MINISTRY OF HEALTH OF THE REPUBLIC OF UZBEKISTAN

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ANATOMY OF THE NERVOUS SYSTEM

EDUCATIONAL MANUAL

60910200-General medicine

This educational manual on the anatomy of the nervous system has been developed in accordance with the approved curriculum of the module.
Its study among foreign faculty students helps to deepen their understanding of the structure and functions of the human nervous system, to strengthen their theoretical knowledge, and to form the necessary practical skills in human anatomy.
The manual can also serve as a supplementary resource for independent learning and preparation for practical and theoretical classes.

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INTRODUCTION

According to the topographical principle, the unified nervous system is divided into the central and peripheral systems. The central nervous system (CNS) includes the brain and spinal cord. The brain consists of the brainstem, cerebrum, and cerebellum. Although the structure of each division of the CNS follows general patterns, each possesses specific features, the understanding of which is essential for clinical practice in neurology, neurosurgery, and psychiatry.

Objective – to acquire knowledge of the structural organization of the divisions of the central nervous system, as well as their morphological and functional interrelations.

As a result of studying this discipline, students must know:

- the basic anatomical terminology used to describe any division of the CNS (in Russian and Latin);
- the anatomical terms characterizing the structure of specific parts of the CNS;
- the structure of the gray and white matter of the spinal cord (names of elements, functional characteristics, and topography);
- the structure of the gray and white matter of the brain divisions (names of elements, functional characteristics, and topography);
- sensory and motor pathways (their structural and functional characteristics, and decussations);
- the meninges of the brain and spinal cord;
- the cerebrospinal fluid system of the brain (formation and drainage of cerebrospinal fluid).

As a result of studying this discipline, students must be able to:

- identify the details of the external structure of the spinal cord and brain;
- describe the details of the internal structure in cross-sections of the spinal cord and brain divisions;
- locate and identify the nuclei and the positions of the conduction pathways in cross-sections;
- describe the spatial arrangement and characteristics of the meninges of the brain and spinal cord;
- describe the pathways of circulation and drainage of cerebrospinal fluid;
- identify the projection of individual dural venous sinuses using external bony landmarks;
- use educational, scientific, and popular scientific literature, as well as internet resources, for professional purposes.

As a result of studying this discipline, students must possess:

- a medical-anatomical conceptual framework;
- basic skills in information processing technologies, including independent work with educational literature in printed and electronic formats, and the use of online anatomy resources.

This textbook will help students master the learning material and develop the following competencies:

- ability for abstract thinking, analysis, and synthesis (GC-1);
- readiness for self-development, self-realization, self-education, and the use of creative potential (GC-5);
- readiness to solve standard professional tasks using informational and bibliographic resources, biomedical terminology, information and communication technologies, while adhering to the basic requirements of information security (PC-1);
- readiness to apply basic physical, chemical, mathematical, and other natural science concepts and methods in solving professional problems (PC-7);
- ability to assess morphofunctional and physiological states, as well as pathological processes in the human body, for solving professional problems (PC-9).

SPINAL CORD (MEDULLA SPINALIS)

The spinal cord is located within the vertebral canal.

Borders:

- **Upper border** – at the level of the margin of the foramen magnum, where it continues into the medulla oblongata;
- **Lower border** – at the level of the second lumbar vertebra (may vary from the first to the third lumbar vertebra), ending with the *conus medullaris*, which continues as the spinal portion of the *filum terminale*.

Cavity:
The central cavity of the spinal cord is represented by the *central canal (canalis centralis)*, which communicates superiorly with the fourth ventricle.

External structure:

- On the anterior surface lies the *anterior median fissure (fissura mediana anterior)*;
- On the posterior surface – the *posterior median sulcus (sulcus medianus posterior)*;
- On both the anterior and posterior surfaces, lateral to the median fissure and sulcus, respectively, are the *anterolateral and posterolateral sulci (sulci anterolateralis et posterolateralis)*;
- In the region of the anterolateral sulci, **31 pairs of anterior roots (radices anteriores)** emerge from the spinal cord;

- On each posterior root there is a thickening – the **spinal (sensory) ganglion (ganglion sensorium nervi spinalis)**;

Each half of the spinal cord is divided into **three funiculi** (*columns*):

- **Anterior funiculus (funiculus anterior)** – between the anterior median fissure and the anterolateral sulcus (the site of exit of anterior roots);
- **Lateral funiculus (funiculus lateralis)** – between the anterolateral and posterolateral sulci (the sites of exit of anterior and entry of posterior roots);
- **Posterior funiculus (funiculus posterior)** – between the posterior median and posterolateral sulci (the site of entry of posterior roots).

The spinal cord has **two enlargements**:

- **Cervical enlargement (intumescentia cervicalis)**;
- **Lumbosacral enlargement (intumescentia lumbosacralis)**.
  These correspond to the spinal cord segments that provide innervation to the upper and lower limbs, respectively.

Functions of the spinal cord:

1. **Reflex function** – the more primitive one; it provides an automatic response of the spinal cord to external stimuli (reflex arc).
2. **Conductive function** – developed later, along with the evolution of the brain, and ensures bidirectional communication between the spinal cord and the brain.

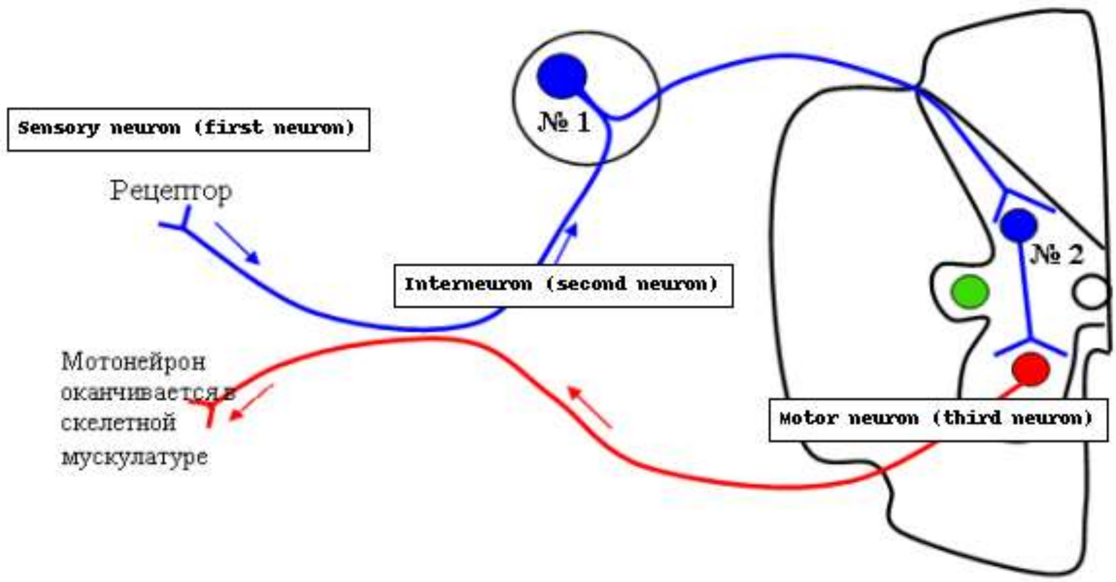

Fig. 1.Somatic Three-Neuron Reflex Arc (schematic):
No. 1 – the first neuron (sensory, afferent) is located in the sensory ganglion of the spinal nerve**;**
No. 2 – the second neuron (interneuron) is located either in the nuclei of the posterior horn or represented by intercalated (scattered) neurons within the spinal cord**;**
No. 3 – the third neuron (motor, efferent) is located in the motor nuclei of the anterior horn of the spinal cord**.**

According to its two primary functions, the spinal cord possesses two functional systems: the segmental apparatus and the conduction (pathway) apparatus.

The segmental apparatus is composed of segments that are both morphologically and functionally interconnected.
A segment is a transverse portion of the spinal cord corresponding to a single pair of spinal nerves (see Fig. 2).
There are 31 segments in total, classified as follows:

- 8 cervical segments (segmenta cervicalia)
- 12 thoracic segments (segmenta thoracica)
- 5 lumbar segments (segmenta lumbalia)
- 5 sacral segments (segmenta sacralia)
- 1 coccygeal segment (segmentum coccygeum)

Each spinal segment consists of three components:

- a transverse portion of gray matter,
- a thin rim of white matter surrounding the gray matter,
- and one pair of spinal nerves emerging from the segment.

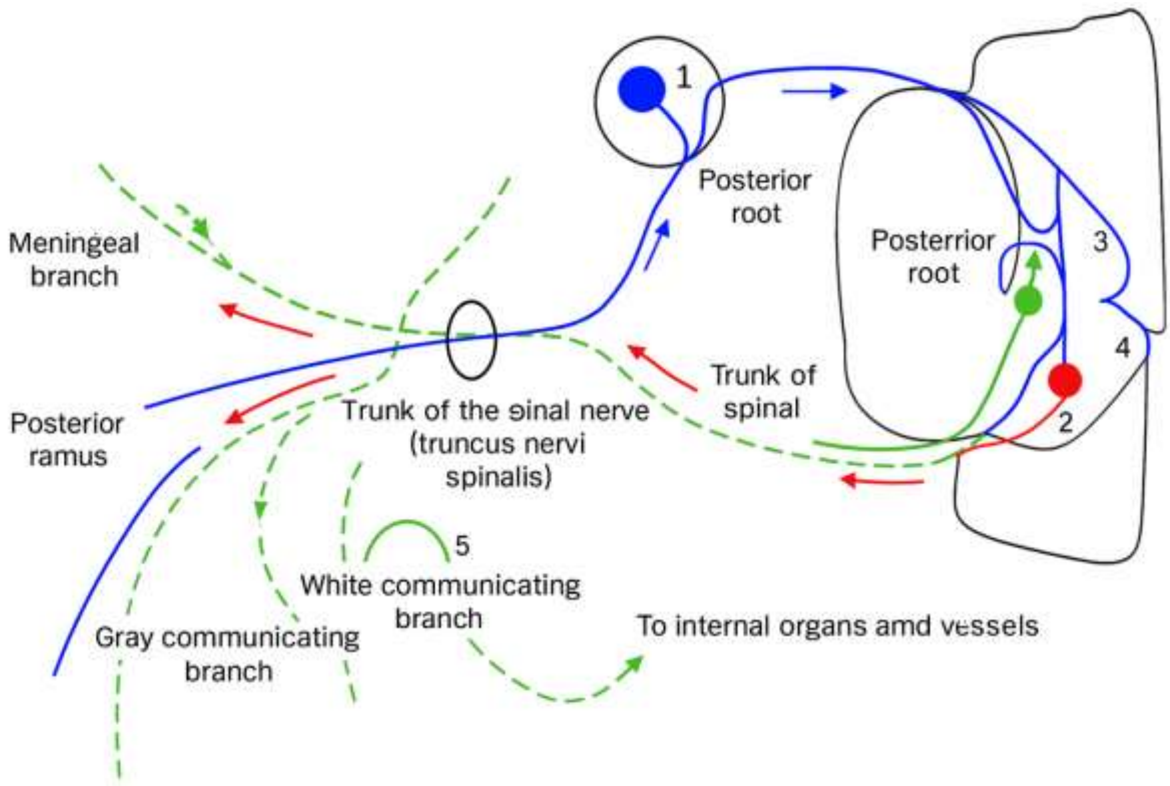

Figure 2. Formation and Branches of the Spinal Nerve (schematic representation):

CMH – trunk of the spinal nerve (*truncus nervi spinalis*)
1 – sensory ganglion of the spinal nerve (sensory neuron) (*ganglion sensorium nervi spinalis*)
2 – interneuron (*neuron intercalatus*)
3 – motor neuron (*neuron motorius*)
4 – autonomic (vegetative) neuron (*neuron autonomicus*)
5 – ganglion of the sympathetic trunk (*ganglion trunci sympathici*)

— afferent nerve fibers (sensory) (*neurofibrae afferentes*)
— efferent nerve fibers (somatic motor) (*neurofibrae efferentes*)
— preganglionic nerve fibers (autonomic) (*neurofibrae preganglionicae*)
— postganglionic nerve fibers (autonomic) (*neurofibrae postganglionicae*)

Arrows – indicate the direction of the nerve impulse.

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The Gray Matter of the Spinal Cord

In cross-section, the gray matter has the characteristic shape of a butterfly. Within it, several distinct regions are identified:

- Anterior (ventral) horns (*cornu anterius*) — broad extensions that form the anterior columns.
- Posterior (dorsal) horns (*cornu posterius*) — narrow projections that form the posterior columns.
- Intermediate zone (*zona intermedia*) — the area between the anterior and posterior horns, often referred to as the intermediate column.
- Lateral horns (*cornu laterale*) — present at the levels from the 8th cervical (C8) to the 2nd lumbar (L2) segments, continuous with the intermediate zone.

The gray matter is composed primarily of neuron cell bodies, though it also contains neuronal processes and their synaptic endings.

The arrangement of neuronal bodies within the gray matter varies: some are clustered together to form distinct nuclei, while others are scattered diffusely throughout the gray matter — known as dispersed (diffuse) cells (see *Fig. 3*).

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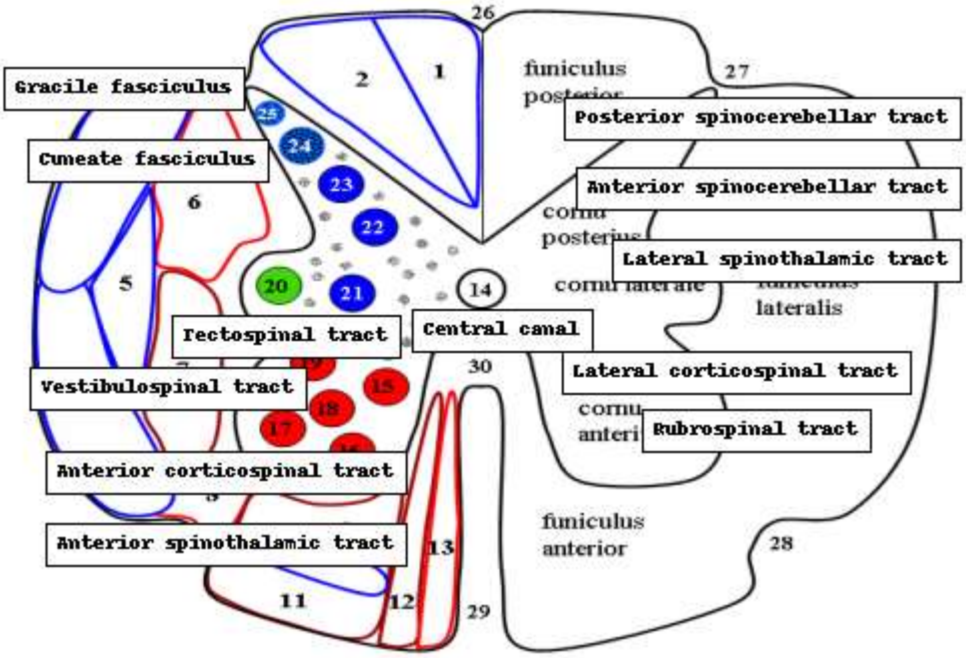

Fig. 3. White and Gray Matter of the Spinal Cord; Transverse Section (Diagram):

1 – Gracile fasciculus (fasciculus gracilis);
2 – Cuneate fasciculus (fasciculus cuneatus);
3 – Posterior spinocerebellar tract (tractus spinocerebellaris posterior);
4 – Anterior spinocerebellar tract (tractus spinocerebellaris anterior);
5 – Lateral spinothalamic tract (tractus spinothalamicus lateralis);
6 – Lateral corticospinal tract (tractus corticospinalis lateralis);
7 – Rubrospinal tract (tractus rubrospinalis).
8 – Olivospinal tract (tractus olivospinalis);
9 – Reticulospinal tract (tractus reticulospinalis).
10 – Anterior spinothalamic tract (tractus spinothalamicus anterior).
11 – Vestibulospinal tract (tractus vestibulospinalis);
12 – Anterior corticospinal tract (tractus corticospinalis anterior);
13 – Tectospinal tract (tractus tectospinalis);
14 – Central canal (canalis centralis);
15 – Posteromedial nucleus (nucleus posteromedialis);
16 – Anteromedial nucleus (nucleus anteromedialis);
17 – Anterolateral nucleus (nucleus anterolateralis);
18 – Central nucleus (nucleus centralis);
19 – Posterolateral nucleus (nucleus posterolateralis);
20 – Intermediolateral nucleus (nucleus intermediolateralis);
21 – Intermediomedial nucleus (nucleus intermediomedialis);
22 – Thoracic nucleus (nucleus thoracicus);
23 – Proper nucleus (nucleus proprius);
24 – Substantia gelatinosa (substantia gelatinosa);
25 – Spongy zone (zona spongiosa);
26 – Posterior median sulcus (sulcus medianus posterior);
27 – Posterolateral sulcus (sulcus posterolateralis);
28 – Anterolateral sulcus (sulcus anterolateralis);
29 – Anterior median fissure (fissura mediana anterior);
30 – Anterior white commissure (commissura alba anterior).

NUCLEI OF THE GRAY MATTER OF THE SPINAL CORD

The gray matter of the spinal cord contains neuronal cell bodies, which are arranged into distinct nuclei or scattered diffusely throughout the substance.

According to their position and function, the nuclei are divided into posterior horn, intermediate zone (lateral horn), and anterior horn nuclei.

1. Nuclei of the Posterior Horn

- Thoracic nucleus (nucleus thoracicus) — located at the base of the posterior horn.
- Proper nucleus (nucleus proprius) — occupies the central part of the posterior horn.
- Substantia gelatinosa — found at the tip of the posterior horn, consisting of small interneurons that modulate sensory input, especially pain.
- Spongy zone (zona spongiosa) — lies adjacent to the apex of the posterior horn.

These nuclei are primarily sensory in function, containing interneurons that receive input from afferent fibers and participate in forming ascending sensory pathways.

2. Nuclei of the Intermediate Zone (Lateral Horn)

- Intermediomedial nucleus (nucleus intermediomedialis)
- Intermediolateral nucleus (nucleus intermediolateralis) — present from C8 to L2 spinal segments; it contains sympathetic preganglionic neurons that send fibers to the sympathetic trunk.

The intermediolateral nucleus represents the autonomic (sympathetic) center, providing sympathetic innervation to nearly all organs — skeletal muscles, internal organs, and the cardiovascular system.

3. Nuclei of the Anterior Horn

- Central nucleus (nucleus centralis)
- Anteromedial nucleus (nucleus anteromedialis)
- Anterolateral nucleus (nucleus anterolateralis)
- Posteromedial nucleus (nucleus posteromedialis)
- Posterolateral nucleus (nucleus posterolateralis)

These nuclei contain large multipolar motor neurons whose axons form the anterior roots of spinal nerves.
They innervate the skeletal muscles of the trunk and limbs, producing muscle contraction in response to motor impulses.

4. Additional Nuclei and Structures

- Between the anterior and posterior horns, at the levels of S2–S4 segments, are located the sacral parasympathetic nuclei (nuclei parasympathici sacrales), which provide parasympathetic innervation to the pelvic organs**.**
- The reticular formation of the spinal cord (formatio reticularis spinalis) is present along the cervical segments.
- The spinal nucleus of the accessory nerve (nucleus nervi accessorii) extends through the upper 5–6 cervical segments and contributes motor fibers to the XI cranial nerve.
- The spinal nucleus of the trigeminal nerve (nucleus spinalis nervi trigemini) is found within the upper four cervical segments and receives somatosensory input from the head and face**.**

Functional Correlations

- The posterior horn nuclei (thoracic and proper nuclei, substantia gelatinosa, and spongy zone) mainly consist of interneurons, forming the second neurons in ascending sensory pathways.
- The intermediolateral nucleus is the origin of the sympathetic outflow.
- The anterior horn nuclei are motor centers — their axons leave via the anterior roots to reach skeletal muscles, forming motor endings that elicit contraction.

At the S2–S4 levels**,** the sacral parasympathetic nuclei give rise to parasympathetic fibers that control the organs of the pelvic cavity (e.g., bladder, rectum, genital organs).

Neuronal Connections

The intercalated neurons of the gray matter, along with neurons of the substantia gelatinosa and spongy zone, act as interneurons within the three-neuron reflex arc, ensuring segmental reflex activity.
Their axons form short association fibers within the gray and adjacent white matter, enabling horizontal (intra-segmental) and vertical (inter-segmental) communication between segments.
These connections guarantee that any local stimulus in the spinal cord triggers a coordinated response involving at least three neighboring segments**.**

WHITE MATTER OF THE SPINAL CORD

The white matter of the spinal cord surrounds the gray matter and consists mainly of myelinated axons that form ascending (sensory) and descending (motor) tracts. These tracts ensure the conductive function of the spinal cord — the transmission of impulses between the brain and various parts of the body.

Functional Division

- Ascending (afferent) tracts carry sensory impulses from receptors to the brain.
- Descending (efferent) tracts transmit motor commands from the brain to the spinal cord and skeletal muscles.

The arrangement of the tracts follows a strict pattern:

- Sensory tracts are mainly located in the posterior funiculi and along the periphery of the lateral funiculi**.**
- Motor tracts occupy the anterior funiculi and the central part of the lateral funiculi**.**

ASCENDING (SENSORY) TRACTS

These tracts convey information generated by receptors in response to various stimuli.
Receptors are specialized sensory nerve endings, each sensitive to a specific type of stimulus and capable of converting it into a nerve impulse**.**

There are three main groups of receptors:

- **Proprioceptors** — located in bones, joints, muscles, and tendons; they sense body position and movement.
- **Exteroceptors** — located in the skin; they sense touch, temperature, and pain.
- **Interoceptors** — located in the walls of internal organs and blood vessels; they sense changes in the internal environment.

All sensory pathways consist of at least three neurons**:**

1. The first neuron **—** a pseudounipolar cell located in the spinal (sensory) ganglion**.**
2. The second neuron — an interneuron located in the gray matter of the spinal cord or medulla oblongata.

3. The third neuron — located in the thalamus, from which fibers project to the sensory cortex of the cerebrum.

Posterior Funiculus

Contains two major tracts that carry conscious proprioceptive and tactile information**:**

1. Gracile fasciculus (fasciculus gracilis) – situated medially.
   - Conducts impulses from the lower limbs and lower trunk**.**
2. Cuneate fasciculus (fasciculus cuneatus) – situated laterally.
   - Conducts impulses from the upper limbs and upper trunk**.**

Both tracts are formed by the axons of the first-order sensory neurons, whose cell bodies lie in the spinal ganglia.
Their dendrites connect to receptors in the skin, muscles, and joints.
The axons ascend without synapsing in the spinal cord and terminate in the gracile and cuneate nuclei of the medulla oblongata.
From these nuclei, the second-order neurons send axons that cross to the opposite side and continue as the medial lemniscus toward the thalamus.

Lateral Funiculus

Contains several ascending tracts, including:

1. **Posterior spinocerebellar tract (tractus spinocerebellaris posterior)**
   - Conducts unconscious proprioceptive impulses from the muscles and joints of the same side of the body to the cerebellum**.**
   - Formed by the axons of second-order neurons located in Clarke’s nucleus (nucleus thoracicus) and the intermediomedial nucleus**.**
2. **Anterior spinocerebellar tract (tractus spinocerebellaris anterior)**
   - Also conveys unconscious proprioceptive impulses, but from both sides of the body.
   - Formed by the axons of neurons in the intermediomedial nucleus.
   - Fibers cross to the opposite side, ascend, and many cross back again within the cerebellum.
3. **Lateral spinothalamic tract (tractus spinothalamicus lateralis)**
   - Transmits pain and temperature sensations.
   - Formed by axons of second-order neurons located in the proper nucleus (nucleus proprius) of the posterior horn.
   - Their fibers cross to the opposite side through the anterior white commissure and ascend to the thalamus**.**

DESCENDING (MOTOR) TRACTS

Motor pathways originate from the motor centers of the brain and are divided into two major systems:

1. **Pyramidal tracts** — conduct voluntary (conscious) movements.
2. **Extrapyramidal tracts** — regulate automatic**,** involuntary, and coordinated movements, as well as muscle tone**.**

Pyramidal (Corticospinal) Tracts

1. Lateral corticospinal tract (tractus corticospinalis lateralis)
   - Originates in the motor cortex of the cerebrum (Betz cells).
   - Fibers descend through the internal capsule**,** brainstem, and pyramids of the medulla oblongata**,** where about 85–90% of them decussate (cross) to the opposite side.
   - These fibers descend in the lateral funiculus and terminate segmentally on the motor nuclei of the anterior horn.
   - Responsible for voluntary movement of the limbs.
2. Anterior corticospinal tract (tractus corticospinalis anterior)
   - The uncrossed portion of the corticospinal fibers; they descend in the anterior funiculus and cross segmentally in the spinal cord before synapsing on anterior horn motor neurons.
   - Controls voluntary movements of the axial muscles (neck and trunk).

Extrapyramidal Tracts

These tracts originate from various brainstem nuclei and regulate muscle tone, balance, posture, and automatic movements**:**

1. Rubrospinal tract (tractus rubrospinalis)
   - Originates from the red nucleus (nucleus ruber) of the midbrain.
   - Facilitates muscle tone and automatic coordinated movements of the trunk and limbs (e.g., walking, running).
2. Vestibulospinal tract (tractus vestibulospinalis)
   - Arises from the vestibular nuclei in the pons and medulla.
   - Regulates muscle tone and postural adjustments in response to balance changes.
3. Tectospinal tract (tractus tectospinalis)
   - Originates from the superior and inferior colliculi of the midbrain.

