SOMATOSENSORY SYSTEM

- part of the sensory nervous system
- is a complex system of sensory neurons and neural pathways that responds to changes at the surface or inside the body
- is a complex system of sensory neurons and neural pathways that responds to changes at the surface or inside the body

formed by:

a. receptor cells
b. axons (as afferent nerve fibers) of sensory neurons connect with, or respond to, various receptor cells

- the somatosensory pathways also know as **ascending tracts** refer to the neural pathways by which sensory information from the peripheral nerves is transmitted to the cerebral cortex

SENSORY RECEPTORS:

send signals along a sensory nerve to the spinal cord where they may be processed by other sensory neurons and then relayed to the brain for further processing

activated by different stimuli such as

a. **thermoreceptor** - carries information about temperature changes.
b. **mechanoreceptors** - responds to mechanical pressure or distortion such as lamellar corpuscles (Pacinian corpuscles), tactile corpuscles (Meissner's corpuscles), Merkel nerve endings, and bulbous corpuscles (Ruffini corpuscle).
c. **chemoreceptors** - transduces a chemical substance to generate a biological signal such as taste receptors, carotid bodies.
d. **nociceptors** - pain receptor

1. external nociceptors found in skin (cutaneous nociceptors), the corneas, and the mucosa
2. internal nociceptors found in muscles, joints, bladder, digestive tract

- the cell bodies of these neurons are located in either the dorsal root ganglia or the trigeminal ganglia. the trigeminal ganglia are specialized nerves for the face, the dorsal root ganglia are associated with the rest of the body

A somatosensory pathway have three neurons

1. first-order
2. second-order
3. third-order.

1. the **first-order neuron** is a type of pseudounipolar neuron and always has its cell body in the dorsal root ganglion of the spinal nerve with a peripheral axon innervating touch mechanoreceptors and a central axon synapsing on the second-order neuron.
2. the **second-order neuron** has its cell body either in the spinal cord or in the brainstem. This neuron's ascending axons will cross (decussate) to the opposite side either in the spinal cord or in the brainstem.
3. in the case of touch and certain types of pain, the **third-order neuron** has its cell body in the ventral posterior nucleus of the thalamus and ends in the postcentral gyrus of the parietal lobe in the primary somatosensory cortex.

GENERAL SOMATOSENSORY (ASCENDING) PATHWAYS

DORSAL COLUMN–MEDIAL LEMNISCUS PATHWAY (LEMNISCUS MEDIALIS)

carries:

a. sensory modalities of **fine touch** (tactile sensation, discriminative touch - is a sensory modality that allows a subject to sense and localize touch.), **and vibration called as epicritic sensation**

b. **proprioception** - referred to as kinaesthesia (or kinesthesia), is the sense of self-movement and body position, mediated by proprioceptors, mechanosensory neurons located within muscles, tendons, and joints

- in the spinal cord, information travels via the dorsal (posterior) columns. In the brainstem, it is transmitted through the **medial lemniscus**.

three groups of neurones involved in this pathway:

a) first order neuron
b) second order neuron
c) third order neurones

a. **first order neuron:** ***ganglion spinale*** - carries sensory information regarding touch, proprioception or vibration from the peripheral nerves to the medulla oblongata. There are two different pathways which the first order neurones take:

- **Signals from the upper limb** – **travel in the fasciculus cuneatus** (the lateral part of the dorsal column). They **then synapse in the nucleus cuneatus of the medulla oblongata**
- **Signals from the lower limb** – **travel in the fasciculus gracilis** (the medial part of the dorsal column). They **then synapse in the nucleus gracilis of the medulla oblongata**

b. **second order neurones:** are the nucleus cuneatus or nucleus gracilis. Within the medulla oblongata, these fibres **decussate** (cross to the other side of the CNS - contralateral). They then travel in the contralateral medial lemniscus to reach the thalamus.

c. **third order neurones: located into the thalamus,** transmit the sensory signals from the thalamus to the ipsilateral primary sensory cortex of the brain. They ascend from the ventral posterolateral nucleus of the thalamus, travel through the internal capsule and terminate at the sensory cortex

ANTEROLATERAL SYSTEM

I. SPINOTHALAMIC TRACT

- somatosensory
- crosses over (decussates) at the level of the spinal cord
- three neurons to convey sensory information from the periphery to the cerebral cortex

in the spinal cord, the spinothalamic tract has somatotopic organization - this is the segmental organization of its cervical, thoracic, lumbar, and sacral components, which is arranged from most medial to most lateral

the spinothalamic tract consists of:

a. **The lateral spinothalamic tract** (tractus spinothalamicus lateralis
   - **transmits pain and temperature**

b. **The anterior spinothalamic tract** (or *ventral* spinothalamic tract, tractus spinothalamicus ventralis) - **transmits crude touch and firm pressure** (protopathic sensation)

TRACTUS SPINOTHALAMICUS VENTRALIS et LATERALIS

ganglion spinale is the first order neuron – its fibres carry sensory information from the skin. After entering the spinal cord the first order neurons synapse and the second order neurons, the axons of the second order neurons decussate via the anterior white commissure – than the crossed axons ascend synapsing in the VPL of the thalamus (third order neuron) – axons of the VPL travel through the internal capsule and terminate at the sensory cortex

II. LEMNISCUS TRIGEMINALIS DORSALIS

(dorsal trigeminal tract)

these tract carries sensory information about discriminative touch from the face and conscious proprioception from the facial and masticatory muscles from the principal sensory nucleus of the trigeminal nerve (nucleus sensorius principalis (pontinus) nervi trigemini) to the ventral posteromedial (VPM) nucleus of the thalamus

The first-order neurons are in the trigeminal ganglion – they axons enter the pons and synapse on second-order neurons in the principal sensory nucleus of the trigeminal nerve - its axons then decussate to enter the trigeminal lemniscus (lemnsicus trigeminalis dorsalis) and then ascend to the ventral posteromedial nucleus of the contralateral thalamus (third order neurons. The third order neurons in the thalamus ascend to the sensory cortex of the postcentral gyrus.

III. LEMNISCUS TRIGEMINALIS

convey:

- crude and discriminative touch, pain, and temperature impulses from the skin of the face, the mucous membranes of the nasal and oral cavities, and the eye

The first order neurons are in the trigeminal ganglion), they axons enter the pons and synapse in the spinal trigeminal nucleus (nucleus tractus spinalis nervi trihemini – second order neurons). Axons of the second order neurons cross the midline and as trigeminal lemniscus (lemniscus trigeminalis) ascend and terminate in the ventral posteromedial nucleus of the contralateral thalamus (thoird order neurons). The third order neuron in the thalamus connects to the sensory cortex of the postcentral gyrus

IV. SPINOCEREBELLAR TRACTS

- carry **unconscious proprioceptive** information - physically can not acknowledge these signals, but they help the brain to co-ordinate and refine motor movements
- transmit infromation from the proprioceptors (muscle receptros, joint receptors, Golgi – tendon organs)
- information processed in the cerebellum and therefore processed unconsciously

the tract is subdivided into:

a. **dorsal spinocerebellar tract (tractus spinocerebellaris dorsalis)**
b. **ventral spinocerebellar tract (tractus spinocerebellaris ventralis)**

TRACTUS SPINOCEREBELLARIS DORSALIS:

- conveys proprioceptive information from proprioceptors in the skeletal muscles and joints from the hindlimb to the cerebellum
- carries proprioceptive information from muscle spindles and Golgi tendon organs of ipsilateral part of trunk and lower limb
- ipsilateral („non - crossed”) pathway

Proprioceptive information is taken to the spinal cord via central processes of dorsal root ganglia (first order neurons). These central processes travel through the dorsal horn where they synapse with second order neurons of Clarke's nucleus (nucleus dorsalis – second order neuron). Axon fibers from Clarke's Nucleus form this pathway and run in the spinal cord in the funiculus lateralis ipsilaterally. The fibers run through the medulla oblongata of the brainstem, than pass through the caudal cerebellar peduncle (pedunculus cerebellaris caudalis) and enter the cerebellum (spinocerebellum)

TRACTUS SPINOCEREBELLARIS VENTRALIS:

- carries proprioceptive information from the hind limbs of the lumbosacral region
- the fibres decussate twice – and so terminate in the ipsilateral cerebellum

gets its proprioceptive/fine touch/vibration information from a first order neuron, with its cell body in dorsal ganglion. The axon runs to the dorsal horn of the grey matter. There it makes a synapse with second order neurons, their axons cross in the commissura alba and run contralateraly as tractus spinocerebellaris ventralis bilaterally to the ventral border of the lateral funiculi. The ventral spinocerebellar tract then enters the cerebellum via the rostral cerebellar peduncle (pedunculus cerebellaris rostralis)

V. TRACTUS SPINOOLIVARIS – OLIVOCEREBELLARIS

- located in the anterior funiculus of the spinal cord
- provides transmission of unconscious proprioception
- involved in balance
- a non - specific indirect ascending pathway and is connected to olivary nuclei

The axons enter the spinal cord from the dorsal root ganglia)first order neuron) and terminate on second-order neurons in the posterior grey column. Axons from the second-order neurons cross the midline and ascend as the spino-olivary tract in the white matter. The axons end by synapsing on third-order neurons in the medial and posterior accessory olivary nuclei (nucleus olivares accessorii med. et lat. – third order neurons) in the medulla oblongata. The axons of the third-order neurons cross the midline and enter the cerebellum through the caudal cerebellar peduncle.

