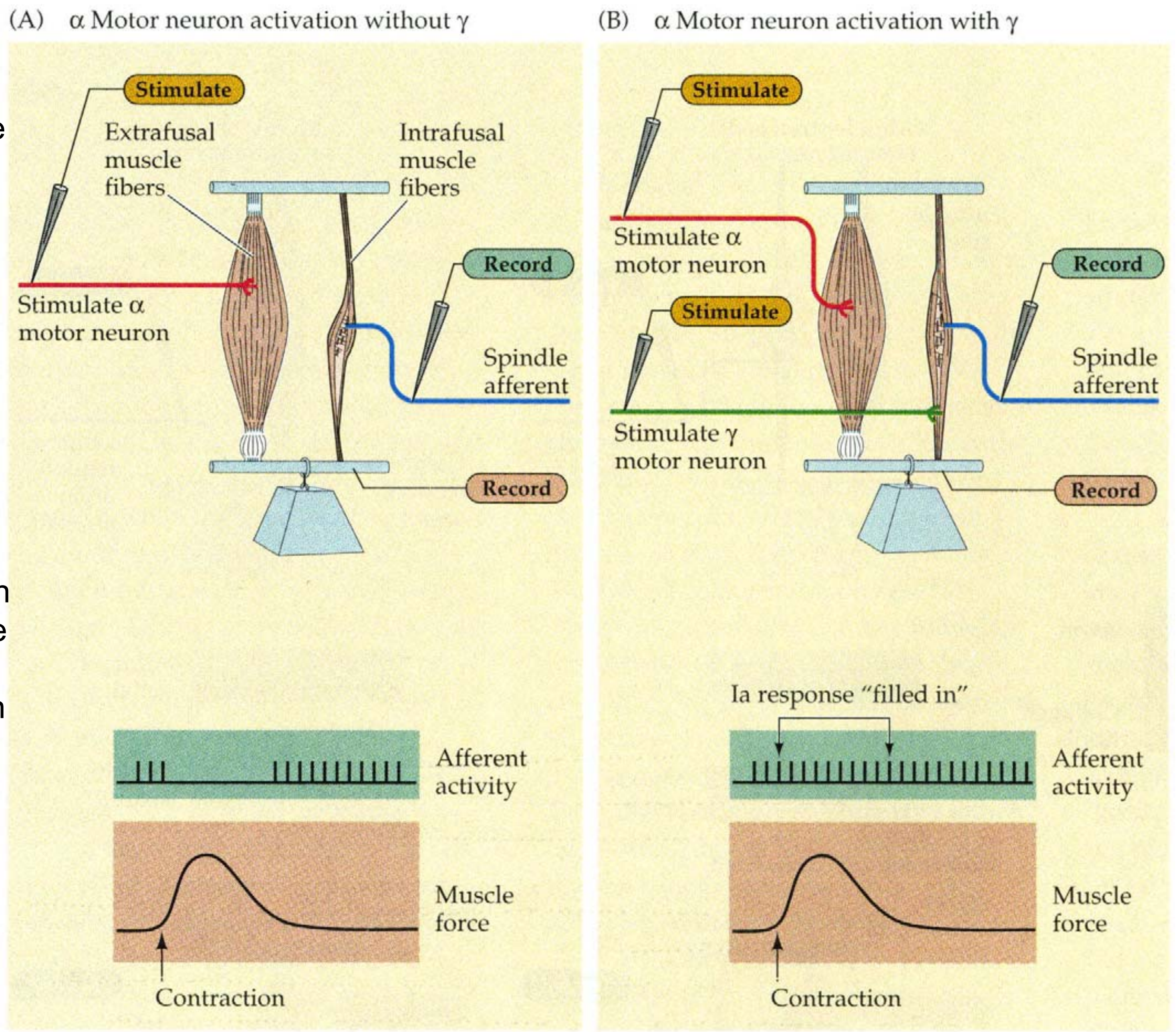
A: sensory innervation of skeletal muscles. The size of the receptors to the muscle exaggerated. Note that the muscle spindle is attached via connecgtive tissue fibers to the tendons. Thus, muscle spindle wherever the whole muscle is stretched.

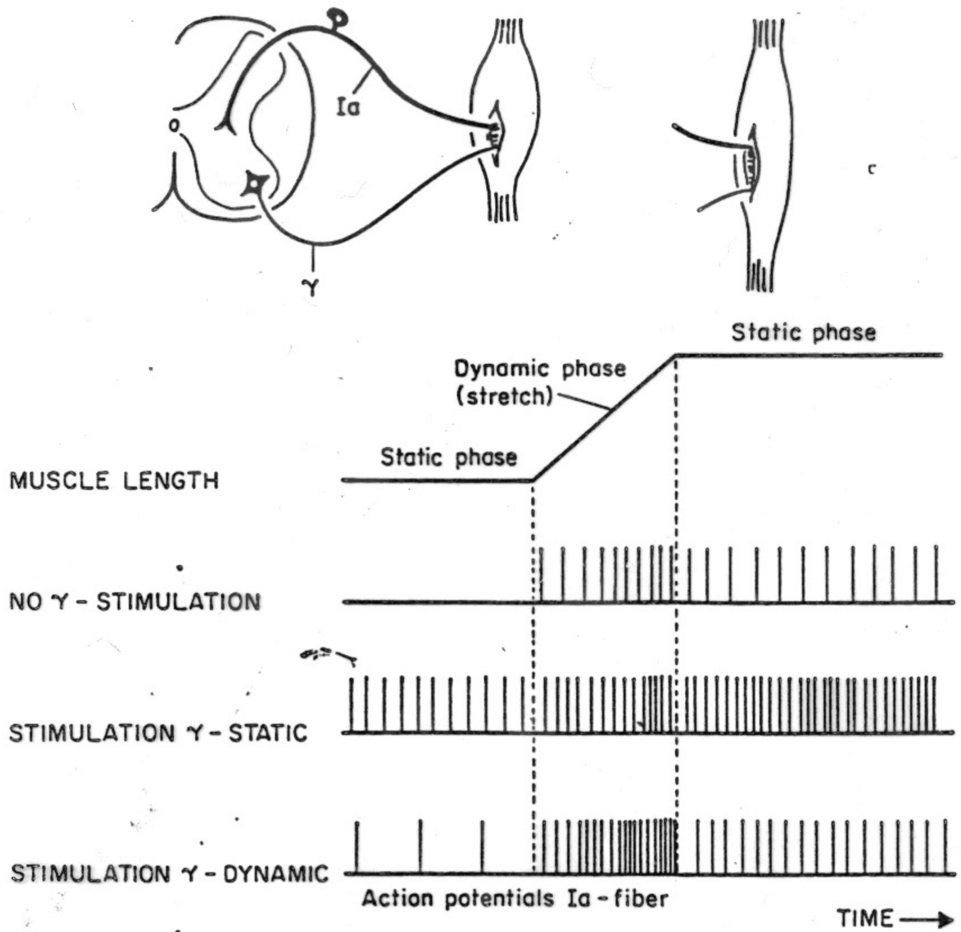
B: Schematic representation of the two kinds of intrafusal muscle fibers and their innervation (Brodal)



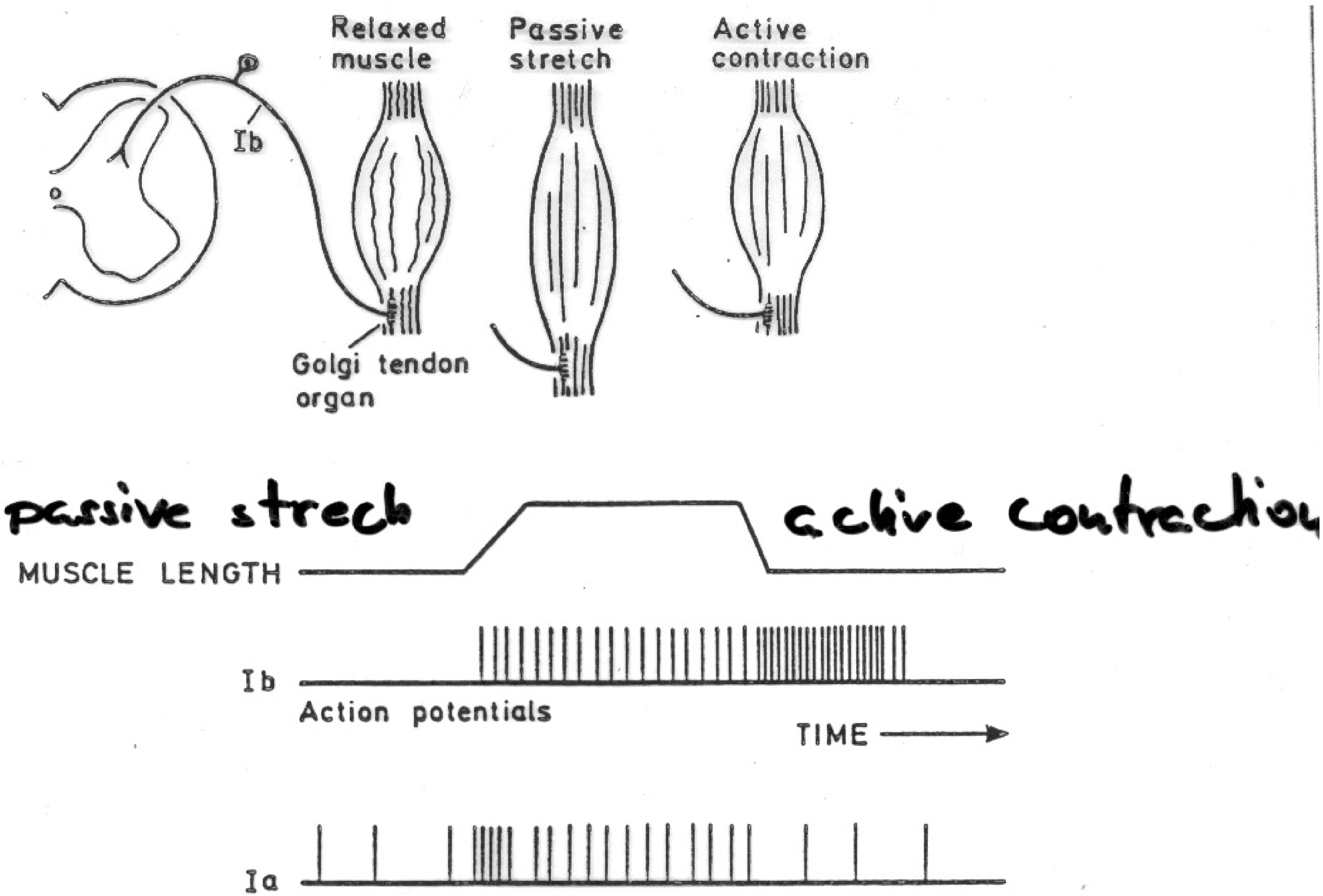
The functional properties of the muscle spindle. The diagram shows how both the primary and the secondary endings signal the static length of the muscle (static sensitivity), whereas only the primary ending signals the length changes (movements) and their velocity (dynamic sensitivity). The change of firring frequency of group Ia and group II fibers can then be related to static muscle length (static phase) and shortening of the muscle (Dynamic phases). The frequency of action potentials in the dorsal root fibers is indicated by the density of the vertical lines on the lower rows (Brodal)

The role of the gamma motor neuron activity in regulating the responses of muscle spindles. A: When both alpha and gamma motor neurons are stimulated without activation of gamma motor neurons, the response of Ia fiber decreases as the muscle contarcts. B: When both alpha and gamma motor neurons are activated, there is no decrease in Ia firing during muscle shortening. Thus, the gamma motor neuron can regulate the gain of muscle spindles so that they can operate efficiently at any length of the parent muscle (Purves)