    - Mediates reflex head and neck movements toward visual, auditory, and tactile stimuli (protective reflexes).
4. Reticulospinal tract (tractus reticulospinalis)
    - Originates from the reticular formation of the brainstem.
    - Modulates voluntary movement, muscle tone, and autonomic activity.
5. Olivospinal tract (tractus olivospinalis)
    - Arises from the inferior olivary nuclei of the medulla oblongata.
    - Plays a role in balance and coordination.

Decussations (Crossings)

In the spinal cord, three major crossings occur within the anterior white commissure (commissura alba anterior):

1. Anterior spinocerebellar tract (partial crossing).
2. Spinothalamic tracts — cross 2–3 segments above their origin.
3. Anterior corticospinal tract — crosses segmentally at its termination.

Summary of Key Principles

- First-order sensory neurons: pseudounipolar neurons in spinal ganglia.
- Gracile and cuneate fasciculi: formed by first-order axons.
- Spinocerebellar and spinothalamic tracts: formed by second-order neurons in spinal gray matter.
- All motor tra
- cts terminate on motor neurons of the anterior horn — the final common pathway to skeletal muscles.

MEDULLA OBLONGATA (BULBUS)

The medulla oblongata (bulbus) is the lower portion of the brainstem, located between the spinal cord and the pons (pons Varolii).
It forms the transition zone between the spinal cord and the higher parts of the brain, preserving the basic structural plan of the spinal cord but containing more complex nuclei and tracts.

External Structure

On the ventral surface of the medulla oblongata are two prominent pyramids (pyramides).
Each pyramid consists of descending corticospinal fibers originating from the motor cortex.
At the lower border of the pyramids, most fibers decussate (cross over) to the opposite side — this crossing is called the pyramidal decussation (decussatio pyramidum).
This is why each hemisphere of the brain controls voluntary movements of the opposite side of the body.

Lateral to the pyramids lies the olive (oliva) — an oval-shaped prominence produced by the inferior olivary nucleus (nucleus olivaris inferior).
The olive is a major center involved in motor coordination, connecting with the cerebellum via the olivocerebellar fibers that pass through the inferior cerebellar peduncle**.**

Behind the olive are the posterior (dorsal) columns — the gracile tubercle and cuneate tubercle (tuberculum gracile et tuberculum cuneatum), which correspond to the gracile and cuneate nuclei — the second-order sensory neurons of the posterior column pathways.

On the dorsal surface, the medulla contributes to the floor of the fourth ventricle (fossa rhomboidea)**,** which also involves structures of the pons and cerebellum**.**

Internal Structure

In transverse section, the medulla oblongata reveals:

- Gray matter: composed of cranial nerve nuclei and other neuronal groups.
- White matter: consisting of ascending and descending tracts that pass through or originate/terminate here.

Main Nuclei and Functional Groups

The medulla oblongata contains nuclei of cranial nerves IX, X, XI, and XII, as well as important autonomic and relay centers**.**

1. Motor Nuclei:

- Nucleus ambiguus — gives rise to the motor fibers of cranial nerves IX (glossopharyngeal), X (vagus), and XI (accessory).

These innervate the muscles of the pharynx, larynx, and soft palate, responsible for swallowing, phonation, and reflex cough.

- Hypoglossal nucleus (nucleus nervi hypoglossi) — forms the XII cranial nerve, which innervates the intrinsic and extrinsic muscles of the tongue, ensuring speech and swallowing movements.
- Accessory nucleus (nucleus nervi accessorii) — located in the lower medulla and upper cervical cord; provides fibers to the sternocleidomastoid and trapezius muscles.

2. Sensory Nuclei:

- Nucleus of the solitary tract (nucleus tractus solitarii) — receives visceral sensory fibers from cranial nerves VII, IX, and X, carrying information about taste and internal organ status.
- Spinal nucleus of the trigeminal nerve (nucleus spinalis nervi trigemini) — extends from the pons into the medulla and upper cervical cord; transmits pain, temperature, and tactile sensations from the face, oral cavity, and dura mater.

3. **Relay Nuclei:**

- Gracile nucleus (nucleus gracilis) and cuneate nucleus (nucleus cuneatus) — receive fibers from the posterior funiculi of the spinal cord and form the second-order neurons of the posterior column–medial lemniscus pathway. Their axons cross the midline (forming the internal arcuate fibers) and continue as the medial lemniscus (lemniscus medialis) to the thalamus.
- Inferior olivary nucleus (nucleus olivaris inferior) — relays information from the spinal cord and red nucleus to the cerebellum, playing a major role in motor coordination and learning.

4. **Autonomic Centers:**
Located in the reticular formation of the medulla oblongata:

- Respiratory center — regulates rhythmic breathing movements.
- Vasomotor center — maintains vascular tone and regulates blood pressure.
- Cardiac center — controls heart rate and cardiac output.

Vomiting, coughing, and swallowing centers — coordinate complex reflexes essential for survival

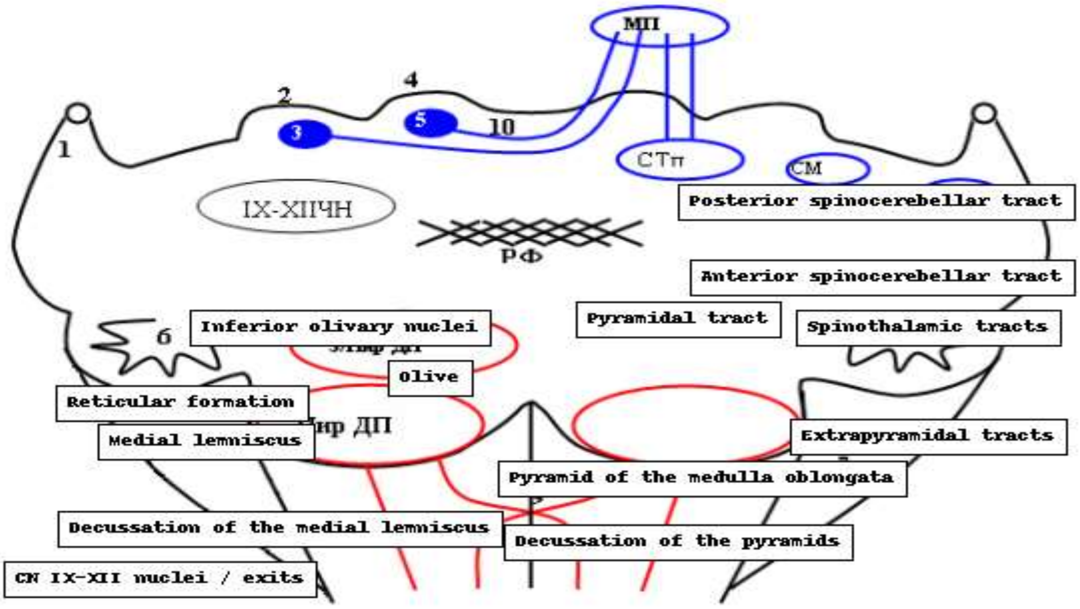

Figure 4. Cross-section of the medulla oblongata (diagram):

1 – Inferior cerebellar peduncle (pedunculus cerebellaris inferior);
2 – Tubercle of the cuneate nucleus (tuberculum cuneatum);
3 – Cuneate nucleus (nucleus cuneatus);
4 – Tubercle of the gracile nucleus (tuberculum gracile);
5 – Gracile nucleus (nucleus gracilis);
6 – Inferior olivary nuclei (nuclei olivares inferiores);
7 – Olive (oliva);
8 – Pyramid of the medulla oblongata (pyramis medullae oblongatae);
9 – Decussation of the pyramids (decussatio pyramidum);
10 – Decussation of the medial lemniscus (decussatio lemnisci medialis; fasciculus bulbothalamicus);

IX–XII CN – Nuclei of the IX, X, XI, and XII cranial nerve pairs; individual numbers correspond to the nerve exit points from the medulla oblongata.

ML – Medial lemniscus (lemniscus medialis);
RF – Reticular formation (formatio reticularis);
STt – Spinothalamic tracts (tractus spinothalamicus);
ASCT – Anterior spinocerebellar tract (tractus spinocerebellaris anterior);
PSCT – Posterior spinocerebellar tract (tractus spinocerebellaris posterior);

Pyramidal tracts (Tractus pyramidalis):

- Corticospinal tract (tractus corticospinalis);
- Corticobulbar tract (tractus corticonuclearis, partially).

Extrapyramidal tracts (Tractus extrapyramidales):

- Rubrospinal tract (tractus rubrospinalis);
- Tectospinal tract (tractus tectospinalis);
- Reticulospinal tract (tractus reticulospinalis, partially);
- Vestibulospinal tract (tractus vestibulospinalis).

Pass through transitively:
Ascending (afferent):

- Spinothalamic tracts (tractus spinothalamici) – lateral and anterior – conduct cutaneous sensations (temperature, pain, tactile sensations, and stereognosis); formed by the axons of the second-order neurons, the cell bodies of which are located in the nuclei of the spinal cord;
- Anterior and posterior spinocerebellar tracts (tractus spinocerebellares anterior et posterior) – conduct proprioceptive (muscle-joint) sensations to the cerebellum; also formed by the axons of the second-order neurons, the cell bodies of which are located in the nuclei of the spinal cord.

Descending (efferent):

- Corticospinal tract (tractus corticospinalis) – conducts impulses from the cortex to the motor nuclei of the spinal cord and provides conscious (voluntary) movements of the trunk and limbs; forms the pyramids of the medulla oblongata;
- Rubrospinal tract (tractus rubrospinalis): originates in the red nucleus of the midbrain and extends to the motor nuclei of the spinal cord (the main extrapyramidal tract);
- Tectospinal tract (tractus tectospinalis): originates from the gray matter of the quadrigeminal plate of the midbrain and extends to the motor nuclei of the spinal cord;
- Reticulospinal tract (tractus reticulospinalis): originates from the reticular nuclei along the entire length of the brainstem; the part that starts above the medulla oblongata passes through it transitively (extrapyramidal tract);
- Vestibulospinal tract (tractus vestibulospinalis): originates from the lateral and inferior vestibular nuclei located in the pons and extends to the motor nuclei of the spinal cord (extrapyramidal tract).

Tracts that synapse in the medulla oblongata on new neurons:

- Gracile and cuneate fasciculi (fasciculi gracilis et cuneatus), conducting proprioceptive impulses from the trunk and limbs to the cerebral cortex; they are formed by the axons of the first-order neurons, the cell bodies of which are located in the spinal ganglia and terminate in the neurons of the gracile and cuneate nuclei (cell bodies of the second-order neurons); the axons of these nuclei form the bulbothalamic fasciculus (fasciculus bulbothalamicus).

Terminate in the medulla oblongata:

- Corticonuclear fibers (tractus corticonuclearis) of the pyramidal tract (partially) – in the motor nuclei of the IX, X, XI, and XII pairs of cranial nerves.

Originate in the medulla oblongata:

- Reticulospinal tract (tractus reticulospinalis) (partially) – from the reticular nuclei of the medulla oblongata to the motor nuclei of the spinal cord;
- Olivospinal tract (tractus olivospinalis) – from the nuclei of the inferior olive to the motor nuclei of the spinal cord.

Decussations of the conduction tracts in the medulla oblongata:
There are two decussations in the medulla oblongata:

- Decussation of the pyramids (decussatio pyramidum) (motor decussation) is carried out by most of the fibers of the corticospinal tract ventrally – in the depth of the anterior median fissure: the crossed fibers descend in the lateral funiculi of the spinal cord (lateral corticospinal tract), while the uncrossed fibers descend in the anterior funiculi (anterior corticospinal tract);
- Decussation of the medial lemnisci (decussatio lemnisci medialis) (sensory decussation) is carried out by the fibers of the bulbothalamic fasciculus.

PONS (PONS)
Boundaries:

- Inferior (ventrally) – bulbopontine sulcus (sulcus bulbopontinus), separating the pons from the medulla oblongata;
- Inferior (dorsally) – medullary striae of the fourth ventricle (striae medullares ventriculi quarti) on the rhomboid fossa (bordering the medulla oblongata);
- Superior – cerebral peduncles;
- Lateral – sites of emergence of the trigeminal nerve.

External structure:

- On the ventral surface – along the midline – the basilar sulcus (sulcus basilaris);
- On both sides of this sulcus – small elevations (eminentiae) (containing the bundles of corticospinal tracts (tractus corticospinales));
- Ventrally – transverse fibers of the pons (fibrae pontis transversae) (pontocerebellar fibers), directed into the middle cerebellar peduncles (pedunculi cerebellares medii);
- Dorsal surface – the upper half of the rhomboid fossa (fossa rhomboidea);
- The upper half of the rhomboid fossa is bounded above by the superior cerebellar peduncles (pedunculi cerebellares superiores).

Cranial nerve exits – four pairs of cranial nerves emerge from the pons (V–VIII pairs):

- Vestibulocochlear nerve (nervus vestibulocochlearis) (VIII pair) – through the pontocerebellar angle (angulus pontocerebellaris) (more laterally);
- Facial nerve (nervus facialis) (VII pair) – through the pontocerebellar angle (angulus pontocerebellaris) (more medially);
- Abducent nerve (nervus abducens) (VI pair) – through the bulbopontine sulcus between the pons and the pyramid;
- Trigeminal nerve (nervus trigeminus) (V pair) – between the pons and the middle cerebellar peduncle.

Internal structure – consists of gray and white matter: the gray matter is represented by nuclei, and the white matter – by conduction tracts (Fig. 5).

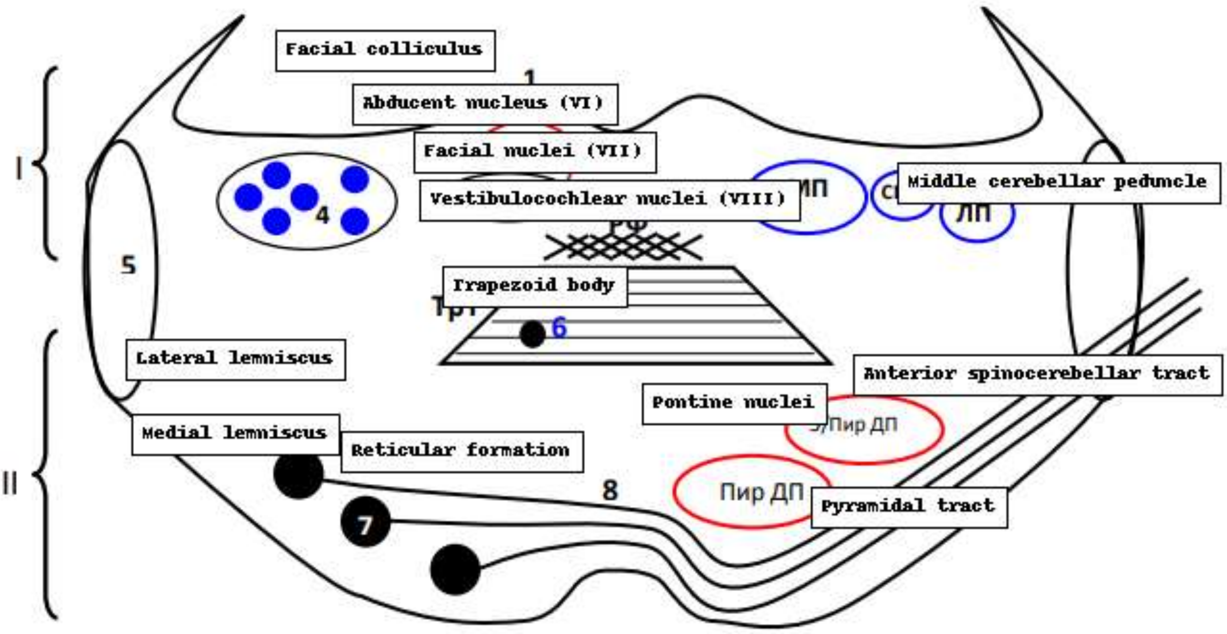

Fig. 5. Cross section of the pons (diagram):

I – tegmentum of the pons (tegmentum pontis);
II – basilar part of the pons (pars basilaris pontis);
1 – facial colliculus (colliculus facialis);
2 – nucleus of the VI pair of cranial nerves (abducent nerve, n. abducens);
3 – nuclei of the VII pair of cranial nerves (facial nerve, n. facialis);
4 – nuclei of the VIII pair of cranial nerves (vestibulocochlear nerve, n. vestibulocochlearis);
5 – middle cerebellar peduncle (pedunculus cerebellaris medius);
6 – nuclei of the trapezoid body (nuclei corporis trapezoidei);
7 – pontine nuclei (proper) (nuclei pontis (proprii));
8 – pontocerebellar fibers (fibrae pontocerebellares), their decussation;

TrT – trapezoid body (corpus trapezoideum);
ML – medial lemniscus (lemniscus medialis);
LL – lateral lemniscus (auditory fibers) (lemniscus lateralis);
RF – reticular formation (formatio reticularis);
ASC – anterior spinocerebellar tract (tractus spinocerebellaris anterior);
PyT – pyramidal tract (tractus pyramidalis):
corticospinal tract (tractus corticospinalis);
corticonuclear tract (tractus corticonuclearis).

E/PyT – extrapyramidal tracts:
rubrospinal tract (tractus rubrospinalis);
tectospinal tract (tractus tectospinalis);
reticulospinal tract (partially) (tractus reticulospinalis).

In the transverse section of the pons, three parts are distinguished: the basilar part (pars basilaris pontis), the tegmentum of the pons (tegmentum pontis), and the trapezoid body (corpus trapezoideum) located between them.

Nuclei:

- Cranial nerve nuclei – pairs V–VIII – are located in the tegmentum of the pons.
- Pontine nuclei (nuclei pontis) are situated in the basilar part: the corticopontine tract (tractus corticopontinus) terminates here; the axons of their neurons cross to the opposite side (decussate) and, as part of the middle cerebellar peduncles, enter the cerebellum.
- The locus coeruleus (nucleus caeruleus) is located in the tegmentum of the pons and belongs to the reticular formation. It is responsible for the physiological response to tension and anxiety; its neurons secrete noradrenaline and exert diverse influences on many brain structures, affecting the phase of rapid sleep and periods of wakefulness.
- Nuclei of the trapezoid body (nuclei corporis trapezoidei) receive axons from the cells of the ventral and dorsal cochlear nuclei (nuclei cochleares anterior et posterior); the axons of neurons from the trapezoid body nuclei participate in the formation of the lateral lemniscus (lemniscus lateralis).
- Reticular nuclei (nuclei reticulares) are located in the tegmentum of the pons.

The conducting pathways of the pons are divided into short and long.
The short pathways connect the pontine nuclei with each other and also with the nuclei of neighboring brainstem regions.

The long conducting pathways of the pons include:

- those passing transitively;
- those switching to new neurons;
- those ending in the pontine nuclei;
- those originating in the pontine nuclei.

Transitively passing pathways:

Ascending (afferent) – pass through the tegmentum of the pons:

- The medial lemniscus (lemniscus medialis) is formed at the boundary between the medulla oblongata and the pons and terminates in the lateral nucleus of the thalamus (nucleus lateralis thalami). It includes the spinothalamic tracts, the bulbothalamic bundle, vestibular pathways, and axons of neurons from the sensory nuclei of cranial nerves V, VII, IX, and X.
- The anterior spinocerebellar tract (tractus spinocerebellaris anterior) runs along the lateral edge of the tegmentum.

Descending (efferent) – pass through the base of the pons:

- Corticospinal tract (tractus corticospinalis).
- Corticonuclear fibers (tractus corticonuclearis) of the pyramidal pathway (partially) – those descending to the medulla oblongata to the nuclei of cranial nerves IX–XII.
- Rubrospinal tract (tractus rubrospinalis).
- Tectospinal tract (tractus tectospinalis).

- Reticulospinal tract (tractus reticulospinalis) (partially) – the part originating from the reticular nuclei of the midbrain (above the pons).

Pathways switching to new neurons within the pons:

- Auditory pathways, formed by the axons of bipolar cells of the spiral ganglion of the cochlea (ganglion spirale cochleae), switch to neurons in the ventral and dorsal cochlear nuclei (nuclei cochleares anterior et posterior).
- The axons of neurons from the dorsal cochlear nucleus (nucleus cochlearis posterior) emerge on the dorsal surface of the pons and form the medullary striae of the fourth ventricle (striae medullares ventriculi quarti), descend deeper, and synapse in the trapezoid body nuclei.
- The axons of neurons from the ventral cochlear nucleus (nucleus cochlearis anterior) also synapse in the trapezoid body nuclei. The axons of neurons of these nuclei participate in forming the lateral lemniscus (lemniscus lateralis).
- The corticopontocerebellar tract (tractus corticopontocerebellaris) (part of the pyramidal system) begins in the cortex and synapses in the pontine nuclei; the axons of the pontine neurons cross to the opposite side and, via the middle cerebellar peduncles, enter the cerebellum.
- Vestibular pathways: the axons of bipolar neurons of the vestibular ganglion (ganglion vestibulare) synapse in the vestibular nuclei, and the axons of the vestibular nuclei neurons join the medial lemniscus.

Pathways ending in the pons:

- Corticonuclear fibers (tractus corticonuclearis) of the pyramidal tract (partially) terminate in the motor nuclei of cranial nerves V, VI, and VII.

Pathways originating in the pons:

- Reticulospinal tract (tractus reticulospinalis) (partially) – originates from the reticular nuclei of the pons and descends to the motor nuclei of the spinal cord.
- Vestibulospinal tract (tractus vestibulospinalis) – originates from the lateral and inferior vestibular nuclei and descends to the motor nuclei of the spinal cord.

Decussations of the conducting pathways in the pons:

- Auditory pathways: the axons of neurons from the dorsal nucleus forming the medullary striae of the fourth ventricle cross within the depth of the median sulcus of the rhomboid fossa (sulcus medianus); the axons of neurons from the ventral nucleus cross within the trapezoid body.
- Vestibular pathways: the axons of neurons from the vestibular nuclei undergo decussation.
- Pontocerebellar fibers (fibrae pontocerebellares) – continuations of the corticopontine fibers of the corticopontocerebellar tract, i.e., axons of neurons from the pontine nuclei that cross and enter the cerebellum via the middle cerebellar peduncles.
- Vestibulospinal tract (tractus vestibulospinalis) – axons of neurons from the lateral and inferior vestibular nuclei.

Midbrain (Mesencephalon)

It is formed by:

- The cerebral peduncles (pedunculi cerebri) – ventrally;
- The tectal plate (lamina tecti) (the quadrigeminal plate) – dorsally;
- The cavity – the cerebral aqueduct (aqueductus mesencephali).

External structure:

- Between the cerebral peduncles lies the interpeduncular fossa (fossa interpeduncularis);
- In the interpeduncular fossa is located the posterior perforated substance (substantia perforata posterior);
- At the base of the cerebral peduncles is the oculomotor nerve groove (sulcus nervi oculomotorii);
- Along the lateral margin of the cerebral peduncle runs the lateral sulcus of the midbrain (sulcus lateralis mesencephali);
- On the tectal plate there are two superior (colliculus superior) and two inferior colliculi (colliculus inferior), separated by grooves that cross each other at right angles;
- Posterior to the inferior colliculi, along the midline, lies the frenulum of the superior medullary velum (frenulum veli medullaris superioris);
- From the superior colliculi laterally extend the brachia of the superior colliculi (brachium colliculi superioris);
- From the inferior colliculi extend the brachia of the inferior colliculi (brachium colliculi inferioris);
- Between the lateral sulcus of the midbrain and the brachia of the inferior colliculi lies the triangle of the lemniscus (trigonum lemnisci lateralis);
- The triangle of the lemniscus is bounded on its medial-inferior side by the superior cerebellar peduncle (pedunculus cerebellaris superior).

Cranial nerve exits:
Two pairs of cranial nerves (III and IV) emerge from the midbrain:

- The oculomotor nerve (III pair) (nervus oculomotorius) – through the oculomotor nerve groove;
- The trochlear nerve (IV pair) (nervus trochlearis) – on both sides of the frenulum of the superior medullary velum (the only cranial nerve that emerges on the dorsal surface of the brain).

Internal structure:
In the transverse section of the midbrain, the following parts are distinguished:

- The roof of the midbrain (tectum mesencephali) – dorsal to the aqueduct;
- The cerebral peduncles, divided into the base of the peduncles (basis pedunculi) and the tegmentum of the midbrain (tegmentum mesencephali);
- Between the base of the peduncles and the tegmentum lies the substantia nigra.

Gray matter – nuclei of the midbrain:

- The substantia nigra, located between the base of the peduncles and the tegmentum of the midbrain, belongs to the extrapyramidal system;
- The nuclei of the oculomotor (III pair) (nuclei nervi oculomotorii) and trochlear (IV pair) (nucleus nervi trochlearis) nerves;
- The mesencephalic nucleus of the trigeminal nerve (V pair) (nucleus mesencephalicus nervi trigemini);
- The red nucleus (nucleus ruber) – an efferent center of the extrapyramidal system;
- Reticular nuclei (nuclei reticulares);
- The central gray substance (substantia grisea centralis) – located around the aqueduct, containing autonomic centers;
- Nuclei of the inferior colliculi (nuclei colliculi inferioris) – subcortical auditory centers;
- The gray matter of the superior colliculi (substantia grisea colliculi superioris) – has a layered structure typical for integrative centers (subcortical visual centers). It also receives impulses from the organs of smell and tactile sensation, thus serving as an integrative center of the midbrain;
- The nuclei of Cajal and Darkschewitsch (centers of the medial longitudinal fasciculus, MLF) – ensure coordinated function of the eye and neck muscles.