TRACTUS OLIVOCEREBELLARIS: neural fibers which originate at the olivary nucleus. it attaches tot he spinoolivar tract and enter the cerebellum through the caudal cerebellar peduncle

VI. TRACTUS SPINORETICULARIS

- an ascending pathway in the white matter of the spinal cord
- its fibers run into the ventral spinothalamic tract
- the tract is from spinal cord—to reticular formation (in brain stem) — to thalamus.
- responsible for automatic responses to pain, such as in the case of injury

DESCENDING PATHWAYS

I. **PYRAMIDAL TRACT (tractus corticospinalis et tractus corticonuclearis)**
II. **EXTRAPYRAMIDAL SYSTEM**
III. **ASCENDING VEGETATIV and MONOAMINERG PATHWAYS**

I. PYRAMIDAL TRACT (TRACTUS CORTICOSPINALIS)

- the efferent (descending) nerve fibers come from the upper motor neurons that travel from the cerebral cortex and terminate either in:
  a. the brainstem (corticobulbar tract)
  b. spinal cord (corticospinal tract)
- involved in the control of motor functions of the body

Nerve fibres originate from pyramidal cells in layer V of the cerebral cortex (so called Betz – giant neurons). Axons of the Giant pyramidal cells of Betz form the pyramidal tract. The axons travel from the cortex through the posterior limb of internal capsule, through the cerebral peduncle into the brainstem and medulla oblongata. In medulla oblongata the majority of axons (about 80%) cross over to the opposite side (decussatio pyramidorum). The axons that cross over move to lasteral funiculus of the medulla oblongata and form the lateral corticospinal tract (tractus corticospinalis lat. seu crutiatus). The fibres that remain (10%, non – crossed) form the anterior corticospinal tract (tractus corticospinalis ventralis seu directus). These tracts travel down in the white matter of the spinal cord until they reach the vertebral level of the muscle that they will innervate and at this point, the axons synapse with lower motor neurons (alpha – motoneurons). The axons of the lateral corticospinal tract that did not cross over in the medulla oblongata, will be crossed at the level of the spinal cord they terminate

TRACTUS CORTICOBULBARIS

- conducts impulses from the brain to the cranial nerves - these cranail nerves control the muscles of the face and neck and are involved in facial expression, mastication, swallowing, and other motor functions

Fibres from the motor cortex travel with the corticospinal tract through the internal capsule, but terminate on the lower motor neurons located in the motor cranial nerve nuclei, namely oculomotor, trochlear, motor nucleus of the trigeminal nerve, abducens, facial nerve and accessory and in the nucleus ambiguus to the hypoglossal, vagus and accessory nerves

II. EXTRAPYRAMIDAL SYSTEM

- part of the motor system network
- causes involuntary actions
- centers on the modulation and regulation (indirect control) of alpha – motoneurons
- modulated by nigrostriatal pathway, the basal ganglia, the cerebellum, the vestibular nuclei, and different sensory areas of the cerebral cortex

the extrapyramidal tracts include:

- rubrospinal tract (tractus rubrospinalis)
- vestibulispinal tract (tractus vestibulospinalis)
- tectospinal tract (tractus tectospinalis)
- olivospinal tract (tractus olivospinalis)

TRACTUS RUBROSPINALIS

- responsible for large muscle movement
- regulate flexor and inhibiting extensor tone
- controls the fine motoric
- originates in the magnocellular red nucleus (in midbrain)
- in midbrain crosses to the other side of the midbrain
- descends in the spinal cord
- found in the lateral funiculus of the spinal cord
- terminates primarily in the cervical and thoracic portions of the spinal cordm – controlls the functions in upper limb

TRACTUS VESTIBULOSPINALIS

- a component of the extrapyramidal system
- part of the vestibular system also

The primary role of the vestibular system is to maintain head and eye coordination, upright posture and balance, and conscious realization of spatial orientation and motion

originates in the lateral vestibular nucleus or Deiters' nucleus in the pons. the fibers descend uncrossed, or ipsilateral, in the anterior portion of the lateral funiculus of the spinal cord. Fibers run down the total length of the spinal cord and terminate at the interneurons, which relay the signal to the motor neurons in antigravity muscles, these antigravity muscles are extensor muscles in the legs that help maintain upright and balanced posture.

TRACTUS TECTOSPINALIS

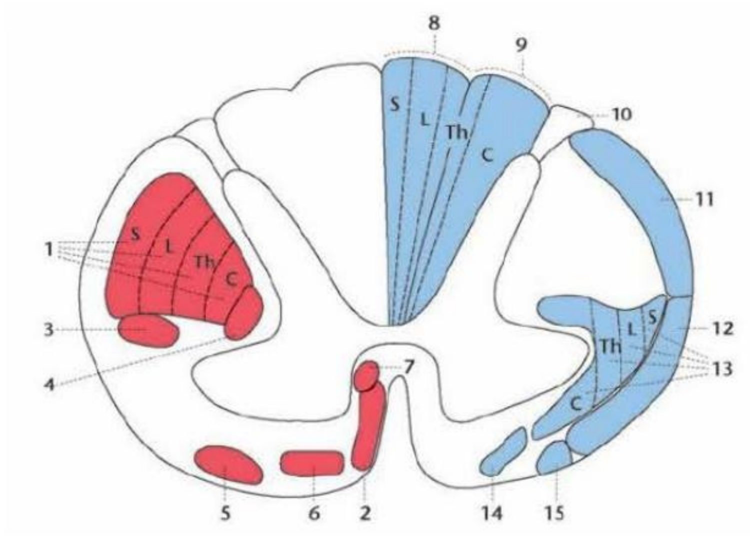
- coordinates head and eye movements - mediating reflex postural movements of the head in response to visual and auditory stimuli
- connects the tectum mesencephali and cervical regions of the spinal cord

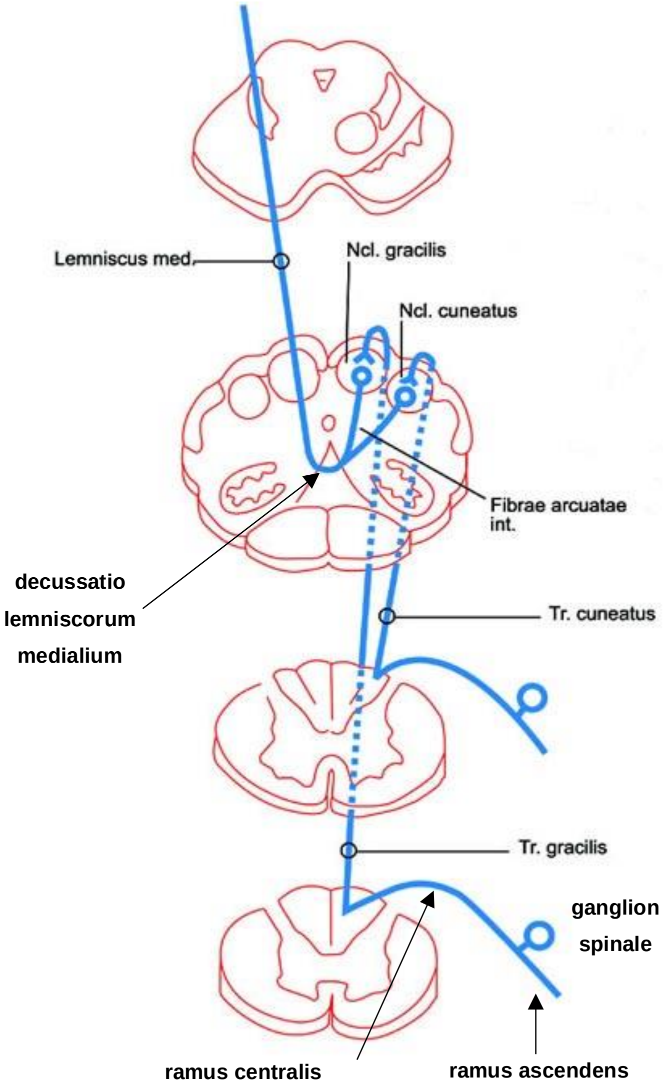
originates from the rostral colliculus, which receives afferents from the visual nuclei (primarily the oculomotor nuclei complex) then the fibers cross each others (decussatio tegmenti dorsalis Meynert) and project to the contralateral and ipsilateral portion of the first cervical segments of the spinal cord, the oculomotor and trochlear nuclei in the midbrain and the abducens nucleus in the caudal portion of the pons

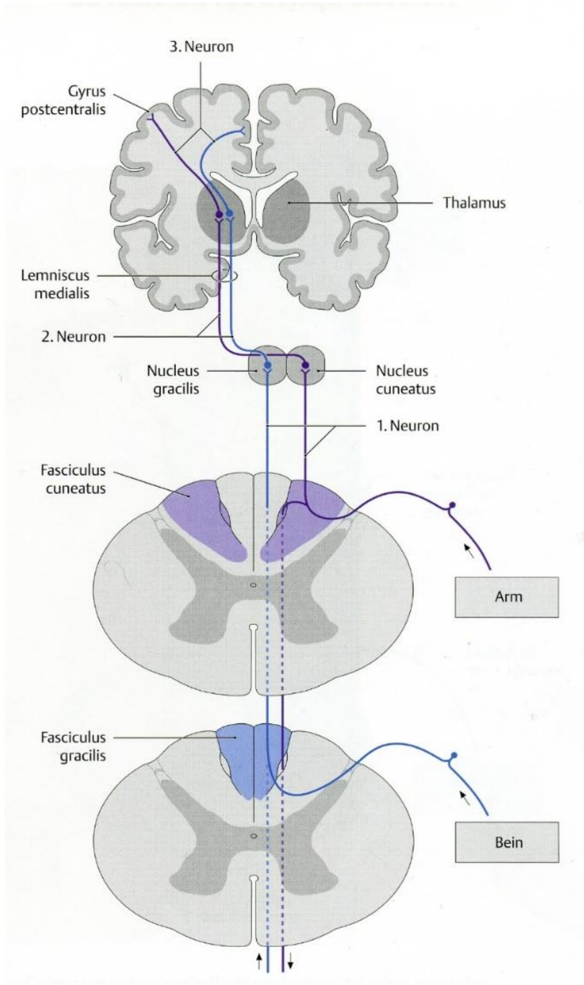
TRACTUS OLIVOSPINALIS

- arise in the vicinity of the inferior olivary nucleus in the medulla oblongata,
- descends close to the most lateral of the anterior nerve roots.
- exists in the cervical region of the medulla spinalis

Abb. 3.13 Lokalisation und Somatotopik der auf- und absteigenden Rückenmarksbahnen. Links absteigende Bahnen (motorisch, rot), **rechts** aufsteigende Bahnen (sensibel, blau). **Motorisch: 1** Tractus corticospinalis lateralis (somatotopisch gegliedert), **2** Tractus corticospinalis anterior (**1** und **2** = Pyramidenbahn). **3–7:** Extrapyramidale Bahnen. **3** Tractus rubrospinalis, **4** Tractus reticulospinalis (Fibrae reticulospinales), **5** Tractus olivospinalis, **6** Tractus vestibulospinalis, **7** Tractus reticulospinalis (zusätzlicher Anteil zu **4**).
Sensibel: 8 Fasciculus gracilis (Fasern aus Sakral-, Lumbal- und kaudalen Thorakalsegmenten), **9** Fasciculus cuneatus (Fasern aus kranialen Thorakal- und allen Zervikalsegmenten), **10** Hinterwurzel (Radix dorsalis), **11** Tractus spinocerebellaris posterior, **12** Tractus spinocerebellaris anterior (**11** und **12**: Kleinhirnseitenstrangbahn), **13** Tractus spinothalamicus lateralis (somatotopisch gegliedert), **14** Tractus spinothalamicus anterior (**13** und **14**: sensible Vorderseitenstrangbahn), **15** Tractus spinoolivaris. (aus [4])







