Summary of pathways
Course: Coursera Medical Neuroscience

Only the important pathways indicated by prof. White are discussed

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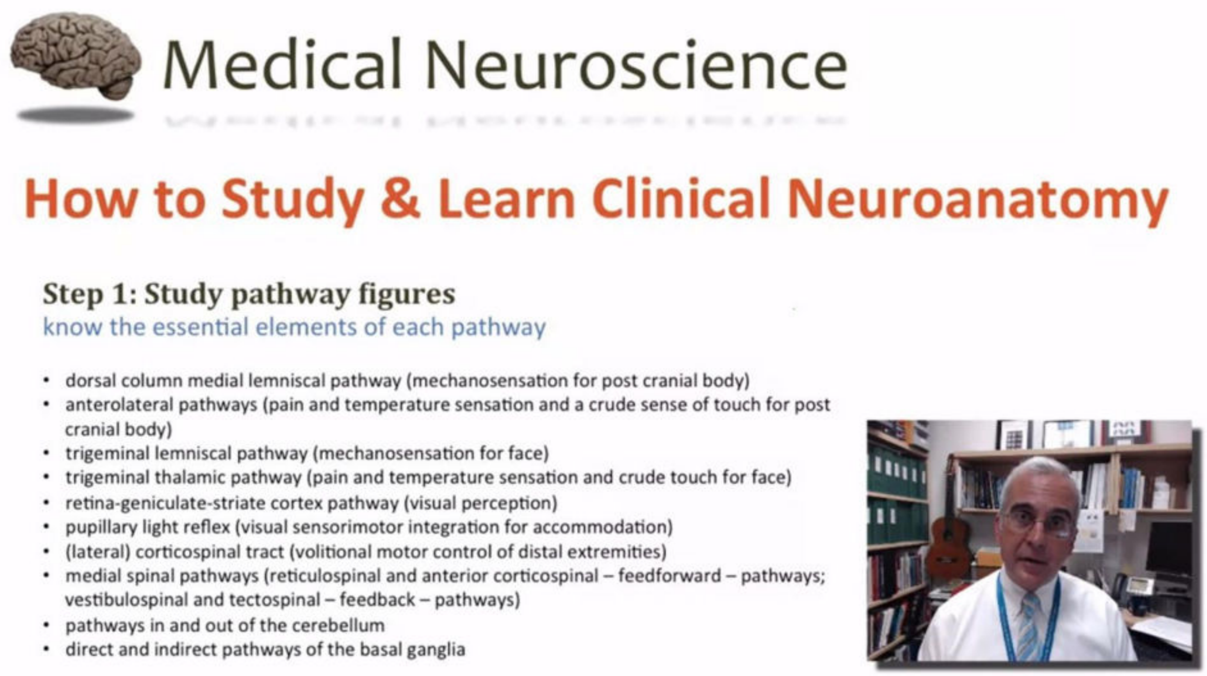
(2020)



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Sensory pathways

The first major function of the nervous system is sensation. Receiving information about the environment to gain input about what is happening outside the body and inside the body.

Sensory pathways are designed for a speedy delivery of information to the cortex and cerebellum, they share general principles.

A sensory pathway consists of; stimulus receptors and three neurons . Most sensory pathways cross the midline of the body, they decussate. In most sensory pathways the cell body of the third order neuron is in the thalamus. Only one of the pathways stays on the same side of the body (ipsilateral) and has no cell body in the thalamus, the spinocerebellar pathway for unconscious proprioception (not included in the summary). The third order neurons in the spinocerebellar pathway are in the ipsilateral cerebellum .

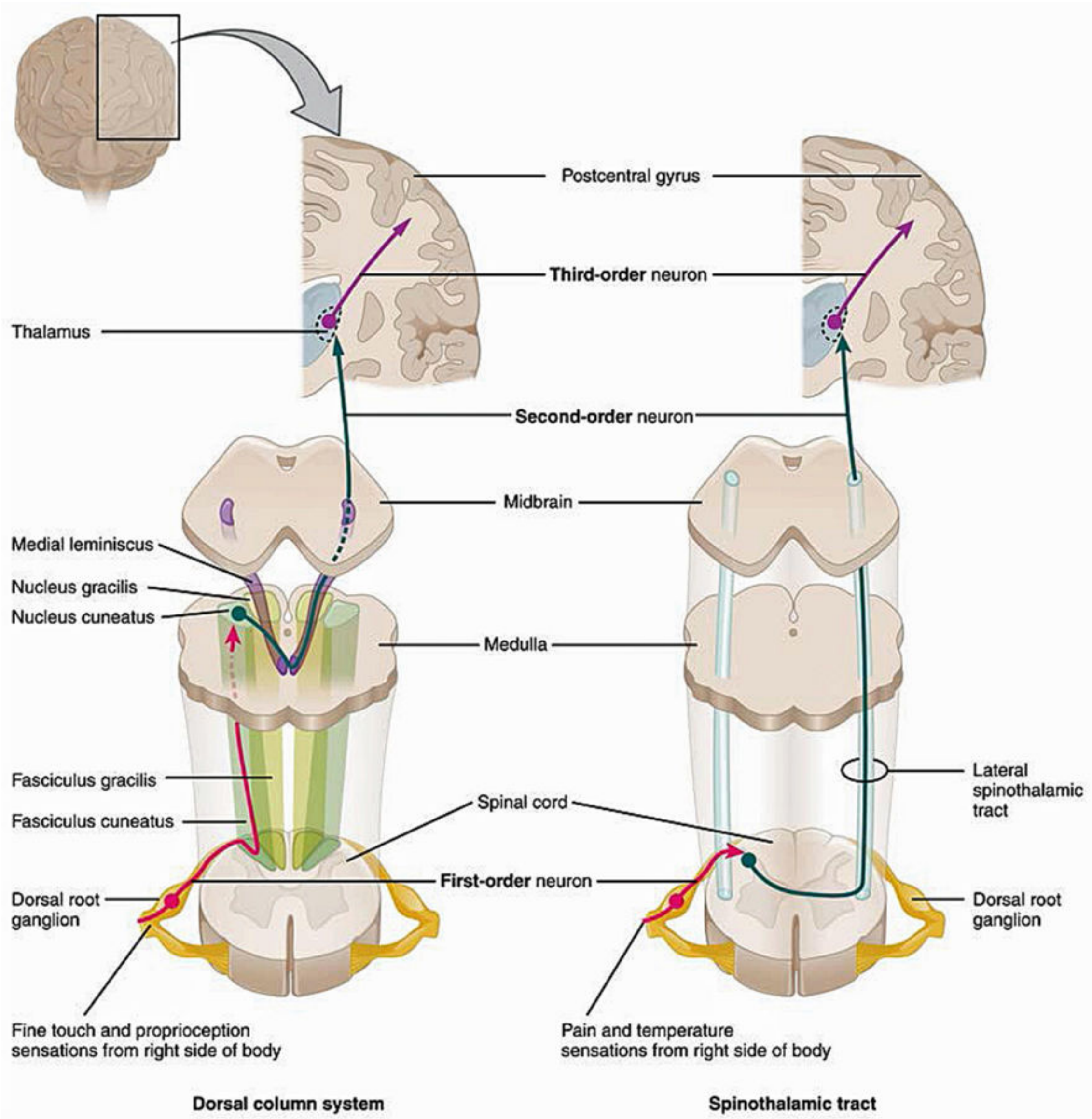
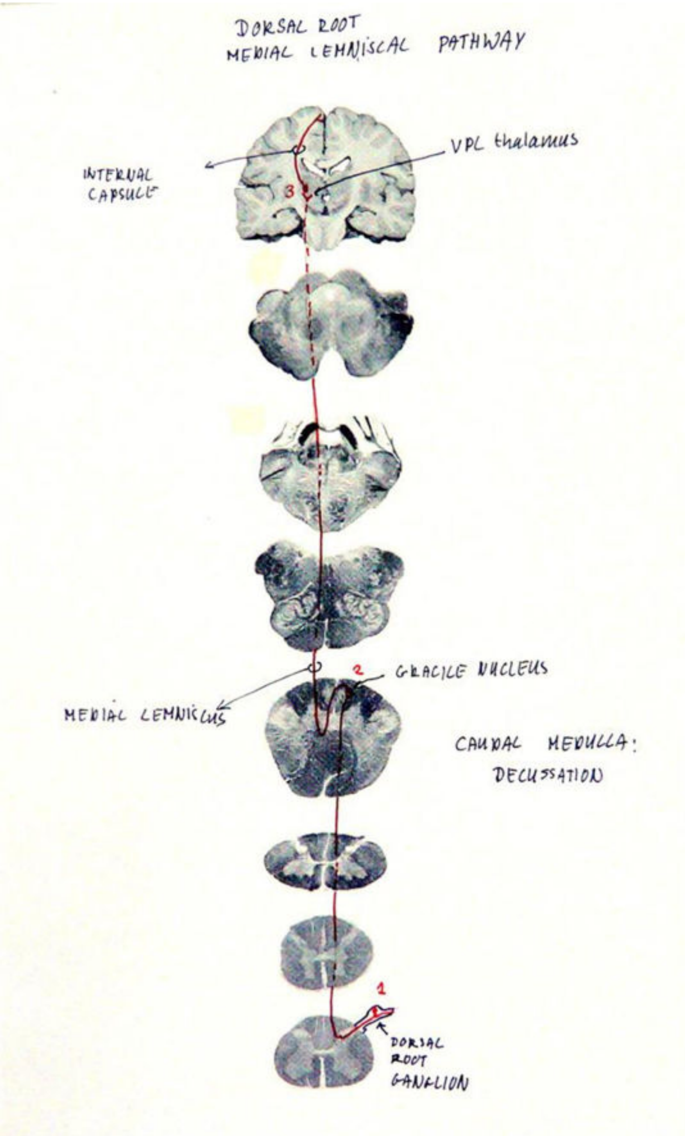


Figure 1: Ascending Sensory Pathways
Source: Anatomy & Physiology OpenStax College; Download for free at http://cnx.org/content/col11496/latest/"

Dorsal column medial lemniscal pathway.

Ascending Figure 9.8 page 199 Neuroscience, fifth edition, Figure 9.8 page 203 Neuroscience, sixth edition
http://www.ncbi.nlm.nih.gov/books/NBK10799/ ,→ figure 9.6



Information:
Mechanosensation (fine touch, vibration) post-cranial body.

Source:
Meissner corpuscles, Pacinian corpuscles, Merkel disc's, Ruffini corpuscles.