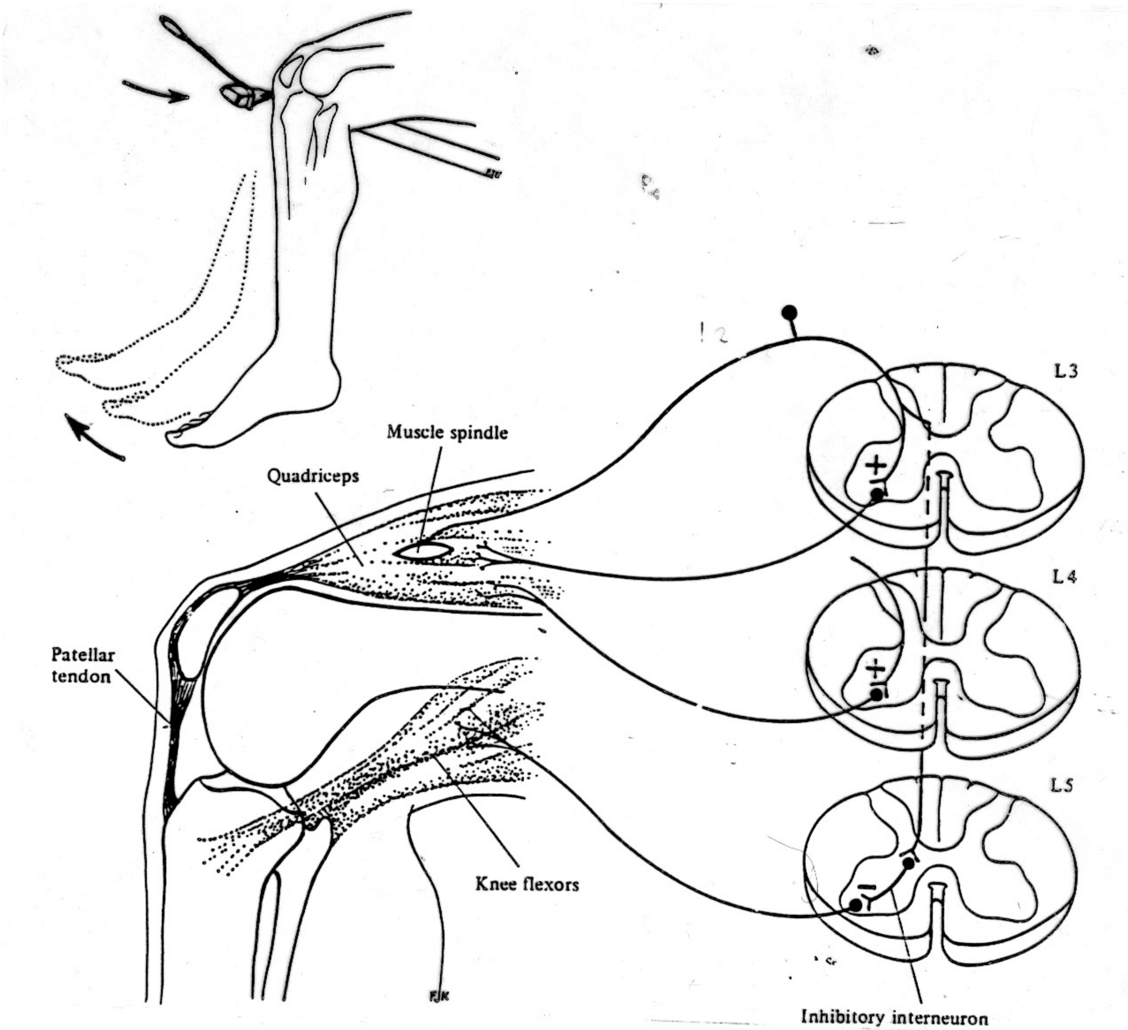




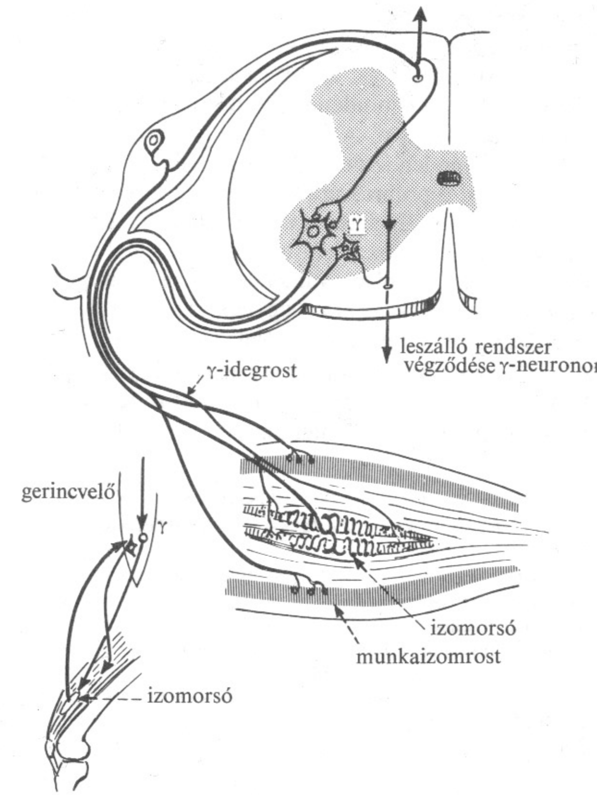
The action of gamma motorneurons on the muscle spindle. In this example, there is no firing of the Ia fiber at the resting length of the muscle when the gamma fibers are not stimulated. Stimulation of the static gamma fibers makes the Ia fiber frire even at the static resting length, and stretching the muscle to a new static length increases the firing frequency to a new stable level. Stimulation of adynamic gamma fiber increases the firing frequency of the Ia fiber mainly during the stretching phase.



Functional properties of the tendon organ. Both passive stretching and active contarction of the muscle increases the firing frequency of the Ib fiber, but active contarction produces the greater increase. The firing frequency of a Ia fiber during the same experiment is shown for comparison.

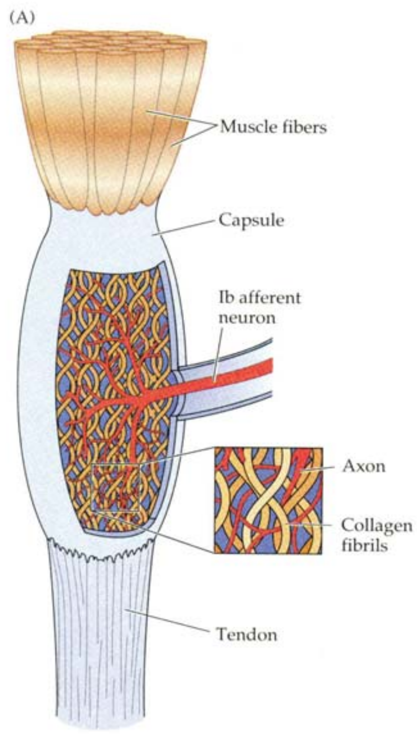


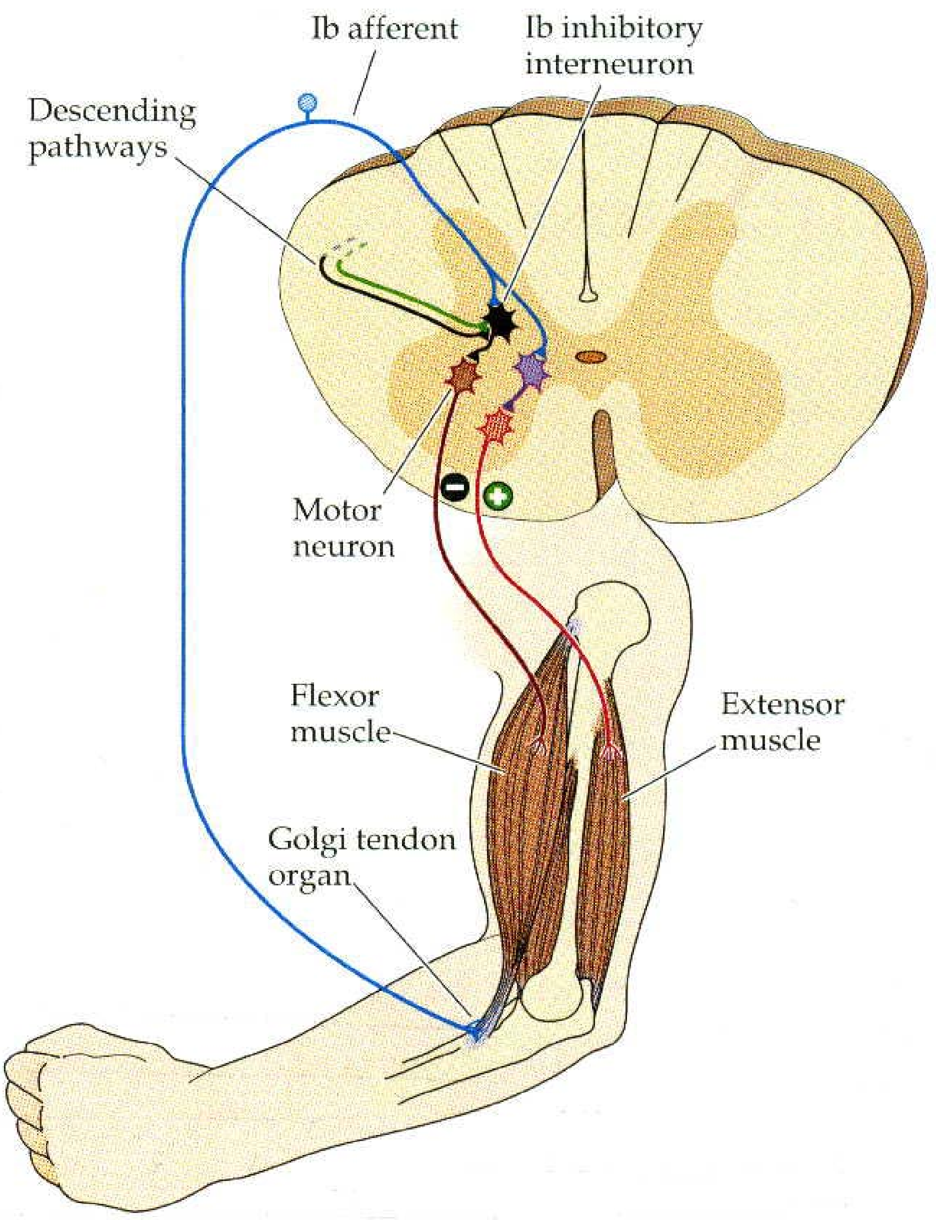
The knee jerk reflex.



