Central nervous system (CNS)

spinal cord and **brain, division, vessels, ventricles, coverings, tracts**

Spinal cord

borders	cranial – foramen magnum, pyramidal decussation, exit of first pair of spinal nerves caudal – level of L1 – L2 vertebrae medullary cone, filum terminale (S2), cauda equine
enlargements	cervical enlargement (C5 – Th1): for brachial plexus (upper limb) lumbosacral enlargement (L1 – S2): for lumbar and sacral plexus (lower limb)
segments	31 segments of spinal cord, segment – part of spinal cord from which 1 pair of spinal nerves emerges: 8 cervical, 12 thoracic, 5 lumbar, 5 sacral, and 1 coccygeal pair vertebro-medullary topography (Chipault's rule) – correlation between spinal and vertebral segments numerical marking
external features	anterior median fissure, posterior median sulcus anterolateral sulcus – anterior roots of spinal nn. posterolateral sulcus – posterior roots of spinal nn. posterior intermediate sulcus
internal features	white matter – anterior, lateral, and posterior funiculi gracile and cuneate fasciculi gray matter anterior (ventral) horn – motor function: Rexed's laminae I – VI lateral horn – visceral function: Rexed's lamina VII dorsal (posterior) horn – sensory information: Rexed's laminae VIII – IX central grey matter – interneurons: around central canal Rexed's lamina X
central canal	cranially opens into IVth ventricle caudally expands into terminal ventricle
vessels of spinal cord	arteries: spinal brr. from near arteries – anterior and posterior radicular aa., posterior spinal aa. (in posterolateral sulci) – for posterior 1/3 of spinal cord anterior spinal a. (in anterior median fissure) – for anterior 2/3 of spinal cord veins: internal vertebral venous plexi open to external vertebral venous plexi
coverings of spinal cord	endorhachis – periosteum of vertebral canal epidural space: fatty tissue, internal vertebral venous plexuses 1/ dura mater 2/ arachnoid mater subarachnoid space: cerebrospinal fluid 3/ pia mater

Brain

rhombencephalon (hindbrain) myelencephalon – medulla oblongata (bulb of spinal cord)
metencephalon – pons and cerebellum
mesencephalon (midbrain)
prosencephalon (forebrain) – diencephalon and telencephalon

brainstem – medulla oblongata, pons, and mesencephalon

Brainstem

Medulla oblongata structures

from cranial border of spinal cord
to bulbopontine sulcus (groove between medulla oblongata and pons)
ventrally: anterior median fissure – foramen cecum, pyramid – pyramidal decussation, anterolateral sulcus – exit of CN XII, olive, posterolateral sulcus – exits CN IX, X, and XI, inferior cerebellar peduncles
dorsally: posterior median sulcus, gracile fasciculus – gracile tubercle, posterior intermediate sulcus, cuneate fasciculus – cuneate tubercle, lower part of rhomboid fossa

Pons structures

cranial continuation of medulla oblongata
ventrally: bulbopontine sulcus – exit of CN VI, pontocerebellar angle (pontocerebellar trigone) – exits of CN VII and VIII, basilar sulcus for basilar a., middle cerebellar peduncle, trigeminofacial line – forms lateral border of pons, connects exits of CN V and CN VII
dorsally: upper part of rhomboid fossa

Rhomboid fossa

posterior surface of medulla oblongata and pons, forms floor of IVth ventricle
median sulcus of rhomboid fossa, median eminence, sulcus limitans (border between alar and basal plates from developmental period)
superior part: superior fovea, locus ceruleus, facial colliculus (fibers of facial n. loop around ncl. of abducent n.)
intermediate part: medullary striae of rhomboid fossa, vestibular area and acoustic tubercle (vestibular and cochlear ncll.)
inferior part: hypoglossal trigone (ncl. of hypoglossal n.), vagal trigone (ncl. of vagus n.), area postrema, inferior fovea (on top of vagal trigone)

Midbrain

cerebral peduncle – ventral to cerebral aqueduct
cerebral crus (base of peduncle) – interpeduncular fossa (posterior perforating substance), exit of CN III
tegmentum of midbrain – substantia nigra, red nucleus
cerebral aqueduct between tectum and tegmentum
tectum of midbrain – dorsal to cerebral aqueduct
superior colliculi – brachium of superior colliculi (part of visual tract)
inferior colliculi – brachium of inferior colliculi (part of auditory tract)
exit of CN IV, superior cerebellar peduncles, superior medullary velum (frenulum of superior medullary velum)