White matter consists of short and long conducting tracts.
The short tracts connect the centers (nuclei) of the midbrain with each other and also with nuclei of adjacent brainstem regions.
One example is the medial longitudinal fasciculus (fasciculus longitudinalis medialis, MLF). Its fibers connect the motor nuclei of cranial nerves III, IV, VI, and XI, and also establish connections with the nuclei of cranial nerve VIII. The centers of the MLF are the reticular formation nuclei of Darkschewitsch and Cajal.
The function of the MLF and its centers is to coordinate contractions of the eye muscles, the combined movements of the eyes and neck, and to maintain balance in response to visual input.

Long conducting pathways in relation to the midbrain are divided into four groups:

- those passing transitively;
- those switching to new neurons;
- those ending in the nuclei of the midbrain;
- those originating in the nuclei of the midbrain.

Transitively passing pathways:

Ascending (afferent):

- Medial lemniscus (lemniscus medialis);
- Anterior spinocerebellar tract (tractus spinocerebellaris anterior) – from the midbrain, through the superior cerebellar peduncles, enters the cerebellum.

Descending (efferent):

- Corticospinal tract (tractus corticospinalis) – pyramidal pathway;
- Corticonuclear tract (tractus corticonuclearis) of the pyramidal system (partially) – those descending to the pons (to the motor nuclei of cranial nerves V–VII) and to the medulla oblongata (to the motor nuclei of cranial nerves IX–XII);

- Corticopontine tract (tractus corticopontinus) of the pyramidal system – extends to the pontine nuclei and continues as pontocerebellar fibers (fibrae pontocerebellares) that travel through the middle cerebellar peduncles to the cerebellum.
  All pyramidal tracts pass through the cerebral peduncles.

Pathways switching in the midbrain:

- The lateral lemniscus (lemniscus lateralis) – auditory pathways formed by the axons of neurons from the anterior and posterior cochlear nuclei and the nuclei of the trapezoid body, which terminate in the nuclei of the inferior colliculi (subcortical auditory centers).
- The optic tracts (tractus opticus) – terminate in the gray matter of the superior colliculi (subcortical visual centers).

Pathways ending in the midbrain:

- The corticonuclear tract (tractus corticonuclearis) (partially) – in the motor nuclei of cranial nerves III and IV.

Pathways originating in the midbrain:

- Rubrospinal tract (tractus rubrospinalis) – originates from the red nucleus and descends to the motor nuclei of the spinal cord (extrapyramidal pathway).
- Tectospinal tract (tractus tectospinalis) – originates from the gray matter of the quadrigeminal plate and descends to the motor nuclei of the spinal cord; regulates automatic movements in response to sudden strong visual, auditory, olfactory, and tactile stimuli.
- Reticulospinal tract (tractus reticulospinalis) (partially) – originates from the reticular nuclei of the midbrain, joins fibers of the same name arising from the reticular nuclei of the pons and medulla oblongata, and descends to the motor nuclei of the spinal cord.

Decussations of conducting pathways in the midbrain:
There are two decussations in the midbrain:

- The rubrospinal tract – Forel's decussation – the ventral tegmental decussation (decussatio tegmentalis anterior);
- The tectospinal tract – Meynert's decussation – the dorsal tegmental decussation (decussatio tegmentalis posterior).

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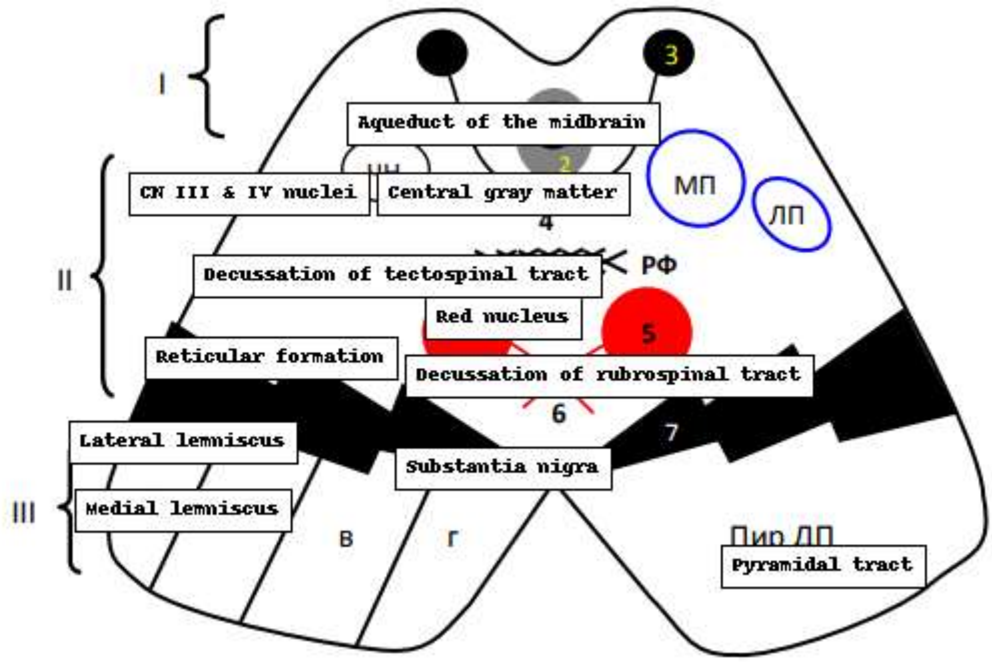


Fig. 6. Cross section of the midbrain (diagram):
I – roof of the midbrain (tectum mesencephali);
II – tegmentum of the midbrain (tegmentum mesencephali);
III – base of the cerebral peduncle (basis pedunculi);
1 – aqueduct of the midbrain (aqueductus mesencephali);
2 – central gray matter (substantia grisea centralis);
3 – nuclei of the inferior (superior) colliculi (nuclei colliculi inferioris (superioris));
4 – decussation of the tectospinal tract (decussatio tegmentalis posterior) (Meynert's decussation);
5 – red nucleus (nucleus ruber);
6 – decussation of the rubrospinal tract (decussatio tegmentalis anterior) (Forel's decussation);
7 – substantia nigra.

CN – nuclei of the III and IV pairs and the mesencephalic nucleus of the V pair of cranial nerves;
ML – medial lemniscus (lemniscus medialis);
LL – lateral lemniscus (auditory fibers) (lemniscus lateralis);
RF – reticular formation (formatio reticularis);
Pyr Tr – pyramidal tract (tr. pyramidalis):
a – occipitotemporoparietopontine fibers (fibrae occipitotemporoparietopontinae);
b – corticospinal tract (tr. corticospinalis);
c – corticonuclear tract (tr. corticonuclearis);
d – frontopontine fibers (fibrae frontopontinae).

CEREBELLUM (CEREBELLUM)
Located in the posterior cranial fossa.
Function – provides coordination of movements and balance.

External structure:

- The middle part – the vermis (vermis cerebelli);
- The lateral parts – the hemispheres (hemispherii cerebelli);
- On the ventral side, adjacent to the hemisphere – the flocculus (flocculus);
- Both the vermis and hemispheres have two surfaces – superior and inferior;
- The surface of the cerebellum is marked by numerous fissures (fissurae cerebelli), dividing it into lobules and folia (lobuli et folia cerebelli);
- The cerebellar fissures, without interruption, continue from the vermis to the hemispheres.

The cerebellum is connected with the brainstem by three pairs of cerebellar peduncles:

- The inferior cerebellar peduncles (pedunculi cerebellares inferiores) connect the cerebellum with the medulla oblongata;
- The middle cerebellar peduncles (pedunculi cerebellares medii) connect it with the pons;
- The superior cerebellar peduncles (pedunculi cerebellares superiores) connect it with the midbrain.

Internal structure – consists of gray and white matter (Fig. 7).

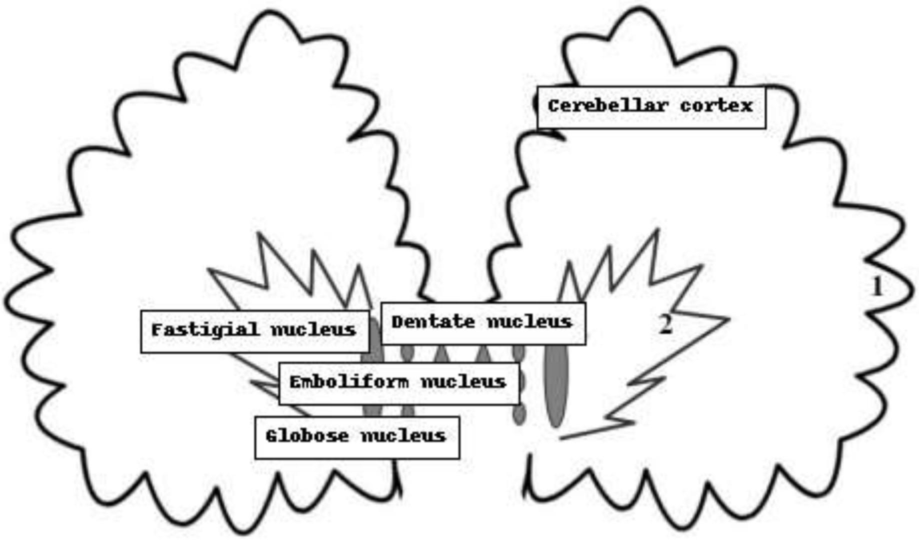


Fig. 7. Gray matter of the cerebellum (diagram):
1 – cerebellar cortex (cortex cerebelli);
2 – dentate nucleus (nucleus dentatus);
3 – emboliform nucleus (nucleus emboliformis);
4 – globose nucleus (nucleus globosus);
5 – fastigial nucleus (nucleus fastigii).

The gray matter is represented by the nuclei and the cortex of the cerebellum.
Nuclei: fastigial nucleus (nucleus fastigii), globose nucleus (nucleus globosus), emboliform nucleus (nucleus emboliformis), dentate nucleus (nucleus dentatus).

The **cortex** (cortex cerebelli) covers the hemispheres; in the cortex, neurons are arranged in three layers.

The **white matter** consists of short and long conducting pathways:

- The **short fibers** connect individual areas of the cortex and the cortex with the nuclei on the same side (association pathways), as well as cortical areas and nuclei of the opposite sides (commissural pathways);
- The **long fibers** connect the cerebellum with the spinal cord, brainstem, and cerebrum. They pass through the three pairs of cerebellar peduncles.

Through the inferior cerebellar peduncles pass:

- The posterior spinocerebellar tract (tractus spinocerebellaris posterior) – conducts proprioceptive impulses from the trunk and limbs of the same side;
- The external arcuate fibers (fibrae arcuatae externae anteriores) – from the gracile and cuneate nuclei;
- Bilateral connections of the cerebellar nuclei with the inferior olivary nuclei, vestibular nuclei, and the reticular nuclei of the medulla oblongata.

Through the middle cerebellar peduncles pass:

- The corticopontocerebellar tract (tr. corticopontocerebellaris) – part of the pyramidal tract; originating from the cerebral cortex, it passes through the pontine nuclei and continues to the cerebellum;
- Bilateral connections of the cerebellar nuclei with the reticular nuclei of the pons.

Through the superior cerebellar peduncles pass:

- The anterior spinocerebellar tract (tractus spinocerebellaris anterior) – conducts proprioceptive impulses from the trunk and limbs of the opposite side;
- The cerebellotegmental tract (tr. cerebellotegmentalis) – runs from the dentate nucleus to the red nucleus;
- Bilateral connections of the cerebellar nuclei with the reticular nuclei of the midbrain.

Fourth ventricle (ventriculus quartus) is the cavity of the rhomboid brain. Its floor is the rhomboid fossa (fossa rhomboidea).

Boundaries of the rhomboid fossa:

- Lower sides – inferior cerebellar peduncles (pedunculi cerebellares inferiores);
- Upper sides – superior cerebellar peduncles (pedunculi cerebellares superiores);
- Lower half – dorsal surface of the medulla oblongata (facies dorsalis medullae oblongatae);
- Upper half – dorsal surface of the pons (facies dorsalis pontis);
  The upper and lower halves are separated by the medullary striae of the fourth ventricle (striae medullares ventriculi quarti) – axons of neurons of the posterior cochlear nucleus.

External structure:

- Along the midline lies the median sulcus (sulcus medianus);
- On both sides of the sulcus – the medial eminence (eminentia medialis);

- Lateral to the eminence – the limiting sulcus (sulcus limitans), which forms the boundary between the projections of the motor and sensory nuclei of the cranial nerves;
- In the lower angle – the hypoglossal triangle (trigonum nervi hypoglossi);
- Lateral to the hypoglossal triangle – the vagal triangle (trigonum nervi vagi);
- In the upper part of the medial eminence – the facial colliculus (colliculus facialis);
- Lateral to the medial eminence – the locus coeruleus (locus caeruleus), the site of the bluish nucleus;
- In the area of the lateral angles – the vestibular area (area vestibularis).

Roof of the fourth ventricle (tegmen ventriculi quarti) – tent (fastigium):

- Anterior part – superior medullary velum (velum medullare superius), stretched between the superior cerebellar peduncles;
- Posterior part – inferior medullary velum (velum medullare inferius), located between the upper parts of the inferior cerebellar peduncles;
- Dorsal to the inferior medullary velum lies the pia mater (vascular base);
- Between the superior and inferior medullary vela is the cerebellum (cerebellum).

Connections of the fourth ventricle:

- Below – with the central canal (canalis centralis) of the spinal cord;
- Above – with the cerebral aqueduct (aqueductus mesencephali);
- With the subarachnoid space – through the median aperture (apertura mediana) (above the lower angle of the rhomboid fossa) and the lateral apertures (aperturae laterales) (above the lateral angles of the rhomboid fossa) in the vascular base of the roof.

On the rhomboid fossa are projected the nuclei of eight pairs (V–XII) of cranial nerves located in the pons and medulla oblongata: the nuclei of pairs V–VIII occupy the upper half, and the nuclei of pairs IX–XII – the lower half.
Motor nuclei are projected medially, sensory nuclei – laterally, and between them lie the autonomic nuclei.

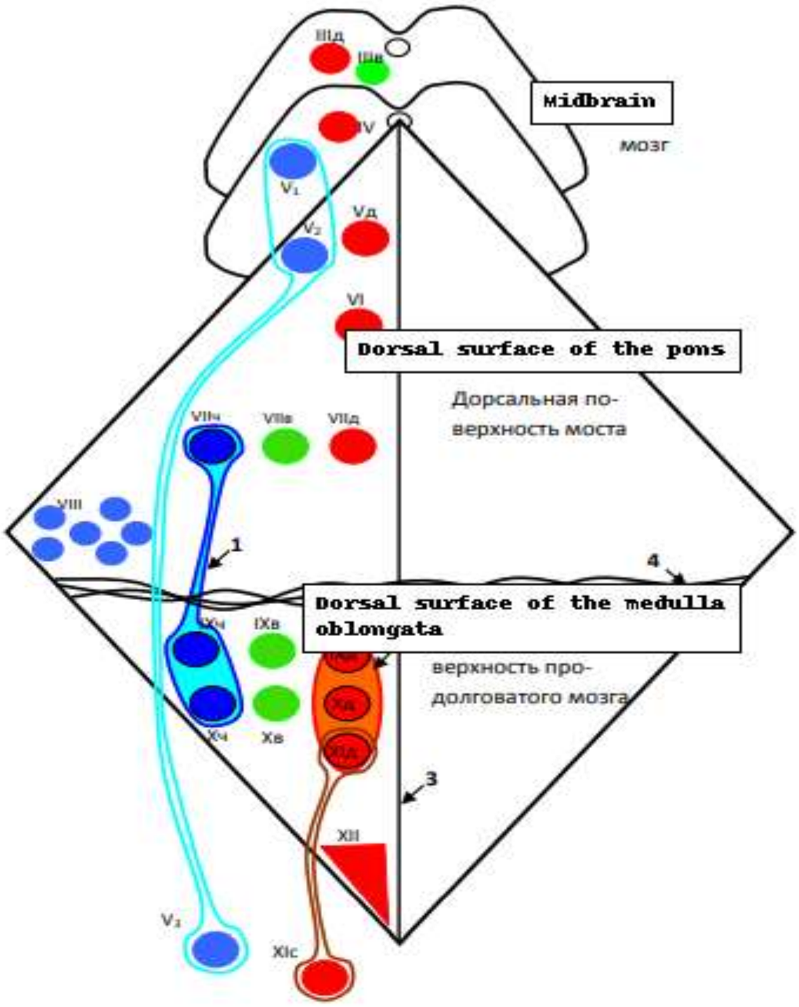


Fig. 8. Projection of the cranial nerve nuclei onto the midbrain and rhomboid fossa (diagram):
1 – nuclei of the solitary tract (nuclei tractus solitarii);
2 – ambiguous nucleus (nucleus ambiguus);
3 – median sulcus (sulcus medianus);
4 – medullary striae of the fourth ventricle (striae medullares ventriculi quarti).

III – nuclei of the oculomotor nerve (nuclei nervi oculomotorii):
IIId – nucleus of the oculomotor nerve (nucleus nervi oculomotorii);
IIIa – accessory nuclei of the oculomotor nerve (nuclei accessorii nervi oculomotorii).

IV – nucleus of the trochlear nerve (nucleus nervi trochlearis).

V – nuclei of the trigeminal nerve (nuclei nervi trigemini):
Vd – motor nucleus of the trigeminal nerve (nucleus motorius nervi trigemini);
V1 – mesencephalic nucleus of the trigeminal nerve (nucleus mesencephalicus nervi trigemini);
V2 – principal nucleus of the trigeminal nerve (nucleus principalis nervi trigemini);
V3 – spinal nucleus of the trigeminal nerve (nucleus spinalis nervi trigemini).

VI – nucleus of the abducent nerve (nucleus nervi abducentis).

VII – nuclei of the facial nerve (nuclei nervi facialis):
VIId – nucleus of the facial nerve (nucleus nervi facialis);

VIIc – nuclei of the solitary tract (nuclei tractus solitarii);
VIIv – superior salivatory nucleus (nucleus salivatorius superior).

VIII – nuclei of the vestibulocochlear nerve (nuclei nervi vestibulocochlearis):
vestibular nuclei (4) (nuclei vestibulares);
cochlear nuclei (2) (nuclei cochleares).

IX – nuclei of the glossopharyngeal nerve (nuclei nervi glossopharyngei):
IXd – ambiguous nucleus (nucleus ambiguus);
IXc – nuclei of the solitary tract (nuclei tractus solitarii);
IXv – inferior salivatory nucleus (nucleus salivatorius inferior).

X – nuclei of the vagus nerve (nuclei nervi vagi):
Xd – ambiguous nucleus (nucleus ambiguus);
Xc – nuclei of the solitary tract (nuclei tractus solitarii);
Xv – dorsal nucleus of the vagus nerve (nucleus dorsalis nervi vagi).

XI – nuclei of the accessory nerve (nuclei nervi accessorii):
XId – ambiguous nucleus (nucleus ambiguus);
XIc – nucleus of the accessory nerve (nucleus nervi accessorii).

XII – nucleus of the hypoglossal nerve (nucleus nervi hypoglossi).

DIENCEPHALON

The diencephalon is divided into the thalamic brain and the hypothalamus. The thalamic brain consists of the thalamus (thalamus), epithalamus (epithalamus), and metathalamus (metathalamus). The cavity of the diencephalon is the third ventricle (ventriculus tertius).

Thalamus (thalamus)

External structure of the thalamus:

- The medial and dorsal surfaces are free;
- The ventral and lateral surfaces are fused with the telencephalon;
- The lateral surface borders the posterior limb (crus posterius) of the internal capsule (capsula interna);
- The anterior end is pointed – anterior tubercle of the thalamus (tuberculum anterius thalami);
- The posterior end is thickened – pulvinar of the thalamus (pulvinar thalami);
- The dorsal surface of the thalamus is covered by white matter (substantia alba);
- Along the medial edge of the dorsal surface runs the medullary stria of the thalamus (stria medullaris thalami);
- Posteriorly, the medullary stria of the thalamus borders the habenular triangle (trigonum habenulare);
- Laterally, on the dorsal surface, there is a narrow thalamic band (taenia thalami);
- The medial surface faces the cavity of the third ventricle;
- Between the medial surfaces of both thalami there is the interthalamic adhesion (adhesio interthalamica).

Internal structure of the thalamus:
The gray matter of the thalamus includes more than 40 nuclei, grouped into eight categories:

- Anterior nuclei of the thalamus (nuclei anteriores thalami) – subcortical centers of olfaction;
- Ventro-lateral nuclei (nuclei ventrolaterales thalami) – subcortical centers of general sensation;
- Dorsal nuclei of the thalamus (pulvinar nuclei) (nuclei dorsales thalami, nuclei pulvinares) – subcortical centers of vision;
- Median nuclei of the thalamus (nuclei mediani thalami**)** – subcortical centers of equilibrium and hearing;
- Medial and posterior nuclei of the thalamus (nuclei mediales et posteriores thalami) – integrative centers of the diencephalon; their neurons provide interconnections among all thalamic nuclei and groups of nuclei; they are the sensory centers of the extrapyramidal system;
- **Reticular nuclei of the thalamus (nuclei reticulares thalami)** – subcortical sensory centers of the reticular formation;
- **Intralaminar (central) nuclei (nuclei intralaminares thalami)** – also associated with the reticular formation.

Connections of the thalamus:

- The anterior nuclei (nuclei anteriores thalami) receive impulses from the mammillary bodies (via the Vicq d'Azyr bundle); they have bilateral connections with the orbital cortex of the frontal lobe (limbic system);
- In the ventro-lateral nuclei (nuclei ventrolaterales thalami), the medial lemniscus terminates, and its continuation to the cortex forms the thalamocortical tract (fasciculus thalamocorticalis); fibers from the cortex to these nuclei form the corticothalamic tract (fasciculus corticothalamicus);
- The median nuclei (nuclei mediani thalami) have bilateral connections with the corpus striatum;
- The dorsal nuclei of the pulvinar (nuclei dorsales thalami, nuclei pulvinares) receive part of the fibers from the optic tract and have bilateral connections with the cerebral cortex;

- The medial and posterior nuclei (nuclei mediales et posteriores thalami) have bilateral connections with all thalamic nuclei, with the orbital cortex (limbic system), hypothalamic nuclei, and basal ganglia; through descending pathways, they connect with the red nucleus;
- The reticular and intralaminar nuclei (nuclei reticulares et intralaminares thalami) connect via ascending pathways with the reticular formation of the brainstem and have bilateral connections with the cerebral cortex.

Functions of the thalamus:

- The thalamic nuclei are subcortical centers of nearly all sensory conduction pathways leading to the cortex; they are also the sensory centers of the entire extrapyramidal system;
- The medial and posterior nuclei ensure the integration of the functions of all thalamic nuclei;
- In the thalamus, impulses carried by sensory pathways acquire the first degree of subjective sensation.

Epithalamus (epithalamus)

Located posterior to the thalamus.
Its parts include:

- Pineal gland (epiphysis, glandula pinealis);
- Habenulae (habenulae);
- Habenular triangle (trigonum habenulare).

Pineal gland (glandula pinealis)

Located in the groove between the superior colliculi of the corpora quadrigemina.
Below the pineal gland lies the posterior commissure;
Above it is the habenular commissure.

Functions of the pineal gland:

- It is a neuroendocrine organ that produces neurohormones depending on illumination – melatonin, serotonin, and vasotocin. The synthesis of serotonin occurs during the day, and in darkness serotonin is converted into melatonin; the hormones of the pineal gland enter the bloodstream and cerebrospinal fluid;
- Controls the activity of the hypothalamo-adenohypophyseal system;
- Regulates the activity of peripheral endocrine glands in accordance with biological rhythms;
- Regulates the functional activity of the immune system;
- Regulates carbohydrate and lipid metabolism;
- Maintains homeostasis under extreme environmental conditions and during aging;
- Prevents the development of neoplasms induced by chemical carcinogens and ionizing radiation.

Metathalamus (metathalamus)
It is represented by the medial (corpus geniculatum mediale) and lateral geniculate bodies (corpus geniculatum laterale).

The medial geniculate bodies (corpus geniculatum mediale) are located ventral to the pulvinar of the thalamus and are connected by their brachium to the inferior colliculi (colliculus inferior). They are the subcortical centers of hearing.
The lateral geniculate bodies (corpus geniculatum laterale) receive the termination of the optic tracts; they are located on the inferolateral surface of the pulvinar of the thalamus and are connected by their brachium to the superior colliculi (colliculus superior). They are the subcortical centers of vision.

Hypothalamus (hypothalamus)
It is located ventral to the third ventricle, forming its lower wall. It consists of the following structures:
The subthalamic region proper – a continuation of the tegmentum of the midbrain peduncle; it contains the nucleus of Luys (Luys' body), which belongs to the extrapyramidal system.
The mammillary bodies (corpora mammillaria) – subcortical centers of olfaction.
The tuber cinereum – located anterior to the mammillary bodies and continues into the infundibulum.
The pituitary gland (hypophysis) – located in the hypophyseal fossa of the sella turcica; it consists of three lobes: the anterior (adenohypophysis), the posterior (neurohypophysis), and the intermediate lobe.
The optic chiasm and tract (tractus opticus) – located anterior to the tuber cinereum; this is the site of decussation of the medial fibers of the optic nerves, from which the optic tracts originate.