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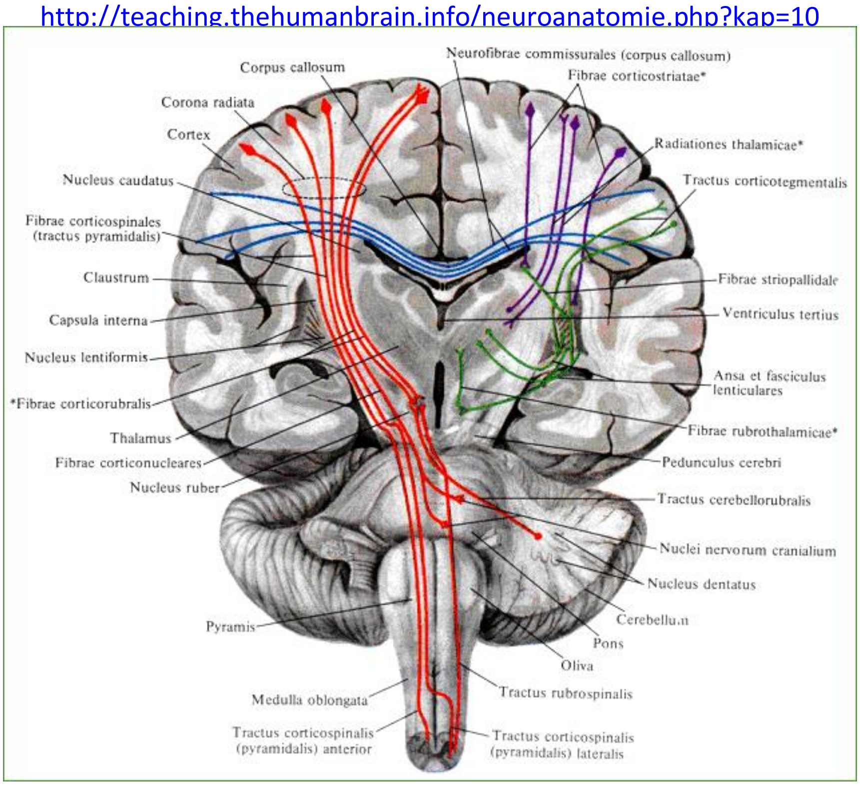
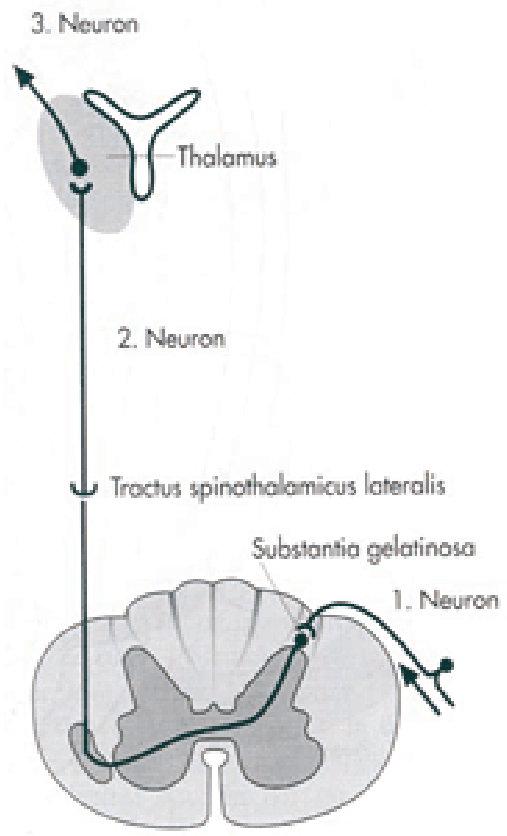
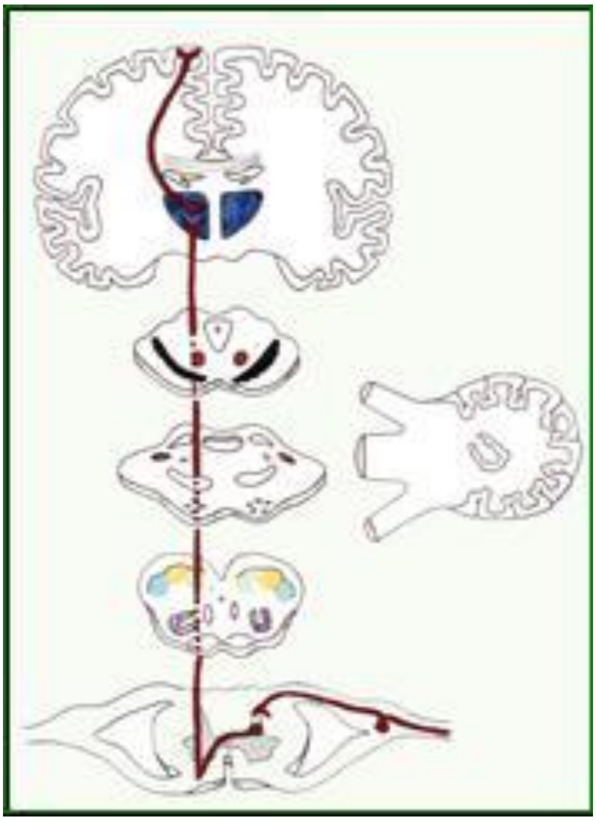
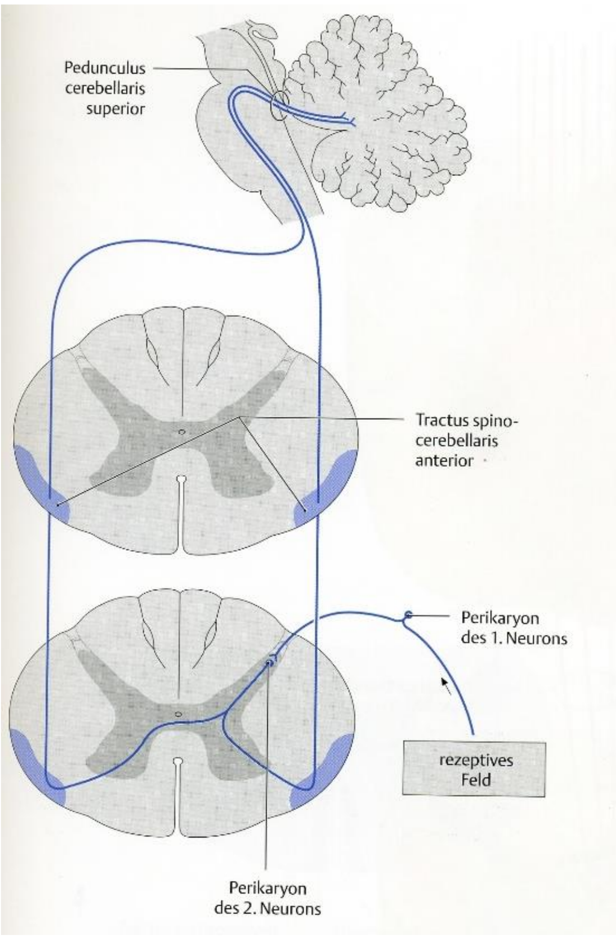
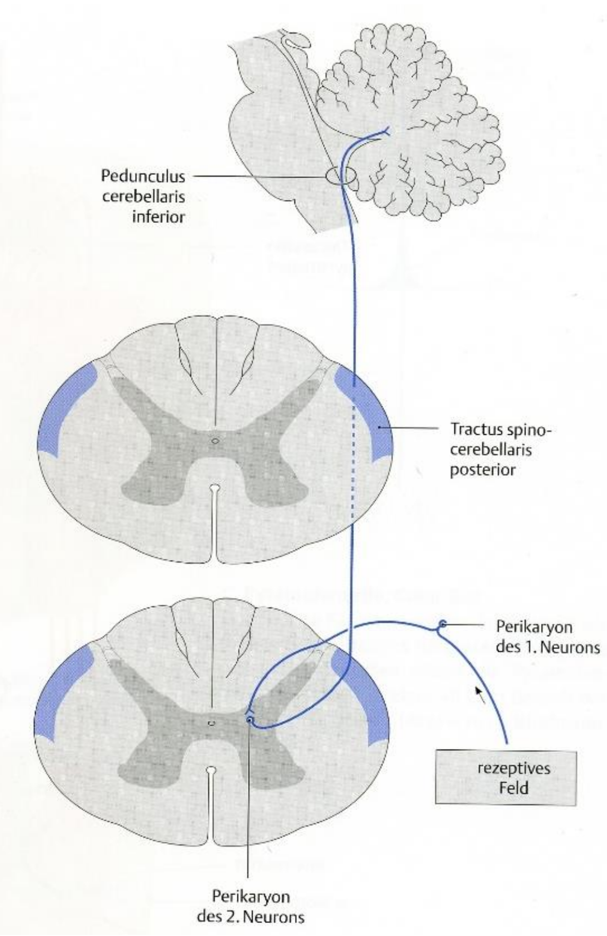