Reticular formation

reticular ncll. – from upper spinal cord to midbrain, nuclei of various functions arranged to network, center of vital reflexes, cardiovascular and respiratory center, regulates biological rhythms (circadian rhythm), autonomic functions

Nuclei of cranial nerves functional components

1/ general somatomotor – for muscles of tongue except of palatoglossus m.
2/ special somatomotor – for muscles of eyeball
3/ special visceromotor – for muscles which derived from branchial arches
4/ general visceromotor (PS) – heart, smooth muscles, glands, and vessels
5/ general viscerosensory – bring information from internal organs and vessels
6/ special viscerosensory – bring information on taste and smell
7/ general somatosensory – touch, pressure, pain, temperature, vibration
8/ special somatosensory – retina and organs of hearing and balance

CN I and CN II – have special somatosensory fibers, no nuclei, no branches
parts of forebrain: CN I – telencephalon, CN II – diencephalon

median sulcus ↓ | sulcus limitans ↓

	SM - G	SM - S	VM - S	VM - G (PS)	VS - G	VS - S	SS - G	SS - S
CN III		[3]ncl. of III		[3]accessory ncl.				
CN IV		[3]ncl. of IV						
CN V			[2]motor ncl. of V				[1]spinal ncl. [2]pontine ncl. [3]mesencephalic ncl.	
CN VI		[2]ncl. of VI						
CN VII			[2]ncl. of VII	[2]superior salivatory ncl.		[1,2]gustatory ncl.		
CN VIII								[1,2]vestibular ncll. [1,2]cochlear ncll.
CN IX			[1]ambiguus ncl.	[1]inferior salivatory ncl.	[1]solitary ncl.	[1]gustatory ncl.		
CN X			[1]ambiguus ncl.	[1]posterior ncl. of vagus	[1]solitary ncl.	[1]gustatory ncl.		
CN XI			[1]ambiguus ncl.					
CN XII	[1]ncl. of XII							
Nuclei in: [1]medulla oblongata [2]pons [3]midbrain	tongue mm. except of palato-glossus m.	oculo-motor muscles	branchial mm.: head, larynx, pharynx, esophagus	miosis, glands, heart, smooth muscles of organs	visceral sense	taste	head: [1]rude sensation [2]fine sensation [3]proprioception	balance hearing

Cerebellum

coordinates muscle activity, controls muscle tension, ensures upright position and balance of the body, voluntary movements and reflex motor skills
under tentorium cerebelli, in posterior cranial fossa, in cerebellar fossae

structures
vermis – middle unpaired part
hemisphere – anterior, posterior, and flocculonodular lobes
superior and inferior surfaces
primary fissure – between anterior and posterior lobes
horizontal fissure – between superior and inferior surfaces
posterolateral fissure – between posterior and flocculonodular lobes
cerebellar cortex – gray matter; tree of life (arbor vitae) – white matter
cerebellar nuclei – gray matter: dentate nucleus (the biggest), fastigial nuclei emboliform nucleus, globose nuclei
superior cerebellar peduncles – connect cerebellum to midbrain
middle cerebellar peduncles – connect cerebellum to pons
inferior cerebellar peduncles – connect cerebellum to medulla oblongata

anatomical division	*lobe*	*vermis / hemispheria*	*surface*
	anterior	lingula / vinculum lingulae	superior
	anterior	central lobule / ala of central lobule	superior
	anterior	culmen / quadrangular lobule	superior
		primary fissure	
	posterior	declive / lobulus simplex	superior
	posterior	folium / superior semilunar lobule	superior
		horizontal fissure	
	posterior	tuber / inferior semilunar lobule	inferior
	posterior	pyramis / biventral lobule	
inferior	posterior	uvula / tonsil	inferior
		posterolateral fissure	
	flocculonodular	nodulus / flocculus	inferior

developmental division	vestibulocerebellum (archicerebellum) – developmentally the oldest part of cerebellum, maintenance of balance and posture spinocerebellum (paleocerebellum) – maintenance of muscle tension, gross motor skills cerebrocerebellum (neocerebellum) – the youngest part of the cerebellum, coordination and planning of conscious movements, fine motor skills