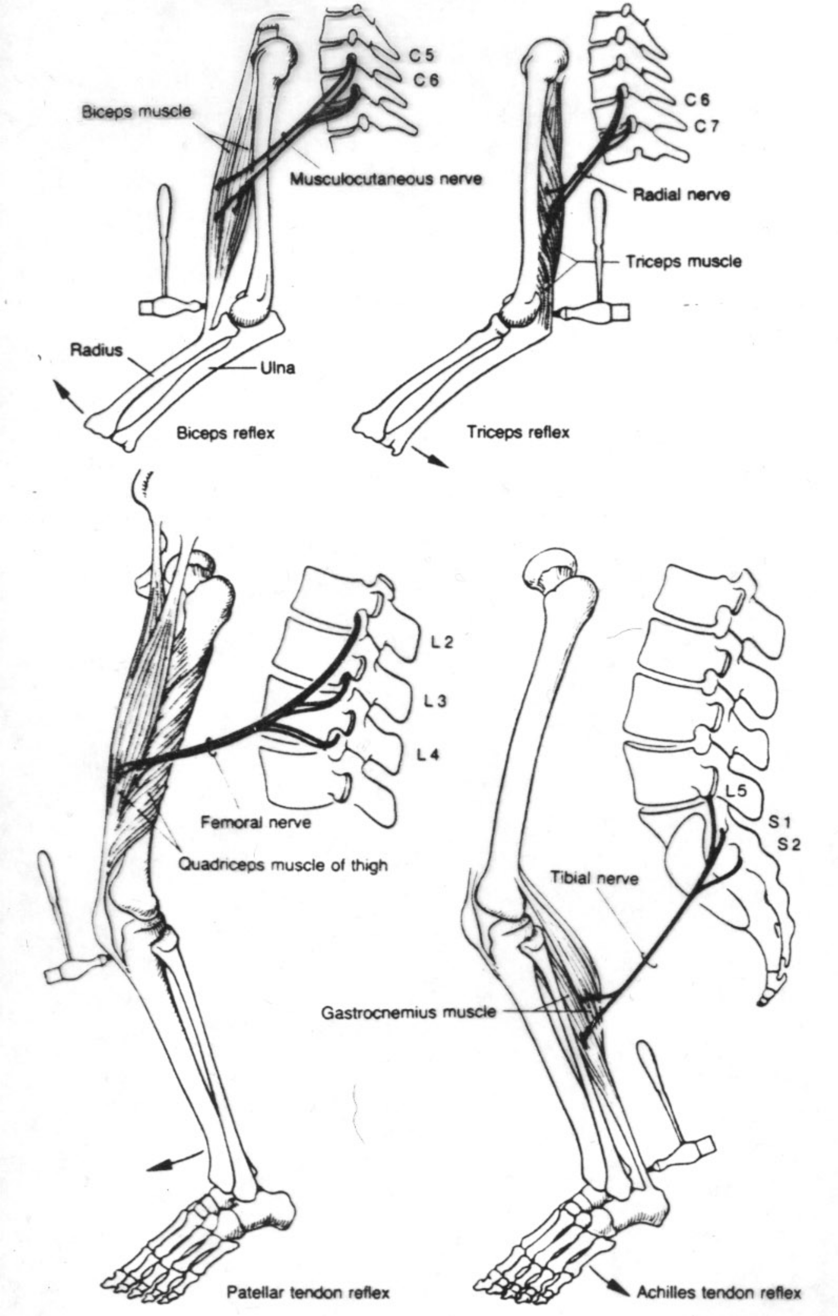
The mechanism of the gamma loop (Szentagothai)

Negative feedback regulation of muscle tension by Golgi tendon organs. Ib afferents from tendon organs contact inhibitory interneurons that decrease the activity of alfa motorneurons innervating the same muscle. Ib inhibitory interneurons also receive descending input. This arrangement prevents muscles from generating excessive tension. (Purves)

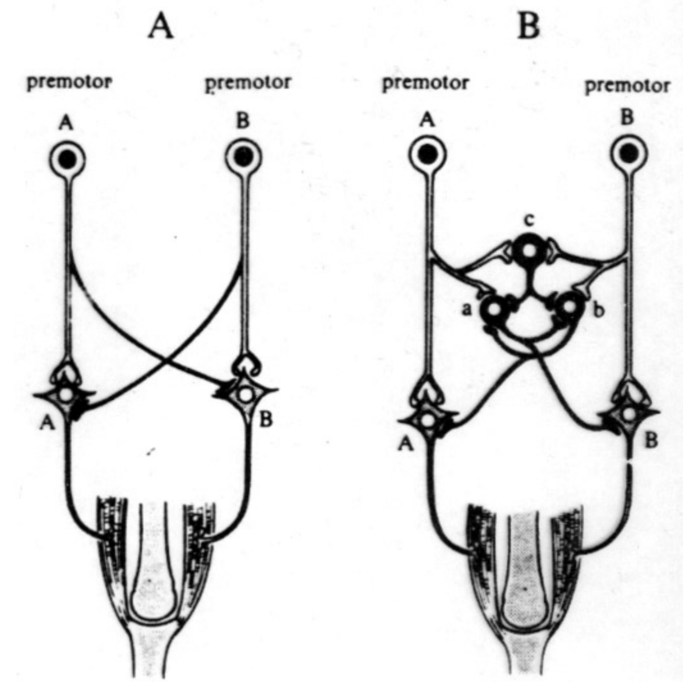




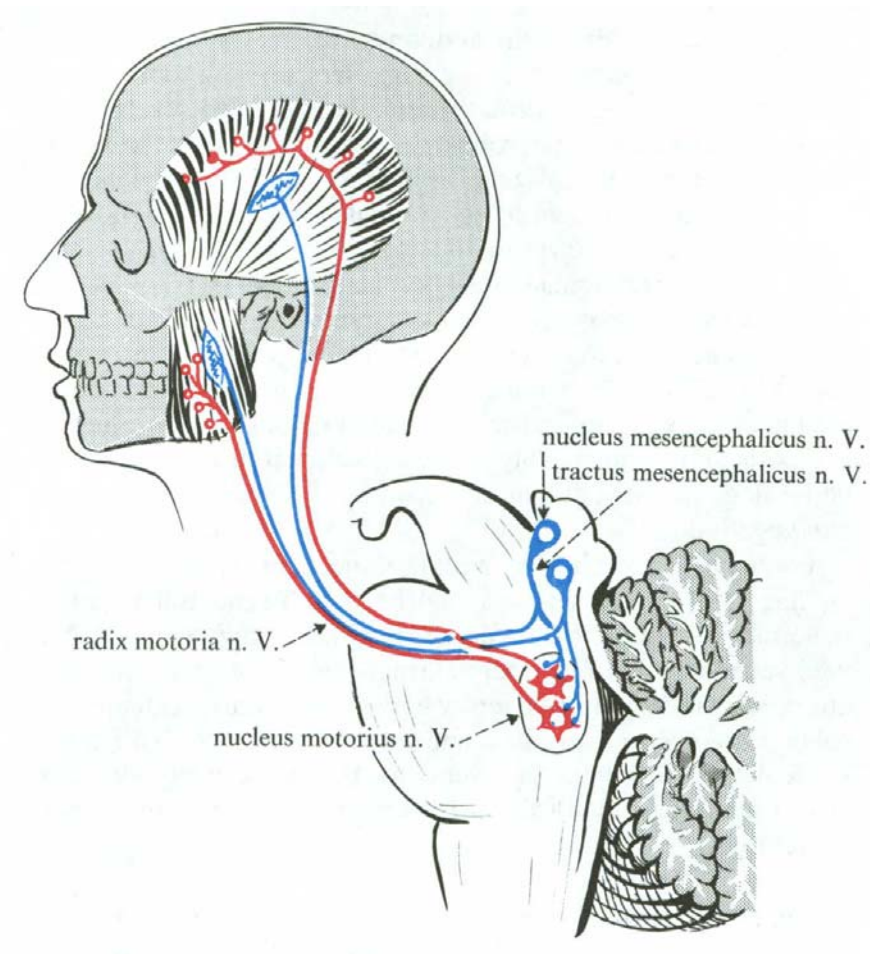
C

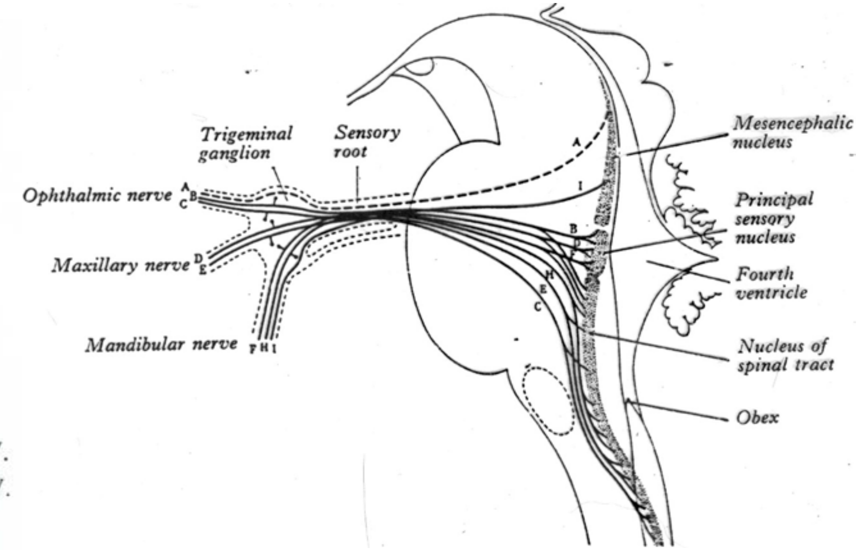


The most important proprioceptive reflexes (Duus).



Mechanism of reciprocal innervation. A: classical explanation. In this case either A or B motorneuron active in an exclusive fashion. B: involvements of inhibitory interneurons A and B motorneuron can work antagonistically or synergistically. Interneuron c is only active if both A and B premotor neurons are active, in this case c inhibits the inhibitory action of a and b inhibitory neurons, thus the stimulation of the premotor neurons A and B activate A and B motorneurons (Szentagothai).