The hypothalamus contains 16 nuclei, which are grouped into anterior, intermediate, and posterior groups.
Neurons of the supraoptic and paraventricular nuclei produce hormones that are transported to the pituitary gland through the hypothalamo-hypophyseal neural tracts and the portal vein.

Third ventricle (ventriculus tertius)
This is the cavity of the diencephalon, representing a sagittal slit located in the median plane.
It has six walls:

- Lateral – formed by the medial surfaces of the thalami;
- Anterior – formed by the columns of the fornix (columna fornicis) and the anterior commissure (commissura anterior);
- Posterior – formed by the posterior commissure (commissura posterior, epithalamic commissure);
- Inferior – formed by the hypothalamus;
- Superior – formed by the choroid plexus covered by ependyma.

Connections:

- Through the interventricular foramina (foramen interventriculare) – with the lateral ventricles (ventriculus lateralis);
- Through the cerebral aqueduct (aqueductus mesencephali) – with the fourth ventricle (ventriculus quartus).

Telencephalon (telencephalon)

The telencephalon consists of two hemispheres.
Its cavity is represented by the lateral ventricles.
Each hemisphere has three surfaces (superolateral, medial, and inferior) and three poles (frontal, temporal, and occipital).
Each hemisphere consists of three phylogenetically distinct parts:

- the olfactory brain (rhinencephalon) (ancient part);
- the basal nuclei (nuclei basales) (old part);
- the pallium (pallium) (new part).

The olfactory brain (rhinencephalon) consists of peripheral (pars peripherica) and central parts (pars centralis).

Peripheral part (pars peripherica):

- olfactory bulb (bulbus olfactorius);
- olfactory tract (tractus olfactorius);
- olfactory trigone (trigonum olfactorium);
- anterior perforated substance (substantia perforata anterior).

Central part (pars centralis):

- fornicate gyrus (gyrus fornicatus (BNA)), ending with the uncus (uncus);
- hippocampus (hippocampus);
- dentate gyrus (gyrus dentatus).

The olfactory brain forms the basis of the limbic system (systema limbicus).
One of the conducting elements of the olfactory brain is the fornix (fornix).
The fornix is formed by arching nerve fibers that connect the hippocampus with the mammillary bodies. It consists of columns (columnae fornicis), a body (corpus fornicis), and crura (crura fornicis).
The columns of the fornix begin from the mammillary bodies, ascend behind the anterior commissure (commissura anterior), and lie anterior to the thalamus. Together with the thalamus, the columns form the boundaries of the interventricular foramina.
Reaching the corpus callosum, the columns continue into the body, which forms part of the superior wall of the third ventricle.
Posteriorly, the body of the fornix divides into two crura, which run along the surface of the thalamus into the inferior horn of the lateral ventricle and continue as the fimbriae of the hippocampus (fimbria hippocampi).
The crura of the fornix are connected by a commissure (commissura fornicis).
The fornix also belongs to the limbic system.

Basal nuclei
The basal nuclei (nuclei basales) are located at the base of the hemisphere.
They include (Fig. 10):

- the corpus striatum (corpus striatum);
- the claustrum (claustrum);
- the amygdaloid body (corpus amygdaloideum).

The corpus striatum (corpus striatum) consists of:

- the caudate nucleus (nucleus caudatus);
- the lentiform nucleus (nucleus lentiformis).

The caudate nucleus (nucleus caudatus) has the shape of a comma, located in the sagittal plane.
It consists of:

- the head (caput) (located anterior to the thalamus and forming the lateral wall of the anterior horn of the lateral ventricle (paries lateralis cornu anterius ventriculi lateralis));
- the body (corpus) (located lateral to the thalamus, forming with it the inferior wall of the central part of the lateral ventricle (paries inferius partis centralis ventriculi lateralis));
- the tail (cauda) (gradually tapering, running along the upper wall of the inferior horn of the lateral ventricle (paries superior cornu inferius ventriculi lateralis)).

The lentiform nucleus (nucleus lentiformis) is located lateral to the caudate nucleus and thalamus, separated from them by the internal capsule (capsula interna).
It is divided into two parts:

- the putamen (putamen) (the darker lateral part);
- the globus pallidus (globus pallidus) (the lighter medial part).

Connections of the corpus striatum are bilateral with:

- the cerebral cortex;
- the median nuclei of the thalamus;
- the substantia nigra;
- the red nucleus;
- the reticular nuclei;
- the nuclei of the inferior olive.

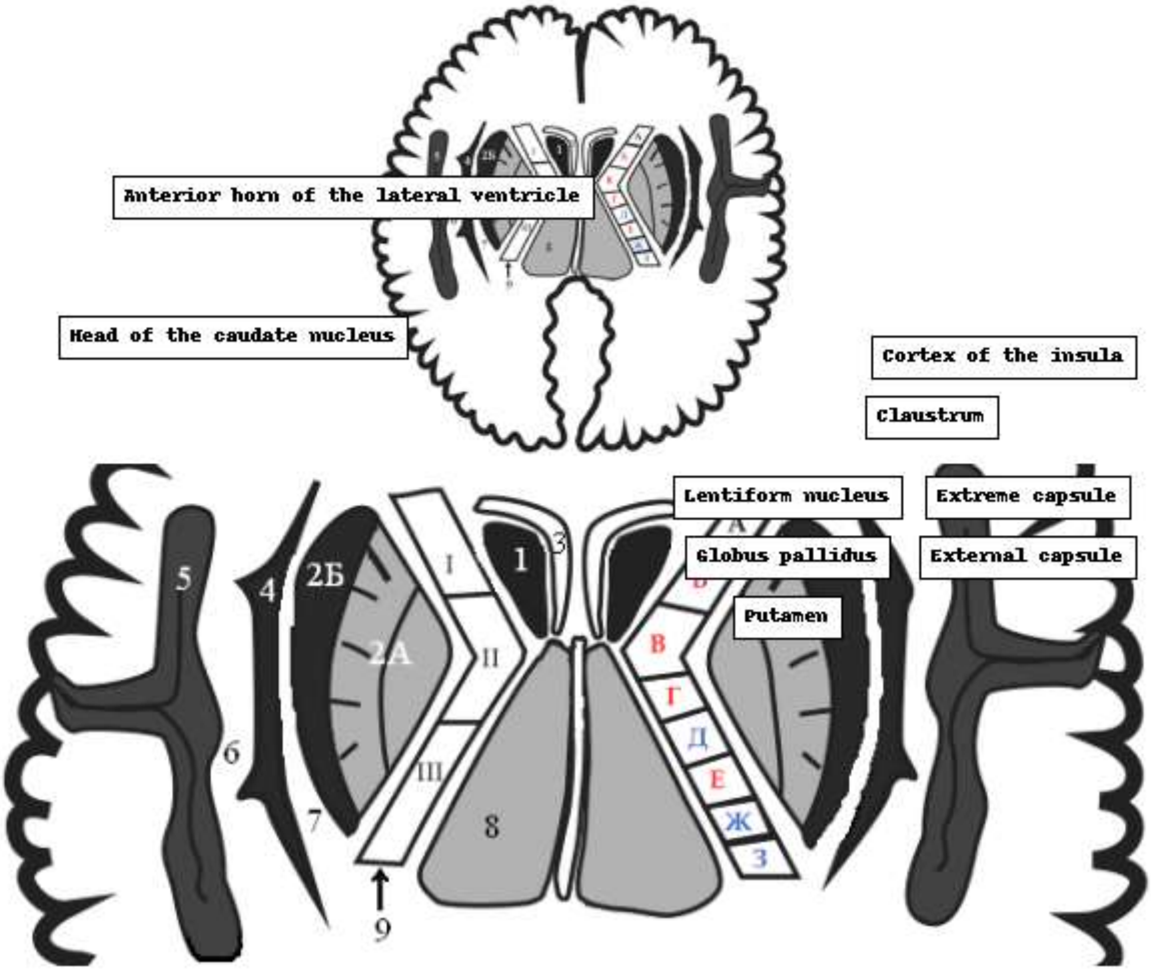


Figure 10. Basal nuclei and conduction pathways on a horizontal section of the brain (diagram):

1 – Head of the caudate nucleus (caput nuclei caudati);
2 – Lentiform nucleus (nucleus lentiformis);
2A – Globus pallidus (globus pallidus);
2B – Putamen (putamen);
3 – Anterior horn of the lateral ventricle (cornu anterius ventriculi lateralis);
4 – Claustrum (claustrum);
5 – Cortex of the insula (cortex insulae);
6 – Extreme capsule (capsula extrema);
7 – External capsule (capsula externa);
8 – Thalamus (thalamus);
9 – Internal capsule (capsula interna):
  I – Anterior limb (crus anterius);
  II – Genu (genu);
  III – Posterior limb (crus posterius).

Conduction pathways of the internal capsule:

A – Short association fibers of the telencephalon;
B – Frontopontine fibers (fibrae frontopontinae);
C – Corticobulbar tract (tractus corticonuclearis);
D – Corticospinal tract (tractus corticospinalis);
E – Thalamocortical tract (tractus thalamocorticalis);
F – Occipitotemporoparietopontine fibers (fibrae occipitotemporoparietopontinae);
G – Auditory radiation (radiatio acustica);
H – Optic radiation (radiatio optica).

The striatum represents the highest center of the extrapyramidal system.
Functions of the striatum:

- maintenance of the vertical position of the body;
- regulation of muscle tone;
- regulation of complex automatic movements;
- regulation of emotional reactions.

At the same time, the globus pallidus together with the substantia nigra and the red nucleus (nucleus ruber) are the primary motor centers: involuntary rhythmic motor activity in newborns is provided by them.

The putamen and the caudate nucleus (nucleus caudatus) coordinate more complex movements and emotions: the appearance of emotional activity in a child is ensured by these nuclei.

The claustrum is located between the putamen and the insular cortex (cortex insulae). It is a thin plate of gray matter, separated from the putamen by the external capsule (capsula externa), and from the insular cortex (cortex insulae) by the extreme capsule (capsula extrema).

Connections of the claustrum are bilateral with:

- the olfactory brain;
- the cerebral cortex;
- the thalamic nuclei.

The functions of the claustrum have not been clarified.

The amygdaloid body (corpus amygdaloideum) is located within the white matter of the temporal pole of the hemisphere. The amygdaloid body consists of 12 nuclei and 5 fields.

The amygdaloid body belongs to the limbic system (systema limbicus).

Pallium
The pallium is covered externally by the cortex (cortex), which is a layer of gray matter. The surface of the cortex is uneven, having numerous sulci and gyri. Three main sulci divide each hemisphere into four lobes:

- the central sulcus (sulcus centralis) — located on the dorsolateral surface, separates the frontal lobe (lobus frontalis) from the parietal lobe (lobus parietalis);
- the parieto-occipital sulcus (sulcus parietooccipitalis) — located posteriorly on the medial surface and serves as a boundary between the parietal and occipital (lobus occipitalis) lobes;
- the lateral sulcus (sulcus lateralis) — begins on the inferior surface of the hemisphere from the lateral fossa (fossa lateralis cerebri), runs laterally upward and backward. It separates the temporal lobe (lobus temporalis) from the frontal (anteriorly) and parietal (posteriorly) lobes;
- in the depth of the lateral sulcus lies a small lobe — the insula.

Each lobe is divided by sulci into gyri.

Sulci and gyri of the hemispheres on the dorsolateral surface

Frontal lobe (lobus frontalis):

- the precentral sulcus (sulcus precentralis) runs anterior and parallel to the central sulcus. It may consist of upper and lower parts;
- the superior frontal sulcus (sulcus frontalis superior) and the inferior frontal sulcus (sulcus frontalis inferior) run horizontally forward from the precentral sulcus.

These three sulci divide the dorsolateral surface of the frontal lobe into four gyri (Fig. 11):

- the precentral gyrus (gyrus precentralis) (between the central and precentral sulci);
- the superior frontal gyrus (gyrus frontalis superior);
- the middle frontal gyrus (gyrus frontalis medius);
- and the inferior frontal gyrus (gyrus frontalis inferior).

Parietal lobe (lobus parietalis):

- the postcentral sulcus (sulcus postcentralis) runs parallel to the central sulcus;
- the intraparietal sulcus (sulcus intraparietalis) runs horizontally from the postcentral sulcus. These sulci divide the dorsolateral surface of the parietal lobe into:
- the postcentral gyrus (gyrus postcentralis);
- the superior parietal lobule (lobulus parietalis superior); and
- the inferior parietal lobule (lobulus parietalis inferior) (located above and below the intraparietal sulcus).

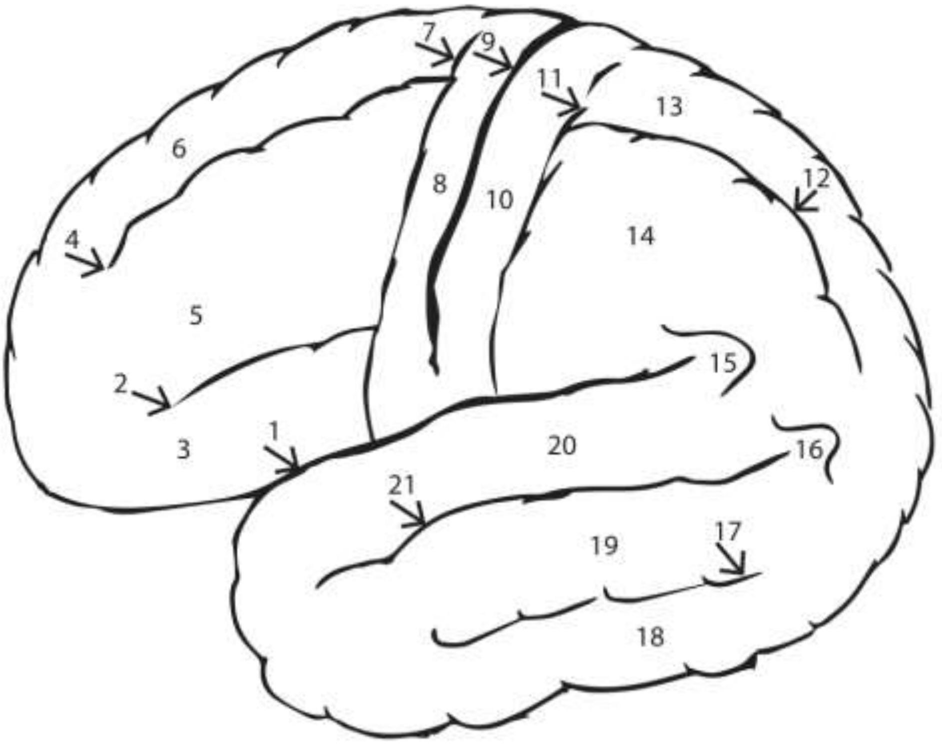


Figure 11. Sulci and gyri of the cerebral hemispheres on the dorsolateral surface of the telencephalon (diagram):

1 – Lateral sulcus (sulcus lateralis);
2 – Inferior frontal sulcus (sulcus frontalis inferior);
3 – Inferior frontal gyrus (gyrus frontalis inferior);
4 – Superior frontal sulcus (sulcus frontalis superior);
5 – Middle frontal gyrus (gyrus frontalis medius);
6 – Superior frontal gyrus (gyrus frontalis superior);
7 – Precentral sulcus (sulcus precentralis);
8 – Precentral gyrus (gyrus precentralis);
9 – Central sulcus (sulcus centralis);
10 – Postcentral gyrus (gyrus postcentralis);
11 – Postcentral sulcus (sulcus postcentralis);
12 – Intraparietal sulcus (sulcus intraparietalis);
13 – Superior parietal lobule (lobulus parietalis superior);
14 – Inferior parietal lobule (lobulus parietalis inferior);
15 – Supramarginal gyrus (gyrus supramarginalis);
16 – Angular gyrus (gyrus angularis);
17 – Inferior temporal sulcus (sulcus temporalis inferior);
18 – Inferior temporal gyrus (gyrus temporalis inferior);
19 – Middle temporal gyrus (gyrus temporalis medius);
20 – Superior temporal gyrus (gyrus temporalis superior);
21 – Superior temporal sulcus (sulcus temporalis superior).

In the inferior parietal lobule, the following structures are distinguished:

- the supramarginal gyrus (gyrus supramarginalis), which surrounds the end of the lateral sulcus;
- the angular gyrus (gyrus angularis), which curves around the posterior end of the superior temporal sulcus.

Temporal lobe (lobus temporalis):

- the superior temporal sulcus (sulcus temporalis superior) runs along the dorsolateral surface in the anteroposterior direction;
- the inferior temporal sulcus (sulcus temporalis inferior) lies closer to the inferior margin of the temporal lobe.

Between these sulci and the lateral sulcus are three gyri:

- the superior temporal gyrus (gyrus temporalis superior);
- the middle temporal gyrus (gyrus temporalis medius);
- the inferior temporal gyrus (gyrus temporalis inferior).

Insula (insula):
The insula is located at the bottom of the lateral sulcus and is clearly visible when its edges are separated or when the overlying lobes are removed. It is surrounded by the circular sulcus of the insula (sulcus circularis insulae) and the central sulcus of the insula (sulcus centralis insulae). The insula is divided into anterior and posterior lobules.

Occipital lobe (lobus occipitalis):
The sulci and gyri of this lobe vary. The following are distinguished:

- the superior occipital sulci (sulci occipitales superiores);
- the lateral occipital sulci (sulci occipitales inferiores).

Corresponding to these sulci are:

- the superior occipital gyri (gyri occipitales superiores);
- the lateral occipital gyri (gyri occipitales inferiores).

Sulci and gyri of the medial surface of the hemispheres (Fig. 12):

- the sulcus of the corpus callosum (sulcus corporis callosi) surrounds the corpus callosum and continues as
- the hippocampal sulcus (sulcus hippocampalis);
- the cingulate sulcus (sulcus cinguli) runs midway between the sulcus of the corpus callosum and the superior margin of the hemisphere. The posterior end of this sulcus turns toward the upper margin of the hemisphere and is called
- the marginal branch (ramus marginalis);
- the parieto-occipital sulcus (sulcus parietooccipitalis) lies between the parietal and occipital lobes;
- the calcarine sulcus (sulcus calcarinus) extends at an acute angle from the parieto-occipital sulcus.

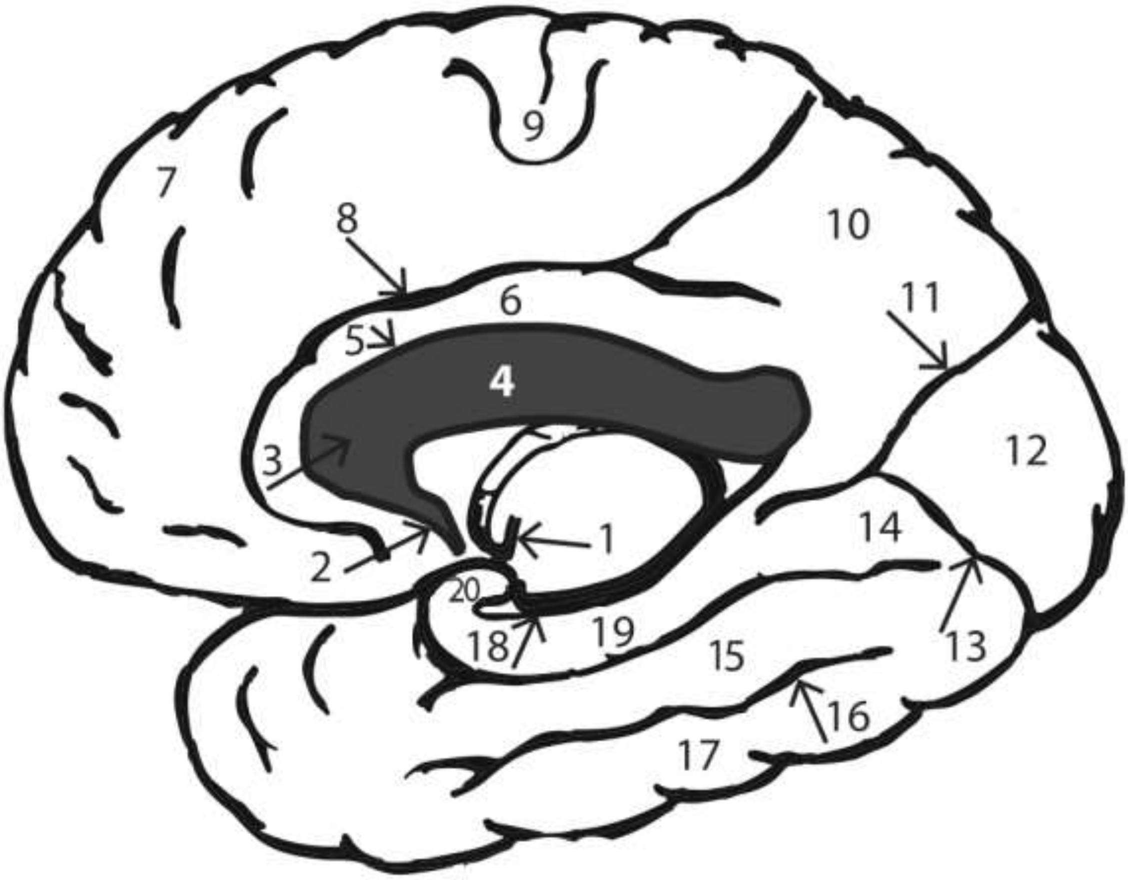


Figure 12. Sulci and gyri of the medial surface of the cerebral hemispheres (diagram):

1 – Fornix (fornix);
2 – Rostrum of the corpus callosum (rostrum corporis callosi);
3 – Genu of the corpus callosum (genu corporis callosi);
4 – Trunk of the corpus callosum (truncus corporis callosi);
5 – Sulcus of the corpus callosum (sulcus corporis callosi);
6 – Cingulate gyrus (gyrus cinguli);
7 – Superior frontal gyrus (gyrus frontalis superior);
8 – Cingulate sulcus (sulcus cinguli);
9 – Paracentral lobule (lobulus paracentralis);
10 – Precuneus (precuneus);
11 – Parieto-occipital sulcus (sulcus parietooccipitalis);
12 – Cuneus (cuneus);
13 – Calcarine sulcus (sulcus calcarinus);
14 – Lingual gyrus (gyrus lingualis);
15 – Medial occipitotemporal gyrus (gyrus occipitotemporalis medialis);
16 – Occipitotemporal sulcus (sulcus occipitotemporalis);
17 – Lateral occipitotemporal gyrus (gyrus occipitotemporalis lateralis);
18 – Hippocampal sulcus (sulcus hippocampi);
19 – Parahippocampal gyrus (gyrus parahippocampalis);
20 – Uncus (uncus).

Gyri:

- Above the cingulate sulcus, extending to the level of the upper end of the central sulcus projection — the medial surface of the superior frontal gyrus.
- The **cingulate gyrus (gyrus cinguli)** lies between the cingulate sulcus and the sulcus of the corpus callosum. It is located anterior and superior to the body of the corpus callosum, and behind its splenium it continues as the
- **isthmus of the cingulate gyrus (isthmus gyri cinguli)**, which extends onto the inferior surface to become the **parahippocampal gyrus**.
- The **paracentral lobule (lobulus paracentralis)** lies posterior to the superior frontal gyrus and is bounded posteriorly by the marginal branch of the cingulate sulcus.
- The **precuneus** is located between the marginal branch (anteriorly) and the parieto-occipital sulcus (posteriorly).
- The **cuneus** lies between the parieto-occipital sulcus (in front) and the calcarine sulcus (behind and below).

Sulci and gyri on the inferior surface of the hemispheres (Fig. 13):
On the inferior surface of the temporal lobe:

- the **hippocampal sulcus (sulcus parahippocampalis)** surrounds the cerebral peduncles;
- the **collateral sulcus (sulcus collateralis)** runs lateral and parallel to both the hippocampal sulcus and the inferior temporal sulcus.

Gyri:

- the **parahippocampal gyrus (gyrus parahippocampalis)**, which anteriorly ends with the **uncus**; this gyrus lies between the hippocampal and collateral sulci;
- the **medial occipitotemporal gyrus (gyrus occipitotemporalis medialis)** lies posterior to the parahippocampal gyrus, bounded above by the calcarine sulcus and below by the posterior end of the collateral sulcus;
- the **lateral occipitotemporal gyrus (gyrus occipitotemporalis lateralis)** lies between the collateral and inferior temporal sulci.

On the inferior surface of the frontal lobe (**orbital cortex**):

- the **olfactory sulcus (sulcus olfactorius)**;
- the **orbital sulci (sulci orbitales)**;
- the **straight gyrus (gyrus rectus)**;
- the **orbital gyri (gyri orbitales)**.

The **cingulate gyrus (gyrus cinguli)** is connected to the **parahippocampal gyrus** through the **isthmus of the cingulate gyrus (isthmus gyri cinguli)**, located posterior to the splenium of the corpus callosum. Together they form the **fornicate gyrus (gyrus fornicatus, BNA)** — the **limbic lobe (lobus limbicus)**.

The limbic lobe (lobus limbicus) includes:

- the cingulate sulcus;
- the cingulate gyrus;
- the isthmus of the cingulate gyrus;

- the band-like gyrus;
- the parahippocampal gyrus;
- the uncus;
- the dentate gyrus;
- the fimbrio-dentate sulcus;
- the fimbria of the hippocampus;
- the collateral sulcus;
- and the orbital cortex.