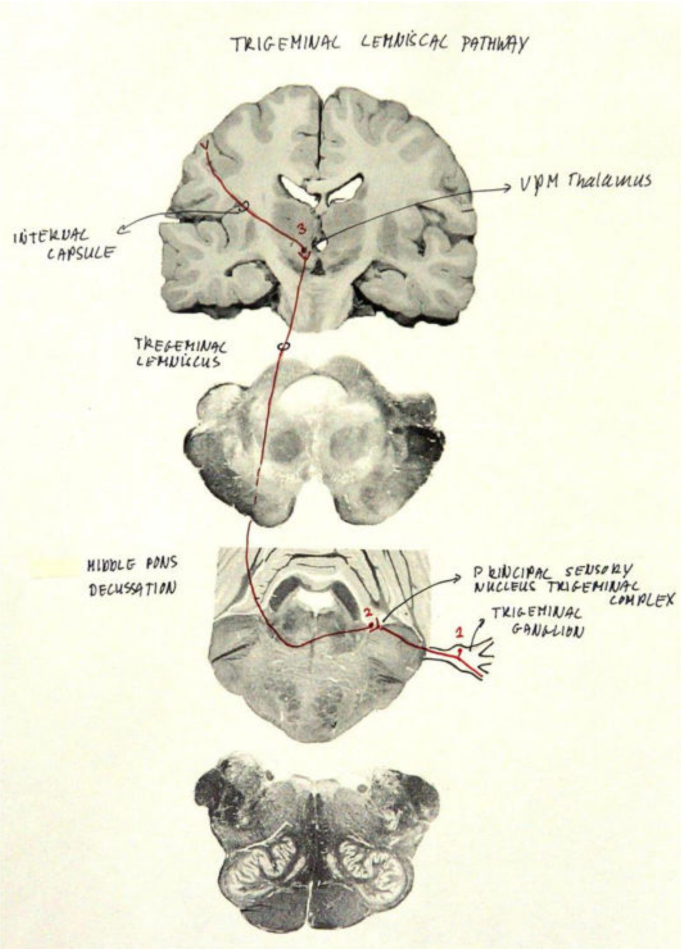
Orientation caudal of decussation:
Cell body first order neuron in dorsal root ganglion, axon enters spinal cord dorsally. The axon travels through the gracile tract if its receptor comes from the lower body and through the cuneate tract if it comes from the upper body.(see pathways in the cervical cord, page 13)

Decussation: Caudal medulla
Second order neuron in gracile nucleus or cuneate nucleus, axon crosses the midline, forms part of the medial lemniscus. Joins trigeminal lemniscus (mechanosensation face) at the midbrain.

Orientation rostral of decussation:
Axon travels medially in the medulla in left (information right part of postcranial body) and right (information of left part of postcranial body) **medial lemniscus**. Cell body of the third order neuron is in the ventral posterior lateral (VPL) of the thalamus. Axons travel in internal capsule to postcentral gyrus (primary somatosensory cortex).

Trigeminal lemniscal pathway.

Ascending Figure 9.8 page 199 Neuroscience, fifth edition, Figure 9.8 page 203 Neuroscience, sixth edition
http://www.ncbi.nlm.nih.gov/books/NBK10799/, → figure 9.6



Information:
Mechanosensation (fine touch, vibration) face.

Source:
Meissner corpuscles, Pacinian corpuscles, Merkel disc's, Ruffini corpuscles.

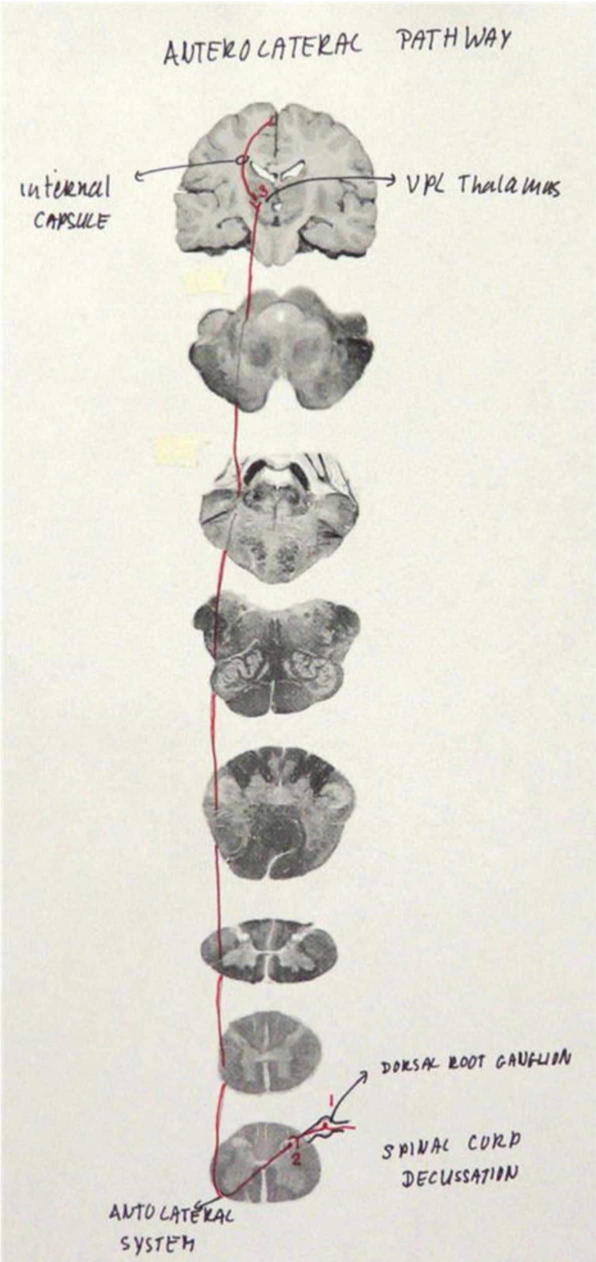
Orientation caudal of decussation:
Cell body first order neuron in trigeminal ganglion, signal enters brainstem through trigeminal tract.

Decussation: Middle pons
Second order neuron principal nucleus of the trigeminal complex., axon crosses the midline to the **trigeminal lemniscus**. Joins medial lemniscus (mechanosensation post-cranial body) at the midbrain.

Orientation rostral of decussation:
Axon travels medially in the medulla, left (information right part the face) and right (information of left part the face)in trigemial lemniscus . Cell body of the third order neuron is in the Ventral Posterior Medial nucleus (VPM) of the thalamus. Axons travel in internal capsule to postcentral gyrus (primary somatosensory cortex)

Anterolateral pathway/Spinothalamic tract

Ascending Figure 10.6 page 219 Neuroscience, fifth edition, Figure 10.6 page 223 Neuroscience, sixth edition
http://www.ncbi.nlm.nih.gov/books/NBK10799/ , →fig. 10.3



Information:
Pain, temperature and a crude sense of touch for post cranial body.

Source:
Aδ-fibers, sharp first pain
C-fibers, second pain.

Orientation before decussation:
Cell body first order neuron in dorsal root ganglion. Axon enters spinal cord through dorsal horn.

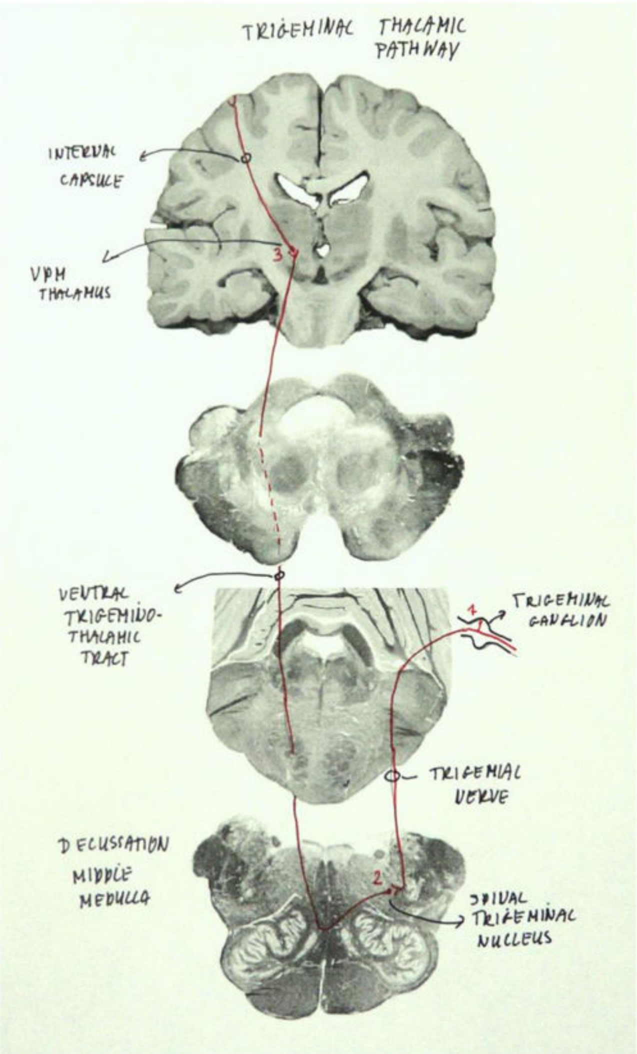
Decussation Spinal cord
In spinal cord. Second order neuron dorsal horn, axon crosses the midline, enters the contralateral **anterolateral (or spinothalamic) tract**. (see pathways in the cervical cord, page 13).

Orientation rostral of decussation:
First painand sensory-discriminative aspect of pain.
Axon travels anterolaterally in the **spinothalamic tract** to ventral posterior lateral (VPL) of the thalamus
Second pain and affective motivational aspect or pain
Axons travel anterolaterally to reticular formation (**spinoreticular tract**), periaqueductal gray matter and the superior colliculus (**spinomesencephalic tract**).and continue to midline thalamic nuclei.

Cell body of the third order neuron is in the VPL and midline thalamic nuclei. Axons travel in internal capsule to postcentral gyrus (primary somatosensory cortex)

Trigeminal thalamic pathway

Ascending Figure 10.6 page 219 Neuroscience, fifth edition, Figure 10.6 page 223 Neuroscience, sixth edition
hhttp://www.ncbi.nlm.nih.gov/books/NBK10799/, → fig.10.3



Information:
Pain, temperature and a crude sense of touch for face.

Source:
Aδ-fibers, sharp first pain
C-fibers, second pain.

Orientation before decussation:
Cell body first order neuron in trigeminal ganglion. Axon enters brainstem through trigeminal CN V) nerve and synaps in the spinal trigeminal nucleus (of the 5^{th} nerve).