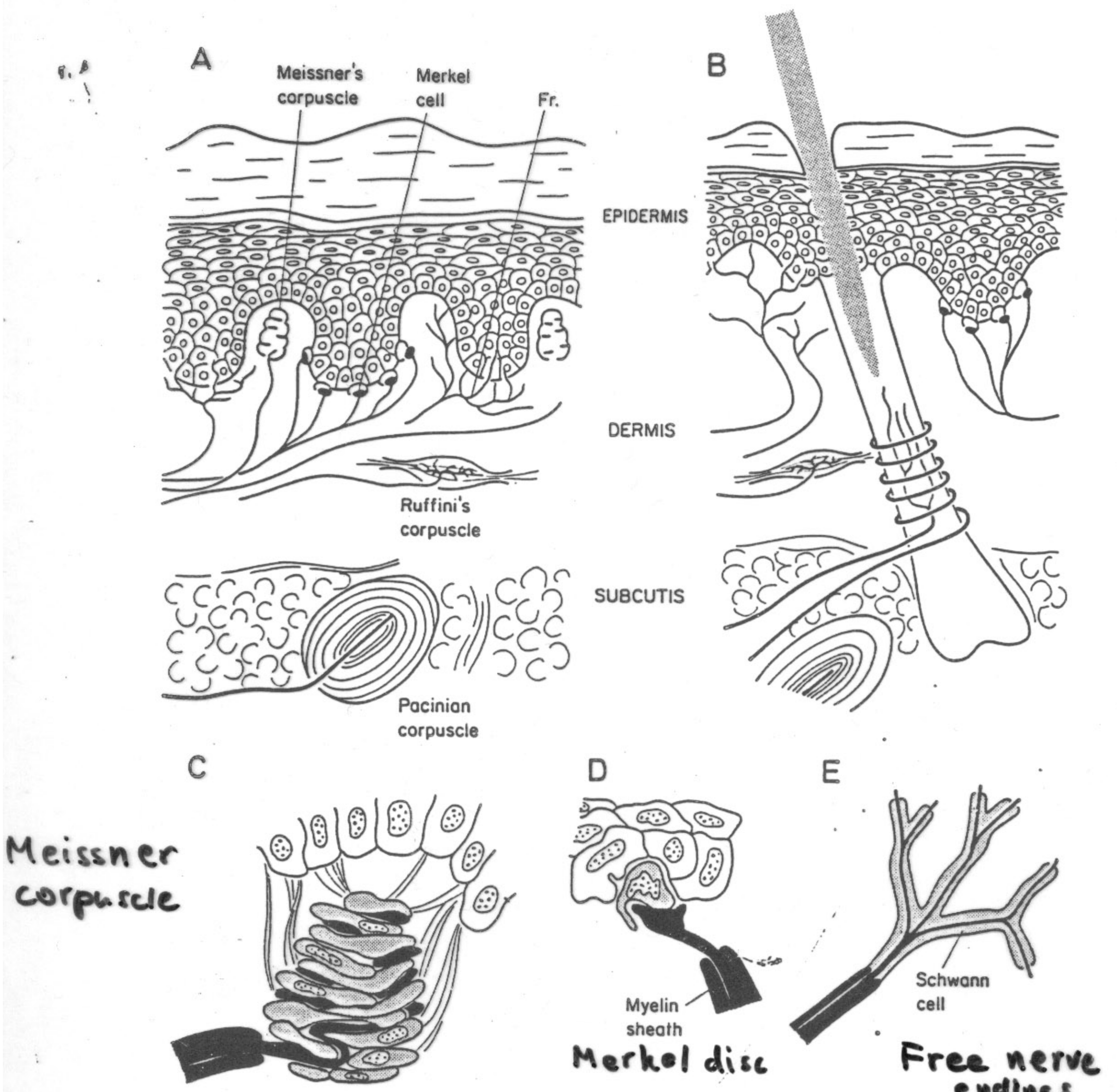




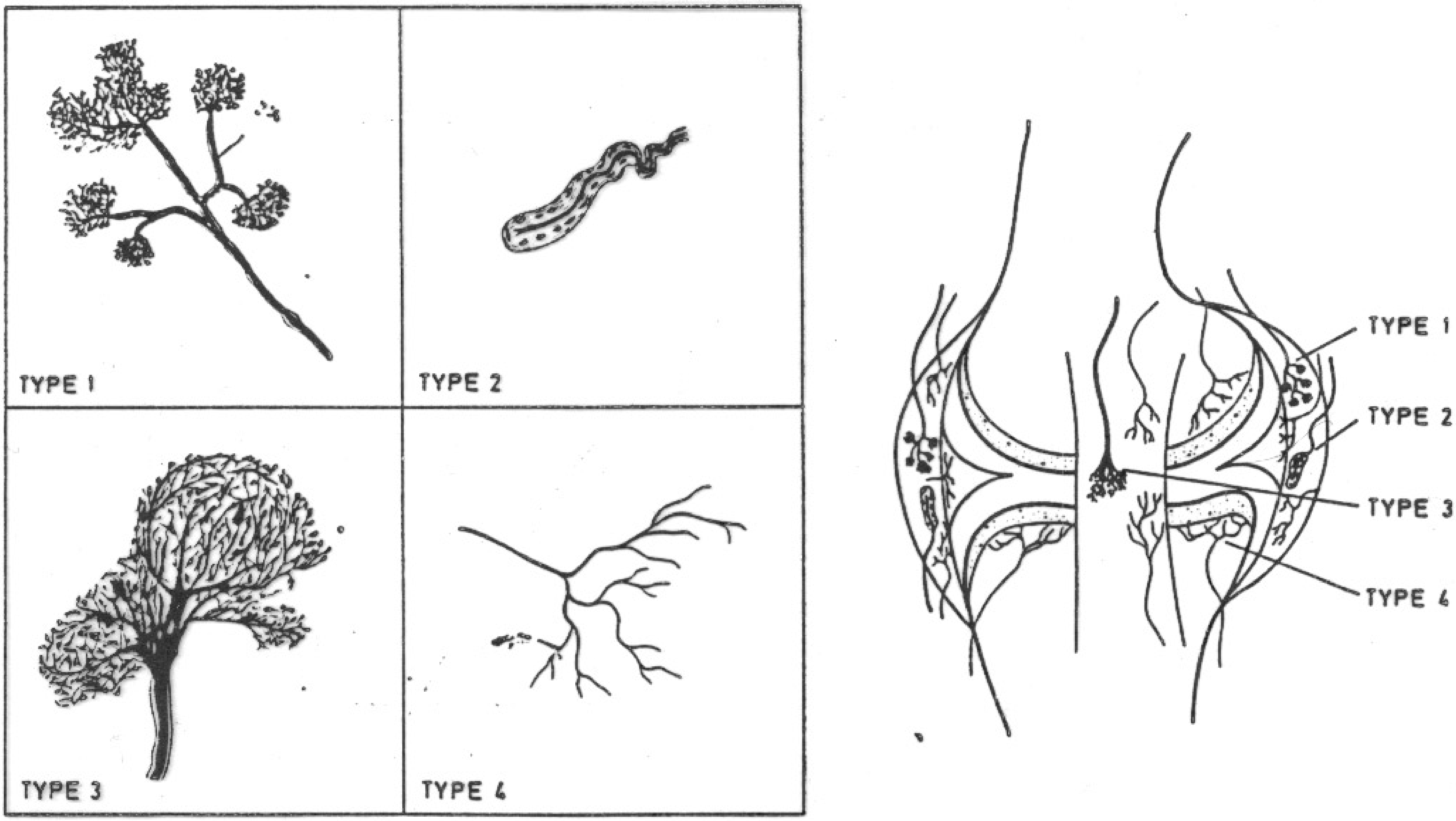
The nuclei receiving receiving the primary afferent fibers of the trigeminal nerve. A, I proprioceptive fibers. B,D, F: tactile and pressure, C, H: pain and temperature

Propriocetive reflex of the muscles of mastication (Szentagothai)

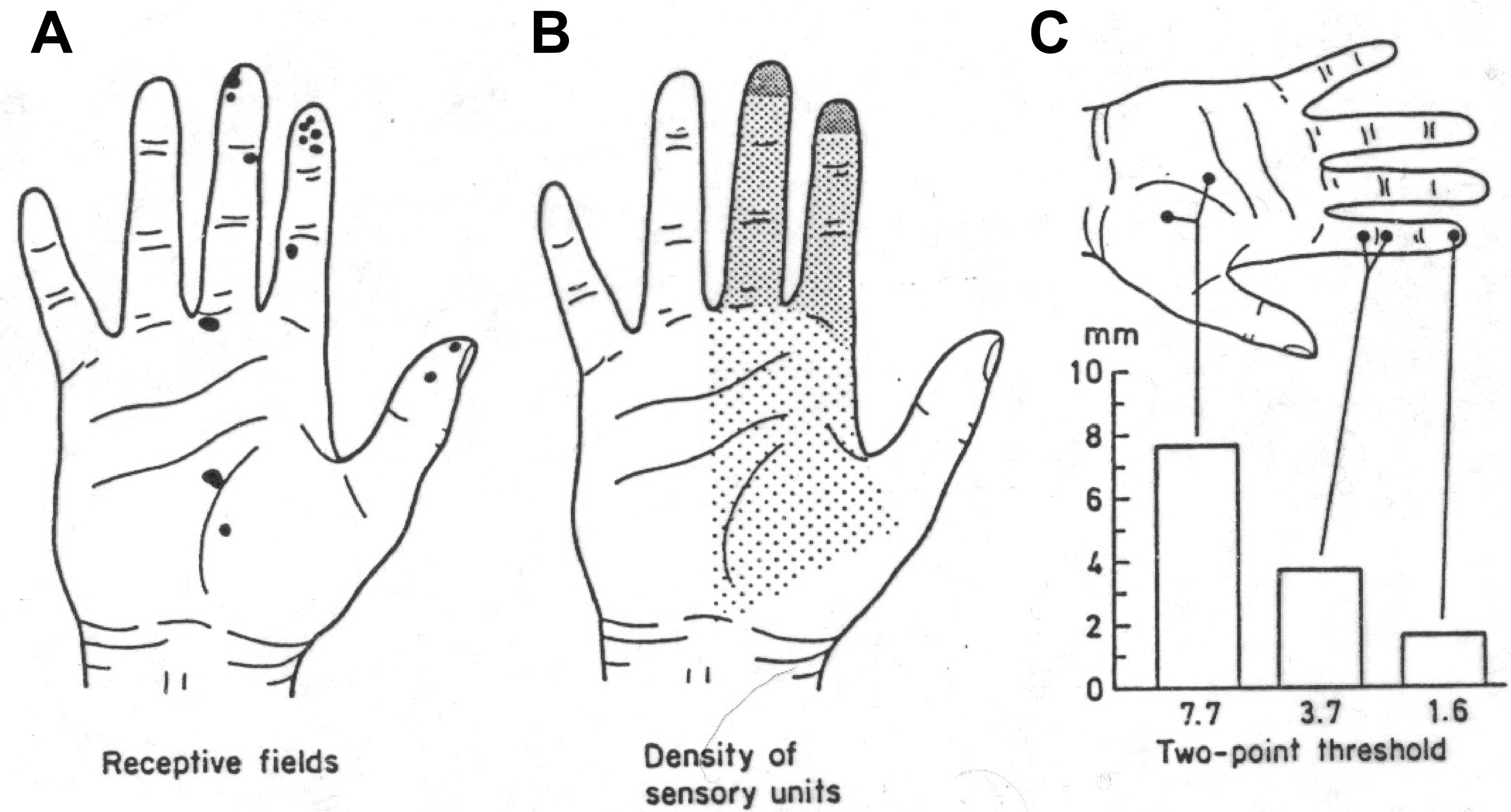
Cutaneous receptors



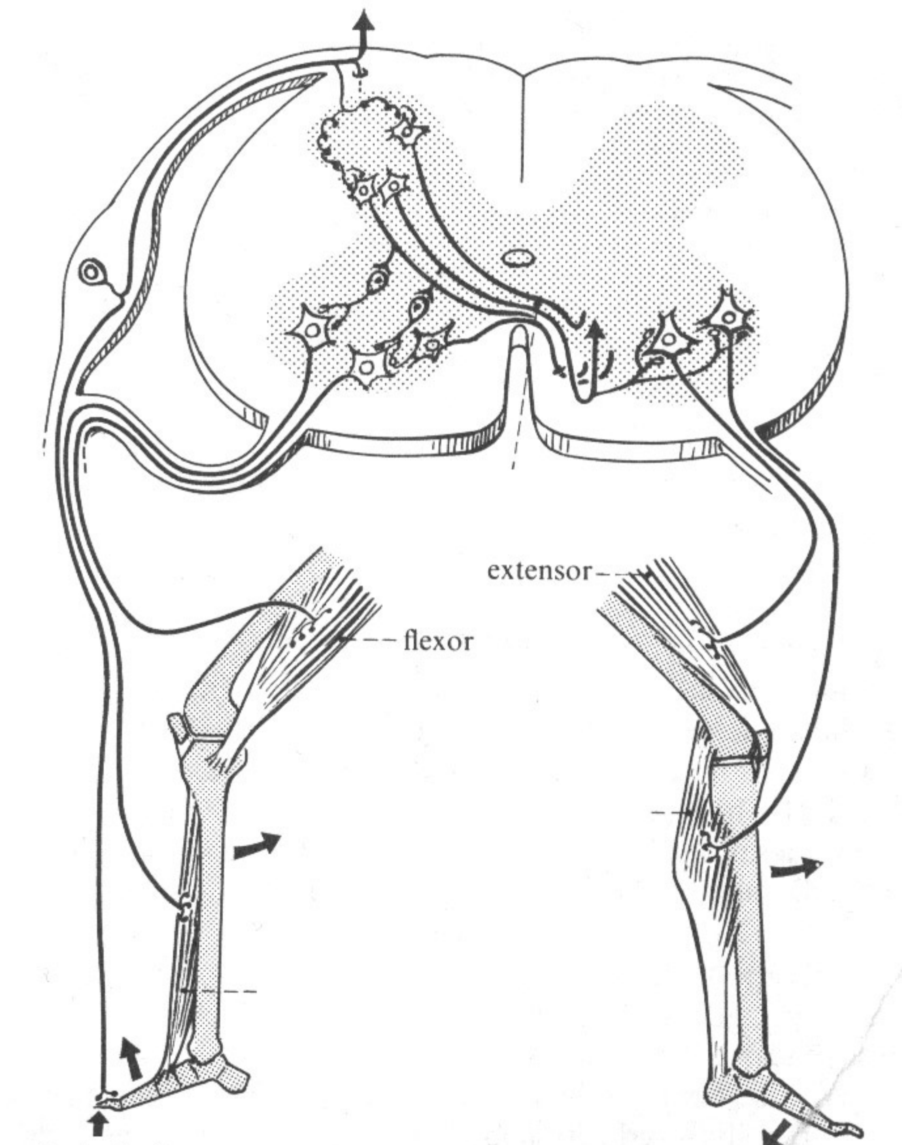
Schematic drawing of cutaneous receptors in the (A) glabrous skin (palm of the hands and soles of the feet) and (B) hairy skin. Nerve endings in hairy skin wind around the hair follicles and are activated by the slightest bending of the hair. Free nerve endings are covered by Schwann cells except at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