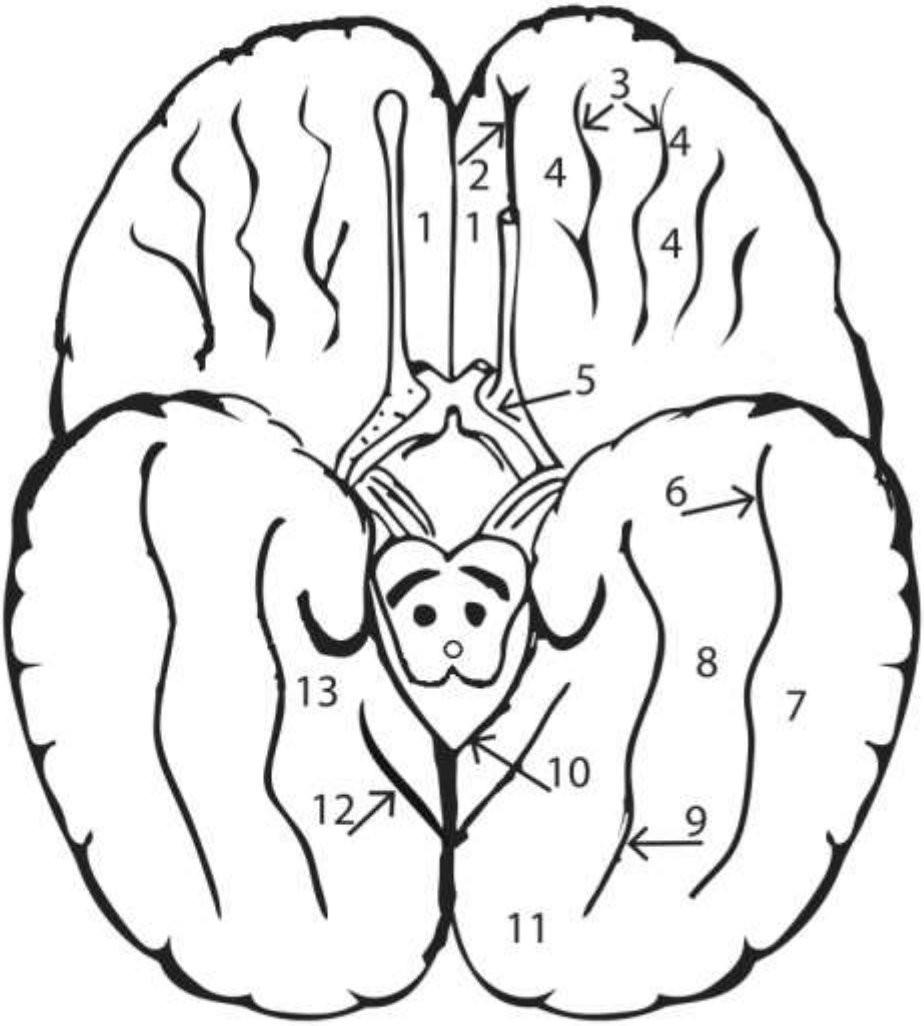


Figure 13. Sulci and gyri of the inferior surface of the cerebral hemispheres (diagram):

1 – Straight gyrus (gyrus rectus);
2 – Olfactory sulcus (sulcus olfactorius);
3 – Orbital sulci (sulci orbitales);
4 – Orbital gyri (gyri orbitales);
5 – Anterior perforated substance (substantia perforata anterior);
6 – Occipitotemporal sulcus (sulcus occipitotemporalis);
7 – Lateral occipitotemporal gyrus (gyrus occipitotemporalis lateralis);
8 – Medial occipitotemporal gyrus (gyrus occipitotemporalis medialis);

9 – Collateral sulcus (sulcus collateralis);
10 – Parahippocampal sulcus (sulcus parahippocampalis);
11 – Lingual gyrus (gyrus lingualis);
12 – Calcarine sulcus (sulcus calcarinus);
13 – Parahippocampal gyrus (gyrus parahippocampalis).

Localization of functions in the cerebral cortex (Fig. 14)
The cortex of the cerebral hemispheres represents a collection of cortical centers of analyzers, which consist of nuclear and diffuse parts. The cortical centers of analyzers provide the analytical function of the cortex:

- the **nucleus of the motor analyzer** — located in the precentral gyrus (neurons of the middle layers of this cortical area receive impulses from the musculoskeletal system; the reflex arc closes here in response to these impulses, and the corresponding reaction is provided through the large Betz pyramidal cells, which form the beginning of the pyramidal tracts);
- the **nucleus of the cutaneous analyzer** (for temperature and pain) — located in the postcentral gyrus.

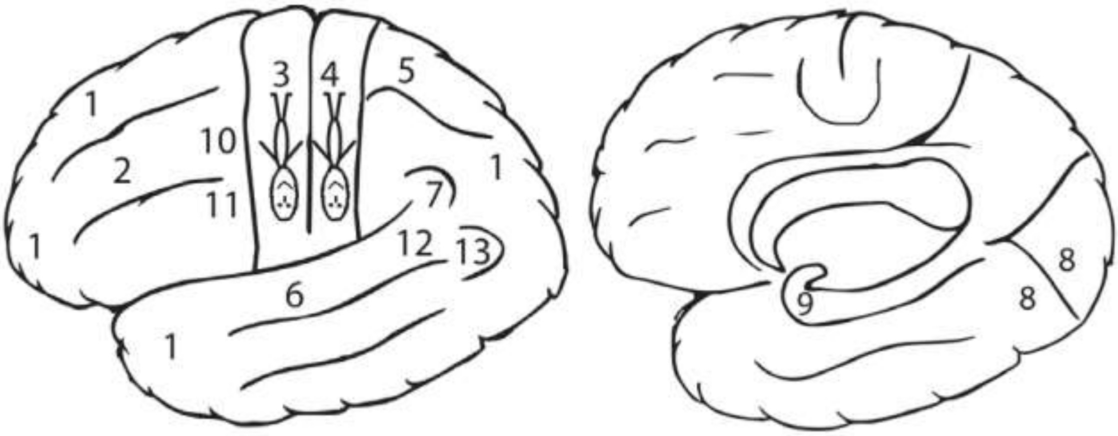


Figure 14. Localization of functions in the cerebral hemispheres (diagram):

1 – **Center of equilibrium** – localized throughout the cortex.
2 – **Center of conjugate turning of the head and eyes to the opposite side** – posterior part of the middle frontal gyrus.
3 – **Nucleus of the motor analyzer** – precentral gyrus.
4 – **Nucleus of the cutaneous (sensory) analyzer** – postcentral gyrus.
5 – **Center of stereognosis** – superior parietal lobule (each hemisphere is connected only with the opposite limb).
6 – **Nucleus of the auditory analyzer** – located in the depth of the lateral sulcus, in the middle part of the superior temporal gyrus.
7 – **Center of practical skills (praxis center), only in the opposite hemisphere** – supramarginal gyrus, inferior parietal lobule.
8 – **Nucleus of the visual analyzer** – on both sides of the calcarine sulcus.
9 – **Center of taste and smell** – uncus.
10 – **Center of writing** – posterior part of the middle frontal gyrus.
11 – **Speech motor center** – posterior part of the inferior frontal gyrus.
12 – **Center of understanding spoken language (Wernicke's area)** – posterior part of the

superior temporal gyrus.
13 – **Center of reading** – angular gyrus.

Localization of Functions in the Cerebral Cortex (Fig. 14)

In the precentral and postcentral gyri, the human body is represented *upside down*; the projection is mapped onto the cortex of the *opposite hemisphere*.

- **Auditory analyzer nucleus** — located in the middle third of the superior surface of the superior temporal gyrus;
- **Visual analyzer nucleus** — along the edges of the calcarine sulcus;
- **Olfactory analyzer nucleus** — in the cortex of the parahippocampal gyrus and the uncus (limbic region);
- **Gustatory analyzer nucleus** — in the uncus (and in the lower part of the postcentral gyrus);
- **Visceral sensory center** — in the lower third of the precentral and postcentral gyri;
- **Equilibrium analyzer center** — has no distinct nuclear part and is diffusely distributed throughout the cortex.

All the centers listed above are *innate* and common to animals as well.

Acquired centers are formed on the basis of innate ones and are also present in higher vertebrates:

- **Center of stereognosis** — recognition of objects by touch and tactile sense — located in the superior parietal lobule;
- **Center of praxis** — responsible for habitual, purposeful movements — located in the supramarginal gyrus (in animals — corresponds to the training center).

Speech centers are specific to humans. There are centers for oral and written speech, each with *motor* and *sensory* components.

Centers of oral speech:

- **Articulation (motor speech) center** — in the posterior part of the inferior frontal gyrus (near the motor analyzer nucleus of the head and neck);
- **Auditory speech analyzer center** — in the posterior part of the superior temporal gyrus (next to the auditory analyzer nucleus).

Centers of written speech:

- **Writing center** — in the posterior section of the middle frontal gyrus (close to the middle part of the precentral gyrus — projection of the upper limb);
- **Reading center** — in the angular gyrus (near the occipital lobe, where the visual analyzer nucleus is located).

All speech centers are located in the left hemisphere in right-handed individuals, and in the right hemisphere in left-handed individuals.

White Matter of the Cerebrum (Substantia Alba Cerebri)

It consists of nerve tracts, which are divided into short and long fibers.
Short fibers include association fibers (fibrae associationes telencephali) and commissural fibers (fibrae commissurales telencephali); long fibers are represented by projection fibers**.**

Association fibers connect different cortical areas within the same hemisphere and are divided into *short* and *long* association fibers.

- *Short association fibers* connect adjacent gyri.
- *Long association fibers* connect cortical areas of different lobes within the same hemisphere.

Major long association tracts:

- **Cingulum** — fibers pass beneath the cortex of the cingulate gyrus on the medial surface of the hemispheres, connecting areas of the frontal, occipital, and temporal lobes; part of the limbic system.
- **Superior longitudinal fasciculus (fasciculus longitudinalis superior)** — connects cortical areas of the frontal, parietal, occipital, and temporal lobes.
- **Inferior longitudinal fasciculus (fasciculus longitudinalis inferior)** — connects cortical areas of the occipital and temporal lobes.
- **Uncinate fasciculus (fasciculus uncinatus)** — connects cortical areas of the frontal and anterior temporal lobes.

Association fibers provide the synthetic function of the cortex, interlinking different cortical centers.

Commissural fibers connect corresponding cortical areas of both hemispheres. They pass through:

- **Corpus callosum (corpus callosum)** — with three main parts: the posterior thickened *splenium*, the *trunk (truncus)*, and the anterior *rostrum*.
- **Anterior commissure (commissura anterior)** — participates in forming the anterior wall of the third ventricle.
- **Posterior commissure (commissura posterior)** — located above the entrance to the cerebral aqueduct (in the posterior wall of the third ventricle).
- **Fornix commissure (commissura fornicis)** — located between the crura of the fornix.

Commissural fibers ensure coordinated function of the two hemispheres, which are characterized by *functional asymmetry*:
the left hemisphere is responsible for abstract and generalized processing, while the right hemisphere handles concrete, emotional, and artistic perception of the external world.

Projection fibers are long conducting tracts connecting various cortical areas with lower brain regions and the spinal cord, thus linking the cortex with the entire body. They provide the integrative function of the cortex.

Projection fibers (ascending and descending tracts) pass through (see Fig. 10):

- **Internal capsule (capsula interna)** — located between the caudate nucleus and thalamus medially, and the lentiform nucleus laterally;
- **External capsule (capsula externa)** — between the putamen and claustrum;
- **Extreme capsule (capsula extrema)** — between the claustrum and the insular cortex.

Lateral Ventricles (VENTRICULI LATERALES)

They represent the cavities of the telencephalon; they are paired, corresponding to the two hemispheres. Four parts are distinguished in each:

- **central part (pars centralis)** – located in the parietal lobe;
- **anterior horn (cornu anterius)** – located in the frontal lobe;
- **posterior horn (cornu posterius)** – located in the occipital lobe;
- **inferior horn (cornu inferius)** – located in the temporal lobe.

The lateral ventricles lie beneath the corpus callosum, and therefore the upper walls of all their parts, as well as partly other walls, are formed by the corpus callosum.

The lower wall of the central part is formed by the body of the caudate nucleus and the dorsal surface of the thalamus.
The anterior horn is bordered medially by the septum pellucidum and laterally by the head of the caudate nucleus.
The posterior horn has on its medial side the calcar avis—a projection corresponding to the calcarine sulcus, and on its lower wall the collateral trigone (trigonum collaterale), corresponding to the collateral sulcus.
The inferior horn, medially and partly inferiorly, contains the hippocampus with the fimbria hippocampi along its medial margin, and on its lower wall lies the **collateral eminence (eminentia collateralis)**—a continuation of the collateral trigone from the posterior horn.

The lateral ventricles communicate with the third ventricle through the **interventricular foramen (foramen interventriculare)**, located between the **column of the fornix (columna fornicis)** and the **anterior tubercle of the thalamus (tuberculum anterius thalami)**. Through this foramen, the **choroid plexus (plexus choroideus)** extends from the third ventricle into each lateral ventricle, producing cerebrospinal fluid.

Tracts of the Spinal Cord and Brain

Sensory (ascending) pathways are divided into those that conduct:

- Proprioceptive sensation (from the musculoskeletal system);
- Exteroceptive sensation (from the skin);
- Interoceptive sensation (from the walls of the internal organs and the cardiovascular system).

The pathways conducting proprioceptive sensation are subdivided into conscious and unconscious: the conscious pathways carry impulses to the cerebral cortex, while the unconscious pathways carry impulses to the cerebellum (the center of balance and coordination of movements).

Conscious proprioceptive pathway

It informs the cortex about the functional state of the locomotor apparatus (muscle tone, the position of body parts in space, and the senses of pressure, weight, and vibration).

Receptors: in the muscles and tendons; the ligaments and joint capsules; the periosteum; and in the bones of the trunk and limbs.

The pathway has three neurons (Figure 15):

- First-order neuron cell bodies are in the (sensory) spinal—dorsal root—ganglia. Nerve impulses arising in proprioceptors travel along the dendrites of pseudounipolar cells to their cell bodies; from there they pass along the axons of these cells, which form the posterior (dorsal) roots of the spinal nerves, into the spinal cord. The axons, bypassing the gray matter, ascend in the posterior funiculus of the spinal cord and form two bundles: the gracile fasciculus (fasciculus gracilis) medially and the cuneate fasciculus (fasciculus cuneatus) laterally.

  The gracile fasciculus conducts impulses from the lower limbs and the lower half of the trunk and extends along the entire length of the spinal cord. The cuneate fasciculus conducts impulses from the upper half of the trunk and from the upper limbs.

The gracile and cuneate fasciculi continue to the gracile tubercle (tuberculum gracile) and the cuneate tubercle (tuberculum cuneatum) of the medulla oblongata, where the nuclei of the same names are located.

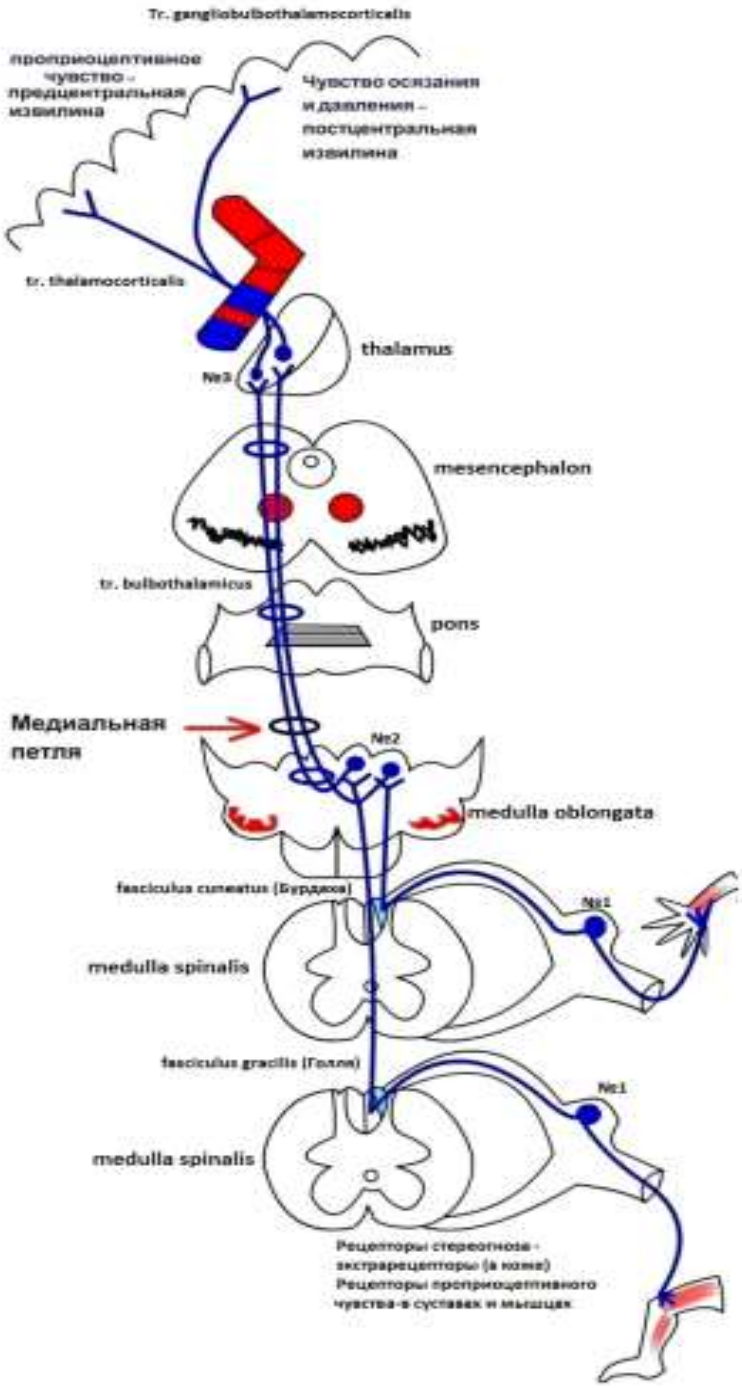


Figure 15. Pathway of conscious proprioceptive sensitivity (tractus gangliobulbothalamocorticalis) — schematic

No. 1 — sensory ganglion of the spinal nerve (sensory neuron) (ganglion sensorium nervi spinalis)

No. 2 — gracile and cuneate nuclei (nuclei gracilis et cuneatus)

No. 3 — ventrolateral nuclei of the thalamus (nuclei ventrolaterales thalami)

- Second-order neuron cell bodies are in the gracile and cuneate nuclei (nuclei gracilis et cuneatus).

The axons of these neurons form the bulbothalamic fasciculus (fasciculus bulbothalamicus) which, joining the medial lemniscus, ascends to the ventrolateral nuclei of the thalamus.

- Third-order neuron cell bodies are in the ventrolateral nuclei of the thalamus.

  Their axons form the thalamocortical tract (tractus thalamocorticalis) and pass through the internal capsule to the cortical center—into layer IV of the precentral gyrus.

- Cortical center (motor analyzer "nucleus") — in the precentral gyrus (gyrus precentralis).

The pathway is crossed: the axons of the second-order neurons decussate in the medulla oblongata—decussation of the medial lemniscus (sensory decussation).

Topography:

- in the spinal cord — in the posterior funiculi;
- in the brainstem — dorsally within the medial lemniscus;
- in the internal capsule — in the posterior half of the posterior limb.

Collaterals from second-order neurons project:

- to the cerebellum via the inferior cerebellar peduncles (as external arcuate fibers);
- to the reticular formation of the brainstem;
- to the limbic system.

Unconscious proprioceptive pathways

Nerve impulses arising in proprioceptors reach the cerebellum and inform it about the state of the locomotor system. By analyzing these impulses, the cerebellum regulates muscle tone, coordination of movements, and maintenance of body balance in space.

Unconscious proprioception is carried by two tracts: the anterior and posterior spinocerebellar tracts (tractus spinocerebellares anterior et posterior).

Receptors: in muscles and tendons; ligaments and joint capsules; periosteum; and the bones of the trunk and limbs.

Both pathways are two-neuron tracts (Figure 16):

- First-order neuron cell bodies are in the (sensory) dorsal root ganglia.

  Impulses from proprioceptors travel along the dendrites of pseudounipolar cells to their bodies, then along their axons—which form the posterior (dorsal) roots of the spinal nerves—into the spinal cord.

The axons enter the gray matter and terminate on neurons of two nuclei, where the second-order neuron cell bodies are located:

- in the thoracic (Clarke's) nucleus — for the posterior spinocerebellar tract;
- in the intermediomedial nucleus — for the anterior spinocerebellar tract.

- The axons of cells of the thoracic (Clarke's) nucleus exit into the posterior part of the peripheral lateral funiculus of the white matter on the same side and form the posterior spinocerebellar tract.
- The axons of cells of the intermediomedial nucleus exit into the anterior part of the peripheral lateral funiculus of the white matter, partly ipsilaterally and partly contralaterally, and form the anterior spinocerebellar tract.

Both tracts course to the cerebellum.

- The posterior spinocerebellar tract is short: from the spinal cord it ascends to the medulla oblongata, then enters the cerebellum via the inferior cerebellar peduncle.
- The anterior spinocerebellar tract is long: from the spinal cord it continues into the medulla oblongata, then passes successively through the pons and midbrain, and enters the cerebellum via the superior cerebellar peduncle.

  Those fibers that did not decussate in the spinal cord decussate in the superior medullary velum.

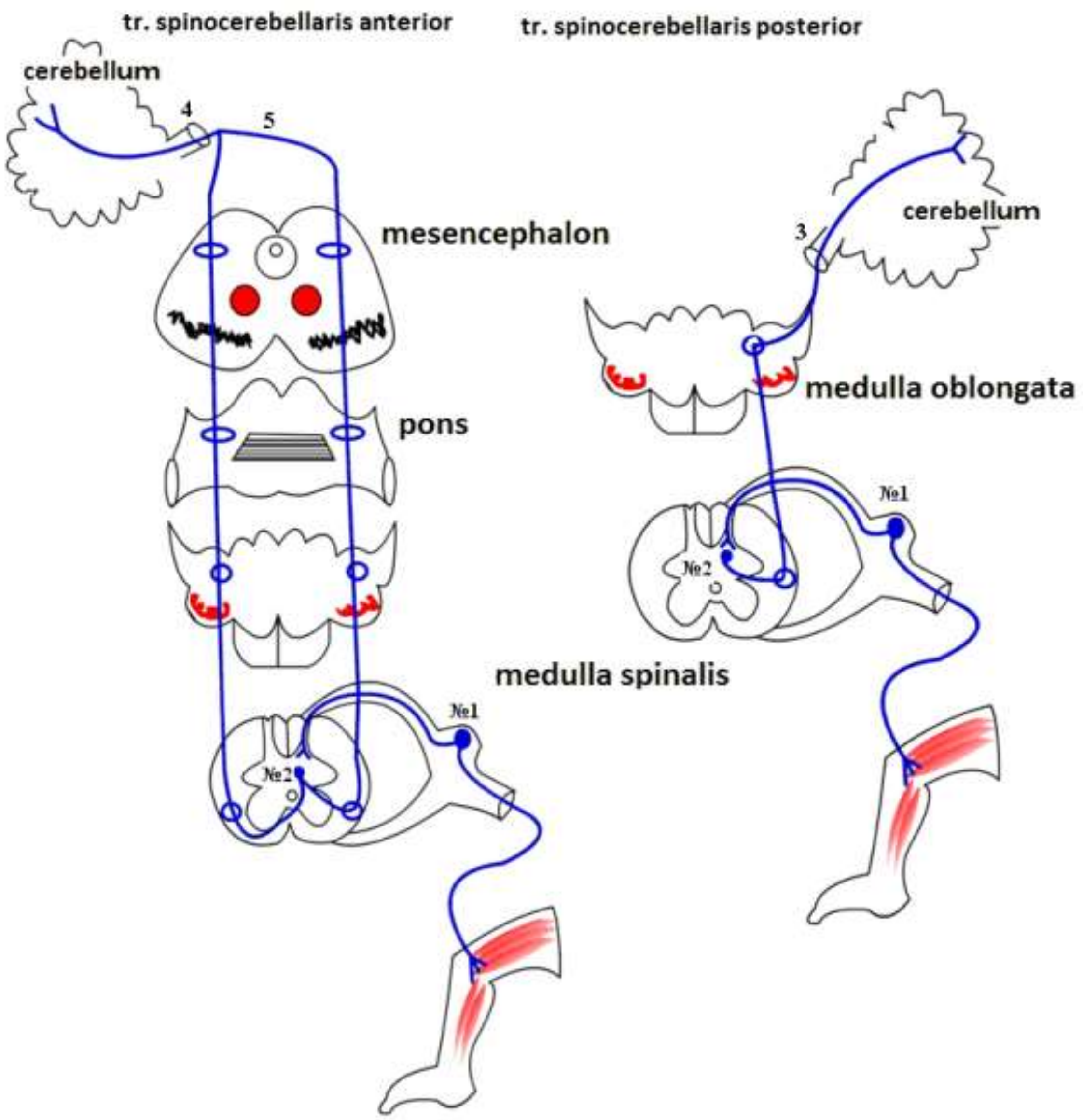


Figure 16. Unconscious proprioceptive pathways

(tracti gangliospinocerebellares anterior (Gowers) et posterior (Flechsig); schematic)

No. 1 — sensory ganglion of the spinal nerve (sensory neuron) (ganglion sensorium nervi spinalis)

No. 2 — intermediomedial nucleus (nucleus intermediomedialis) for the anterior tract, and thoracic (Clarke's) nucleus (nucleus thoracicus) for the posterior tract

3 — inferior cerebellar peduncle (pedunculus cerebellaris inferior)

4 — superior cerebellar peduncle (pedunculus cerebellaris superior)

5 — superior medullary velum (velum medullare superius)

Thus, the posterior and anterior spinocerebellar tracts share several features:

- they conduct unconscious proprioceptive impulses;

- their receptors are in organs of the locomotor system;
- first-order neuron bodies lie in the spinal (dorsal root) ganglia;
- in the spinal cord they run in the lateral funiculi;
- they convey impulses to the cerebellum.