Decussation Middle medulla
Second order neuron in spinal trigeminal nucleus, axon crosses the midline, enters the contralateral **ventral trigeminothalamic tract**.

Orientation rostral of decussation:

- First pain and sensory-discriminative aspect of pain

Axon travels in **the ventral trigeminothalamic tract** to ventral posterior medial (VPM) of the thalamus.

- Second pain and affective motivational aspect or pain

Axons travel to various targets in reticular formation and midbrain. By the midline nuclei of the thalamus, which supply the cingulate and insular regions of the cortex.

Cell body of the third order neuron is in the VPL and midline thalamic nuclei. Axons travel in internal capsule to postcentral gyrus (primary somatosensory cortex)

Retina-geniculate-striate cortex pathway

Figure 12.6 page 262 Neuroscience, fifth edition, Figure ‘Visual Field Deficits’ page 263 Neuroscience, sixth edition
http://www.ncbi.nlm.nih.gov/books/NBK10799/, →fig. 12.8

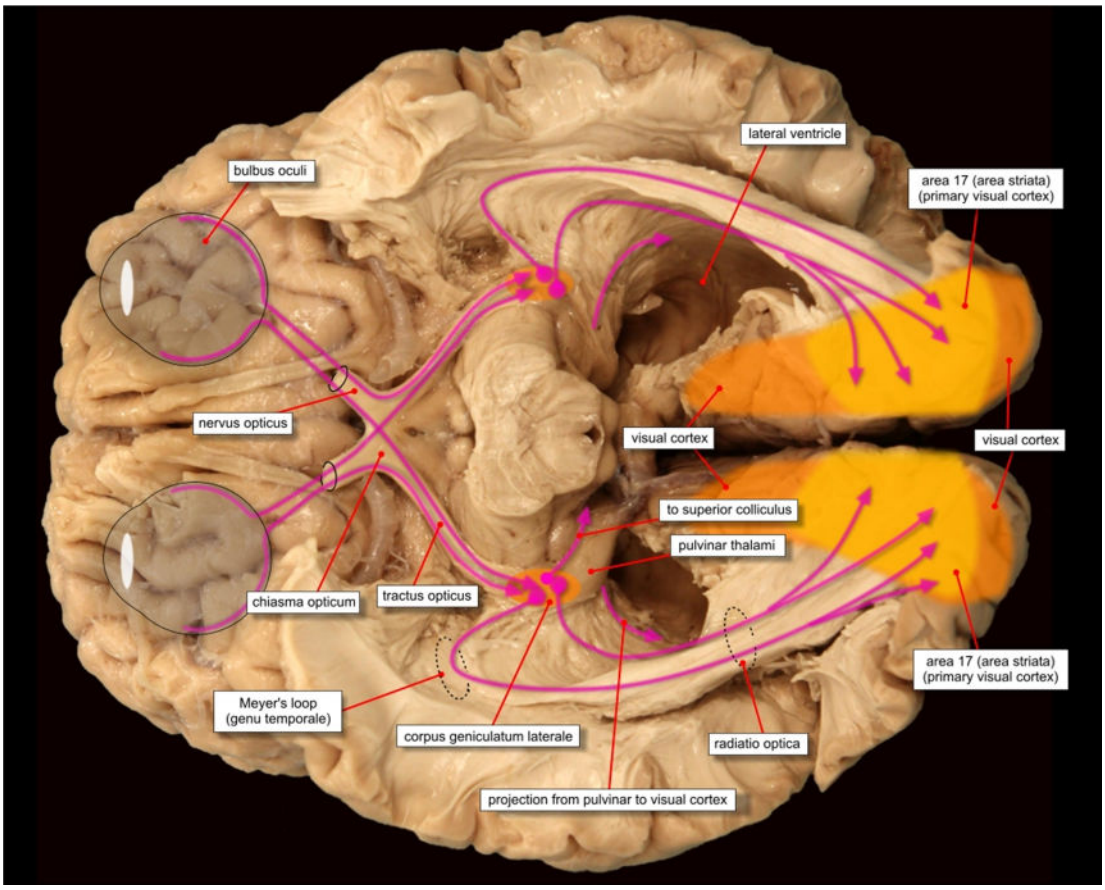


Figure 2: Overview optic tract
Source: www.anatomie –amsterdam.nl
http://www.anatomie-amsterdam.nl/sub_sites/anatomie-zenuwwerking/123_neuro/html_pages/tracts/tracts_005_lb.htm

Information: Visual perception

Source: Rods and cones in retina

Decussation at the optic chiasm.

Orientation anterior of decussation:
The first order neuron, the bipolar cell, can be found in the retina. The second order neuron is also in the retina. Its axon travels through the **optic nerve** to the **optic chiasm**. In the right eye through right **optic tract** in the left eye through left optic tract. Information of temporal retina does not cross the midline and remains ipsilateral (45%). Information of nasal retina crosses midline (55%).

Orientation posterior optical tract
Axons travel to lateral geniculate nucleus (LGN) of the thalamus (third order neuron)
Projection trough the optic radiation to the visual parts of the cerebral cortex terminates in V1, Brodmann’s Area 17 (striate cortex).

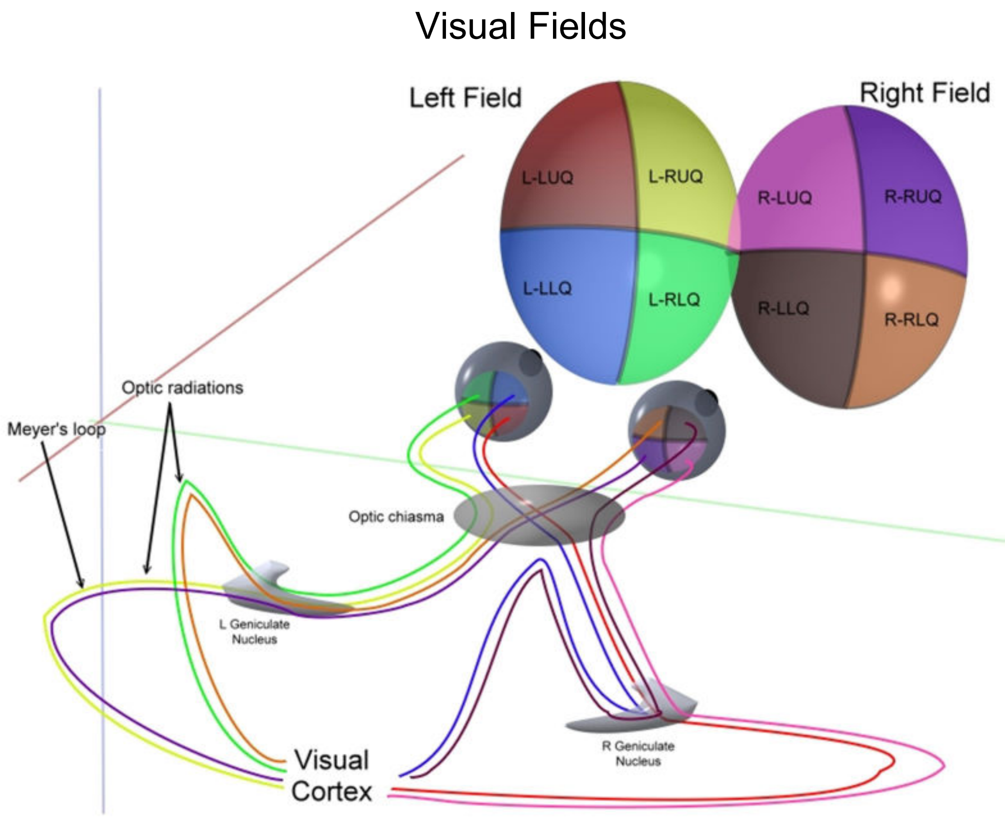


Figure 3: 3D Eye fields:
Source file: http://en.wikipedia.org/wiki/File:ERP_-_optic_cabling.jpg#globalusage

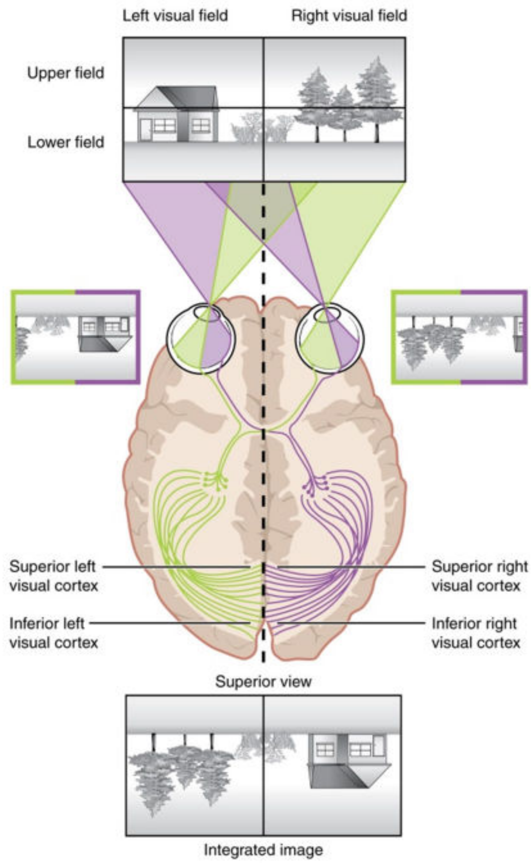


Figure 4: Topographic mapping or the retina on the cortex
Source: Anatomy & Physiology OpenStax College; Download for free at http://cnx.org/content/col11496/latest/

Motor pathways

Motor pathways are having to do with behavior, they are more diverse than sensory pathways. Fine-tuning by other neural structures, basal ganglia and cerebellum is important. The most direct pathways, leading signals to the lower motor circuits are the corticospinal (body) and corticobulbar (face) tracts).

There are ± 20 $x10^6$ in each cerebral peduncle, only $1x10^6$ (or less) travel down in the corticospinal tract. 95% of the axons in the cerebral peduncle form the "corticopontine" projection (input from cerebral cortex to pontinal nuclei that relay cortical signals into the cerebellum). There are ± 20 $x10^6$ axons in each middle cerebellar peduncle. So only a small part of the axons of neurons in the motor cortex form the corticospinal tract.

Neurons in the motor cortex travelling down the corticospinal pathway form collateral connections to structures in the brainstem to inform these centers about the intention of movement.