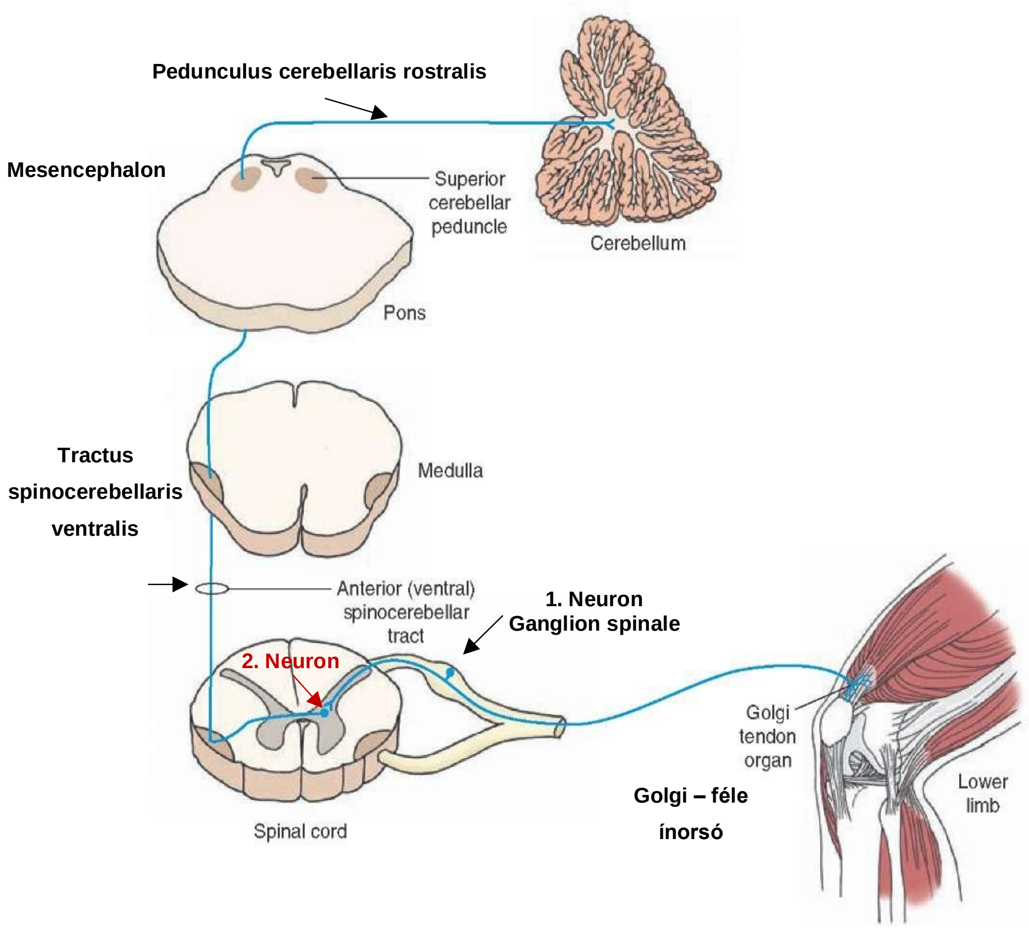




Tractus spinothalamicus anterior







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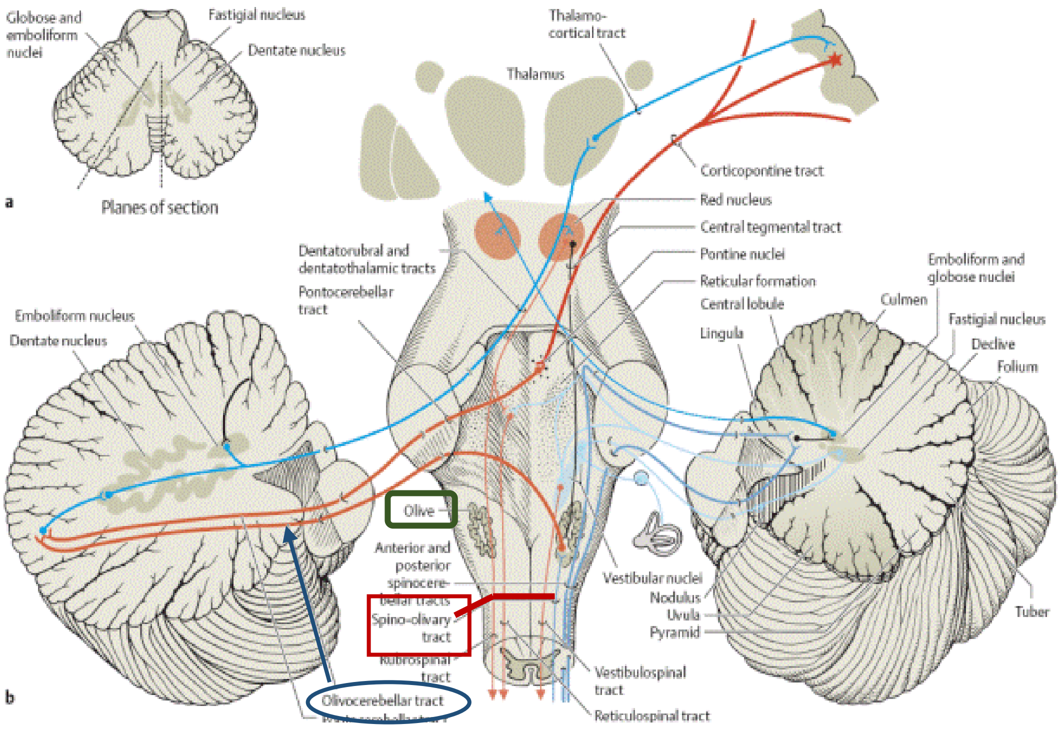

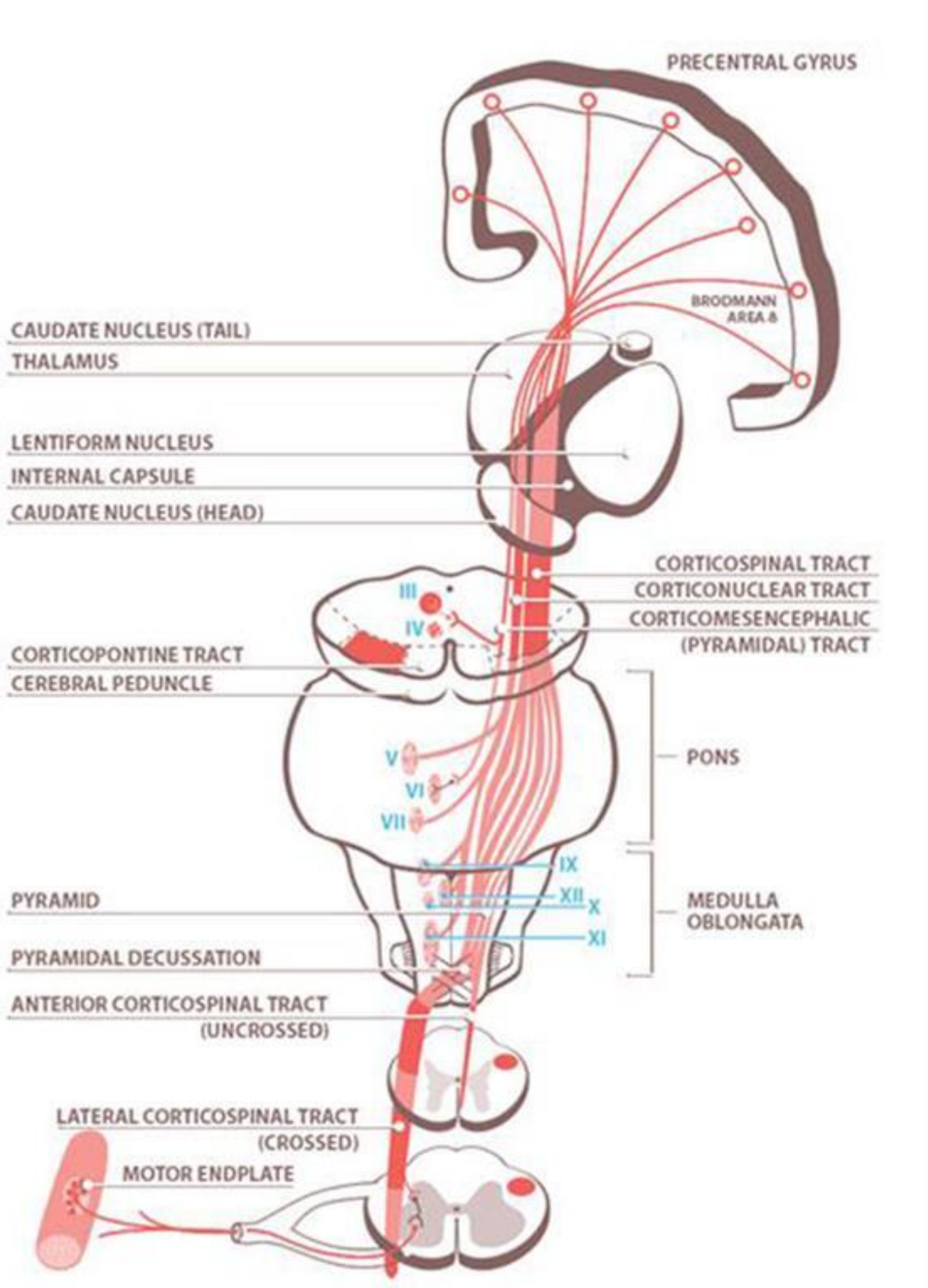

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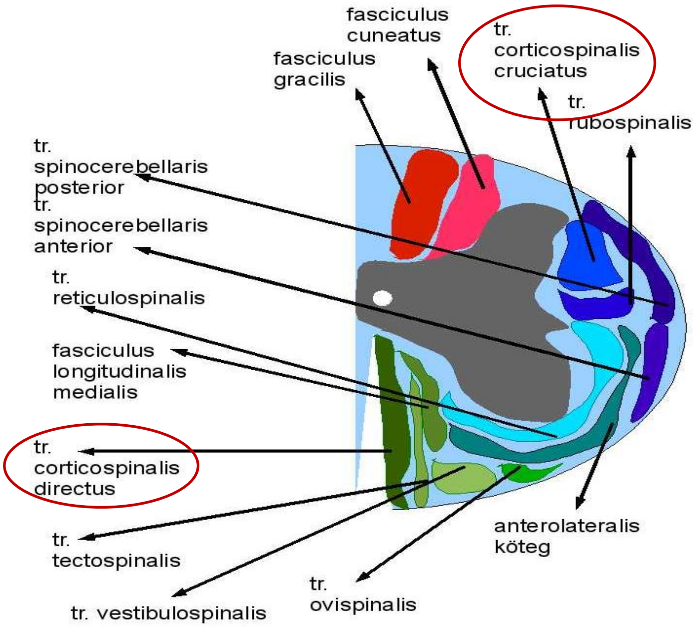