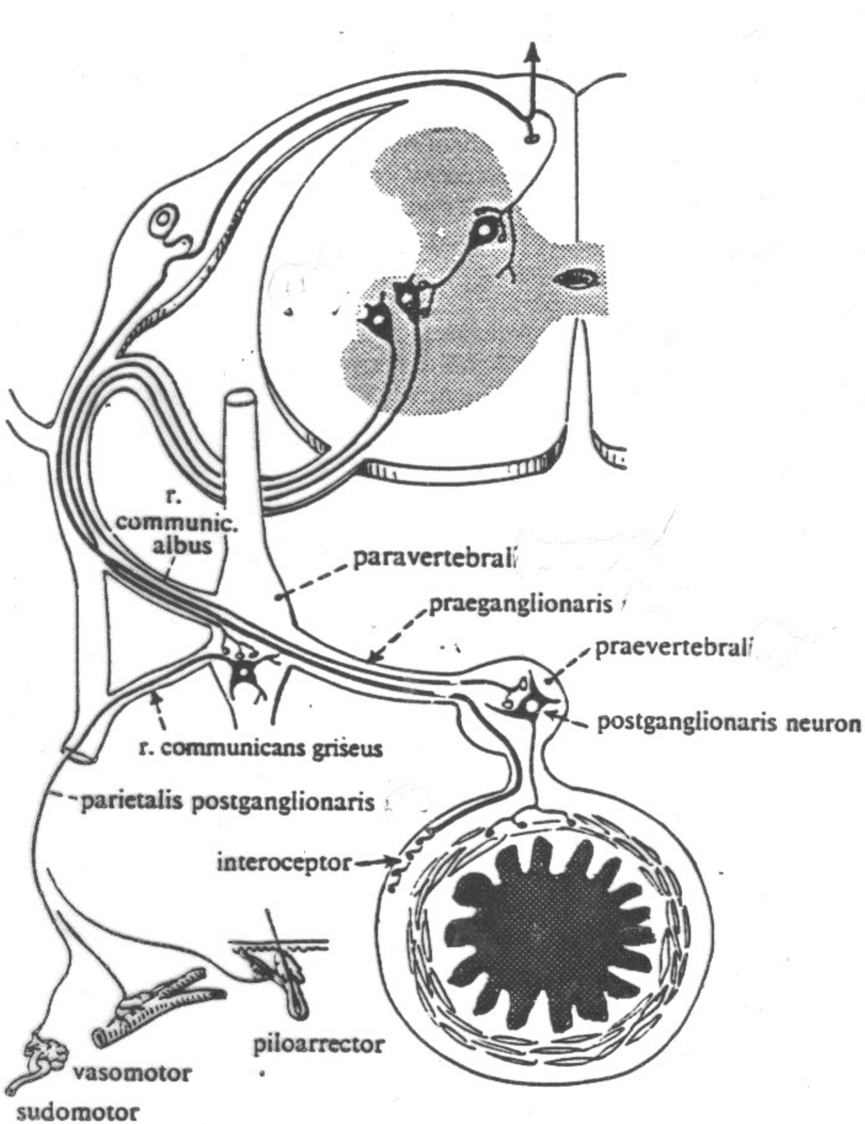
Joint innervation. A knee joint, showing the distribution of the various kinds of joint receptors, to the left shown in more detail (Brodal).



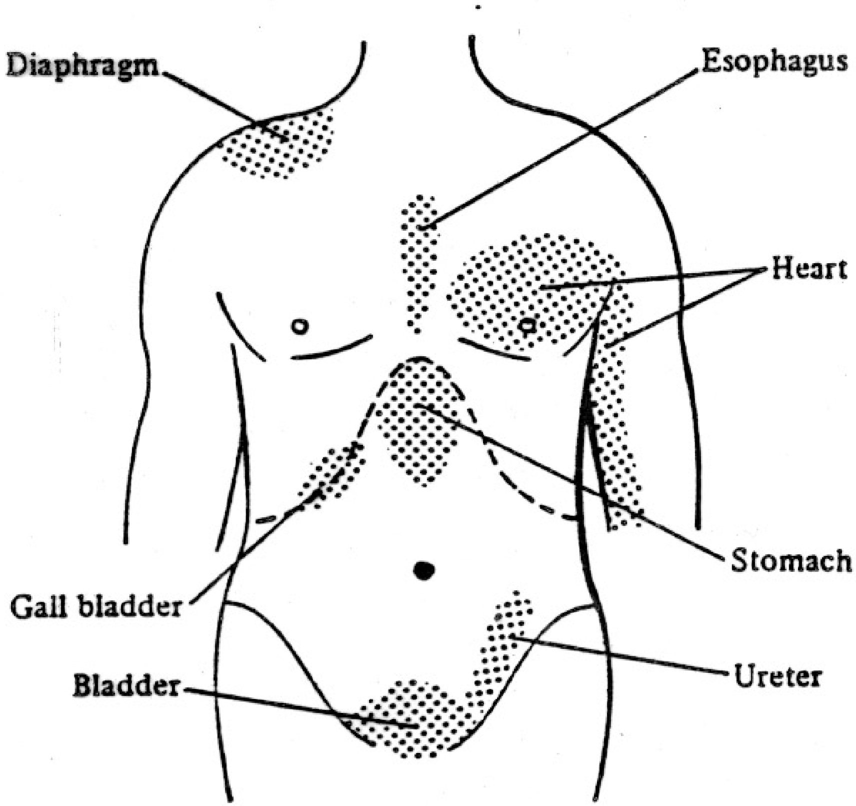
A: Receptive fields. Size and locations of the receptive fields of 15 sensory units, determined by recording from the median nerve. All of these sensory units were rapidly adapting and were most likely conducting from Meisner-corpuscles. Within each receptive fields there are many Meissner corpuscles, 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).



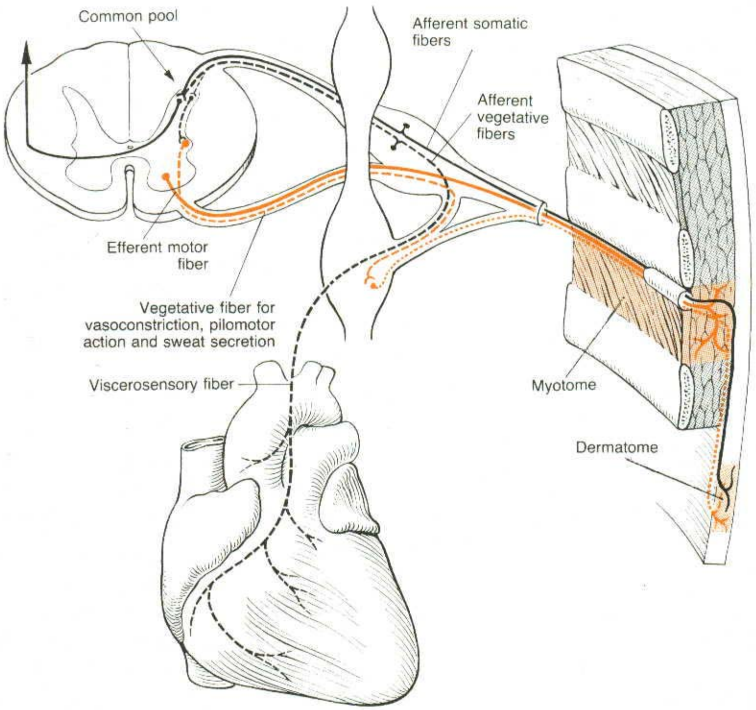
Flexion-crossed extension reflex. Stimualtion of cutaneous receptors in the foot leads to activation of spinal cord circduits that withdraw (flex) the stimulated extremitgy and extend th eother extremity to provide compensatory support (Szentagothai)



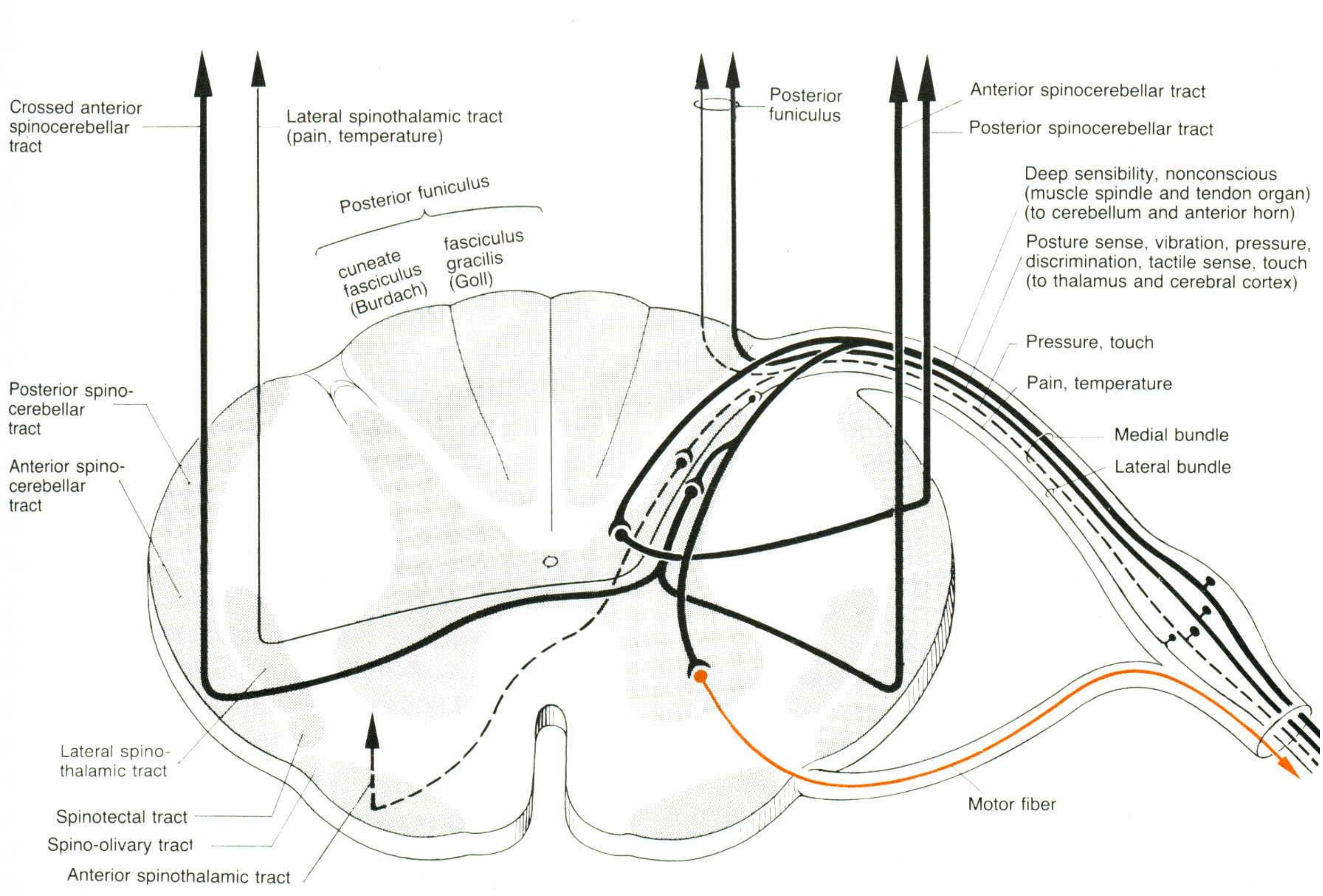
The vegetative reflex (Szentagothai).