Diencephalon

	located upward and in front of midbrain, hypothalamic sulcus – border between sensory and motor parts of diencephalon
Thalamus	above hypothalamic sulcus, the largest portion of diencephalon "gate to consciousness", receives all sensory information (except olfactory)
structures	medial surface: interthalamic adhesion (intermediate mass), medullary stria of thalamus (thalamic tenia) dorsal surface: terminal sulcus (superior thalamostriate v., terminal stria), choroid tenia (choroid plexus of lateral ventricle), lamina affixa, anterior tubercle, pulvinar metathalamus: medial geniculate body – subcortical auditory centre lateral geniculate body – subcortical visual centre
nuclei	are separated from each other by internal and external medullary laminae 1/ anterior group – connected with limbic system (anterior ncll.) 2/ medial group – personality, emotions, feelings (mediodorsal ncl.) 3/ lateral group – sensitivity from head (ventral posteromedial ncl.), sensitivity from trunk and limbs (ventral posterolateral ncl.) 4/ reticular ncll. – connections with reticular formation and cerebral cortex
Epithalamus	dorsomedially to thalamus, connected with limbic system
structures	medullary stria of thalamus, habenular trigone, habenular sulcus, habenula (habenular commissure), epiphysis (pineal body), posterior commissure
Hypo-thalamus	located below hypothalamic sulcus, primary centre of ANS, structures: mammillary body, tuber cinereum, infundibulum, hypophysis thalamus opticus (optic n., optic chiasma, optic tract)
	hypophysis (pituitary gland) – 2 functionally different lobes: anterior lobe (adenohypophysis) – it is not part of CNS (endocrine gland) posterior lobe (neurohypophysis) – is part of hypothalamus
nuclei	two zones separated by fornix: 1/ medial ncll.: anterior group – parasympathetic function (supraoptic and paraventricular ncll., suprachiasmatic ncl., anterior hypothalamic ncl.), middle group: sympathetic function, synthetises releasing factors that stimulate hormones production of adenohypophysis (dorsomedial and ventromedial ncll.), posterior group – sympathetic function, connection with limbic system (mammillary ncll.) 2/ lateral ncll.: lateral hypothalamic ncl. (center of hunger)
Sub-thalamus	subthalamic ncl. – involved in motor tracts of basal ganglia zona inzerta – belongs to reticular formation

Telencephalon (cerebrum)

parts

cerebral hemispheres: cerebral cortex (gray matter), medullary body (white matter), basal ganglia (gray matter), rhinencephalon and limbic systems
surfaces: superolateral, medial, and inferior surfaces
margins: superior, medial, and inferior margins
lobes: frontal, parietal, occipital, temporal lobes, and insula
poles: frontal, occipital, and temporal poles

cerebral cortex
gyri, sulci
gray matter

1/ superolateral surface of telencephalon

central sulcus, lateral sulcus – anterior, ascending, and posterior rami

frontal lobe: precentral gyrus, precentral sulcus, superior frontal gyrus, superior frontal sulcus, middle frontal gyrus, inferior frontal sulcus, inferior frontal gyrus (orbital part, anterior ramus of lateral sulcus, triangular part, ascending ramus of lateral sulcus, opercular part, posterior ramus of lateral sulcus

parietal lobe: postcentral gyrus, postcentral sulcus, superior parietal lobule, intraparietal sulcus, inferior parietal lobule, supramarginal gyrus, angular gyrus

occipital lobe: occipital gyri, transverse occipital sulcus, lunate sulcus, preoccipital notch

temporal lobe: superior temporal gyrus (transverse temporal gyri), superior temporal sulcus, middle temporal gyrus, inferior temporal sulcus, inferior temporal gyrus

insula: limen of insula, circular sulcus, long gyrus of insula, central sulcus of insula, short gyri of insula

2/ medial surface of telencephalon

medial frontal gyrus, paracentral lobule, precuneus, parietooccipital sulcus, cuneus, calcarine sulcus, cingulate sulcus, cingulate gyrus (isthmus of cingulate gyrus), sulcus of corpus callosum, corpus callosum (rostrum, genu, body, splenium), medial and laterals longitudinal striae), fasciolar gyrus, septum pellucidum (laminae and cave of septum pellucidum), fornix (column, body, and crus of fornix), paraterminal gyrus, subcallosal area