Other motor pathways are the indirect pathways, the brainstem–to-spinal cord pathways. The extrapyramidal system includes projections from the brain stem and higher centers that influence movement, mostly to maintain balance and posture, as well as to maintain muscle tone. The superior colliculus (Tectospinal tract)and red nucleus in the midbrain, the vestibular nuclei (Vestibulospinal tract) in the medulla, and the reticular formation (Reticulospinal tract) throughout the brain stem each have tracts projecting to the spinal cord in this system. Descending input from the secondary motor cortices, basal nuclei, and cerebellum connect to the origins of these tracts in the brain stem.

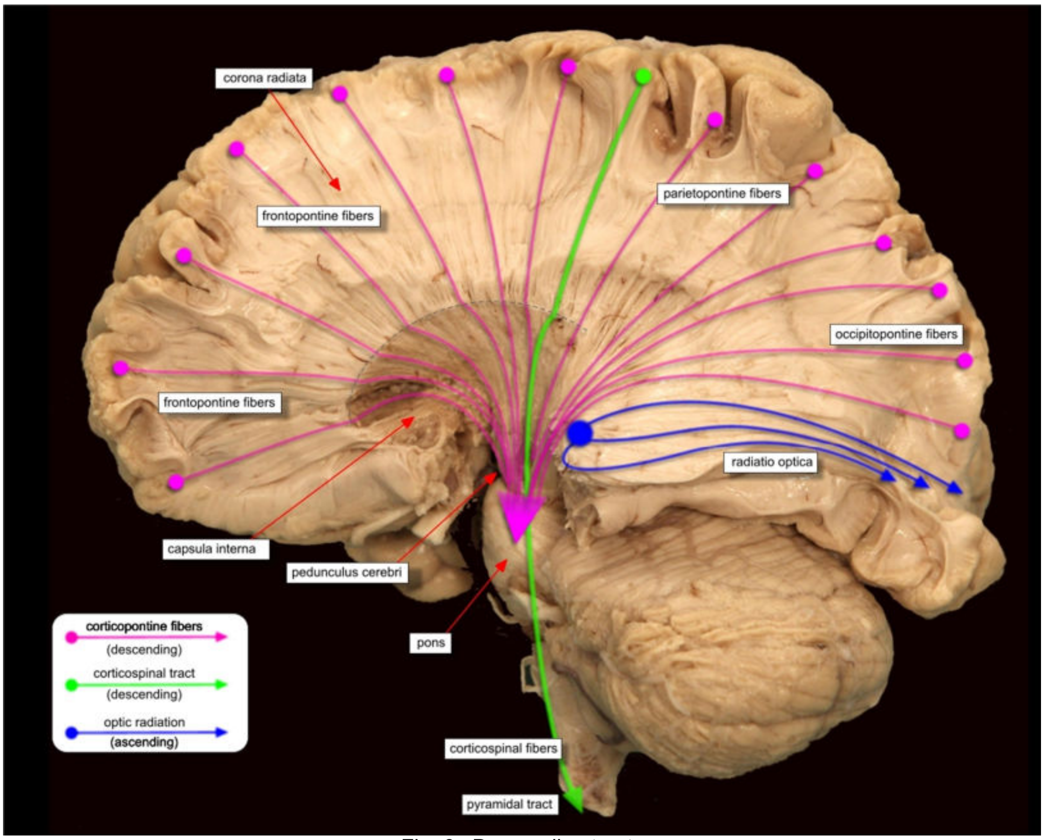
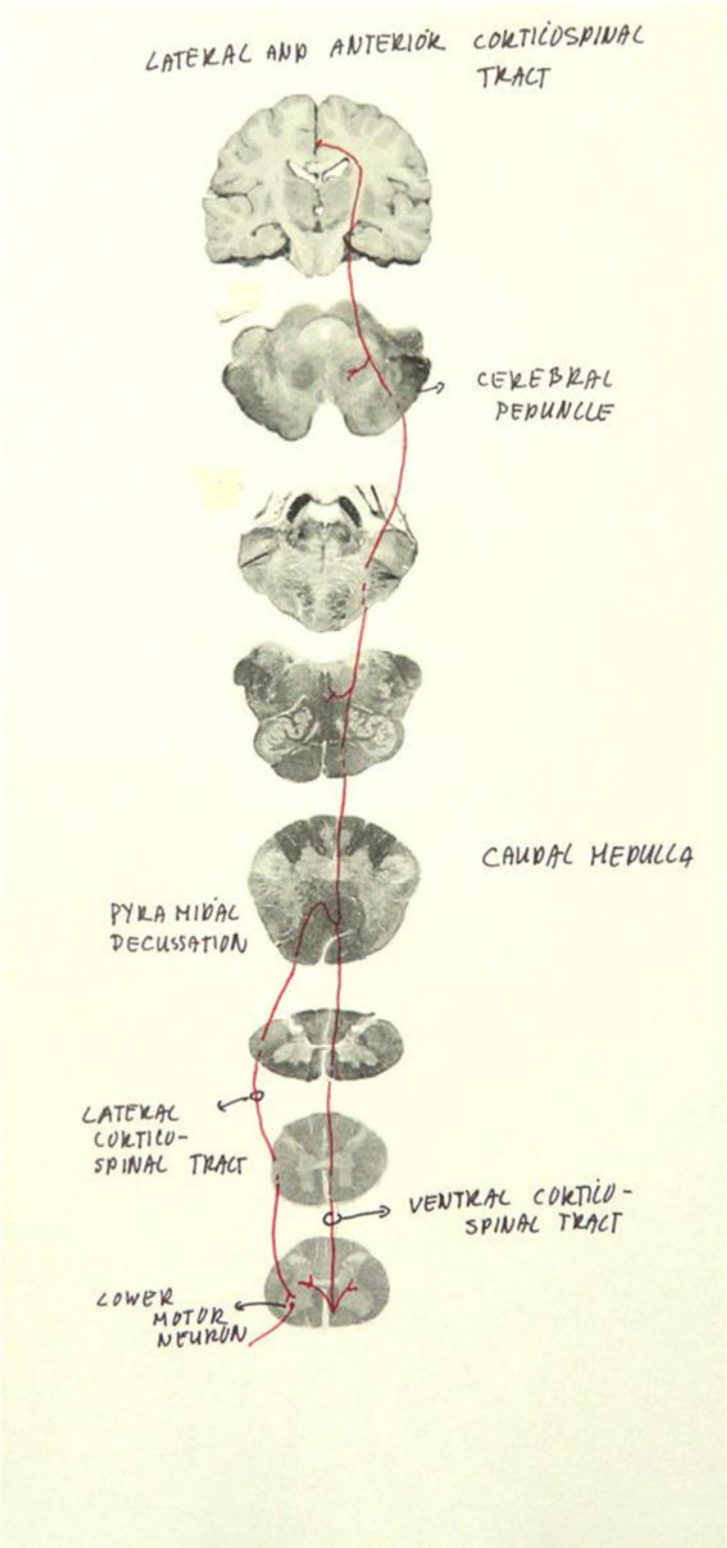


Fig. 6: Descending tracts
Source: www.anatomie –amsterdam.nl
http://www.anatomie-amsterdam.nl/sub_sites/anatomie-zenuwwerking/123_neuro/html_pages/tracts/tracts_004_lb.htm

Pyramidal tracts
(Lateral and anterior) corticospinal tract

Descending Figure 17.4 page 378 Neuroscience, fifth edition
http://www.ncbi.nlm.nih.gov/books/NBK10799/, → fig.17.8



Information:
Corticobulbar tract → leads to the motor neurons in the brainstem.
Lateral corticospinal tract →volitional skilled motor control of distal extremities
Anterior (ventral) corticospinal tract → posture and balance, to axial and proximal limb muscles

Source:
Neurons in layer V of the motor cortex

Orientation before decussation:
Axons originating in de motor cortex travel through the internal capsule, the cerebral peduncle to the medullary pyramids.

Decussation: Caudal medulla
Axons travel to the caudal medulla where most of them cross in the pyramidal decussation. Crossed fibers descend to lateral corticospinal tract, they terminate on motor neurons and interneurons in the lateral aspect of the ventral horn → skilled movements from distal limb muscles. A small number of fibers do not cross but travel ipsilaterally (= anterior corticospinal tract), innervate medial aspects of the ventral horn bilaterally → axial and proximal limb muscles (posture and balance, feedforward). It ends about the middle of the thoracic region.

Extra pyramidal tracts
Reticulospinal, vestibulospinal and tectospinal tract

Descending

Information:
Reticulospinal tract → feedforward adjustments of posture that anticipate instability associated with voluntary movements.
Vestibulospinal tract → feedback adjustments of posture in response to head movements and disturbances of postural stability.
Tectospinal tract → feedback adjustments of head and neck posture that support a chance in direction of gaze

Source:
Brainstem
Reticulospinal tract → reticular formation
Vestibulospinal tract → vestibular nuclei
Tectospinal tract → superior colliculus, mediated via indirect connections through reticulospinal projections

See figure 15 (Pathways in the cervical spinal cord) on page 20 to find the place of these motor pathways in the spinal cord.

Pupillary light reflex

Figure 12.2 page 259 Neuroscience, fifth edition, Figure 12.2 page 262 Neuroscience, sixth edition
hhttp://www.ncbi.nlm.nih.gov/books/NBK10799/, → fig.12.3

Information:
Visual sensorimotor integration for accommodation.

Source:
Rods and cones in retina

Route:
Bilatarал projection from retina to the pretectum (so light in one eye travels to both Edinger-Westphal nuclei). Pretectal neurons project to Edingher-Westphal nuclei. Neurons in the Edinger-Westphal nucleus terminate in ciliary ganglion. Neurons in ciliary ganglion innervate pupillary constrictor muscle.