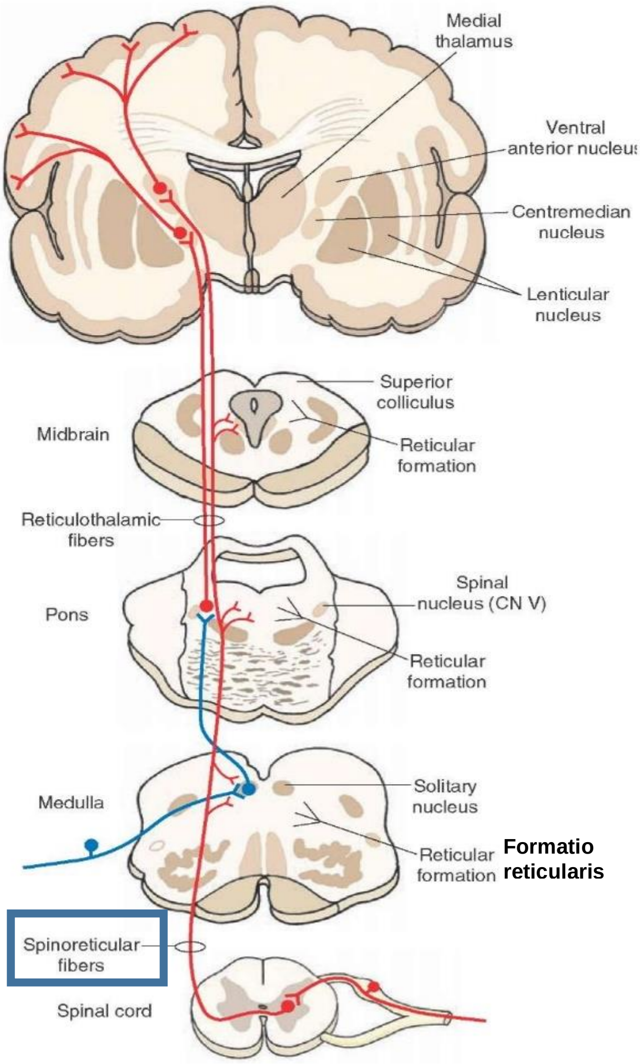

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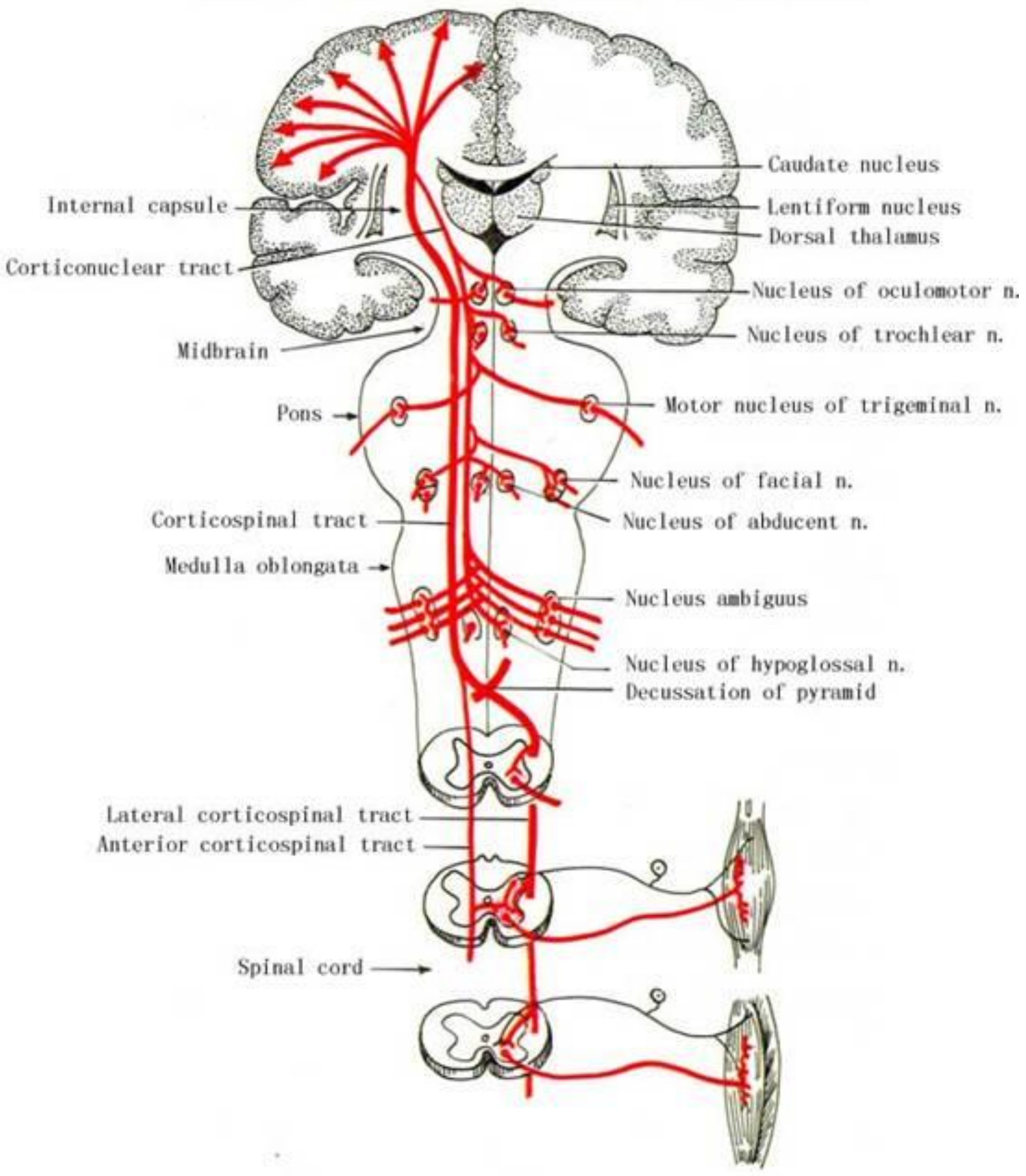

Fig. 15-24 The pyramidal system

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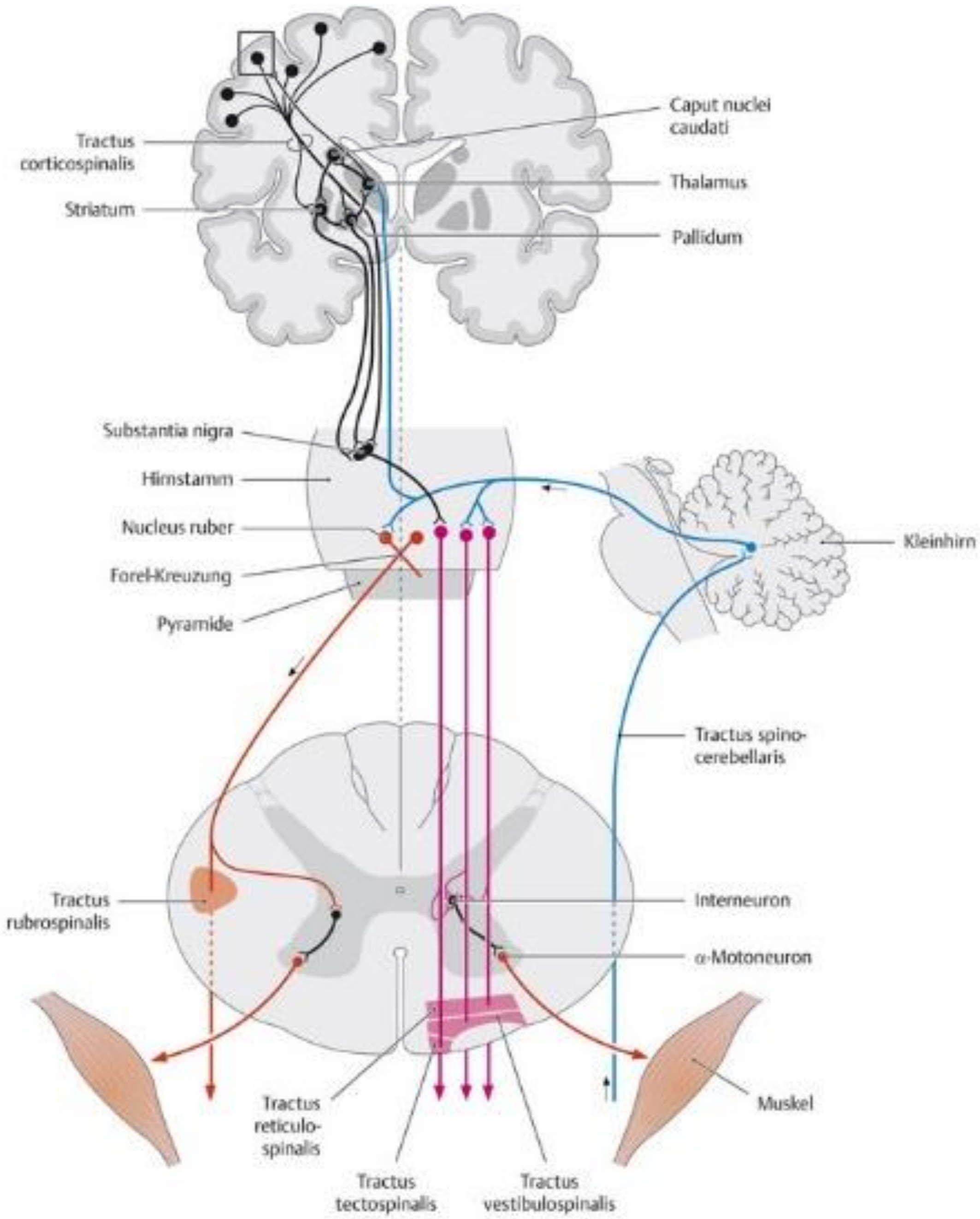