3/ inferior surface of telencephalon

straight gyrus, olfactory sulcus, olfactory bulb, olfactory tract, medial and lateral olfactory striae, olfactory trigone, anterior perforating substance, optic n., optic chiasma, optic tract, orbital gyri, orbital sulci, hippocampal sulcus, parahippocampal gyrus (uncus), lingual gyrus, collateral sulcus, rhinal sulcus, medial occipitotemporal gyrus, occipitotemporal sulcus, lateral occipitotemporal gyrus

Basal ganglia
gray mater
lentiform ncl.

initiation and control of voluntary movements, inhibition of involuntary

caudate ncl. – head, body, and tail of caudate ncl.
globus pallidus lateral (external) and medial (internal)
putamen
striatum = putamen + caudate ncl.
lentiform ncl. = putamen + globus pallidus
corpus striatum = caudate ncl. + lentiform ncl.
claustrum
amygdaloid body (amygdala)

Medullary body	myelinated nerve fibers, have origin or/and termination in cerebral cortex
	semioval centre – in horizontal section between cortex and basal ganglia
white matter	corona radiata – below semioval centre, above of corpus callosum
	corpus callosum – radiation of corpus callosum (forceps major and minor)
	internal capsule – between head of caudate ncl., thalamus and lentiform ncl.
	anterior limb, genu, and posterior limb (in horizontal section V shaped)
	external capsule – between putamen and claustrum
	extreme capsule – between claustrum and cortex of insula

Rhinencephalon (olfactory system)

structures	olfactory bulb, olfactory tract, medial and lateral olfactory striae,
	olfactory trigone, anterior perforating substance
	piriform lobe: 1/ primary olfactory cortex – piriform area in uncus of
	parahippocampal gyrus (prepiriform and periamygdalar area)
	2/secondary olfactory cortex – enthorinal area and orbitofrontal cortex)

Limbic systém (LS)

	border (limbus) between cortical areas and subcortical nuclei
	between mind and instincts, between consciousness and subconscious
	functions: somatic – food and sex, autonomic – digestion, heart function
	sensitive – emotions, behavior, learning, memory
	parts of telencephalon, diencephalon, and mesencephalon
	connects with hypothalamus, expresses by ANS
structures	limbic lobe – septum, cingulate gyrus, parahippocampal gyrus, amygdala
	telencephalon – cortical areas: hippocampal formation, septum
	limbic association cortex: orbitofrontal cortex, cingulate gyrus,
	parahippocampal gyrus, entorhinal area
	subcortical areas: amygdala, basal ganglia
	diencephalon – thalamus: anterior ncl., mediodorsal ncl. (associating nucleus)
	hypothalamus: mammillary body, ventromedial ncl.
	epithalamus: habenular ncll. (connect with olfactory system)
	mesencephalon: reticular formation
1/ hippo-campal formation	learning, memory
	hippocampus, dentate gyrus (medially to hippocampus)
	subiculum (below hippocampus, on upper part of parahippocampal gyrus)
2/ septum verum	positive emotions, pleasure, releases serotonin (like drugs, sex)
	septal area – paraterminal gyrus, subcallosal area
3/ amygdala	developmentally belongs to basal ganglia, functionally to LS
	negative emotions, aggression, anger, anxiety, fear
	unconscious memory from early childhood when hippocampus is still immature
connections of LS	Papez circuit – hippocampus, fornix, mammillary body, anterior ncl. of
	thalamus, cingulate gyrus, hippocampus …
	fornix – the biggest efferent tract of hippocampus, begins as fimbria of fornix
	connects hippocampus with septum and mammillary body
	stria terminalis – efferent tract of amygdala, connects amygdala with septum
	and hypothalamus

Vessels and dural sinuses

Arteries of brain

vertebral a.
from subclavian a., through transverse foramens of C6 – C1
enters skull through foramen magnum
branches: anterior and posterior spinal aa., posterior inferior cerebellar a.
basilar a.: connection of two vertebral aa. – for brainstem and cerebellum
anterior inferior cerebellar a., pontine and mesencephalic aa.,
superior cerebellar a.
posterior cerebral a. (final branch): mostly for inferior surface of hemisphere
and pons – posterior communicating a.

internal carotid a.
from common carotid a., through carotid canal
cervical, petrous, cavernous and cerebral parts
branches: anterior cerebral a.: mostly for medial surface of hemisphere
– anterior communicating a.
middle cerebral a.: mostly for superolateral surface of hemisphere

arterial circle of Willis
circulus arteriosus cerebri
cerebral aa. for brain cortex and central aa. for deep parts of brain
1/ posterior cerebral a.
2/ middle cerebral a.
3/ anterior cerebral a.
anterior communicating a. (one): between two anterior cerebral aa.
posterior communicating a. (two): between posterior cerebral a. and
internal carotid a. (or middle cerebral a.)