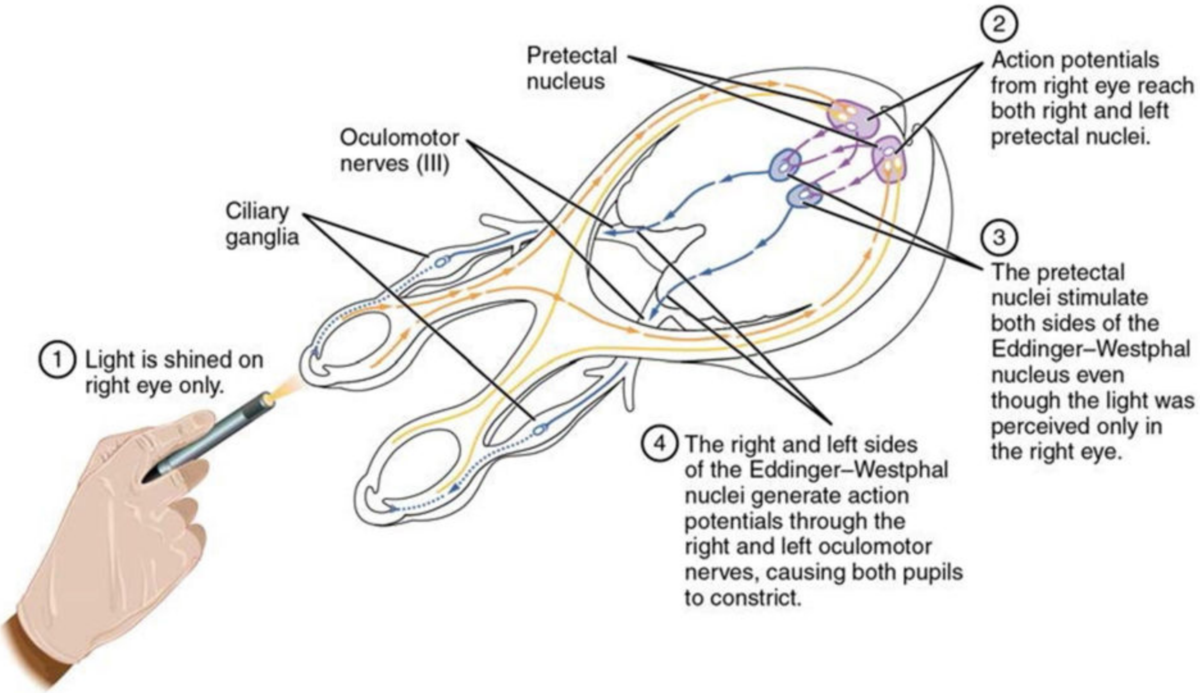


Figure 7: Pupillary Light Reflex
Source: Anatomy & Physiology OpenStax College; Download for free at http://cnx.org/content/col11496/latest/"

Direct and indirect pathway of the basal ganglia

Figure 18.1 page 400 Neuroscience, fifth edition, Figure 18.1 page 406 Neuroscience, sixth edition
http://www.ncbi.nlm.nih.gov/books/NBK10799/ →fig. 18.1

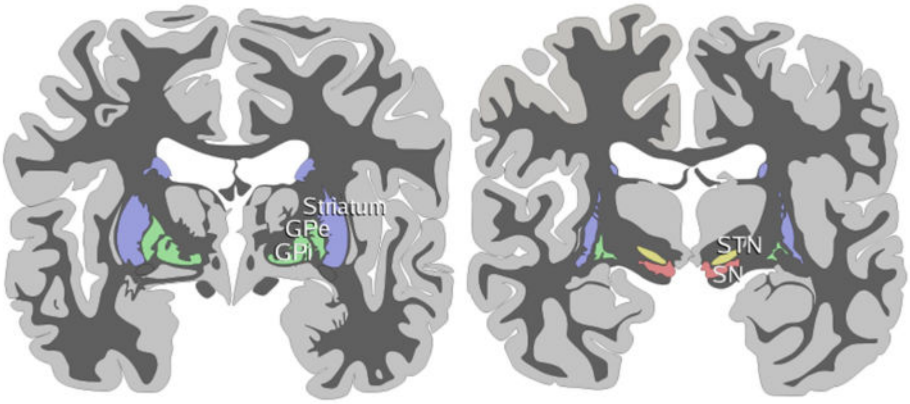


Figure 8: Basal ganlia.
http://en.wikipedia.org/wiki/File:Basal-ganglia-coronal-sections-large.png

schematic drawings of coronal sections of human brain labelling the basal ganglia. Blue=striatum, green=globus pallidus (external and internal segments), yellow=subthalamic nucleus, red=substantia nigra (pars reticulata and pars compacta). The right section is the deeper one, closer to the brainstem.

	Dorsal Motor Stream (volitional movement)	**Ventral Limbic Stream (emotional behavior)**
Cortical input	Sensory and motor cortex	Prefrontal cortex, amygdala, hippocampal formation
Striatum	Caudate nucleus Putamen	Nucleus accumbens Ventral striatum (several small subdivisions)
Pallidum	Globus pallidus, internal segment Globus pallidus, external segment Substantia nigra, pars reticulata	Ventral pallidum Substantia nigra, pars reticulata
Modulatory inputs	Substantia nigra, pars compacta (dopamine) Subthalamic nucleus (glutamate)	Ventral tegmental area (dopamine)
Thalamic target of output	Ventral anterior/ventral lateral nuclei	Mediodorsal nucleus

Table 1. Major components of the basal ganglia
Source table: Tutorial Notes Medical Neuroscience 2013© Duke staff

Disinhibition in direct and indirect pathways of the basal ganglia in a healthy brain.

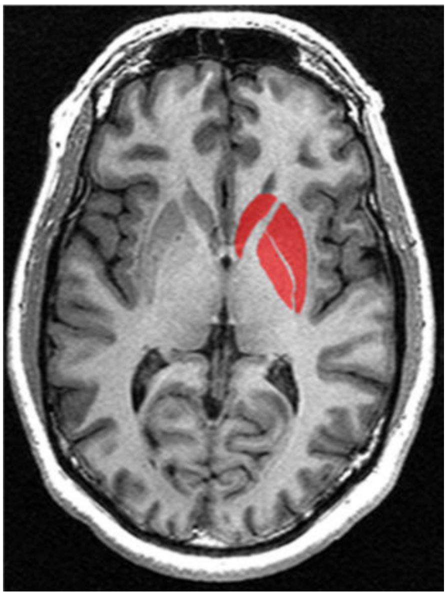


Figure 9: Basal Ganglia MRI
This is a transverse section of the striatum from a structural MR image.
The striatum includes the caudate nucleus (top) and putamen (right) and the globus pallidus(left).
http://en.wikipedia.org/wiki/File:Striatum_Structural_MRI.png

Basal ganglia:
- Putamen: concerned with the regulation of *bodily movement.*
- Caudate nucleus: regulates *movement of the mind and eyes.*
- Nucleus accumbens concerned with the *movement of emotion or motivated behavior* (addiction).

Basal ganglia are important for the initiation of movement, not the ongoing coordination of movements (role played by cerebellum).

There are 4 basal ganglia loops. Two motor loops; the oculomotor loop and the body movement loop. Two non-motor loops; the prefrontal loop and the limbic loop. Box 18D, page 414 Neuroscience, fifth edition. Box 18B, page 424 Neuroscience, sixth edition. The limbic loop is important in the neurobiology of addiction (nucleus accumbens). In this course the body movement loop is most important.

Basal ganglia are important because they fine tune the thalamus. They do this by turning down, inhibiting, the thalamus. The regulation principle of the basal ganglia is that they can disinhibit, release, the thalamus. The thalamus can then activate the cortical motor complex. This is done in two pathways, the direct and the indirect pathways of the basal ganglia.

The basal ganglia systems are controlled by dopamine from the substantia nigra:
Excitatory receptors (D1) in the direct pathway.
Inhibitory receptors (D2) in the indirect pathway.

Figure 18.7 page 406 Neuroscience, fifth edition, Figure 18.7 page 416 Neuroscience, sixth edition.
http://www.ncbi.nlm.nih.gov/books/NBK10799/ →fig. 18.8

Direct Pathway (to initiate voluntary movement)

+	transient activation; cerebral cortex → caudate/putamen
-	activated caudate/putamen → transient inhibition of globus pallidus internal segment
-	transient inhibition of globus pallidus internal segment → removes tonic inhibition VA/VL thalamus
+	VA/VL of the thalamus, transiently 'released" → activate motor complex

Disinhibition direct pathway; + = excitatory, - = inhibitory

Indirect Pathway (to reduce unwanted movement)

+	transient activation; cerebral cortex → caudate/putamen
-	activated caudate/putamen → transient inhibition of globus pallidus external segment
-	transient inhibition of globus pallidus external segment → disinhibits subthalamic nucleus
+	subthalamic nucleus 'released' → transiently activates globus pallidus internal segment
-	transient activation of globus pallidus internal segment → increases tonic inhibition VA/VL thalamus
-	VA/VL of the thalamus, further inhibited → does not activate motor complex

Disinhibition indirect pathway; + = excitatory, - = inhibitory

Direct and indirect pathway → opposing effect on the globus pallidus internal segment and thus opposing effect on the thalamus and motor cortex. Output of the basal ganglia depends on the balance between the direct and the indirect pathway.

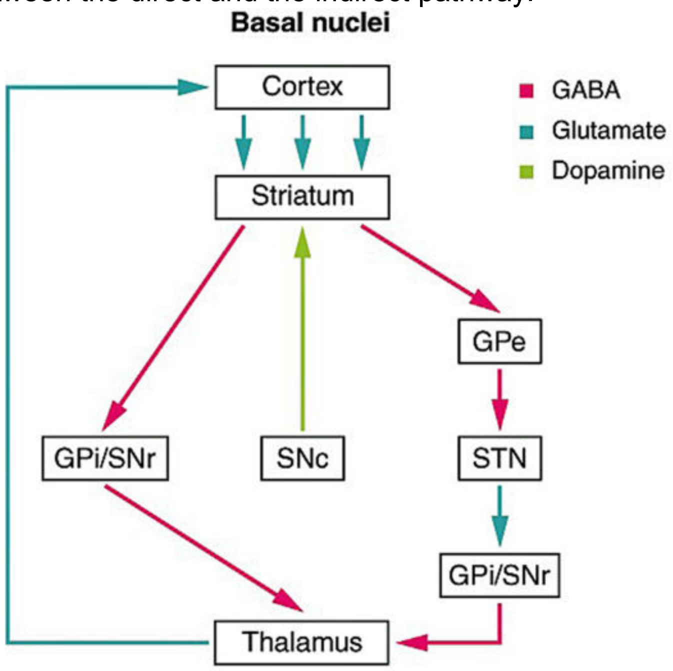


Figure 10: Direct and indirect pathways basal ganglia
Source: Anatomy & Physiology OpenStax College; Download for free at http://cnx.org/content/col11496/latest/"

The **direct pathway** is the projection of axons from the striatum to the globus pallidus internal segment (GPi) and the **substantia nigra pars reticulata** (SNr). The GPi/SNr then projects to the thalamus, which projects back to the cortex.

The **indirect pathway** is the projection of axons from the striatum to the globus pallidus external segment (GPe), then to the subthalamic nucleus (STN), and finally to GPi/SNr. The two streams both target the GPi/SNr, but one has a direct projection and the other goes through a few intervening nuclei.