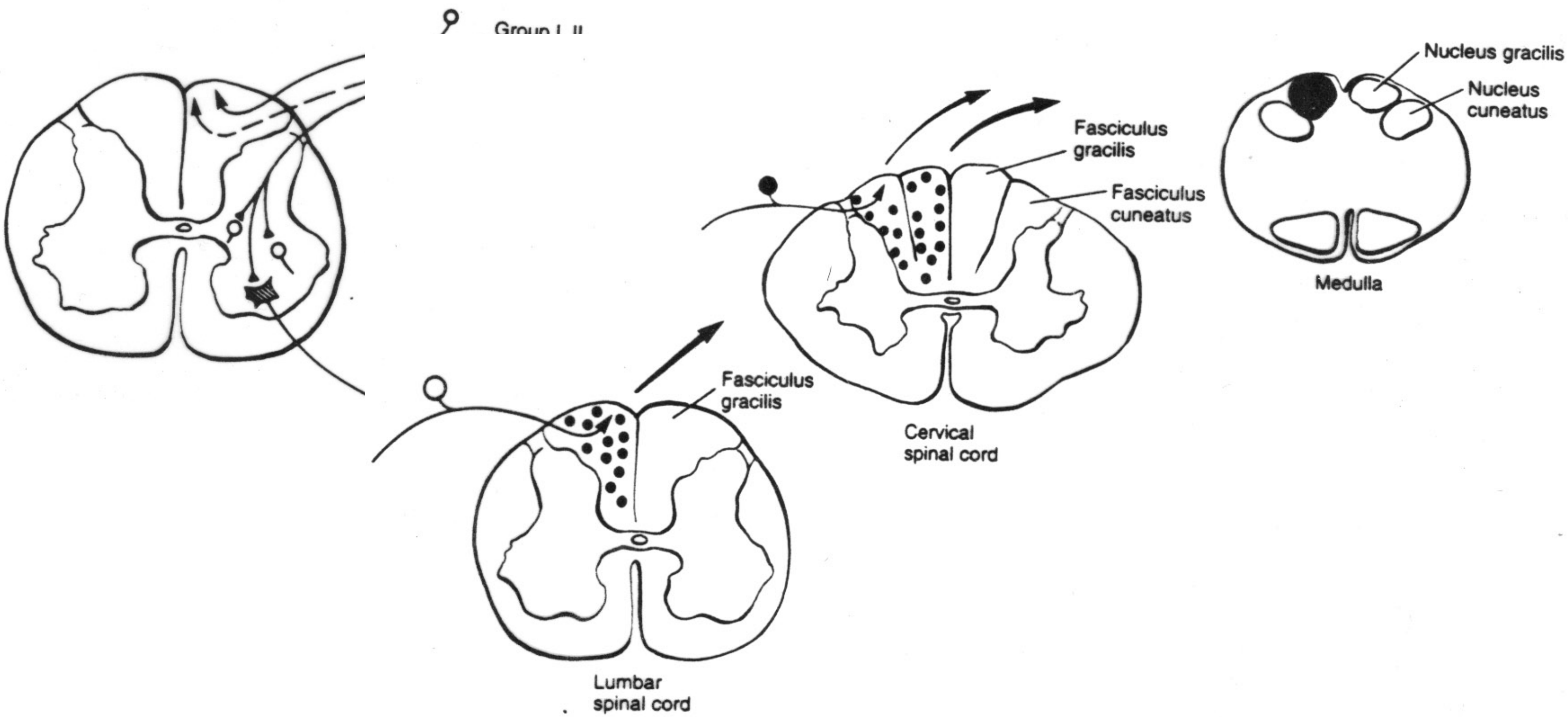
Referred pain. Diagram showing cutaneous sites of reference of visceral pain commonly encountered in medical practice. (Heimer)



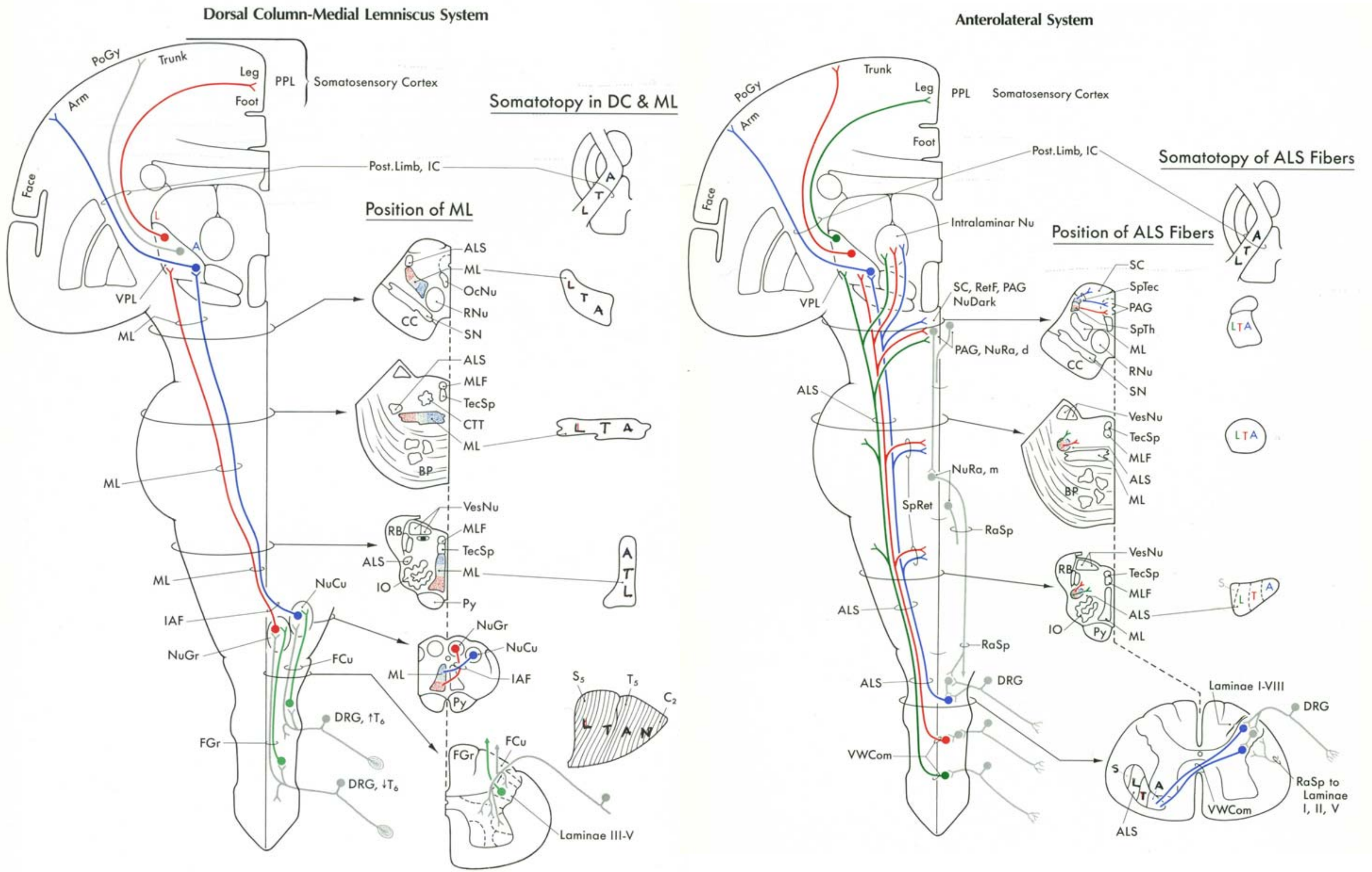
Viscerocutaneous reflex arc with myotome, dermatome and enterotome and somatic and autonomic connections for the explanation of referred pain (Duus)



Course of posterior root fibers in spinal cord (Duus)