At the same time, there are a number of differences between them:

- Second-order neuron bodies are in different nuclei, so the posterior spinocerebellar tract is formed by the axons of neurons in the thoracic (Clarke's) nucleus, whereas the anterior spinocerebellar tract is formed by axons of neurons in the intermediomedial nucleus;
- the posterior spinocerebellar tract is direct (it does not decussate) and therefore carries impulses to the ipsilateral half of the cerebellum; the anterior tract is crossed: it undergoes two partial decussations—in the spinal cord and in the superior medullary velum—and conducts impulses to the contralateral half of the cerebellum. As a result, each half of the cerebellum receives information from both halves of the body. In other words, from each half of the body, information about the state of the locomotor apparatus reaches both cerebellar hemispheres. This is a redundancy mechanism that makes cerebellar control of body equilibrium reliable;
- the posterior spinocerebellar tract is short—it enters the cerebellum directly from the medulla oblongata via the inferior cerebellar peduncle; the anterior tract is long—before entering the cerebellum, it passes through almost all sections of the brainstem: medulla oblongata, pons, midbrain, and then enters the cerebellum via the superior cerebellar peduncle.

Pathways of exteroceptive (cutaneous) sensation

These pathways conduct to the brain the nerve impulses arising in exteroceptors (pain, temperature, and tactile) of the trunk, limbs, and neck.

Temperature and pain are conducted in the spinal cord by the lateral spinothalamic tract, while tactile sensation and stereognosis are conducted by two routes: the anterior spinothalamic tract and the pathways that carry conscious proprioceptive impulses.

Pathway conveying temperature and pain

Receptors: in the skin of the trunk, limbs, and neck.

This is a three-neuron pathway (Figure 17):

- First-order neuron bodies are in the (sensory) dorsal root ganglia.

  Nerve impulses arising in thermoreceptors and nociceptors travel along the dendrites of pseudounipolar cells (within spinal nerves) to their cell bodies, and from there along their axons—which form the posterior (dorsal) roots—into the gray matter of the spinal cord.

Their axons relay the impulses to neurons of the proper (proprius) nucleus of the spinal cord.

- Second-order neuron bodies are in the proper nucleus of the spinal cord.

  The axons of these neurons cross via the anterior white commissure to the opposite side (2–3 segments above) and form the lateral spinothalamic tract (tractus spinothalamicus lateralis), which ascends to the medulla oblongata.

  At the pontomedullary junction this tract joins the medial lemniscus; the medial lemniscus terminates in the ventrolateral nuclei of the thalamus (nuclei ventrolaterales thalami).

- Third-order neuron bodies are in the ventrolateral nuclei of the thalamus.

  Their axons form the thalamocortical tract (tractus thalamocorticalis), pass through the posterior part of the posterior limb of the internal capsule, and reach layer IV of the cortex of the postcentral gyrus (gyrus postcentralis).

- Cortical center (the "nucleus" for temperature and pain) — in the postcentral gyrus (gyrus postcentralis).

The pathway is crossed: the axons of the second-order neurons decussate in the anterior white commissure of the spinal cord 2–3 segments above their entry.

Topography:

- in the spinal cord — in the lateral funiculi;
- in the brainstem — dorsally within the medial lemniscus;
- in the internal capsule — in the posterior half of the posterior limb.

Collaterals: to the cerebellum; to the reticular formation; to the limbic system.

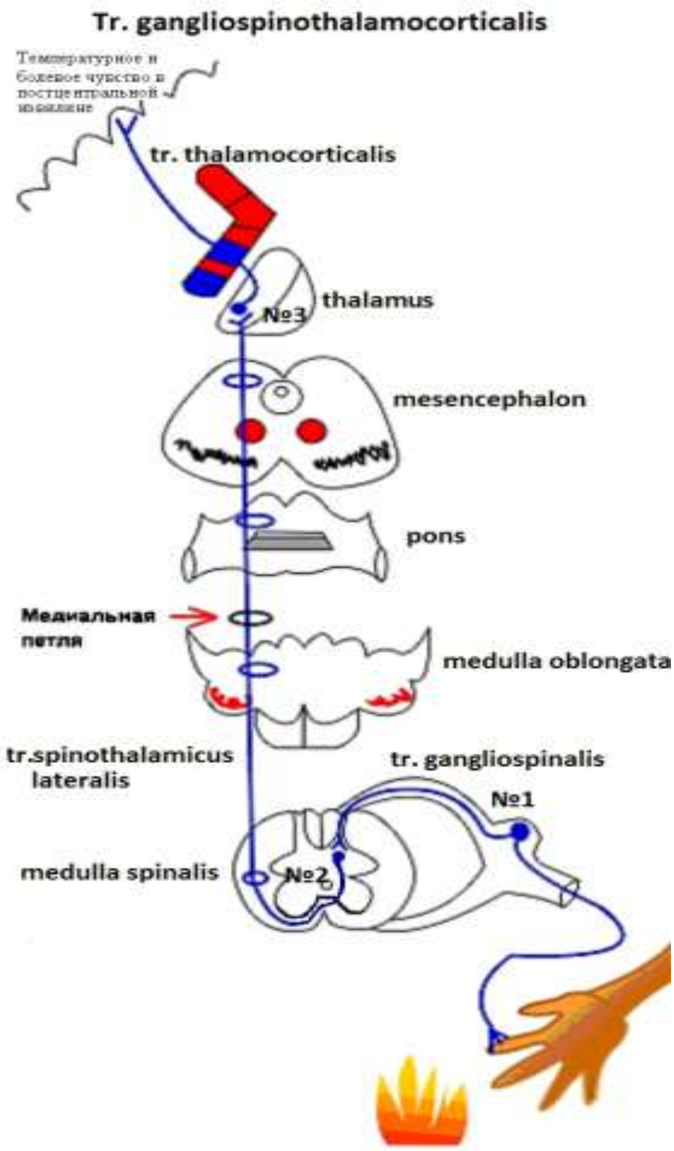


Figure 17. Pathway conveying temperature and pain

(tractus gangliospinothalamocorticalis; schematic)

No. 1 — sensory ganglion of the spinal nerve (sensory neuron) (ganglion sensorium nervi spinalis)

No. 2 — proper nucleus (nucleus proprius)

No. 3 — ventrolateral nuclei of the thalamus (nuclei ventrolaterales thalami)

Pathways conducting tactile sensation and stereognosis

Receptors: in the skin of the trunk, limbs, and neck.

This is a three-neuron pathway:

- First-order neuron cell bodies — sensory pseudounipolar cells of the dorsal root ganglia.

Nerve impulses arising in cutaneous receptors travel along the dendrites of these cells within the spinal nerves to their cell bodies, and from there along their axons in the posterior (dorsal) roots into the spinal cord.

The fibers carrying tactile and stereognostic impulses in the spinal cord proceed in two directions. Some bypass the gray matter, ascend in the posterior funiculi, and contribute to the formation of the gracile and cuneate fasciculi. From there, tactile and stereognostic impulses reach the cortex via the pathways of conscious proprioception—a three-neuron route (see above).

Other fibers carrying tactile and stereognostic impulses enter the gray matter and relay to neurons of the proper (proprius) nucleus.

- Second-order neuron cell bodies — in the proper nucleus of the spinal cord.

  The axons of these neurons cross via the anterior white commissure to the opposite side and form the anterior spinothalamic tract (tractus spinothalamicus anterior), which lies anterior to the lateral spinothalamic tract and ascends to the medulla oblongata. At the junction of the medulla and pons this tract joins the medial lemniscus. The medial lemniscus ends in the ventrolateral nuclei of the thalamus (nuclei ventrolaterales thalami).

- Third-order neuron cell bodies — in the ventrolateral thalamic nuclei.

  Their axons form the thalamocortical bundle, pass through the posterior part of the posterior limb of the internal capsule, and reach layer IV of the cortex of the superior parietal lobule.

Cortical center: superior parietal lobule (lobulus parietalis superior).

The pathway is crossed: the axons of the second-order neurons decussate.

Topography:

- in the spinal cord — lateral funiculi
- in the brainstem — dorsally within the medial lemniscus
- in the internal capsule — posterior half of the posterior limb

Collaterals: to the cerebellum, reticular formation, and limbic system.

Thus, all of the sensory conducting pathways described above provide general sensation (proprioceptive, pain, temperature, tactile) for the trunk and limbs and therefore reach the brain via the spinal cord.

General sensation of the head

General sensation of the head is provided by the trigeminal nerve (cranial nerve V).

Receptors are located in the skin of the head, mucous membranes of organs, the eyeball, dental tissues, the meninges, the bones of the skull, and in the facial and masticatory muscles.

This is a three-neuron pathway:

- First-order neuron cell bodies — pseudounipolar sensory cells of the trigeminal ganglion (ganglion trigeminale).

  Impulses arising in receptors travel along the dendrites within all three divisions of the trigeminal nerve to the neuron bodies; from there, via their axons, they reach the sensory nuclei of the nerve:

  - to the principal (chief) trigeminal nucleus (nucleus principalis nervi trigemini) come impulses of tactile sensitivity of the facial skin, pain and temperature sensitivity, and from deep tissues and organs of the head;

  - to the spinal trigeminal nucleus (nucleus spinalis nervi trigemini) come pain and temperature impulses from the facial skin;

  - to the mesencephalic trigeminal nucleus (nucleus mesencephalicus nervi trigemini) come proprioceptive impulses from the facial and masticatory musculature.

- Second-order neuron cell bodies — in the above-named sensory trigeminal nuclei.

  The axons of the second-order neurons join the medial lemniscus and reach neurons of the ventrolateral thalamic nuclei.

- Third-order neuron cell bodies — in the ventrolateral thalamic nuclei.

  Their axons, within the thalamocortical pathway, pass through the internal capsule to the cortical centers.

Cortical centers:

- lower part of the postcentral gyrus (gyrus postcentralis) — centers for temperature and pain sensitivity of the head region;

- lower part of the precentral gyrus (gyrus precentralis) — center for proprioceptive sensitivity of the head region;

- superior parietal lobule (lobulus parietalis superior) — center for tactile sensitivity.

The pathway is crossed: the axons of the second-order neurons decussate.

Topography:

- in the brainstem — dorsally within the medial lemniscus

- in the internal capsule — posterior part of the posterior limb

Collaterals: to the cerebellum, reticular formation, and limbic system.

Motor conducting pathways

These conduct impulses originating in the motor centers of the brain to the motor nuclei of the spinal cord and cranial nerves, thereby transmitting the regulatory influence of the brain's motor centers to skeletal muscles.

Motor pathways are divided into two groups:

- pyramidal
- extrapyramidal

Pyramidal pathways

They begin in the motor centers of the cerebral cortex and regulate voluntary movements.

Pyramidal pathways include:

- the corticospinal tract
- the corticonuclear (corticobulbar) tract
- the corticopontine tract

Corticospinal tract

(tractus corticospinalis)

Conducts voluntary motor impulses that enable precise, highly differentiated movements of the trunk and limb muscles.

Also conducts inhibitory impulses from the cortex to the motor nuclei of the anterior horns, which exert an inhibitory effect on the segmental apparatus of the spinal cord (Figure 18).

This is a two-neuron pathway:

- First-order neuron cell bodies — giant and large pyramidal cells of layer V of the precentral gyrus and paracentral lobule.

  Their axons form the corticospinal tract and terminate in the motor nuclei of the anterior horns of the spinal cord.

- Second-order neuron cell bodies — in the motor nuclei of the anterior horns of the spinal cord.

Their axons leave the spinal cord in the anterior roots, then within the spinal nerves reach the skeletal muscles of the trunk and limbs and end on the effectors.

Topography:

- in the internal capsule — anterior part of the posterior limb
- in the brainstem — ventral
- in the spinal cord — central parts of the lateral funiculi and in the anterior funiculi

The pathway is crossed: it undergoes two partial decussations.

Most axons of the first-order neurons decussate in the medulla oblongata in the depth of the anterior median fissure — the decussation of the pyramids (decussatio pyramidum) — and, forming the lateral corticospinal tract, descend in the lateral funiculi.

The uncrossed fibers form the anterior corticospinal tract, descend in the anterior funiculi of the spinal cord, and cross segmentally in the anterior white commissure.

Corticonuclear tract

(tractus corticonuclearis)

Conducts voluntary motor impulses to the muscles of the head and neck and regulates their precise, highly differentiated movements (Figure 19).

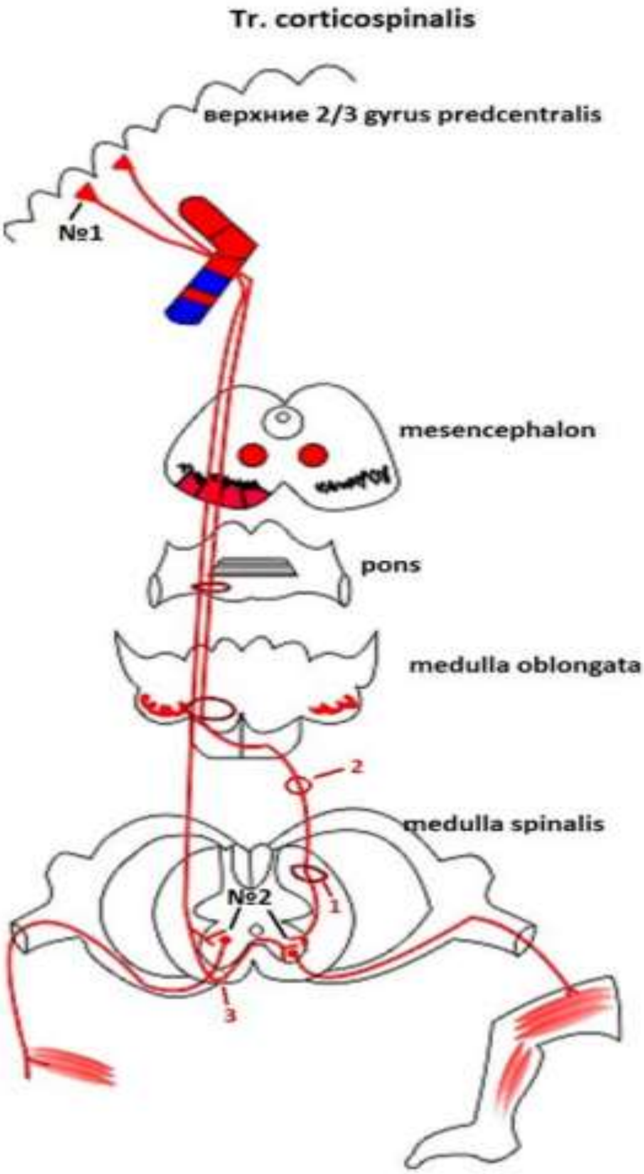


Figure 18. Pyramidal Pathway:

Tractus Corticospinalis (Corticospinal Pathway)

No. 1 – giant and large pyramidal cells of layer V of the cortex of the precentral gyrus and paracentral lobule,

No. 2 – in the motor nuclei of the anterior horns of the spinal cord;

1 – lateral corticospinal pathway (tractus corticospinalis lateralis),

2 – decussation of the pyramids (decussatio pyramidum),

3 – anterior corticospinal pathway (tractus corticospinalis anterior).

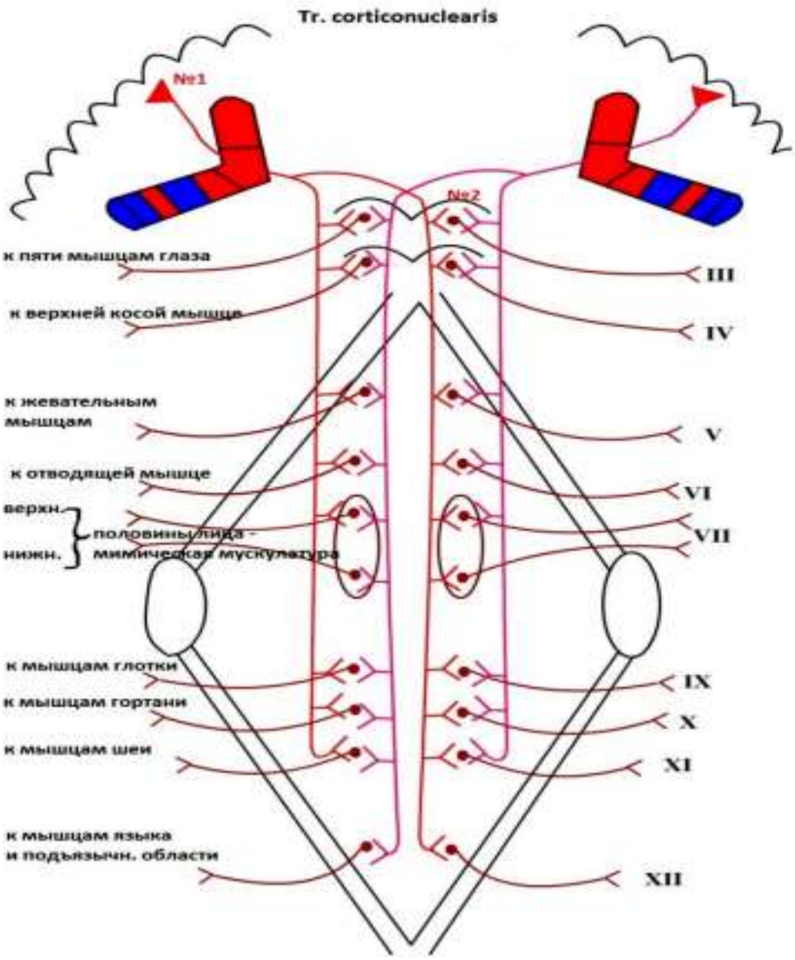


Figure 19. Pyramidal Pathway:

Tractus Corticonuclearis (Corticonuclear Pathway)

No. 1 – pyramidal cells of layer V of the lower third of the precentral gyrus,

No. 2 – in the motor nuclei of the cranial nerves (III, IV, V, VI, VII, IX, X, XI, XII pairs).

The pathway is two-neuron:

- First-order neuron cell bodies – pyramidal cells of layer V of the lower third of the precentral gyrus, whose axons form the corticonuclear pathway leading to the motor nuclei of the cranial nerves (III, IV, V, VI, VII, IX, X, XI, XII pairs);
- Second-order neuron cell bodies – in the motor nuclei of the above-mentioned cranial nerves; their axons, as part of these cranial nerves, reach the muscles of the head and neck and terminate on the effectors.

Topography:

- in the internal capsule – passes through the genu;
- in the brainstem – ventrally.

The pathway is partially crossed, due to which the motor nuclei of most cranial nerves receive impulses from both hemispheres (a reliability mechanism for the functioning of the head and neck muscles).

Exceptions are the fibers going to the nucleus of the XII pair and to the lower third of the motor nucleus of the VII pair – they cross completely; these nuclei receive impulses only from the cortex of the opposite cerebral hemisphere.

Corticopontocerebellar pathway (tr. corticopontocerebellaris) – conducts impulses from the cerebral cortex to the pontine nuclei and through them to the cerebellum; it provides cortical control over the activity of the cerebellum, which is the center of balance and coordination of movements (Figure 20).

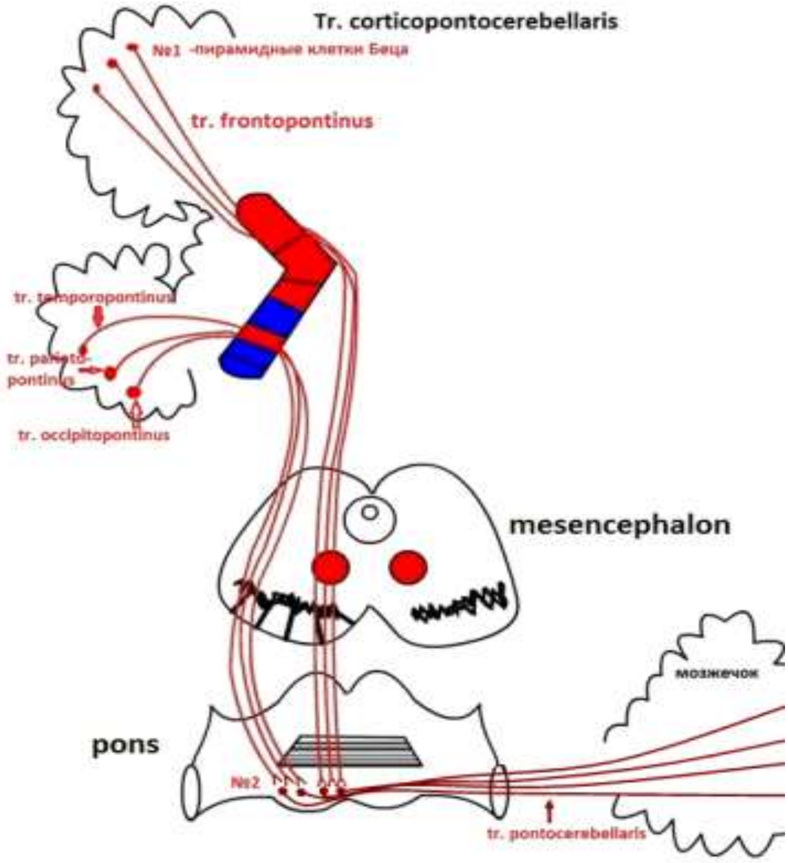


Figure 20. Pyramidal Pathway:

Tractus Corticopontocerebellaris (Corticopontocerebellar Pathway)

No. 1 – neurons are located in layer V of the cortex of the frontal, parietal, temporal, and occipital lobes of the cerebral hemispheres,

No. 2 – in the pontine nuclei.

The pathway is two-neuron:

- First-order neuron bodies – located in layer V of the cortex of the frontal, parietal, temporal, and occipital lobes of the cerebral hemispheres; their axons travel to the pons and transmit impulses to the neurons of its pontine nuclei;

- Second-order neuron bodies – in the pontine nuclei: the axons of these cells run horizontally to the opposite side, forming pontocerebellar fibers (fibrae pontocerebellares), and through the middle cerebellar peduncles enter the cerebellum and terminate on the neurons of the cerebellar cortex.

Topography:

- in the internal capsule – in the anterior limb and in the anterior part of the posterior limb;

- in the midbrain – in the base of the cerebral peduncles.

The pathway is crossed – the axons of the neurons of the pontine nuclei cross before entering the middle cerebellar peduncles.

The pyramidal motor conducting pathways represent the efferent (descending) part of the reflex arc, which closes in the cortex of the cerebral hemispheres. The afferent (ascending) part of the reflex arc is represented by the sensory conducting pathways, delivering nerve impulses to the sensory centers of the cortex. The sensory and motor centers of the cortex are connected with each other by association nerve fibers: these fibers close the multineuronal reflex arc in the cortex. Both hemispheres respond to any stimulus: the corresponding nerve centers of the two hemispheres are connected by commissural fibers (corpus callosum).

Extrapyramidal Pathways

The extrapyramidal system includes the oldest (in phylogenetic terms) subcortical structures and nuclei of the brainstem. The motor pathways of the extrapyramidal system regulate complex automatic movements, muscle tone, balance, and coordination of movements.

The extrapyramidal system includes:

- basal nuclei;

- posterior nucleus of the hypothalamus;

- red nucleus;

- substantia nigra;

- reticular nuclei of the brainstem;

- tectum of the midbrain (corpora quadrigemina);

- cerebellum;

- vestibular nuclei;

- nuclei of the inferior olive;
- thalamus.

The thalamus and sensory reticular nuclei are the afferent centers of the extrapyramidal system: all sensory conducting pathways directed to the cortex relay in the thalamic nuclei and send collaterals to the reticular formation.

All the other listed nuclei are efferent centers of the extrapyramidal system. Among them, through their own descending tracts, the red nucleus, reticular nuclei, tectum (colliculi) of the midbrain, vestibular nuclei, and nuclei of the inferior olive are connected with the motor nuclei of the anterior horns of the spinal cord.

The basal nuclei, posterior hypothalamic nucleus, substantia nigra, and cerebellum send their impulses to the spinal motor nuclei through the red nucleus, via the rubrospinal tract. Therefore, this is the main extrapyramidal tract.

Rubrospinal Tract (

Tractus Rubrospinalis

)

Two-neuron pathway (Figure 21):

- First-order neuron bodies – in the red nucleus of the midbrain, whose axons descend through all lower sections of the brainstem into the spinal cord and terminate in the motor nuclei of the anterior horns of its gray matter;
- Second-order neuron bodies – in the motor nuclei of the anterior horns of the spinal cord; their axons leave the spinal cord in the anterior roots, then, as part of the spinal nerves, reach the skeletal muscles of the trunk and limbs and terminate on the effectors.

Topography:

- through the sections of the brainstem (pons and medulla oblongata) it passes ventrally;
- in the spinal cord, it runs in the central part of the lateral funiculus, anterior to the corticospinal tract.