Hypo and hyperkinetic disorders in movement control pathways

Figure 18.10 page 409 Neuroscience, fifth edition, Figure 18.9 and18.10 on page 418 and 422 Neuroscience, sixth edition
http://www.ncbi.nlm.nih.gov/books/NBK10799/ → fig. 18.10

In both hypokinetic disorders (like Parkinson's disease) and hyperkinetic disorders (like Huntington's disease, the balance of inhibitory signals in the direct and indirect pathways is altered, leading to a diminished ability of the basal ganglia to control the thalamic output to the cortex.

Parkinson's

- ↓	dopaminergic inputs substantia nigra pars compacta diminished → less transient inhibition from caudate/putamen
- ↓	diminished transient inhibition; caudate/putamen → globus pallidus internal segment
- ↑	sustained inhibition of globus pallidus internal segment → more tonic inhibition VA/VL thalamus
+↓	decreased excitation of motor cortex

Disinhibition direct pathway; + = excitatory, - = inhibitory. ↓ = decreased

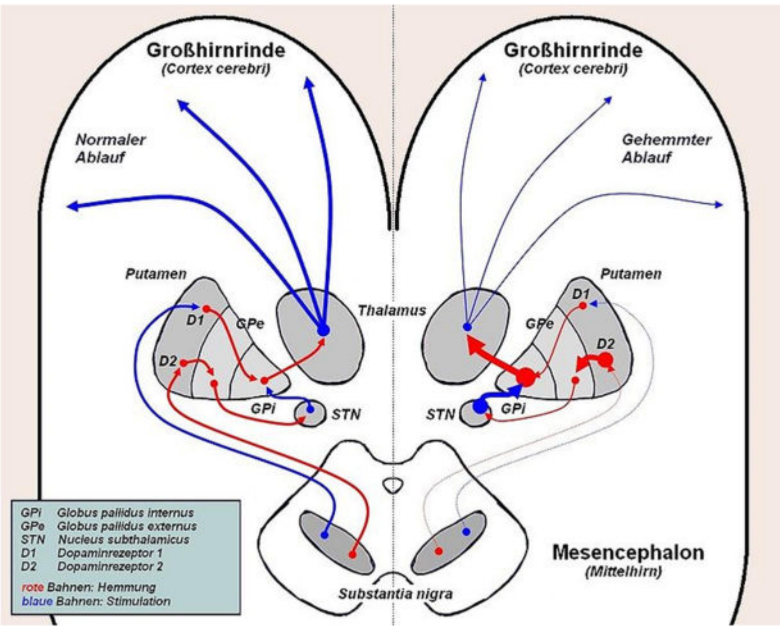


Fig. 11: Parkinson (right side of the figure, healthy individual left side)
http://commons.wikimedia.org/wiki/File:Parkinson_-_Ablauf_auf_funktioneller_Ebene.jpg

Hemmung = inhibition.; Normaler Ablauf = normal excitation; Gehemmter Ablauf = decreased excitation

Huntington's

- ↓	decreased (inhibitory) output from caudate/putamen to external segment of the globus pallidus
- ↑	Increased output (inhibitory) of globus pallidus external segment → increased inhibition subthalamic nucleus
- ↓	increased inhibition of subthalamic nucleus → diminished activation globus pallidus internal segment
- ↑	less activation of globus pallidus internal segment → less tonic inhibition VA/VL thalamus
+ ↑	VA/VL of the thalamus less inhibited → increased excitation motor complex

Disinhibition indirect pathway; + = excitatory, - = inhibitory

Pathways to and from the Cerebellum

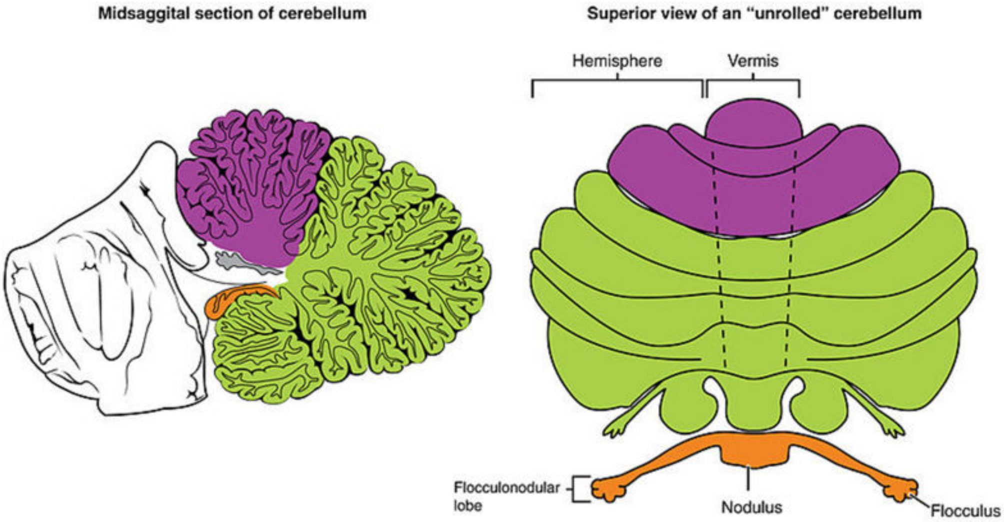


Figure 12. Anatomy cerebellum.
http://commons.wikimedia.org/wiki/File:1613_Major_Regions_of_the_Cerebellum-02.jpg

Major components of the Cerebellum

Cerebellar cortex	Deep cerebellar nuclei	Cerebellar peduncles
	Each projects to the red nucleus → feedback signals to olivary nucleus	
Cerebrocerebellum – skill controlateral, proprioceptive input	Dentate nucleus , output contralateral, superior peduncle, planning and rehearsal	Superior peduncle; output; Dentate/interposed nucei → superior colliculus Decussation (rostral) pons-midbrain
Spinocerebellum- posture, receive visual + audi signals, Ipsilateral, related to processing in cerebral cortex	Interposed nuclei,output contralateral, superior peduncle, planning and rehearsal	Middle peduncle, input; pontine nuclei → cerebellum
Vestibulocerebellum position +movement head, ipsilateral, receives and sends input to vestibular nuclei	Fastigal nuclei, output to reticular formation, posture, balance, gaze	Inferior peduncle, input; spinal cord → cerebellum Vestibular nuclei → cerebellum Output: Fastigal nuclei → superior colliculus, reticular formation Cerebellar cortex → vestibular nuclei

Cerebellar function:

- Error correction, integration of executive commands with sensory feedback regarding environment (external and internal) → moment-to-moment adjustment of behavior.
- Learns new behavioral programs when errors are numerous
- Coordinates ongoing multi-jointed movements (motor agility)
- Assists the premotor cortex in planning movements when motor learning has been stored and errors are few
- Coordinates ongoing sequential cognitive processes (cognitive agility)

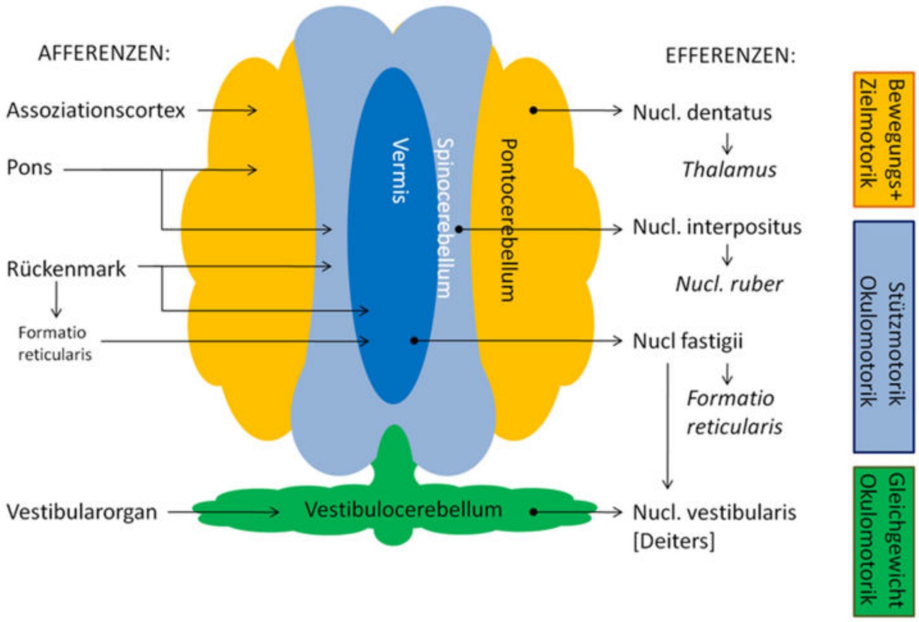


Figure 13. Inputs, outputs and function of the Cerebellum (in German)
https://commons.wikimedia.org/wiki/File:Kleinhirn.png?uselang=de

Bewegungsv+ Zielmotorik=Motion motor activity + Direct motility
Stützmotorik , Okulomotorik = Motor support, Eye movement
Gleichgewich,t Okulomotorik = Balance, Eye movement
Afferentzen = afferents; Rückenmark = Spinal cord
Efferenzen = Efferents, Nucleus Ruber = Red nucleus

Input into cerebellum
Figure 19.3 page 420 Neuroscience, fifth edition, Figure 19.3 page 430 Neuroscience, sixth edition
http://www.ncbi.nlm.nih.gov/books/NBK10799/ →fig. 19.3

- Executive signals, from controlateral cerebral cortex, via pontine nuclei through middle cerebellar peduncle : *conveys the commands for (motor) behavior.*
- Feedback signals from proprioceptive systems to spinocerebellum: *conveys sensory information about ongoing behavior.*
  → dorsal spinocerebellar tract from nucleus of Clarcke through inferior cerebellar peduncle
  → cuneocerebellar tract from external cuneate nucleus through inferior cerebellar peduncle
- Learning signals derived from the inferior olivary nucleus of the medulla: *facilitates adaption (error correction)* → inferior olivary nucleus trough inferior cerebellar peduncle

Output from cerebellum
Figure 19.6 page 422 Neuroscience, fifth edition, Figure 19.6 page 432 Neuroscience, sixth edition
http://www.ncbi.nlm.nih.gov/books/NBK10799/ → fig. 19.6
and Figure 19.7 page 423 Neuroscience, fifth edition, Figure 19.7 page 433 Neuroscience, sixth edition

Ascending output directed to thalamocortical circuits

- Dentate nucleus (superior peduncle) → decussation → VL → control/cognition in motor cortex and prefrontal cortex, sequencing multiple steps

Descending output directed to brainstem circuits (reticular formation)