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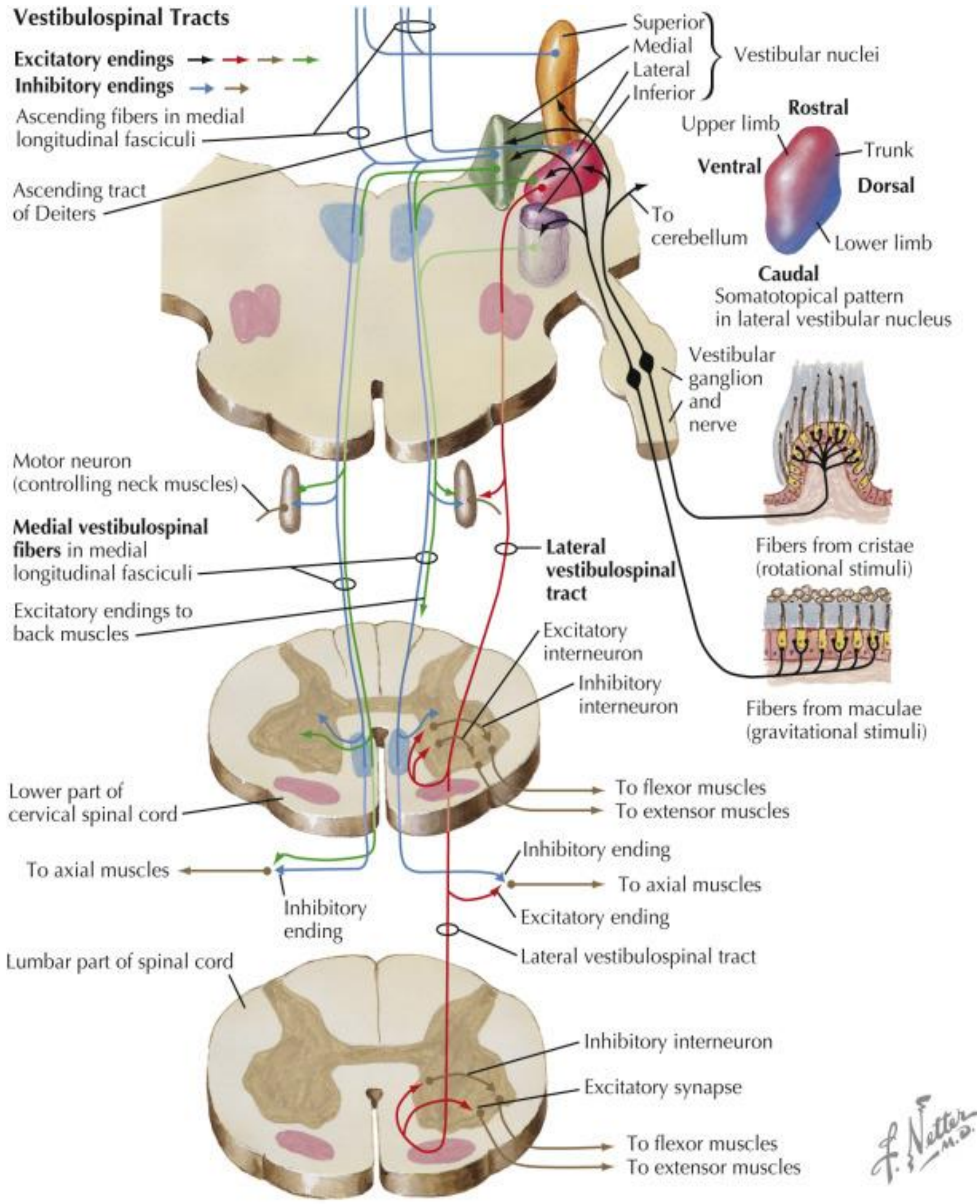

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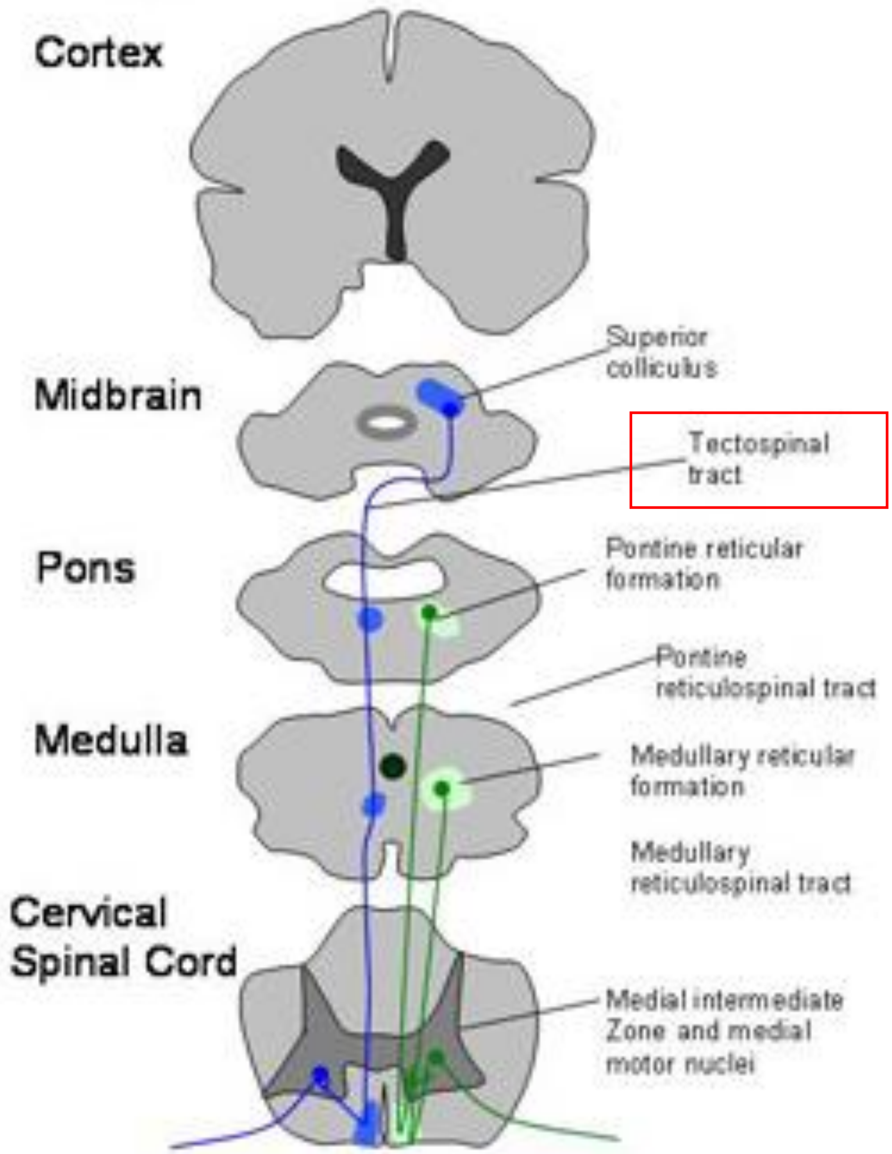

Tectospinal tract and reticulospinal tract

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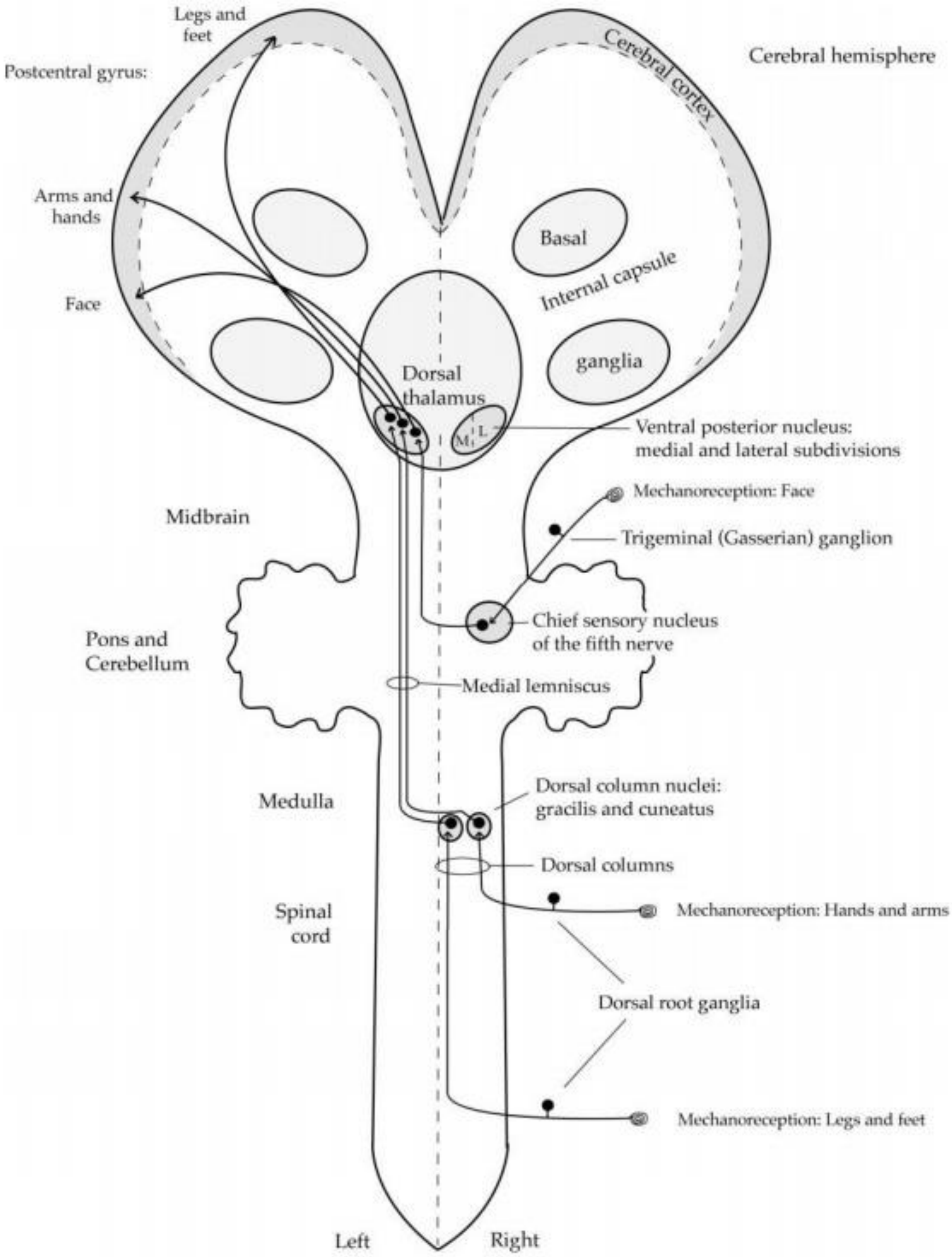


Figure A1-1. Organization of the central pathways that carry information about discriminative touch, pressure, and vibration. Information about the body and posterior head is conveyed via the spinal nerves. Information about the face is conveyed via the fifth cranial nerve. (Illustration by N.B. Cant; cf. Figure 9.8 in *Neuroscience, 5th Ed.*, Sinauer Assoc., Inc.)

https://web.duke.edu/brain/appendix01/appendix01.html https://web.duke.edu/brain/appendix01/appendix01.html