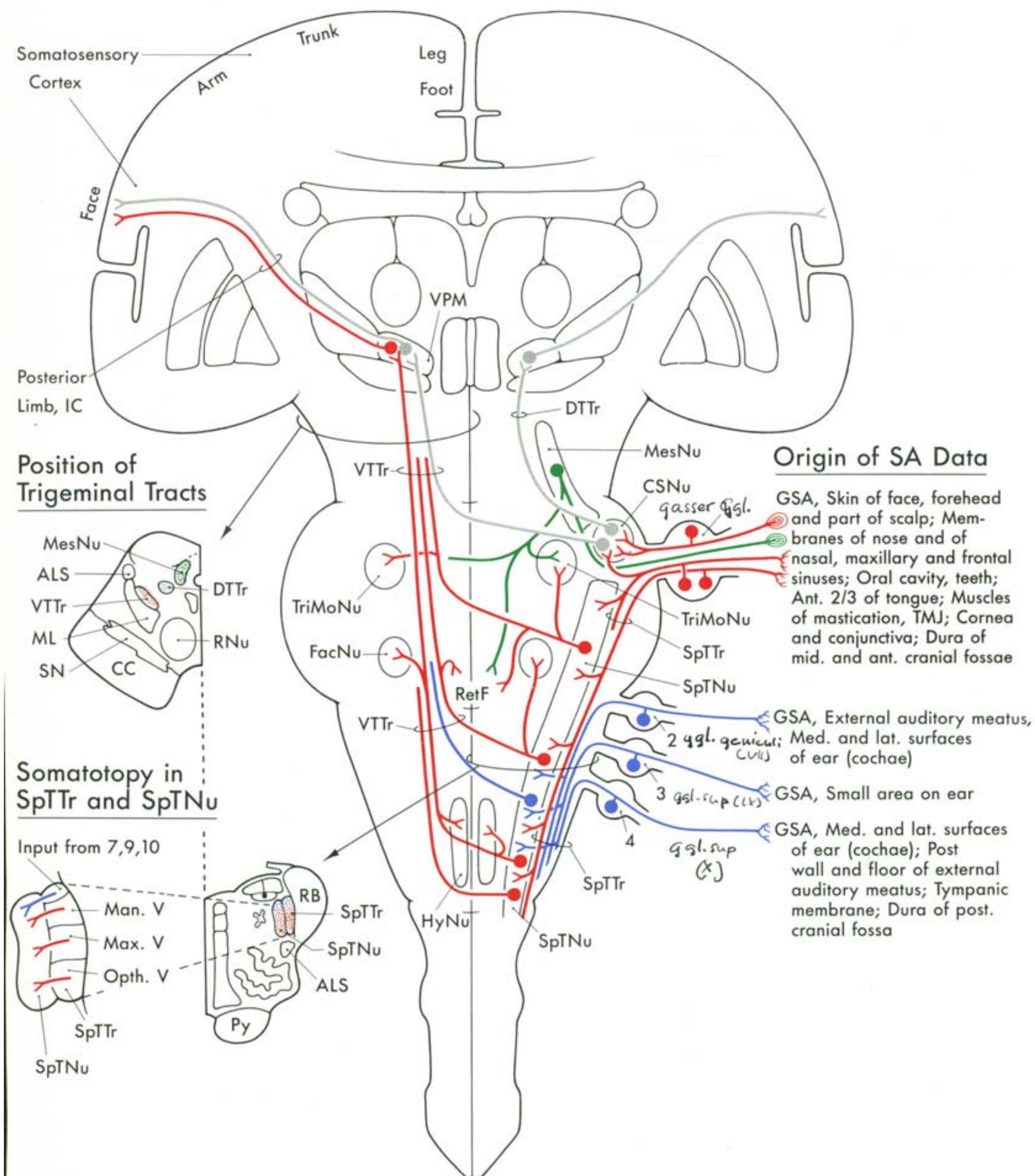


Axons mediating fine tactile sensibility form the medial division and enter the spinal cord and then continue into the gray matter at their level of entry, making reflex connections with motor neurons and interneurons at the level of entry, or ascend in the dorsal columns to terminate in the dorsal column nuclei. The axons arising from lumbar and low thoracic dorsal root ganglia ascend in the fasciculus gracilis and terminate in the n. gracilis. Axons arising from upper thoracic and cervical ganglia ascend in the more lateraqlly located fasc. Cuneatus and terminate in the n. cuneatus (Conn).

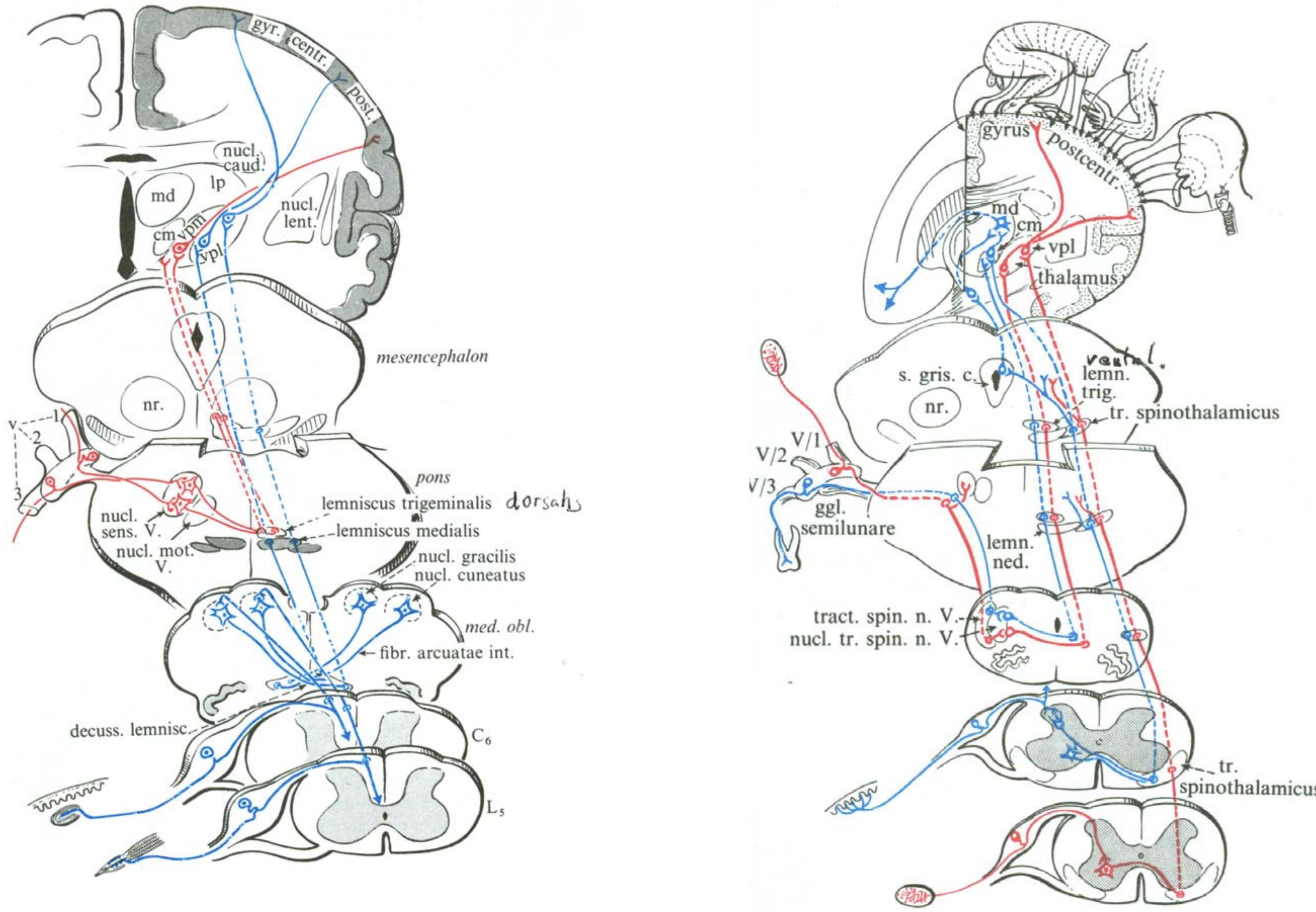


The origin, course and distribution of the dorsal column-medial lemniscus system (left) and the anterolateral system, respectively (Haines).

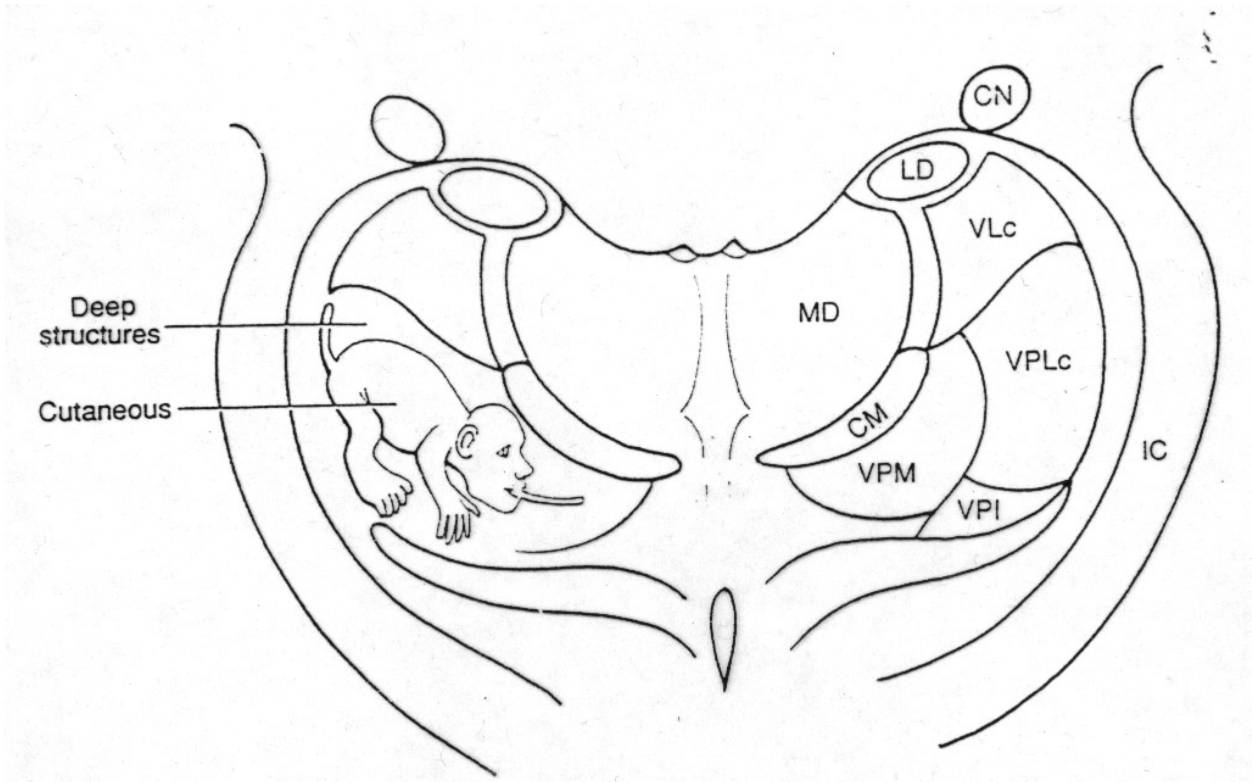
Trigeminal Pathways



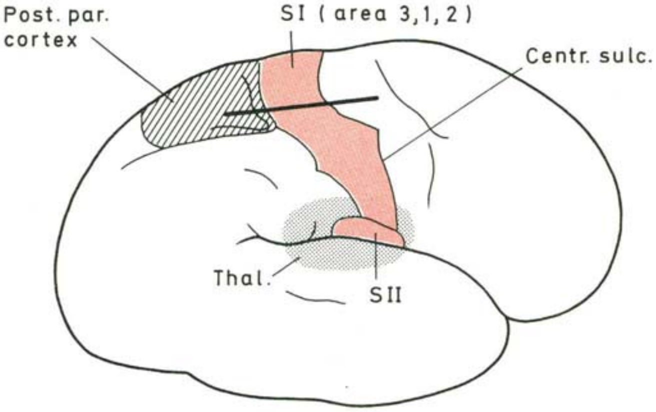
Haines



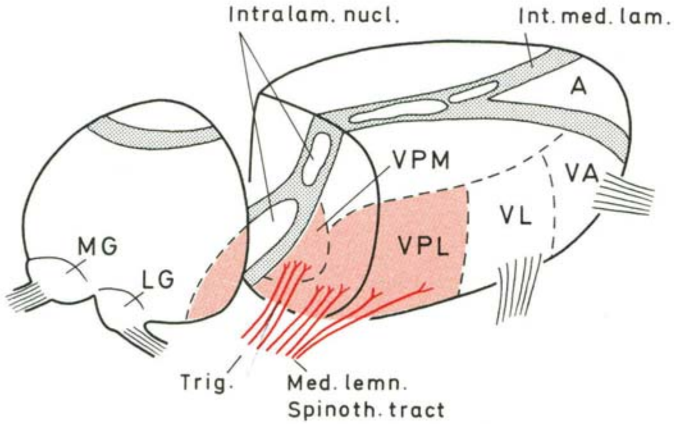
The dorsal column-medial lemniscus (left) and the spinothalamic systems (right). In the left figure the temperature sensitive axons are in blue, the pain-conducting fibers and the trigeminal system in red (Szentagothai)