Veins of brain

have no valves

superficial cerebral veins
in subarachnoid space, drain cerebral cortex
1/ superior cerebral vv.
2/ inferior cerebral vv.
3/ superficial middle cerebral v. and deep middle cerebral v.
– superior and inferior anastomotic vv.

deep cerebral veins
drain internal structures of brain
1/ internal cerebral v. – in choroid tela of IIIrd ventricle
from superior thalamostriate v., anterior septal v., and superior choroidal v.
2/ basal v. – drains brainstem, opens to great cerebral v.
3/ great cerebral v. – under splenium of corpus callosum,
from two internal cerebral vv.

dural sinuses
between two layers of dura matter
confluence of sinuses – junction of
superior sagittal sinus, straight sinus, occipital sinus, transverse sinus
internal jugular v. originates in jugular foramen from:
sigmoid sinus, superior and inferior petrosal sinuses
others sinuses: inferior sagittal sinus, sphenoparietal sinus, cavernous sinus

Brain ventricles

filled by cerebrospinal fluid made by choroid plexus (from arachnoid mater)

Fourth ventricle
IVth ventricle
unpaired ventricle, located in rhombencephalon

borders
floor: rhomboid fossa
roof: superior medullary velum
cerebellum – fastigium (highest point in roof of IVth ventricle)
inferior medullary velum: choroid tela and choroid plexus of IVth ventricle – median aperture of IVth ventricle (unpaired), obex
laterally: lateral recess of IVth ventricle – lateral apertures of IVth ventricle
upward: cerebral aqueduct
downward: central canal

Cerebral aqueduct
along whole midbrain, connects IVth and IIIrd ventricles
contains cerebrospinal fluid

IIIrd ventricle
IIIrd ventricle
unpaired ventricle, located in diencephalon (and partially in telencephalon)
is connected to lateral ventricles through interventricular foramens and to IVth ventricle through cerebral aqueduct

borders
roof: choroid tela and choroid plexus of IIIrd ventricle
in front: lamina terminalis, anterior commissure
floor: optic recess, optic chiasma, infundibular recess, tuber cinereum, mammillary body
behind: posterior commissure, pineal recess, habenular commissure, suprapineal recess
laterally: medial surface of thalamus (medullary stria, choroid tenia, interthalamic adhesion, hypothalamic sulcus, interventricular foramen, column of fornix)

recesses
supraoptic recess – in front of optic chiasma
infundibular recess – above stalk of hypophysis
suprapineal recess – above pineal body
pineal recess – into pineal body

Interventricular foramen
communication between IIIrd and lateral ventricles, paired

Lateral ventricle
paired, in both hemispheres, in four lobes of telencephalon
anteriorly are lateral ventricles separated each other by septum pellucidum

parts
anterior (frontal) horn: septum pellucidum, head of caudate ncl., rostrum and genu of corpus callosum
central part (in parietal lobe): body of caudate ncl., lamina affixa of thalamus, body of fornix, trunk of corpus callosum
posterior (occipital) horn: bulb of posterior horn, calcar avis, collateral trigone
inferior (temporal) horn: collateral eminence, choroid glomus
– in bottom of inferior horn lies hippocampus – pes hippocampi, hippocampal digitations, fimbria of hippocampus (fimbria of fornix), dentate gyrus

Coverings of brain

Dura mater tough fibrous membrane, toughly adherent to skull
forms duplicatures into skull cavity:
falx cerebri – between two cerebral hemispheres
falx cerebelli – between two cerebellar hemispheres
tentorium cerebelli – between cerebellum and occipital lobe
sellar diaphragm – covers sella turcica, has opening for stalk of hypophysis

Arachnoid mater soft translucent membrane, has no vessels and no nerves
arachnoid granulations – protrude to dural sinuses for absorption of cerebrospinal fluid
subarachnoid space – between arachnoid and pia maters, contains vessels and cerebrospinal fluid
subarachnoid cisterns – extension of subarachnoid space, filled by cerebrospinal fluid, the biggest is posterior cerebellomedullary cistern (cisterna magna); others: cistern of lateral fossa, interpeduncular cistern, pontine cistern, chiasmatic cistern, quadrigeminal cistern, pericallosal cistern, cisterna ambiens