- Fastigial nuclei (inferior cerebellar peduncle), posture, balance, gaze
- Deep cerebellar nuclei to red nucleus → inferior olivary nucleus
- Dentate and interposed nuclei (superior cerebellar peduncle) → superior colliculus
- Vestibulocerebellum → eye movement and posture

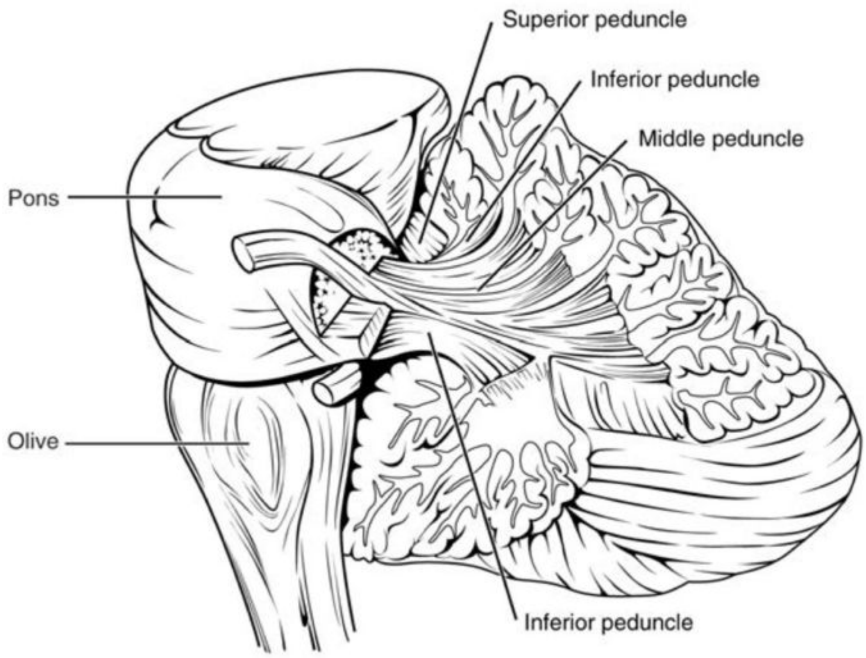


Figure 14 Cerebellar peduncles
Source: Anatomy & Physiology OpenStax College; Download for free at http://cnx.org/content/col11496/1.6

Sensory and motor pathways in the spinal cord

The vertebral column and spinal cord is divided into cervical, thoracic, lumbar, sacral and coccygeal regions. The spinal cord in the cervical and lumbosacral regions is enlarged to accommodate the nerve cells and connections from the upper and lower limbs.

Neurons of the dorsal horns receive sensory information that enters the spinal cord via the dorsal roots of the spinal nerves. The lateral horns are present in the thoracic region. The ventral horn contain the cell bodies of motor neurons that send axons via the ventral roots of the spinal nerves to terminate on striated muscles.

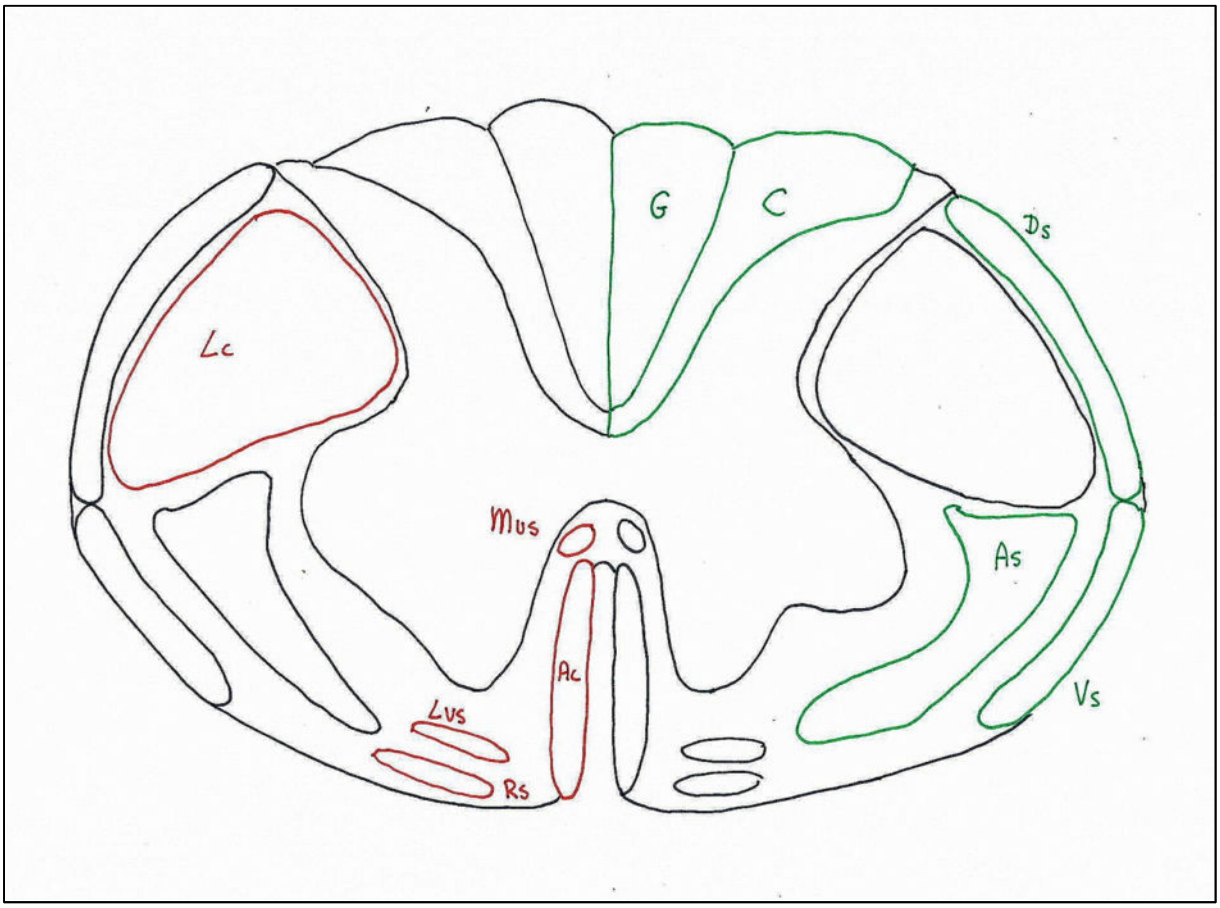


Figure 15: Pathways in the cervical spinal cord.

Sensory Pathways
G = Cracile tract, fine touch and vibration lower limbs
C = Cuneate tract, fine touch and vibration upper limbs
Ds = Dorsal spinocerebellar tract, proprioception
Vs = Ventral spinocerebellar tract, proprioception
As = Anterolateral system, crude touch, pain and temperature
Motor Pathways
Lc = Lateral corticospinal tract, volational control distal limbs.
Mvs = Medial vestibulospinal tract, head and eye coordination, vestibular-cervical reflexes
Ac = Anterior corticospinal tract, posture and balance.
Lvs =Lateral vestibulospinal tract, upright posture and balance
Rs = Reticulo spinal tract, locomotion and anticipatory postural control
Source: Ellen Vos

Cranial and spinal nerves

Figure A7 + table A2 page 723/724 Neuroscience, fifth edition, Figure A8 + table A2 page A7/A8 Neuroscience, sixth edition
http://www.ncbi.nlm.nih.gov/books/NBK10799/ ,→ box A. Neural Systems

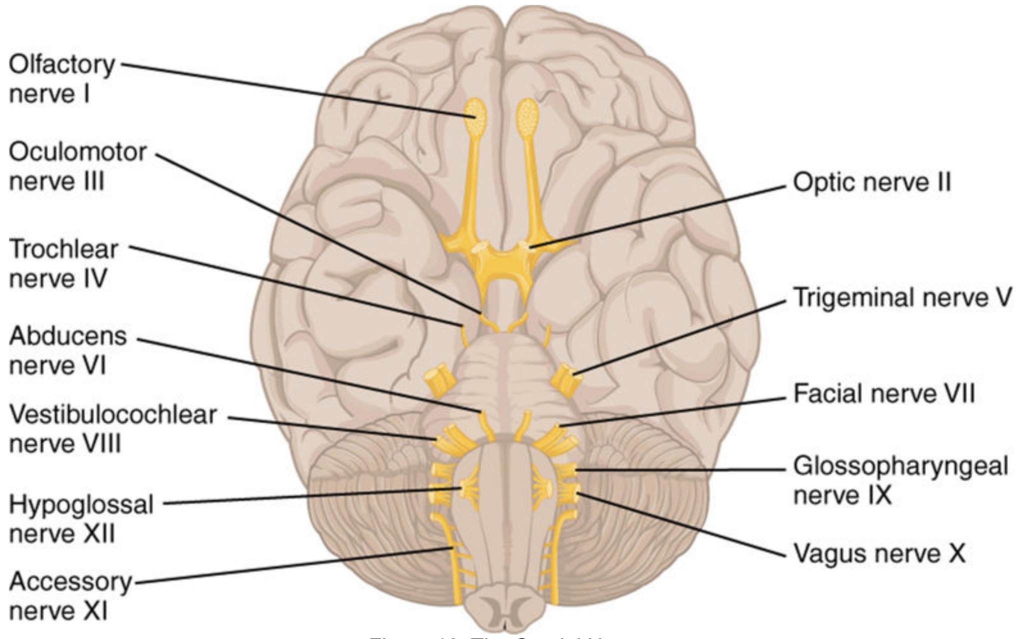


Figure 16. The Cranial Nerves
Source: Anatomy & Physiology OpenStax College; Download for free at http://cnx.org/content/col11496/1.6