The pathway is crossed – the axons of the first-order neurons decussate in the tegmentum of the midbrain – ventral tegmental decussation (decussatio tegmentalis anterior) (Forel’s decussation).

Tectospinal Tract (

Tractus Tectospinalis

)

This tract provides automatic motor reactions in response to sudden strong visual, auditory, tactile, or olfactory stimuli.

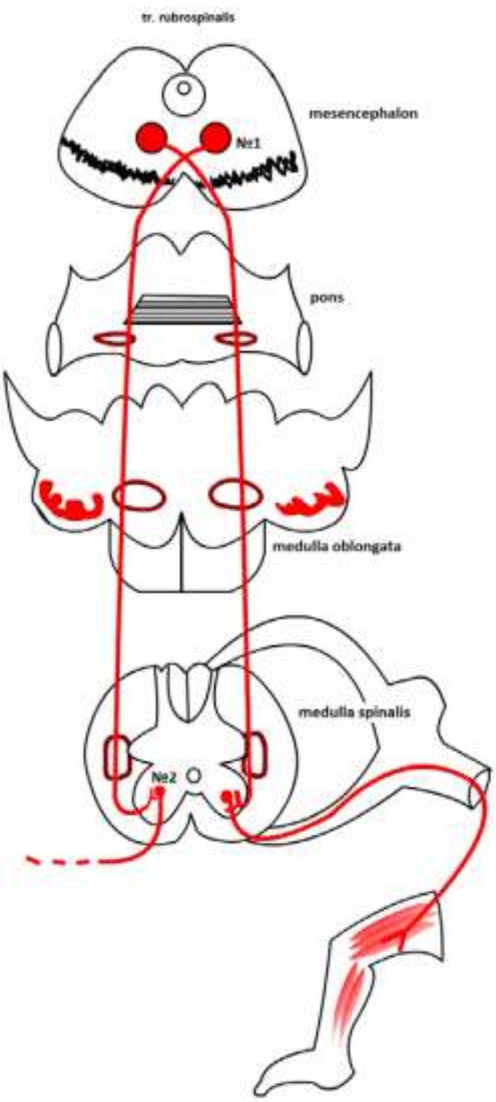
Two-neuron pathway (Figure 22):

- First-order neuron bodies – in the gray matter of the superior colliculi and the nuclei of the inferior colliculi; the axons of these neurons descend through all lower sections of the brainstem into the spinal cord and terminate in the motor nuclei of the anterior horns of the gray matter;
- Second-order neuron bodies – in the motor nuclei of the anterior horns of the spinal cord; their axons leave the spinal cord in the anterior roots, then, as part of the spinal nerves, reach the skeletal muscles of the trunk and limbs and terminate on the effectors.

Topography:

- through the sections of the brainstem it passes ventrally;
- in the spinal cord, it runs in the most medial part of the anterior funiculus.

The pathway is crossed – the axons of the first-order neurons decussate in the dorsal part of the midbrain tegmentum – dorsal tegmental decussation (decussatio tegmentalis posterior) (Meynert's decussation).



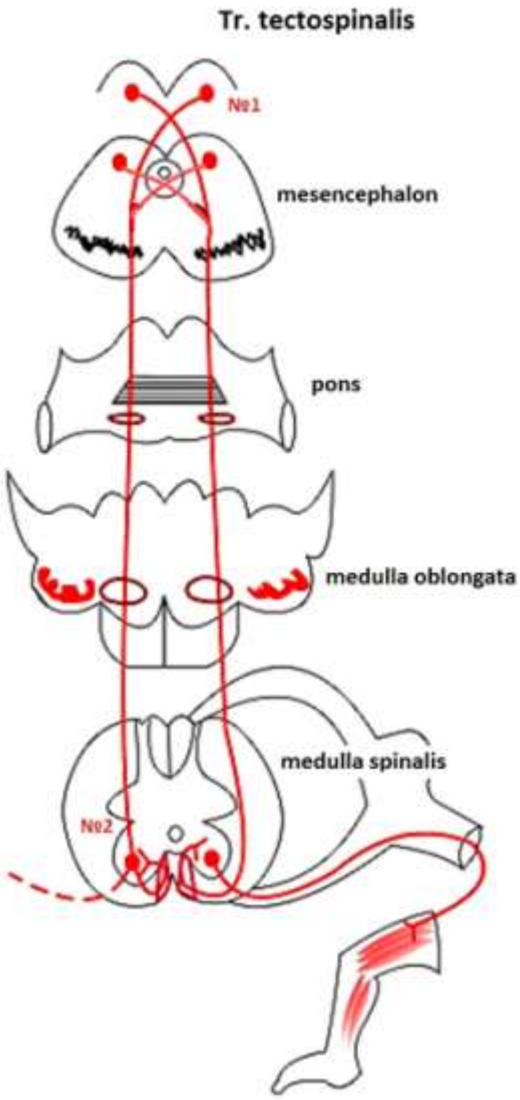


Figure 21. Extrapyramidal Tract:

Tractus Rubrospinalis (Rubrospinal Pathway)

No. 1 – in the red nucleus of the midbrain,

No. 2 – in the motor nuclei of the anterior horns of the spinal cord.

Figure 22. Extrapyramidal Tract:

Tractus Tectospinalis (Tectospinal

Reticulospinal Tract (

Pathway)

No. 1 – in the gray matter of the superior colliculi and the nuclei of the inferior colliculi,

No. 2 – in the motor nuclei of the anterior horns of the spinal cord.

Tractus Reticulospinalis

)

The reticulospinal tract ensures the performance of complex reflex acts (such as respiratory, swallowing, and grasping movements, etc.) that require the simultaneous participation of many groups of skeletal muscles.

This pathway activates or inhibits the activity of the motor neurons of the spinal cord.

Two-neuron pathway (Figure 23A):

- First-order neuron bodies – in the motor centers of the reticular formation of the brainstem (medulla oblongata, pons, midbrain); their axons terminate in the motor nuclei of the anterior horns of the spinal cord;
- Second-order neuron bodies – in the motor nuclei of the anterior horns of the spinal cord; their axons leave the spinal cord in the anterior roots, then, as part of the spinal nerves, reach the skeletal muscles and terminate on the effectors.

Topography:

- passes ventrally through the brainstem;
- in the spinal cord – located in the anterior funiculus.

The pathway is crossed – the axons of the first-order neurons partially decussate at their origin: in the midbrain, pons, and medulla oblongata.

Vestibulospinal Tract (

Tractus Vestibulospinalis

)

The vestibulospinal tract provides motor activity during disturbances of body balance.

Two-neuron pathway (Figure 23B):

- First-order neuron bodies – in the lateral and inferior vestibular nuclei; the axons of these neurons terminate in the motor nuclei of the anterior horns of the spinal cord;
- Second-order neuron bodies – in the motor nuclei of the anterior horns; their axons leave the spinal cord in the anterior roots and then, as part of the spinal nerves, reach the skeletal muscles and terminate on the effectors.

Topography:

- passes ventrally through the medulla oblongata;
- in the spinal cord – located in the anterior funiculus.

The pathway is partially crossed – in the pons.

Olivospinal Tract (

Tractus Olivospinalis

)

The olivospinal tract maintains muscle tone and participates in preserving body balance.

Two-neuron pathway (Figure 23C):

- First-order neuron bodies – in the nuclei of the inferior olive of the medulla oblongata; their axons form the olivospinal tract and terminate in the motor nuclei of the anterior horns of the spinal cord;
- Second-order neuron bodies – in the motor nuclei of the anterior horns of the gray matter of the spinal cord; their axons leave the spinal cord in the anterior roots, then, as part of the spinal nerves, reach the skeletal muscles of the trunk and limbs and terminate on the effectors.

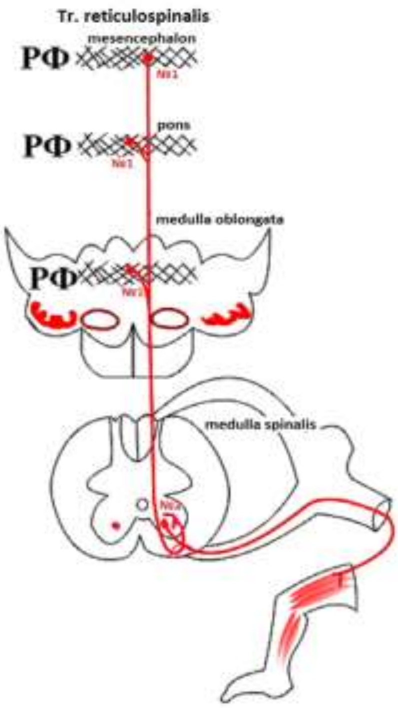
Topography:

- in the spinal cord – runs in the anterior funiculus.

The pathway is partially crossed – in the medulla oblongata.

The extrapyramidal pathways represent the efferent parts of reflex arcs that close in the brainstem and subcortical structures, providing complex automatic movements, muscle tone, balance, and coordination of movements.

The afferent centers of these reflex arcs are the sensory nuclei of the reticular formation and the thalamic nuclei, which receive impulses from all sensory conducting pathways going to the cerebral cortex (their collaterals go to the reticular nuclei, while the thalamus, as a collection of subcortical centers, receives impulses from all sensory conducting pathways).



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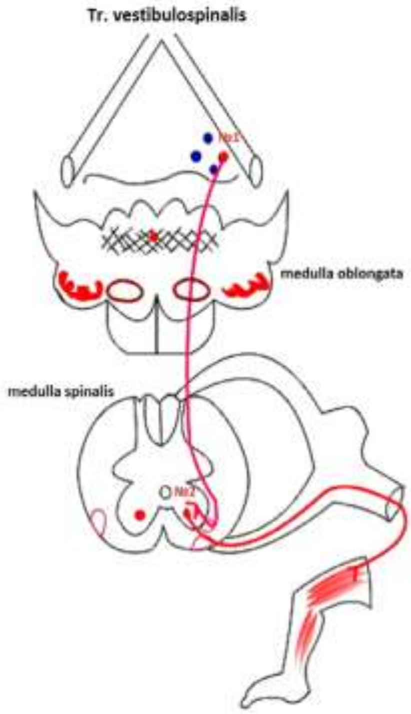

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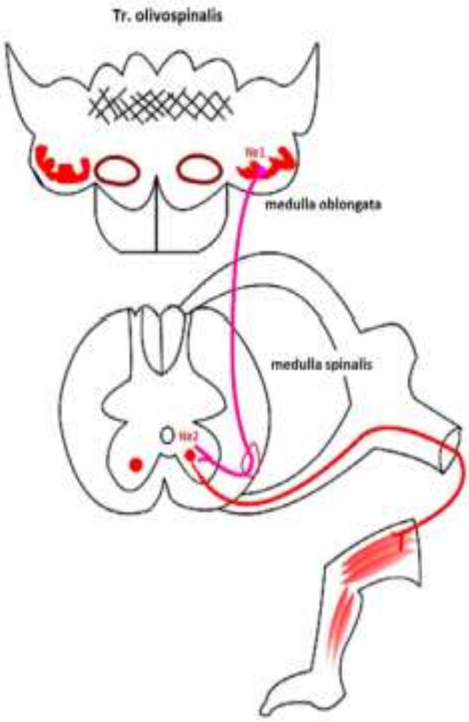

В

Figure 23. Extrapyramidal Pathways

A – Tractus Reticulospinalis (Reticulospinal Pathway)

No. 1 – in the motor centers of the reticular formation of the brainstem,

No. 2 – in the motor nuclei of the anterior horns of the spinal cord.

B – Tractus Vestibulospinalis (Vestibulospinal Pathway)

No. 1 – in the lateral and inferior vestibular nuclei,

No. 2 – in the motor nuclei of the anterior horns of the spinal cord.

C – Tractus Olivospinalis (Olivospinal Pathway)

No. 1 – in the nuclei of the inferior olive of the medulla oblongata,

No. 2 – in the motor nuclei of the anterior horns of the spinal cord.

Ascending and descending cerebellar pathways

As the center of balance and coordination, the cerebellum receives proprioceptive impulses from the trunk and limbs via the anterior and posterior spinocerebellar tracts (see above).

The cerebellum has no direct descending tracts to the spinal cord. It regulates balance and coordination of movements through other efferent centers of the extrapyramidal system:

– the red nucleus — via the rubrospinal tract;

– the reticular formation — via the reticulospinal tract;

– the vestibular nuclei — via the vestibulospinal tract;

– the nuclei of the inferior olive — via the olivospinal tract.

The cerebellum is connected to the red nucleus by the cerebellorubral tract (tr. cerebellorubralis). This tract is two-neuron:

– first-order neuron bodies are the cells of the cerebellar cortical hemispheres, whose axons terminate on neurons of the dentate nucleus (nucleus dentatus);

– second-order neuron bodies are in the dentate nucleus; their axons leave the cerebellum via the superior cerebellar peduncles, decussate in the superior medullary velum, and terminate on neurons of the red nucleus.

The cerebellum is connected with the reticular nuclei of the midbrain, pons, and medulla by axons of its nuclear neurons passing through the superior, middle, and inferior cerebellar peduncles, respectively.

Impulses from the cerebellar nuclei reach neurons of the vestibular nuclei via axons of cerebellar nuclear neurons through the middle cerebellar peduncles.

Impulses from the cerebellar nuclei reach neurons of the inferior olivary nuclei through the inferior cerebellar peduncles.

Thus, the cerebellum receives impulses from the musculoskeletal system via two tracts — the anterior and posterior spinocerebellar tracts — and sends its regulatory influence to the muscles of the trunk and limbs through the red nucleus, the reticular and vestibular nuclei, and the inferior olivary nuclei.

MENINGES OF THE SPINAL CORD AND BRAIN

The spinal cord and brain are surrounded by three meninges of mesenchymal origin:

– dura mater (pachymeninx); arachnoid mater; pia mater.

The meninges of the spinal cord and brain are continuous with one another through the foramen magnum of the occipital bone.

Meninges of the spinal cord (meninges spinales)

The lower border of the spinal dura mater (dura mater spinalis) is at the level of the S2 vertebra, where it ends in a cone (conus); from the apex of the cone the dura fuses with the other spinal meninges to form the filum terminale, which is anchored to the body of the second coccygeal vertebra.

From the lateral surface, sleeve-like processes extend to ensheath the spinal nerves.

The spinal dura is separated from the periosteum of the vertebrae by the epidural space (spatium epidurale), which contains adipose tissue and the internal vertebral venous plexuses (plexus venosi vertebrales interni).

The spinal arachnoid mater (arachnoidea mater spinalis) is a thin transparent avascular membrane.

Its lower border is at S2.

From its lateral surface, processes form sheaths for the roots of the spinal nerves.

Between the arachnoid and the dura of the spinal cord there is a narrow slit-like space — the subdural space (spatium subdurale), containing a fluid resembling tissue fluid.

The spinal pia mater (pia mater) closely invests the spinal cord and contains numerous blood vessels.

Its lower border corresponds to that of the spinal cord — at the level of L2.

From the lateral surface arise the denticulate ligaments (ligg. denticulata); they lie in the frontal plane, pierce the arachnoid, and attach to the dura.

Between the arachnoid and pia is the subarachnoid space (spatium subarachnoideum), filled with cerebrospinal fluid (liquor cerebrospinalis).

Between L2 (the lower border of the spinal cord with pia) and S2 (the lower border of the arachnoid) the subarachnoid space is expanded and is called the lumbar cistern (cisterna lumbalis). It contains cerebrospinal fluid and the cauda equina — the bundle of roots of the lower lumbar, sacral, and coccygeal spinal nerves. These roots descend from the named spinal segments to exit through the corresponding intervertebral foramina.

Meninges of the brain (meninges craniales)

The cranial dura mater (dura mater cranialis) differs from the spinal dura in three ways:

– it is also the inner periosteum of the cranial bones; therefore there is no epidural space around the brain;

– it forms folds that project between parts of the brain and separate them from each other:

– the falx cerebri — between the cerebral hemispheres;

– the falx cerebelli — between the cerebellar hemispheres;

– the tentorium cerebelli — between the occipital lobes and the cerebellum;

– the diaphragma sellae — over the sella turcica, forming a compartment for the pituitary; in the middle it has an opening for the infundibulum;

– the trigeminal cave (cavum trigeminale) — a splitting of the dura forming a cavity around the trigeminal ganglion;

– in places (at the sites where the folds attach to bone) it splits into two layers to form the dural venous sinuses (sinus durae matris), which are collectors of venous blood from the brain.

Dural venous sinuses (sinus durae matris): the superior sagittal sinus (sinus sagittalis superior) — along the superior margin of the falx cerebri; the inferior sagittal sinus (sinus sagittalis inferior) — along the inferior margin of the falx cerebri; the straight sinus (sinus rectus) — at the junction of the posterior part of the falx with the tentorium; the occipital sinus (sinus occipitalis) — along the attachment of the falx cerebelli to the occipital bone; the confluence of sinuses (confluens sinuum) — where the superior sagittal, straight, and occipital sinuses meet; the transverse sinus (sinus transversus) — along the attachment of the tentorium to the occipital bone; the sigmoid sinus (sinus sigmoideus) — as a continuation of the transverse sinus to the jugular foramen; the inferior petrosal sinus (sinus petrosus inferior) — along the posterior margin of the petrous part of the temporal bone; the superior petrosal sinus (sinus petrosus superior) — along the superior margin of the petrous part; the cavernous sinus (sinus cavernosus) — on either side of the sella turcica; the anterior and posterior intercavernous sinuses (sinus intercavernosus anterior et posterior) — connecting the cavernous sinuses anteriorly and posteriorly.

The cranial arachnoid mater (arachnoidea mater encephali) is transparent and avascular. It does not dip into the sulci and depressions of the brain but bridges over them. It forms projections — arachnoid granulations (granulationes arachnoideae) that protrude into the cavities of the venous sinuses or adjacent venous lakes. They serve to drain cerebrospinal fluid from the subarachnoid space into the venous sinuses.

Between the dura and arachnoid is the subdural space (spatium subdurale), containing fluid resembling tissue fluid.

The cranial pia mater (pia mater encephali) closely adheres to the brain, dipping into all sulci and fissures. Within it run blood vessels that enter the brain.

Between the arachnoid and pia of the brain is the subarachnoid space (spatium subarachnoideum) containing cerebrospinal fluid. In places, chiefly at the base of the brain, it widens. These enlargements are called subarachnoid cisterns (cisternae subarachnoideae). They arise because the arachnoid bridges over sulci and depressions while the pia dips into them.

Subarachnoid cisterns (cisternae subarachnoideae):

– the cerebellomedullary cistern (cisterna cerebellomedullaris) — between the cerebellum and dorsal surface of the medulla;

– the cistern of the lateral fossa (cisterna fossae lateralis cerebri) — in the region of the lateral fossae (paired);

– the chiasmatic cistern (cisterna chiasmatica) — anterior to the optic chiasm;

– the interpeduncular cistern (cisterna interpeduncularis) — between the cerebral peduncles.

As large reservoirs of cerebrospinal fluid between the base of the brain and the cranial bones, the cisterns are protective mechanisms that cushion shocks and concussions of the brain.

The CSF system of the brain and spinal cord

These are the structures that provide for the production, circulation, and drainage of cerebrospinal fluid. They include:

– the ventricles of the brain;

– the choroid plexuses of the ventricles;

– the subarachnoid space;

– the pathways of CSF outflow.

CSF is produced by the choroid plexuses of the ventricles — chiefly of the lateral ventricles; from the lateral ventricles it flows into the third ventricle through the interventricular foramina (foramina interventricularia); from the third ventricle it passes to the fourth ventricle through the cerebral aqueduct; from the fourth ventricle it enters the subarachnoid space through the median and lateral apertures (aperturae mediana et laterales) of the roof of the fourth ventricle. From the subarachnoid space CSF drains:

– into the venous blood of the dural sinuses of the brain via arachnoid granulations;

– along the perineural spaces of the olfactory filaments into the lymphatic networks of the nasal mucosa and further into the lymphatic vessels of the head;

– into the lymphatic networks of the cranial dura mater and then into the lymphatic vessels of the head.

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4. Sinelnikov R. D. Atlas of Human Anatomy: in 4 vols. / R. D. Sinelnikov, Ya. R. Sinelnikov. — 2nd ed., stereotyped. — Moscow: Meditsina, 1996 — Vol. 4: The nervous system and the sense organs: atlas. — 1996. — 320 p.: ill.

TEST QUESTIONS

1. THE CERVICAL PART OF THE SPINAL CORD HAS

1. 6 segments;
2. 7 segments;
3. 8 segments;
4. 9 segments.

2. THE POSTERIOR ROOT OF THE SPINAL CORD IS

1. sensory;
2. motor;
3. sympathetic;
4. parasympathetic.

3. THE SPINAL CORD ENDS AT THE LEVEL OF

1. T11–T12 vertebrae;
2. L1–L2 vertebrae;
3. L3–L4 vertebrae;
4. S1–S2 vertebrae.

4. THE NUCLEI OF THE POSTERIOR HORNS OF THE SPINAL CORD ARE

1. the proper (proprius) nucleus;
2. motor nuclei;
3. intermediolateral nucleus;
4. intermediomedial nucleus.

5. THE AUTONOMIC NUCLEI OF THE SPINAL CORD LIE

1. in the anterior horns;
2. in the lateral horns;
3. in the posterior horns;
4. in the anterior funiculi.

6. THE PARASYMPATHETIC AUTONOMIC NUCLEI OF THE SPINAL CORD LIE

1. in C1–C7 segments;
2. in T1–T12 segments;
3. in L4–L5 segments;
4. in S2–S4 segments.

7. THE SYMPATHETIC AUTONOMIC NUCLEI OF THE SPINAL CORD LIE

1. in C1–C7 segments;
2. in T1–T12 segments;
3. in L4–L5 segments;
4. in S2–S4 segments.

8. THE MOTOR NUCLEI OF THE SPINAL CORD LIE

1. in the anterior horns;
2. in the lateral horns;
3. in the posterior horns;
4. in the posterior funiculi.

9. STRUCTURES OF THE MEDULLA OBLONGATA ARE

1. superior cerebellar peduncles;

2. middle cerebellar peduncles;
3. olives;
4. the superior medullary velum.

10. ON THE VENTRAL SURFACE OF THE MEDULLA OBLONGATA ARE LOCATED

1. gracile tubercles;
2. pyramids;
3. cuneate tubercles;
4. middle cerebellar peduncles.

11. ON THE DORSAL SURFACE OF THE MEDULLA OBLONGATA ARE LOCATED

1. the gracile and cuneate tubercles;
2. pyramids;
3. olives;
4. superior cerebellar peduncles.

12. THE GRAY MATTER OF THE MEDULLA OBLONGATA IS REPRESENTED BY

1. the nuclei of the III and IV cranial nerves;
2. the red nucleus;
3. the gracile and cuneate nuclei;
4. the nuclei of the trapezoid body.

13. THE GRAY MATTER OF THE MEDULLA OBLONGATA IS REPRESENTED BY

1. the hypoglossal nucleus;
2. the motor nucleus of the trigeminal nerve;
3. the motor nucleus of the facial nerve;
4. the trochlear nucleus.

14. THE WHITE MATTER OF THE MEDULLA OBLONGATA IS REPRESENTED BY

1. the olivary nucleus;
2. the corticospinal tract;

3. the inferior (double) nucleus;
4. the lateral lemniscus.

15. THE MEDULLA OBLONGATA IS A PART OF THE

1. telencephalon;
2. diencephalon;
3. rhombencephalon;
4. mesencephalon.

16. THE GRAY MATTER OF THE PONS IS REPRESENTED BY

1. the motor nucleus of the facial nerve;
2. the striae acusticae;
3. the medial lemniscus;
4. the nucleus ambiguus.

17. THE GRAY MATTER OF THE PONS IS REPRESENTED BY

1. the oculomotor nucleus;
2. the abducens nucleus;
3. the accessory nucleus;
4. the medial lemniscus.

18. THE WHITE MATTER OF THE PONS IS REPRESENTED BY

1. the abducens nucleus;
2. the lateral lemniscus;
3. the motor nucleus of the trigeminal nerve;
4. the corticospinal tract.

19. THE WHITE MATTER OF THE PONS IS REPRESENTED BY

1. the internal capsule;
2. the trapezoid body;
3. the caudate nucleus;

4. the posterior spinocerebellar tract.

20. THE WHITE MATTER OF THE PONS IS REPRESENTED BY

1. the olivospinal tract;
2. the medial lemniscus;
3. the facial nucleus;
4. the posterior spinocerebellar tract.

21. THE CEREBELLUM IS A PART OF THE

1. medulla oblongata;
2. telencephalon;
3. metencephalon proper;
4. diencephalon.

22. THE NUCLEI OF THE CEREBELLUM ARE

1. nucleus ambiguus;
2. fastigial nucleus;
3. accessory nucleus;
4. facial nucleus.

23. THE INFERIOR CEREBELLAR PEDUNCLES CONNECT THE CEREBELLUM

1. with the medulla oblongata;
2. with the pons;
3. with the midbrain;
4. with the diencephalon.

24. THE MIDDLE CEREBELLAR PEDUNCLES CONNECT THE CEREBELLUM

1. with the medulla oblongata;
2. with the pons;
3. with the midbrain;
4. with the diencephalon.

25. THE SUPERIOR CEREBELLAR PEDUNCLES CONNECT THE CEREBELLUM

1. with the medulla oblongata;
2. with the pons;
3. with the midbrain;
4. with the diencephalon.