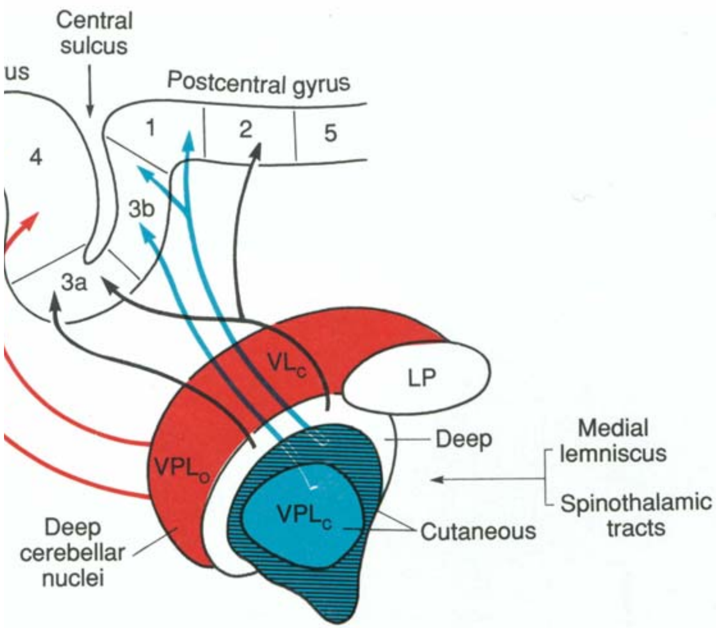


Schematic diagram of the ventrobasal complex in the monkey, indicating the cutaneous somatotopic representation of the body surface on the left. Neurons responsive to stimulation of deep receptors lie in a dorsal shell. Areas representing the head, face and tongue lie in the ventral posteromedial (VPM)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

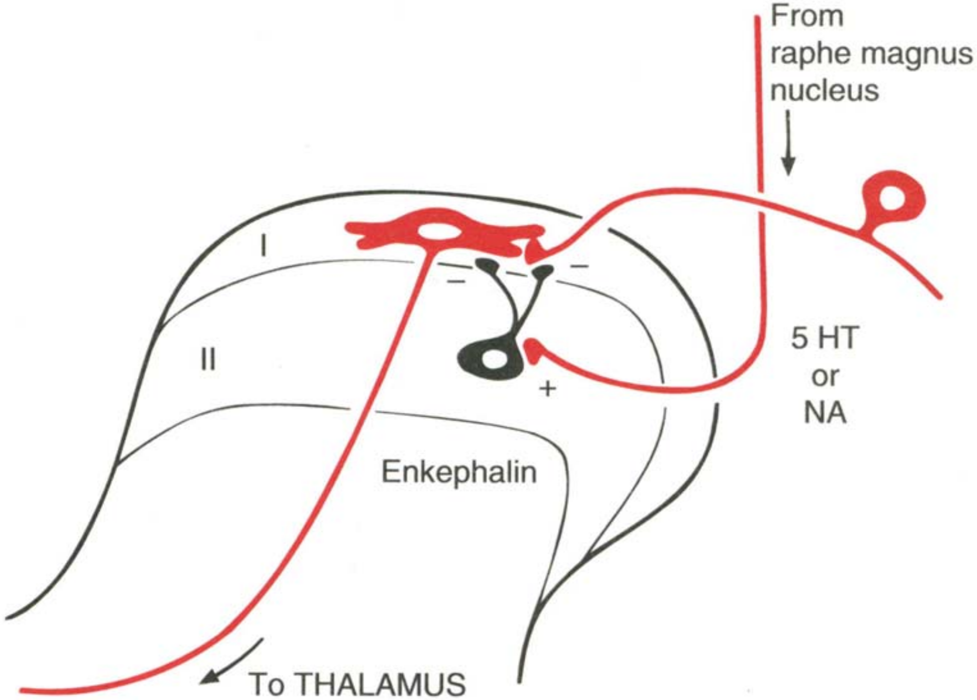


The somatosensory cortex and its thalamic afferent nuclei (Brodal)



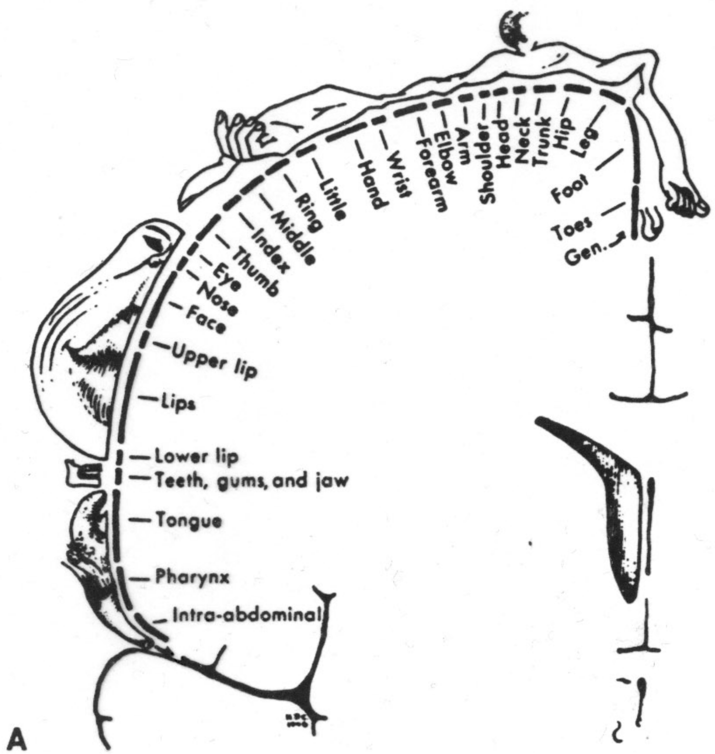


Schematic diagram in a sagittal plane showing projections of thalamic subdivisons to the sensorimotor cortex. Neurons in the ventral posterolateral (VPLc) and ventral poteromedial (VPM) nuclei (not shown) form a central core (blue) consisting of two parts (one represented by solid blue and another by 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).

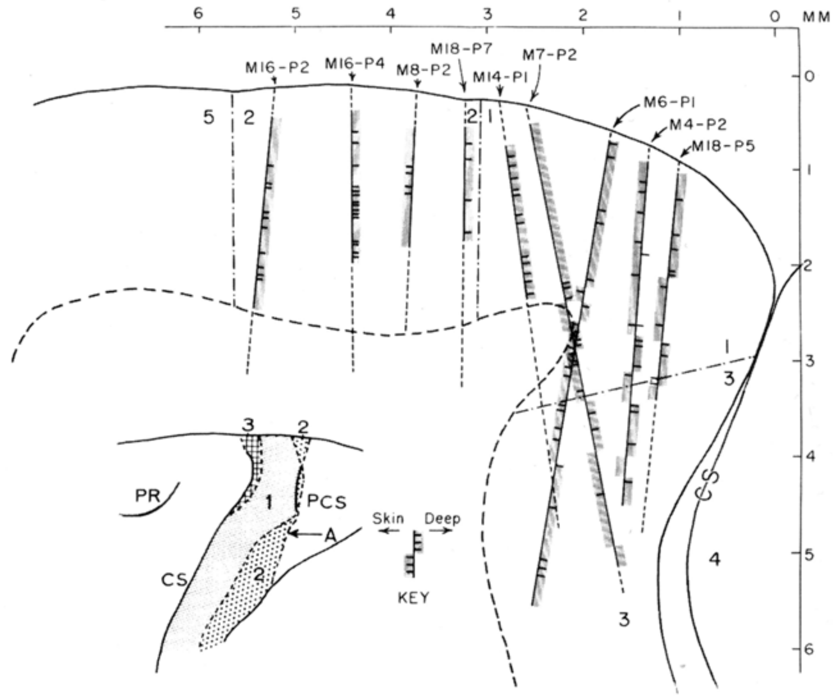


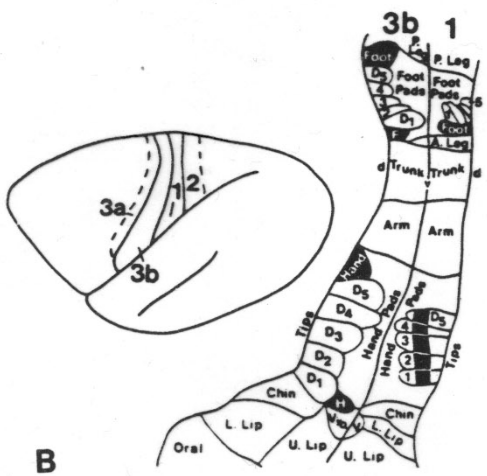
Central control of transmission from nociceptors. Brodal

SENSATION AND PERCEPTION

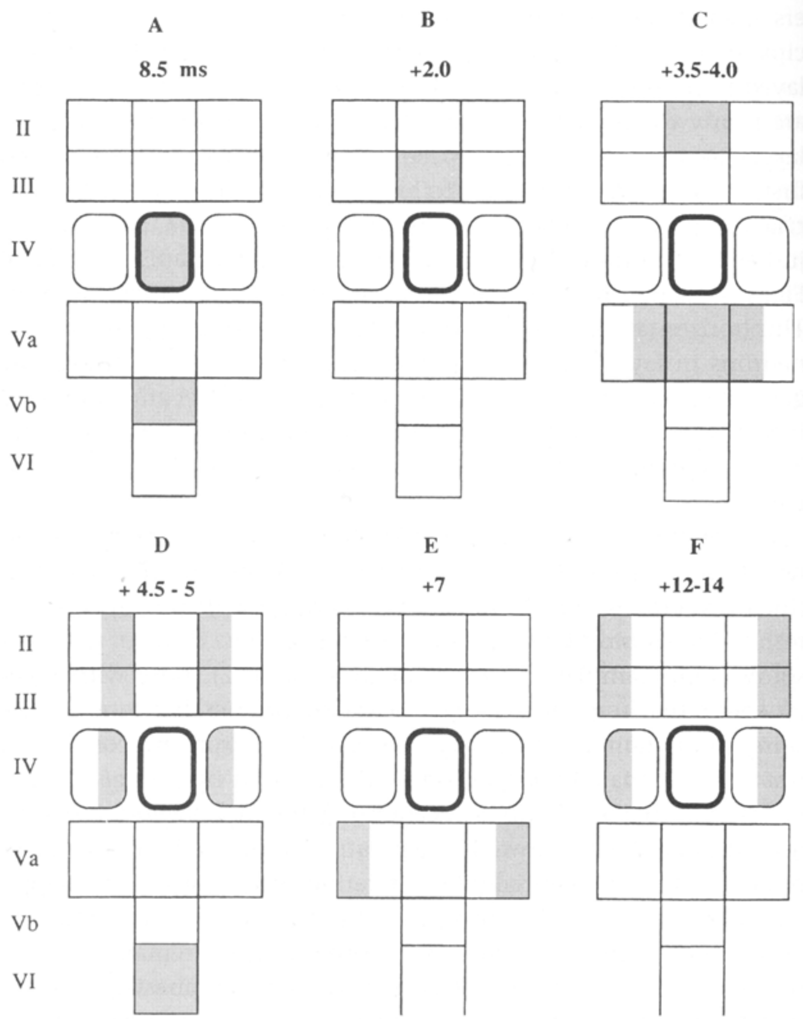


A:_The somatotopical representation in the_postcentral gyrus of man as revealed by electrical stimulation (Penfield, 1937). B: multiple representations of the skin surface in the postcentarl gyrus of Owl moneky (Merzenich and Kaas, 1980).





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)



Intracolumnar and pericolumnar flow of activity in a barrel of the somatic sensory cortex of anesthetized adult rats, evoked by brief deflection of the related contaqrlateral whisker. Cellular discharges were recorded with extracellular microelectrodes. A: cells in layer IV are activated at a mean laqtency of 8.5 msec. Cells within the column in layers II and Vb are activated 2.4 msec after those of LIV, simultaneously with LVa cells in near-neeighbor columns. Activity then spreads to near-neighbor layers II-IV and to LVI within the first column. The next cells activated are the far-neighbor LVa cells and the last group are the far-neighbor cells of LII, III and IV (Armstrong-James et al., 1992)