Pia mater thin, highly vascular membrane closely adherent to gyri and sulci of brain surface, contains a rich network of blood vessels penetrating the brain, forms the choroid plexuses (which produce cerebrospinal fluid)

Nerve pathways (nerve tracts)

white mater, myelinated nerve fibers, located in and brain and spinal cord

Association tracts connect various areas in same hemisphere, ypsilaterally
long intracortical fibers:
inferior longitudinal fasciculus, superior longitudinal fasciculus, cingulum, frontooccipital fasciculus, uncinate fasciculus, and arcuate fasciculus
short subcortical fibers: between two neighbouring gyri, U-fibers

Commissural tracts connect same areas between two hemispheres, contralaterally
corpus callosum, anterior commissure, posterior commissure, habenular commissure, commissure of fornix

Projection tracts connect areas of various levels of CNS, brain cortex with other areas in the CNS, cortical areas and subcortical areas

ascending fibers = sensory = afferent = corticopetal = directed to upper centers
direct sensory tracts – conscious information
general sensory tracts: from skin and movement system
special sensory tracts: from specialised sensory organs
indirect sensory tracts – unconscious information

descending fibers = motor = efferent = corticofugal = directed to lower centers
direct motor tracts – conscious motor activity of skeletal muscles
indirect motor tracts – phylogenetically old, unconscious movements

Projection tracts

Ascending tracts – general and special sensory tracts

Direct sensory tracts

General sensory tracts – system of 3 neurons
1st neuron is inside of sensory ganglion of spinal or cranial nerve
2nd neuron crosses, 3rd neuron terminates in sensory cerebral cortex
superficial sensation = exteroception from skin:
– epicritic (fine) sensation: fine touch, discriminative sensation, vibration
– protophatic (crude) sensation: touch and pressure, pain and temperature
– proprioception – deep sensation from joints, tendons, and muscles

Direct **s**ensory tracts <u>from neck, trunk, and limbs</u> – general sensation:
1/ dorsal column tract = main sensory pathway
spino-bulbo-thalamo-cortical tract – epicritic and proprioceptive sensation
2/ anterior spinothalamic tract – protophatic sensation: touch and pressure
3/ lateral spinothalamic tract – protopathatic sensation
urgent pain and temperature
4/ spinoreticular tract – slow and diffuse pain
5/ spinotectal tract (has only 2 neurons) – spinovisual reflexes

Direct **s**ensory tracts <u>from head</u>
1/ trigeminothalamic tract – orofacial epicritic and protophatic sensation, and orofacial proprioception

Special sensory tracts
1/ visual tract and collaterals from visual tract:
tract of pupillary contraction and accommodation
tract of pupillary dilatation
2/ acoustic (auditory) tract
3/ vestibular tract
4/ gustatory (taste) tract
5/ olfactory tract

Indirect sensory tracts

system of 2 neurons, termination in cerebellum
coordination of movement, posture, and balance
1/ posterior spinocerebellar tract: information from lower half of body
2/ cuneocerebellar tract: information from upper half of body

Descending tracts – motor tracts

Direct motor tracts

motor tracts <u>to muscles of</u> <u>neck, trunk, and limbs</u> and <u>to muscles of head</u>
1/ corticospinal (pyramidal) tract – the youngest pathway phylogenetically,
upper motoneuron: in cerebral cortex, lower: in anterior horn of spinal cord
lateral corticospinal tract: 80% of fibers cross in pyramidal decussation, run in lateral funiculus of spinal cord to muscles of limbs
anterior corticospinal tract: 20% of fibers cross in anterior commissure of spinal cord, run in anterior funiculus of spinal cord to muscles of trunk
2/ corticonuclear tract – facial expression, chewing, speech, upper motoneuron: in cerebral cortex; lower motoneuron: in nuclei of cranial nerves

Indirect motor tracts

extrapyramidal tracts, modify information from cerebral cortex, modulates involuntary reflexes; more upper motoneurons: in ncl. ruber, substantia nigra, reticular formation, vestibular ncll., tectum; lower motoneuron: in motor nuclei of anterior horn of spinal cord and in motor nuclei of cranial nerves