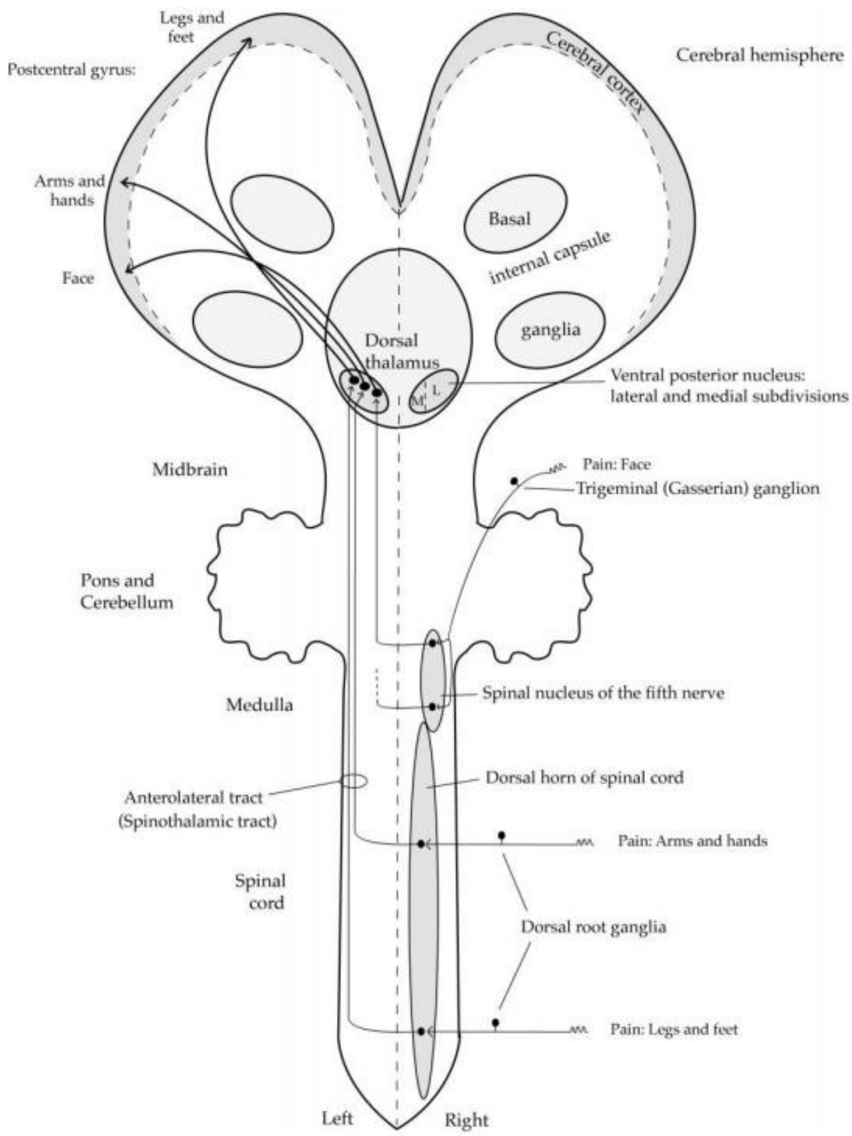


Figure A1-3. Organization of the central pathways for pain and temperature sensation. These pathways also carry crude information about touch. (As discussed in Lab 5 of this *Laboratory Guide*, there is a small input into the trigeminal nuclei from the seventh, ninth and tenth nerves, but this input is of little significance clinically.) (Illustration by N.B. Cant; cf. Figure 10.6 from *Neuroscience*, 5[th] Ed.)

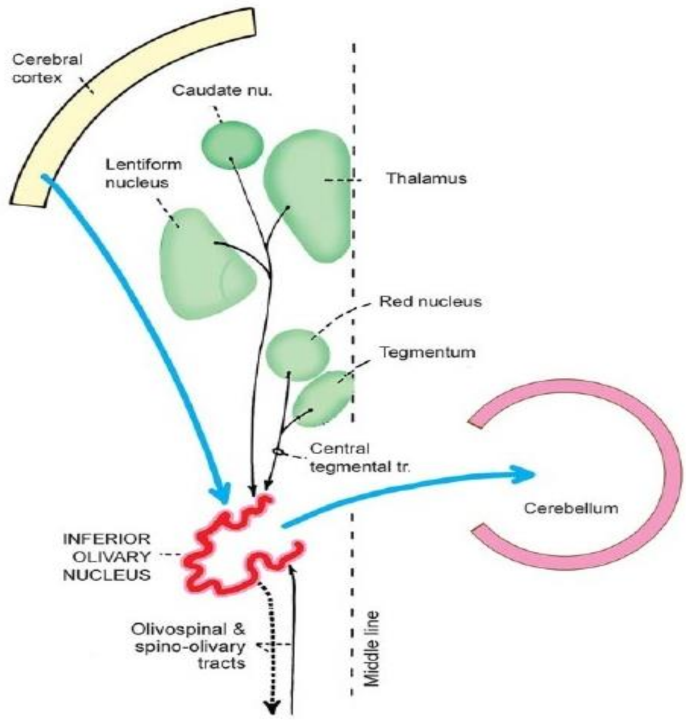
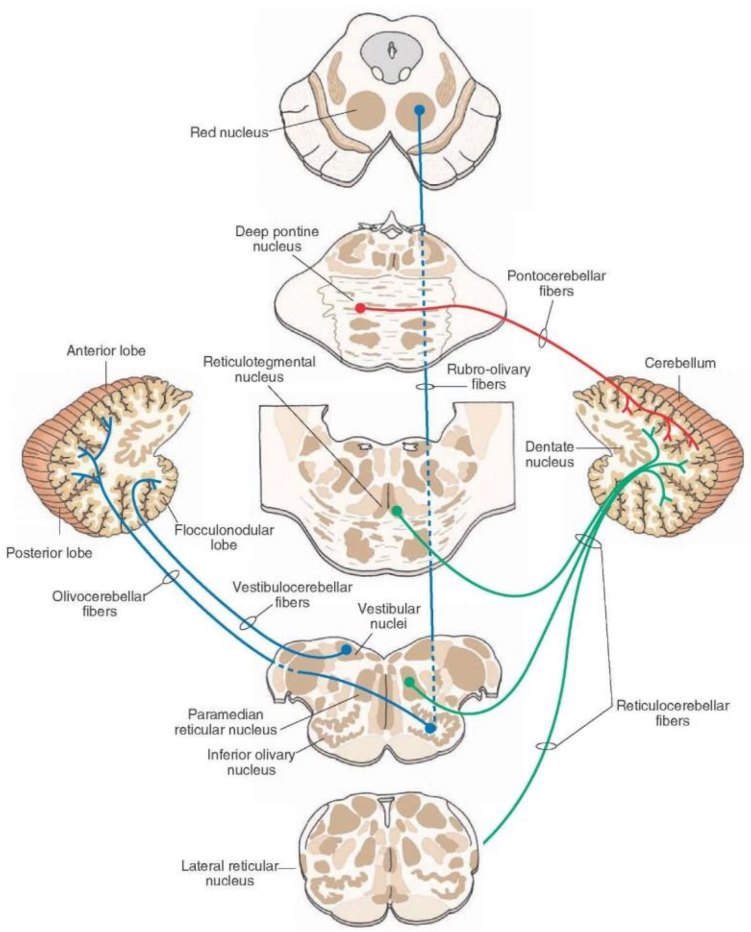


Fig. 11.4. Scheme to show the connections of the inferior olivary nucleus.

https://www.brainkart.com/article/Medulla---Internal-Structure-of-Brainstem_18970/



RETICULAR FORMATION (FORMATIO RETICULARIS)

a set of interconnected nuclei located throughout the brainstem

includes neurons located in different parts of the brain

the neurons of the reticular formation make up a complex set of networks in the core of the brainstem that extend from the upper part of the midbrain to the lower part of the medulla oblongata

includes:

- ascending pathways to the cortex in the **ascending reticular activating system** (**ARAS**)
- descending pathways to the spinal cord via the **reticulospinal tracts**

play role:

- in maintaining behavioral arousal and consciousness
- modulatory and premotor function involving somatic motor control, cardiovascular control, pain modulation, sleep and consciousness, and habituation

divided into three columns:

1. raphe nuclei (median): the place of synthesis of the neurotransmitter serotonin, which plays an important role in mood regulation.
2. gigantocellular reticular nuclei (medial zone): involved in motor coordination
3. parvocellular reticular nuclei (lateral zone): regulate exhalation

consists of neural networks, with varied functions including:

1. Somatic motor control – Some motor neurons send their axons to the reticular formation nuclei, giving rise to the reticulospinal tracts of the spinal cord. These tracts function in maintaining tone, balance, and posture - especially during body movements. The reticular formation also relays eye and ear signals to the cerebellum so that the cerebellum can integrate visual, auditory, and vestibular stimuli in motor coordination. Other motor nuclei include gaze centers, which enable the eyes to track and fixate

objects, and central pattern generators, which produce rhythmic signals of breathing and swallowing.

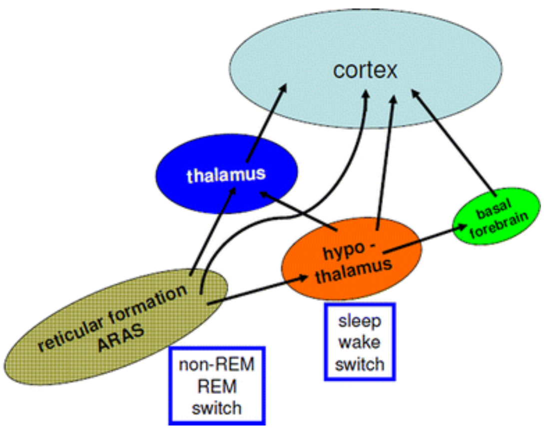
2. Cardiovascular control – The reticular formation includes the cardiac and vasomotor centers in the medulla oblongata.
3. Pain modulation – The reticular formation is one means by which pain signals from the lower body reach the cerebral cortex
4. its origin of the descending analgesic pathways - the nerve fibers in these pathways act in the spinal cord to block the transmission of some pain signals to the brain.
5. *Progressive inhibition of the non-specific activation system (reticular formation) during anesthesia leads to reversible, pharmacological deactivation of sensory functions and consciousness, a procedure of major importance for surgical anesthesia*
6. plays a role in states of consciousness like alertness and sleep

ASCENDING RETICULAR ACTIVATING SYSTEM (ARAS)

- known as the extrathalamic control modulatory system or reticular activating system
- part of the reticular formation

composed of:

a) various nuclei in the thalamus
b) number of dopaminergic, noradrenergic, serotonergic, histaminergic, cholinergic, and glutamatergic brain nuclei
c) several neural circuits connecting the midbrain and pons to the cerebral cortex via distinct pathways that project through the thalamus and hypothalamus
d) consists of evolutionarily ancient areas of the brain, which are crucial to the animal's survival and protected during adverse periods, such as during inhibitory periods of Totsellreflex, aka, "animal hypnosis