Cranial Nerves

Mnemonic	#	Name	Function (S/M/B)	Central connection (nuclei)	Peripheral connection (ganglion or muscle)
On	I	Olfactory	Smell (S)	Olfactory bulb	Olfactory epithelium
Old	II	Optic	Vision (S)	Hypothalamus/ thalamus/midbrain	Retina (retinal ganglion cells)
Olympus'	III	Oculomotor	Eye movements (M)	Oculomotor nucleus	Extraocular muscles (other 4), levator palpebrae superioris, ciliary ganglion (autonomic)
Towering	IV	Trochlear	Eye movements (M)	Trochlear nucleus	Superior oblique muscle
Tops	V	Trigeminal	Sensory/ motor – face (B)	Trigeminal nuclei in the midbrain, pons, and medulla	Trigeminal
A	VI	Abducens	Eye movements (M)	Abducens nucleus	Lateral rectus muscle
Finn	VII	Facial	Motor – face, Taste (B)	Facial nucleus, solitary nucleus, superior salivatory nucleus	Facial muscles, Geniculate ganglion, Pterygopalatine ganglion (autonomic)
And	VIII	Auditory (Vestibulocochlear)	Hearing/ balance (S)	Cochlear nucleus, Vestibular nucleus/ cerebellum	Spiral ganglion (hearing), Vestibular ganglion (balance)
German	IX	Glossopharyngeal	Motor – throat Taste (B)	Solitary nucleus, inferior salivatory nucleus, nucleus ambiguus	Pharyngeal muscles, Geniculate ganglion, Otic ganglion (autonomic)
Viewed	X	Vagus	Motor/ sensory – viscera (autonomic) (B)	Medulla	Terminal ganglia serving thoracic and upper abdominal organs (heart and small intestines)
Some	XI	Spinal Accessory	Motor – head and neck (M)	Spinal accessory nucleus	Neck muscles
Hops	XII	Hypoglossal	Motor – lower throat (M)	Hypoglossal nucleus	Muscles of the larynx and lower pharynx

Table 2. Cranial Nerves
Source: Anatomy & Physiology OpenStax College; Download for free at http://cnx.org/content/col11496/1.6

Cortex

Cortex and cognition

Cognitive process	Metaphor / Example	Neural Process
Attention	cognitive "search light"	modulatory influences of brainstem reticular formation, hypothalamus and basal forebrain nuclei on thalamic and cortical processes
Recognition	finding a friend's face in a crowd	coding of feature representations in primary and higher order sensory cortices
Integration	knowing that friend	integration ("association") of disparate processing streams in associational cortices
Planning	deciding to seek out that friend	processing in executive associational cortices in prefrontal cortex of frontal lobe
Selection & execution	Walking towards that friend and engage in conversation	implementation of short-term and long-term plans via somatic motor, visceral motor and emotional motor systems

Table 3. Neural processes that contribute to cognition
Source table: Tutorial Notes Medical Neuroscience 2013 © Duke staff

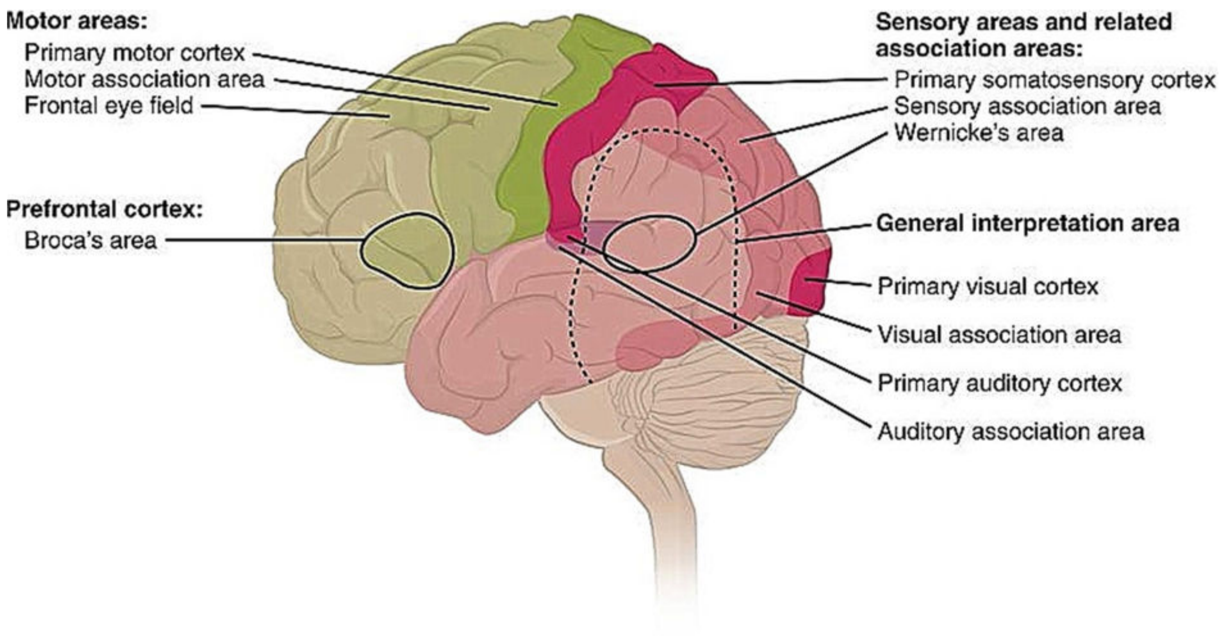


Figure 17: Cortical Areas
Source: Anatomy & Physiology OpenStax College; Download for free at http://cnx.org/content/col11496/latest/"

Blood supply to the brain

Figure A17 Neuroscience fifth edition page 738, Figure A19 page A-24 Neuroscience, sixth edition
hhttp://www.ncbi.nlm.nih.gov/books/NBK10799/, → fig.1.20

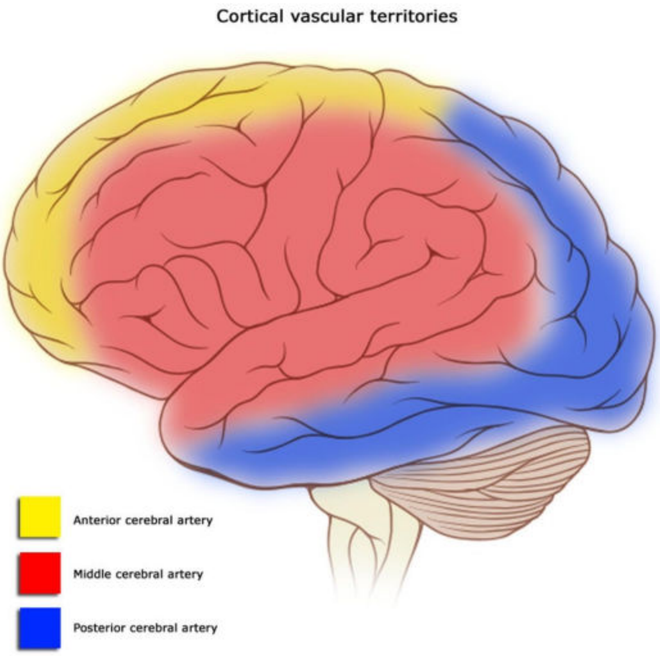


Figure 18: Blood supply lateral cortical Areas
http://upload.wikimedia.org/wikipedia/commons/4/4a/Cerebral_vascular_territories.jpg

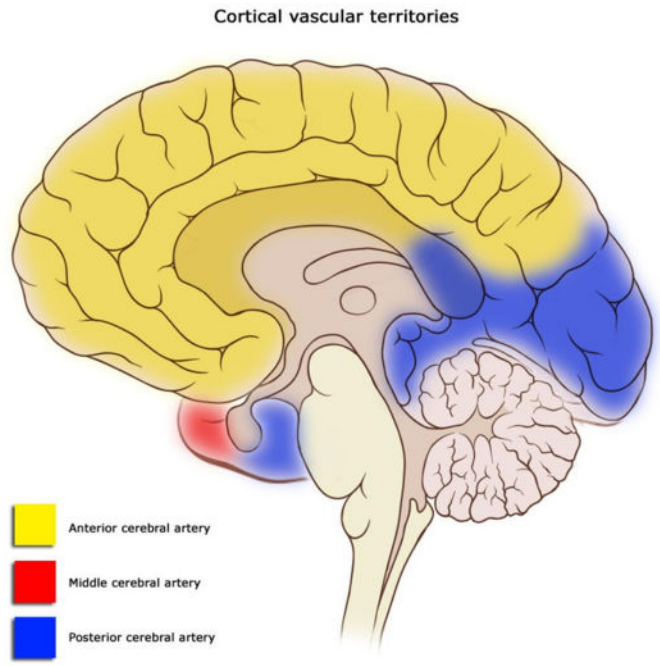


Figure 19: Blood supply sagittal cortical areas
http://upload.wikimedia.org/wikipedia/commons/e/ed/Cerebral_vascular_territories_midline.jpg

Blood supply of the brainstem subdivisions.

Figure A19 Neuroscience fifth edition page 740, Figure A21 page A-26 Neuroscience sixth edition
[hhttp://www.ncbi.nlm.nih.gov/books/NBK10799/,](hhttp://www.ncbi.nlm.nih.gov/books/NBK10799/) → fig.1.21

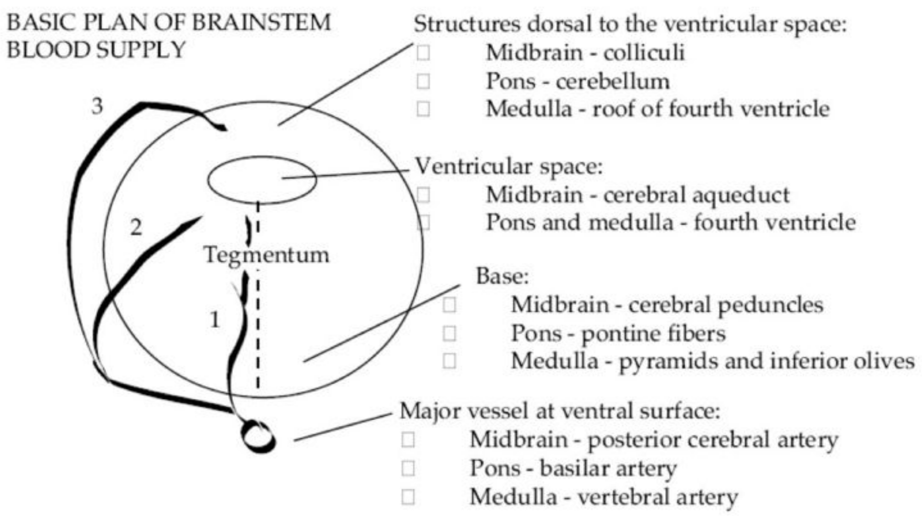


Fig. 1. The basic plan of blood supply to the brainstem. The major vessel on the ventral surface of the brainstem gives rise to:

1. median and paramedian perforating arteries
2. lateral perforating arteries (short circumferential arteries)
3. dorsal perforating arteries (long circumferential arteries)

Figure 20: Basic plan of brainstem blood supply
Medical Neuroscience I Tutorial Notes: Blood Supply to the Brain page 4.

Warning

This summary is based on information in the Coursera course Medical Neuroscience. Spring 2013 and intended for use of students taking course Coursera Medical Neuroscience (Duke University).

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Neuroscience, 2nd edition, http://www.ncbi.nlm.nih.gov/books/NBK10799 /
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