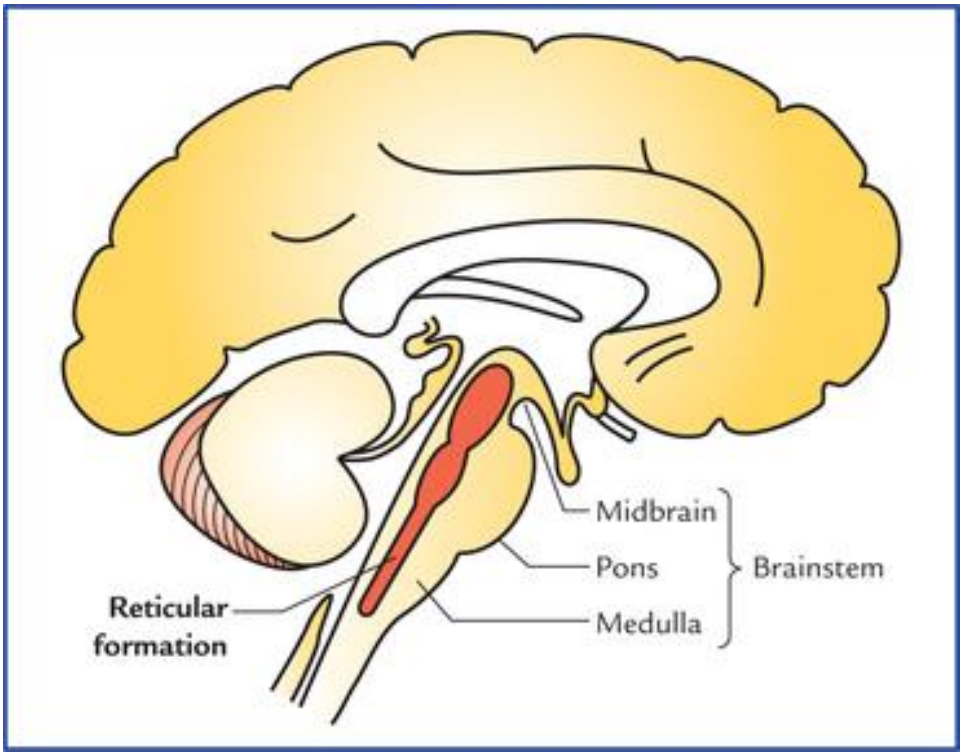


functions:

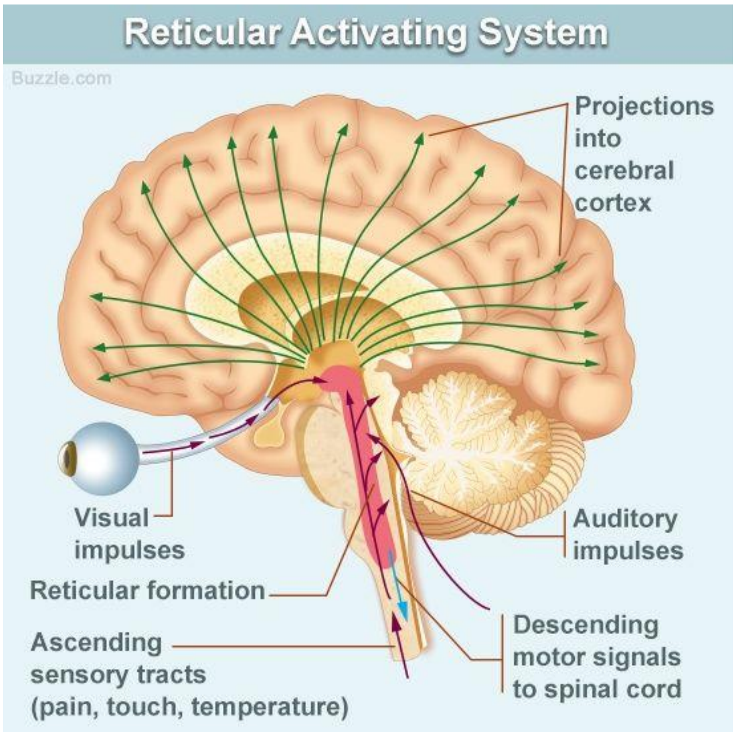
1) an important factor for the state of consciousness
2) the physiological change from a state of deep sleep to wakefulness is reversible and mediated by the ARAS
3) helps to mediate transitions from relaxed wakefulness to periods of high attention
4) lesions that destroy the ARAS cause a comatose state

TRACTUS RETICULOSPIANLIS:

- extrapyramidal motor tracts
- descends from the reticular formation to the spinal cord to act on the motor neurons
- involved in locomotion and postural control
- regulates the musculoskeletal activity
- gives coordinated control of movement, including delicate manipulations



https://neupsykey.com/reticular-formation-and-limbic-system/



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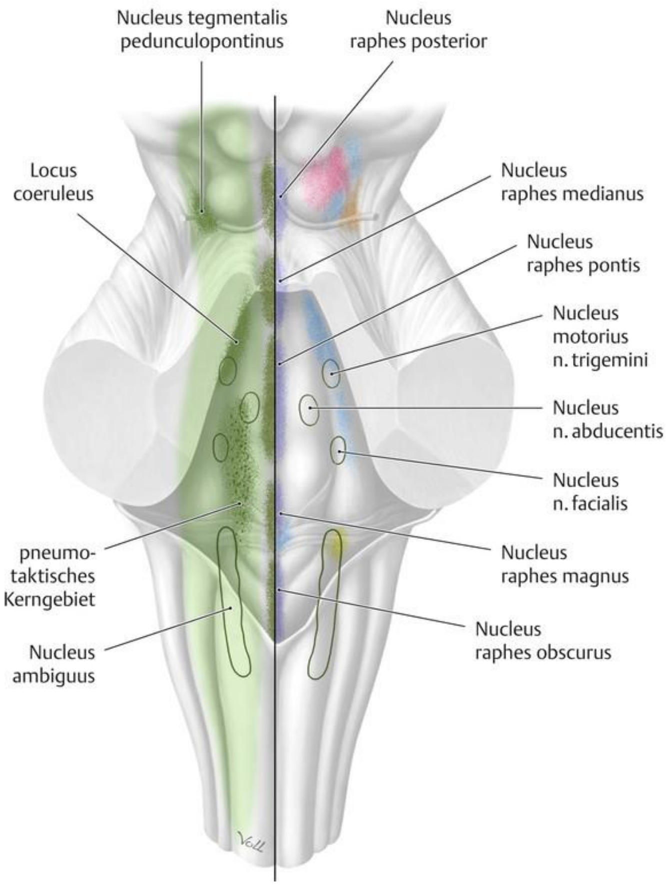

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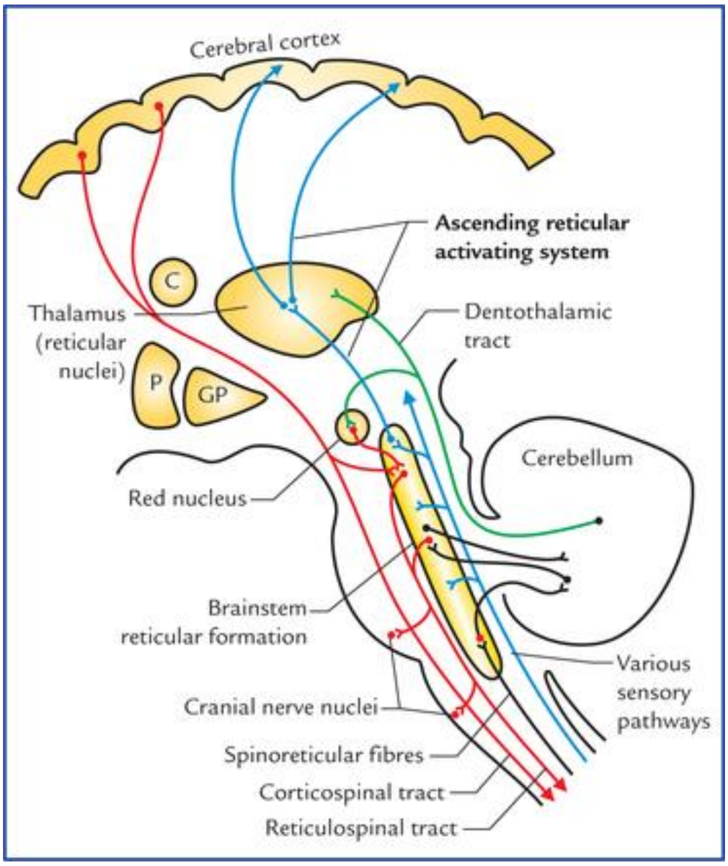

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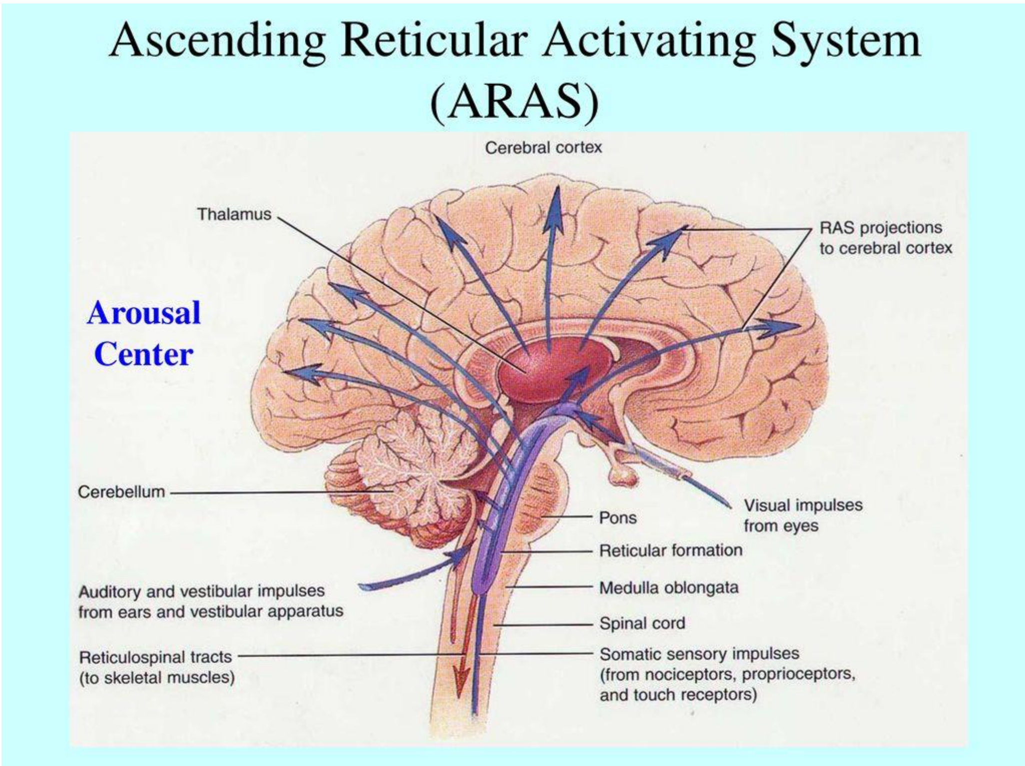

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