26. THE FOURTH VENTRICLE COMMUNICATES

1. with the third ventricle;
2. with the subdural space of the brain;
3. with the lateral ventricles;
4. with the epidural space of the spinal cord.

27. STRUCTURES OF THE MIDBRAIN

1. pyramids;
2. superior colliculi of the tectum;
3. olives;
4. the thalamus.

28. THE CAVITY OF THE MIDBRAIN IS

1. the fourth ventricle;
2. the third ventricle;
3. the aqueduct;
4. the lateral ventricles.

29. THE GRAY MATTER OF THE MIDBRAIN IS REPRESENTED BY

1. the red nucleus;
2. the nucleus ambiguus;
3. the medial lemniscus;
4. the lateral lemniscus.

30. THE NUCLEI OF THE SUPERIOR COLLICULI ARE SUBCORTICAL CENTERS OF

1. hearing;
2. vision;
3. olfaction;
4. balance.

31. THE NUCLEI OF THE INFERIOR COLLICULI ARE SUBCORTICAL CENTERS OF

1. hearing;
2. vision;
3. olfaction;
4. balance.

32. THE WHITE MATTER OF THE MIDbrain IS REPRESENTED BY

1. the trapezoid body;
2. the substantia nigra;
3. the medial lemniscus;
4. the external capsule.

33. STRUCTURES OF THE DIENCEPHALON

1. olives;
2. pyramids;
3. gracile and cuneate tubercles;
4. the thalamus.

34. NOT INCLUDED IN THE DIENCEPHALON ARE

1. the thalamus;
2. the third ventricle;
3. the basal nuclei;
4. the hypothalamus.

35. INCLUDED IN THE METATHALAMUS ARE

1. the tuber cinereum;

2. the hypophysis;
3. the medial geniculate body;
4. the pineal body (epiphysis).

36. THE EPITHALAMUS INCLUDES

1. the hypophysis;
2. the brachia of the superior colliculi;
3. the pineal body (epiphysis);
4. the medial geniculate body.

37. THE HYPOTHALAMUS IS A PART OF THE

1. midbrain;
2. telencephalon;
3. rhombencephalon;
4. diencephalon.

38. INCLUDED IN THE HYPOTHALAMUS ARE

1. the tuber cinereum;
2. the thalamus;
3. the habenulae;
4. the lateral geniculate body.

39. THE GRAY MATTER OF THE DIENCEPHALON IS REPRESENTED BY

1. the interthalamic adhesion;
2. the thalamus;
3. the caudate nucleus;
4. the habenulae.

40. THE CAVITY OF THE THIRD VENTRICLE COMMUNICATES THROUGH THE INTERVENTRICULAR FORAMEN WITH THE

1. aqueduct;

2. fourth ventricle;
3. lateral ventricle;
4. subarachnoid space of the brain.

41. THE CAVITY OF THE DIENCEPHALON IS

1. the fourth ventricle;
2. the third ventricle;
3. the aqueduct;
4. the lateral ventricles.

42. INCLUDED IN THE TELENCEPHALON ARE

1. the subthalamic region;
2. the fornix;
3. the thalamus;
4. the optic chiasm.

43. THE PART OF THE BRAIN TO WHICH THE BASAL NUCLEI BELONG

1. rhombencephalon;
2. midbrain;
3. diencephalon;
4. telencephalon.

44. THE GRAY MATTER OF THE TELENCEPHALON IS REPRESENTED BY

1. the lentiform nucleus;
2. the corpus callosum;
3. the red nucleus;
4. the fornix.

45. THE TERM “BASAL NUCLEI” INCLUDES

1. the tuber cinereum;
2. the thalamus;

3. the cerebral cortex;

4. the lentiform nucleus.

46. NOT BELONGING TO THE WHITE MATTER OF THE HEMISPHERES ARE

1. the putamen;

2. the internal capsule;

3. the corpus callosum;

4. the extreme (outermost) capsule.

47. THE CAVITY OF THE TELENCEPHALON IS REPRESENTED BY

1. the fourth ventricle;

2. the third ventricle;

3. the aqueduct;

4. the lateral ventricles.

48. THE CALCARINE SULCUS IS AN ELEMENT OF THE

1. frontal lobe;

2. temporal lobe;

3. parietal lobe;

4. occipital lobe.

49. THE UNCUS IS AN ELEMENT OF THE

1. frontal lobe;

2. parietal lobe;

3. temporal lobe;

4. occipital lobe.

50. THE PRECENTRAL GYRUS BELONGS TO THE

1. frontal lobe;

2. parietal lobe;

3. temporal lobe;

4. occipital lobe.

Situational tasks

Task 1: A person died as a result of a car accident. At autopsy there was damage to the spinal cord substance at the level of the third and fourth cervical segments. It was suggested that one of the main causes of the rapid fatal outcome was respiratory failure. Provide the anatomical justification for this suggestion.

Task 2: The patient was diagnosed with damage to the lateral funiculus of the spinal cord within the thoracic segments, with corresponding disorders of movement and pain and temperature sensation. At the same time, tactile sensation was affected to a lesser degree. Provide the anatomical explanation for this phenomenon.

Task 3: Which modalities and on which side of the body are lost with a unilateral hemisection of the spinal cord at a given level (Brown–Séquard syndrome)? Provide the anatomical justification.

Task 4: With eyes closed, the patient cannot correctly indicate the position of the limbs, determine the shape and stiffness of an object being palpated, or feel the vibration of a tuning fork placed on a bony prominence. This indicates impairment of deep sensation (proprioceptive and discriminative). Can one assume a lesion of the posterior funiculi of the spinal cord?

Task 5: Why does interruption of one lateral lemniscus not cause complete unilateral deafness, but only a slight decrease in hearing on the side opposite the lesion and some impairment of sound localization?

Task 6: How can the occurrence of nystagmus (spontaneous conjugate movements of both eyeballs) with vestibular stimulation be explained anatomically?

Task 7: A young girl shows signs of precocious puberty. Examination reveals a tumor involving the epithalamus. Based on the functional anatomy of this area, which structure is affected?

Task 8: A patient has a tumor of the anterior lobe of the pituitary gland. Loss of the lateral visual fields is noted. Where has the tumor grown, what has it involved? Provide anatomical justification.

Task 9: A patient has a pituitary tumor requiring surgery. Given the complex topographic relationships with nearby vital structures (brain, vessels, nerves), the surgeon chose an approach through natural cavities/communications. What anatomical route provides such an approach?

Task 10: In a patient with traumatic brain injury, recognition of objects by touch (stereognosis) is impaired. Is this possible? If so, which part of the brain is damaged? Provide anatomical justification.

Task 11: Why, with damage to the occipital lobe, does the patient have visual disturbances but the pupillary reflex is preserved? Provide anatomical justification.

Task 12: The patient understands speech addressed to him but cannot speak. His general condition is satisfactory; there is no physical weakness. The muscles involved in articulation and their innervation are intact. From an anatomo-functional standpoint, how can this clinical situation be explained?

Task 13: After traumatic brain injury, when palpating an object with eyes closed, the patient cannot determine or recognize its shape. Where is the lesion located? Provide anatomical justification.

Task 14: The patient sees objects well and avoids obstacles but cannot recognize what they are. He has lost the ability to compare what is currently seen with his stored visual images and to identify it. At times he tries to touch objects to recognize them by feel. Where is the lesion? Provide anatomical justification.

Task 15: In infections of the subarachnoid space of the brain, involvement of vascular and nerve trunks in the inflammatory process is frequent. Provide the anatomical explanation.

Task 16: A tumor has obliterated (occluded) the cerebral aqueduct. What consequences may arise? Provide anatomical justification.

Task 17: There was an urgent need to examine specifically the ventricular cerebrospinal fluid. It was obtained by a deep puncture at the lower border of the occipital region through the soft tissues of the neck and the posterior atlanto-occipital membrane. Provide the anatomical justification of this procedure.

Task 18: Modern morphologists insist that there is no subdural space — a cleft between the arachnoid and dura. Yet in clinical practice subdural hematomas are encountered. How can this apparent contradiction be explained anatomically?

Task 19: In a patient with a basal skull fracture passing along the floor of the anterior cranial fossa, smell is impaired. There is also discharge of some fluid from the nasal cavity. Provide the anatomical explanation.

Task 20: A patient has a traumatic brain injury. Blood is found in the CSF on lumbar puncture. Into which space(s) has the hemorrhage most likely occurred? Provide anatomical justification.

Task 21: Which nerves may be affected by inflammation in the region of the cavernous sinus of the dura mater? How might this manifest clinically? Provide anatomical justification.

Task 22: How, anatomically, can the spread of a pathological process to the opposite eye be explained in optic neuritis?

Task 23: Elevated intracranial pressure was not excluded in a patient, but this fact was overlooked by a junior physician. During a careless lumbar puncture the patient died. What are the possible causes of death? Provide anatomical justification.

Task 24: A child has an acute respiratory illness. After some time he complains of ear pain, and a bit later — of pain in the head behind the auricle. The physician immediately recognized the situation: urgent and serious treatment is required. What was happening here? Provide anatomical justification.

Control questions

On the spinal cord:

1. Where is the spinal cord located? Its upper and lower borders, length, and weight.
2. What enlargements does the spinal cord have along its length? How are they explained?
3. What fissure and sulci are found on the external surface of the spinal cord?
4. Where do the anterior and posterior roots of the spinal nerves emerge?

5. What is the cauda equina? Where is it located?
6. What does the spinal cord consist of in section?
7. What is the relationship of white and gray matter in the spinal cord?
8. What constitutes the gray matter of the spinal cord?
9. What is a spinal segment? What function does it provide?
10. Number of segments and their distribution. Skeletotopy of segments.
11. Structure of the gray matter; purpose of the nuclei and cell columns.
12. What are the intrinsic white-matter bundles of a segment? Their function?
13. Posterior vs anterior roots: morphological and functional differences?
14. What neurons form the three-neuron reflex arc? Where are their bodies?
15. How are spinal nerves formed? Composition of fibers.
16. Why did the conduction system appear and what is its purpose; what does it consist of?
17. What are the spinal cord tracts and how are they classified?
18. Which tracts run in the posterior funiculi? What impulses do they conduct?
19. Which sensory tracts run in the lateral funiculi? What impulses do they conduct?
20. Which tracts run in the anterior funiculi?
21. Which motor tracts run in the lateral funiculi?
22. Which tracts decussate in the anterior white commissure?

On the medulla oblongata:

1. Which cranial nerves emerge from the medulla? Indicate their exit points.
2. What are the pyramids?
3. What are the gracile and cuneate tubercles?
4. What constitutes the gray matter of the medulla? List the nuclei.
5. Nuclei of which cranial nerves are in the medulla? Where are they located?
6. Which medullary nuclei are related to equilibrium?
7. Where is the reticular formation in the medulla and into which CNS parts does it continue?

8. Which vital centers are located in the medulla, and where?
9. What constitutes the white matter in the medulla?
10. What are the short tracts of the medulla for?
11. How are the long tracts of the medulla classified?
12. Which tracts pass through the medulla in transit?
13. Which tracts relay in the medulla to new neurons?
14. Which tracts originate in the medulla?
15. Which tracts end in the medulla?
16. Which tracts decussate in the medulla?

On the pons:

1. Which cranial nerves emerge from the pons and where?
2. Into what parts is the pons divided in section?
3. What constitutes the gray matter of the pons? List the nuclei.
4. Nuclei of which cranial nerves are in the pons? Where are they?
5. Where are the pontine nuclei and what is their significance?
6. What is the trapezoid body and to which pathway does it belong?
7. Where is the pontine reticular formation and where does it continue?
8. How are the tracts of the pons classified?
9. What are the short tracts of the pons for?
10. How are the long tracts of the pons classified?
11. Which tracts pass through the pons in transit?
12. Which tracts relay in the pons?
13. Which tracts originate in the pons?
14. Which tracts end in the pons?
15. Which tracts decussate in the pons?
16. What is the medial lemniscus? Where is it formed and where does it terminate?

17. Which tracts are included in the medial lemniscus?
18. What is the lateral lemniscus?

On the cerebellum:

1. What is the function of the cerebellum?
2. What parts does the cerebellum consist of?
3. How is the cerebellum connected to different brainstem divisions?
4. What does the cerebellum consist of in section?
5. What constitutes the gray matter of the cerebellum?
6. Name the cerebellar nuclei.
7. What constitutes the white matter of the cerebellum?
8. Purpose of the short tracts of the cerebellum?
9. Where do the long tracts of the cerebellum run?
10. Which tracts pass through the inferior peduncles?
11. Which tracts pass through the middle peduncles?
12. Which tracts pass through the superior peduncles?
13. Which tracts decussate in the superior medullary velum?

On the rhomboid fossa and the fourth ventricle:

1. The fourth ventricle is derived from the cavity of which brain vesicle?
2. What is the shape of the fourth ventricle?
3. What forms the floor of the fourth ventricle?
4. What forms the roof of the fourth ventricle?
5. With what does the fourth ventricle communicate?
6. From where does CSF enter the fourth ventricle and where does it drain from it?
7. Nuclei of which cranial nerves project onto the rhomboid fossa?
8. What are the regularities of cranial nerve nuclear projection in the rhomboid fossa?

9. Which cranial nerves have only motor nuclei?
10. Which cranial nerves have only sensory nuclei?
11. Which cranial nerves have both motor and sensory nuclei?

On the midbrain:

1. What are the components of the midbrain?
2. Which cranial nerves emerge from the midbrain? Where are the exit points?
3. Into what parts is the midbrain divided in section?
4. What is the cavity of the midbrain and with what does it communicate?
5. What constitutes the gray matter of the midbrain? List the nuclei.
6. Nuclei of which cranial nerves are in the midbrain? Where are they?
7. Which midbrain nuclei are involved in regulation of automatic movements?
8. Where are the highest autonomic centers in the midbrain?
9. Where are the subcortical centers of hearing and vision in the midbrain?
10. Where is the reticular formation in the midbrain and where does it continue?
11. How are the tracts of the midbrain classified?
12. Purpose of the short tracts of the midbrain.
13. How are the long tracts of the midbrain subdivided?
14. Which tracts pass through the midbrain in transit?
15. Which tracts relay in the midbrain?
16. Which tracts begin in the midbrain?
17. Which tracts end in the midbrain?
18. Which tracts decussate in the midbrain? Where are the decussations located?
19. What is the medial longitudinal fasciculus and what is its subcortical center?

On the diencephalon and the third ventricle:

1. Into what parts is the diencephalon divided?
2. What belongs to the thalamic region?

3. What are the thalami and how are their nuclei divided?
4. With which functional pathways are the thalamic nuclei associated?
5. In which thalamic nuclei does the medial lemniscus end?
6. Which sensory pathways do not relay in the thalamus?
7. With which telencephalic nuclei are the thalamic nuclei connected as sensory centers of the extrapyramidal system?
8. Where does the subthalamic region continue and what nucleus does it contain?
9. What forms the metathalamus?
10. With what and how do the geniculate bodies connect?
11. What centers are located in the geniculate bodies?
12. What makes up the epithalamus? Where is the pineal body located? Its functions.
13. What makes up the hypothalamus?
14. How do hypothalamic nuclear cells differ functionally?
15. Which structures of the diencephalon regulate autonomic functions?
16. Where is the third ventricle located?
17. With what does the third ventricle communicate?
18. What forms the walls of the third ventricle?
19. From where does CSF enter the third ventricle and where does it flow from it?

On the telencephalon:

1. What constitutes the peripheral part of the olfactory brain?
2. What constitutes the central part of the olfactory brain?
3. What belongs to the basal nuclei?
4. Into what parts is the caudate nucleus divided? Where are they located?
5. Into what parts is the lentiform nucleus divided?
6. Where are the amygdaloid nuclei located?
7. What forms the limbic lobe?

8. What are the functions of the limbic lobe?
9. Into what lobes are the cerebral hemispheres divided? Their boundaries.
10. Which sulci and gyri are on the superolateral surface of the frontal lobe?
11. Which sulci and gyri are on the superolateral surface of the parietal lobe?
12. Which sulci and gyri are on the lateral surface of the temporal lobe?
13. Which lobes form the medial surface of the hemispheres?
14. Which sulci and gyri are on the medial surface of the hemispheres?
15. Which sulci and gyri are on the basal surface of the hemispheres?
16. Where are the cortical centers of the first signaling system located?
17. Where are the cortical centers of the second signaling system located?

On the white matter of the telencephalon:

1. Into which three systems are the cerebral fibers divided?
2. What are association fibers, and how are they classified?
3. Which long association fibers are known? Where do they run and which lobes do they connect?
4. What are commissural fibers? Where do they run?
5. What are the parts of the corpus callosum? To which brain division does it belong?
6. To which division do the anterior and posterior commissures belong and what do they connect?
7. What are projection fibers? Where do most of them pass?
8. Into what parts is the internal capsule divided?
9. Which projection fibers pass through the anterior limb, the posterior limb, and the genu of the internal capsule?
10. Into what parts are the lateral ventricles divided, and which lobes do they correspond to?
11. What walls does the anterior horn have, and what forms them?
12. What walls does the posterior horn have, and what forms them?
13. What walls does the inferior horn have, and what forms them?
14. Where and how is CSF formed in the lateral ventricles and what are its outflow

pathways?

On the tracts:

1. Which tract conducts conscious proprioceptive sensation?
2. Where are the receptors and first-order neurons, and how do their processes run in the pathway of conscious proprioception?
3. Where are the bodies of the second-order neurons of this pathway? How do their axons run?
4. Where are the bodies of the third-order neurons of the conscious proprioceptive pathway? How do their axons run? Cortical center.
5. Which tracts conduct unconscious proprioception?
6. Where are the receptors and first-order neurons, and how do their processes run in the pathway of unconscious proprioception?
7. Where are the bodies of the second-order neurons of unconscious proprioception? What nuclei do they form?
8. How do the axons of neurons of the thoracic and intermediomedial nuclei run? Topography in the spinal cord and brainstem? Decussations?
9. Which pathway conducts temperature and pain sensation?
10. Where are the receptors and first-order neurons, and how do their processes run in the temperature and pain pathway?
11. Where are the bodies of the second-order neurons of the temperature and pain pathway? How do their axons run? Where does decussation occur?
12. Where are the bodies of the third-order neurons of the conscious proprioceptive pathway? How do their axons run? Cortical center.
13. Which pathway conducts stereognosis and tactile sensation?
14. Where are the receptors and first-order neurons, and how do their processes run in the pathway of stereognosis and tactile sensation?
15. Where are the bodies of the second-order neurons of stereognosis and tactile sensation? How do their axons run? Where does decussation occur?
16. Where are the bodies of the third-order neurons of stereognosis and tactile sensation? How do their axons run? Cortical center.
17. Classification of motor tracts.
18. Corticospinal tract: location of first-order neuron bodies. Course of their axons in the internal capsule and brainstem.

19. Where does the corticospinal decussation occur? Its character. Further course of axons of the tract.

20. Location of second-order neuron bodies. Course of their axons.

21. Corticonuclear tract: location of first-order neuron bodies. Course of their axons in the internal capsule and brainstem.

22. Decussation of the tract. Its character. Exceptions.

23. Cortico-ponto-cerebellar tract: location of first-order neuron bodies. Course of their axons in the internal capsule and brainstem.

24. Location of second-order neuron bodies in the cortico-ponto-cerebellar tract. Course of their axons. Decussation of the tract. Its character.

25. Name the extrapyramidal centers of the CNS. From which of them do descending tracts arise?

26. Which descending tracts connect the cerebellum with the spinal cord? The cerebello-rubro-spinal pathway.

On the meninges:

1. List the meninges of the brain and spinal cord.

2. Structure of the cranial dura mater.

3. What folds does the cranial dura mater form? Their location.

4. List the dural venous sinuses. Their location.

5. Structure of the arachnoid and pia of the brain.

6. Name the cranial meningeal spaces.

7. Subarachnoid space: location, cisterns. Subdural space of the brain.

8. Features of the spinal meninges and spaces.

9. List the ventricles and their communications of the brain and spinal cord.

10. Formation of CSF. Flow of CSF within the brain and spinal cord.

11. Outflow pathways from the ventricles to the subarachnoid space.

12. Outflow pathways from the subarachnoid space.

ANSWER KEYS

Test questions

Q no. — answer

1 — 3

2 — 4

3 — 1

4 — 3

5 — 2

6 — 4

7 — 1

8 — 2

9 — 4

10 — 1

11 — 3

12 — 1

13 — 4

14 — 1

15 — 2

16 — 4

17 — 3

18 — 1

19 — 3

20 — 4

21 — 2

22 — 3

23 — 2

24 — 4

25 — 1

26 — 2

27 — 4

28 — 2

29 — 3

30 — 2

31 — 4

32 — 3

33 — 1

34 — 2

35 — 4

36 — 3

37 — 1

38 — 3

39 — 4

40 — 1

41 — 2

42 — 4

43 — 1

44 — 3

45 — 1

46 — 2

47 — 4

48 — 1

49 — 2

50 — 4

Situational tasks — answers

Answer to Task 1. In the anterior columns of the spinal gray at the level of C3–C4 lies a group of motoneurons whose axons innervate the diaphragm. They reach the muscle sequentially as fibers in the anterior rami of the corresponding cervical spinal nerves, the cervical plexus, and the phrenic nerves (from the right and left plexuses). Damage to these spinal segments leads, among other things, to paralysis of the diaphragm and therefore to marked respiratory failure.

Answer to Task 2. These sensory modalities are conveyed by spinothalamic tracts, of which the lateral tract runs within the lateral funiculus and carries mainly pain and temperature. Tactile sensation is provided primarily by the anterior spinothalamic tract, located much more ventrally. In addition, central processes of the first-order neurons of this pathway give numerous collaterals in the spinal cord, creating bypass routes. Finally, fibers conveying fine (epicritic) touch lie in the posterior funiculus together with proprioceptive pathways. Taken together, these facts explain the clinical picture.

Answer to Task 3. The posterior funiculus contains fibers of the cortical-direction proprioceptive and discriminative (epicritic) modalities; their decussation occurs higher, in the medulla. The lateral funiculus contains fibers of the lateral and anterior spinothalamic tracts (pain, temperature, and coarse touch), which decussate segmentally in the spinal cord. Therefore, a hemisection will interrupt as-yet-undecussated fibers in the posterior funiculus, causing loss of proprioceptive (muscle-joint) and discriminative sensation (vibration sense, precise localization, object form recognition) on the ipsilateral side. There will also be loss of pain and temperature on the contralateral side due to interruption of already-decussated fibers in the lateral funiculus. These effects involve body regions innervated by segments one or two levels below the lesion.

Answer to Task 4. Yes, one can, because the tracts for these modalities lie precisely in the posterior funiculi.

Answer to Task 5. Axons from the dorsal cochlear nucleus join, within the lateral lemniscus, fibers arising from the ventral cochlear nucleus and accompany them to the inferior colliculi. Some fibers run ipsilaterally and some contralaterally; hence interruption of one lateral lemniscus does not produce complete unilateral deafness.

Answer to Task 6. The vestibular nuclei are connected to the motor nuclei of the nerves to the extraocular muscles (III, IV, VI) through the right and left medial longitudinal fasciculi, with participation of the interstitial nucleus (of Cajal) and the nucleus of the posterior commissure (of Darkschewitsch). Normally these connections provide ocular orientation with head position/movements. With strong vestibular stimulation they may manifest as nystagmus.

Answer to Task 7. Most likely the pineal gland (epiphysis) is affected — an unpaired organ of this region thought to exert an inhibitory influence on the rate of sexual maturation. Its involvement can lead to precocious puberty.

Answer to Task 8. Light from the lateral visual fields is projected onto the nasal halves of the retinas. Axons from these ganglion cells cross in the optic chiasm to the opposite optic tracts. Here, a tumor of the anterior lobe of the hypophysis has involved the chiasm located anterior to it, producing bitemporal hemianopia.

Answer to Task 9. The system of air passages: nasal cavity → superior nasal meatus → aperture of the sphenoidal sinus → sphenoidal sinus (sinus sphenoidalis). Above its superior bony wall, in the hypophyseal fossa lined by dura, lies the pituitary gland.

Answer to Task 10. Recognition by touch depends on cortical analyzers of the parietal lobes, chiefly the superior parietal lobule. A lesion here causes astereognosis contralaterally.

Answer to Task 11. Along the "banks" of the calcarine sulcus in the occipital lobe lies the cortical part of the visual analyzer; its lesion causes complex visual disturbances. The pupillary reflex pathways are subcortical and close at the level of the midbrain and are not affected here; hence the reflex remains.

Answer to Task 12. Most likely the cortical area constituting the motor analyzer of (oral) speech articulation — part of the second signaling system — is affected. It is in the posterior part of the inferior frontal gyrus (area 44, Broca's area). Lesions here in right-handers cause motor aphasia.

Answer to Task 13. Recognition by touch (stereognosis) depends on the cortical analyzer located in the upper part of the superior parietal lobule (areas 7, 5). Its lesion causes the described picture (tactile agnosia, astereognosis).

Answer to Task 14. The picture indicates loss of visual memory. The cortical center involved occupies the region above the calcarine sulcus on the medial surface and the posterior part of the lateral surface of the occipital lobe (mainly area 18, partly 19).

Answer to Task 15. The subarachnoid space is filled with slowly circulating CSF. Cerebral arteries and veins for much of their course, until entering/leaving the pia, lie in this same space. The same applies to the cranial nerves. Although these structures do not directly contact CSF (their walls have a glial barrier membrane), spread of inflammation to them is quite possible.

Answer to Task 16. CSF flows through the aqueduct from the third to the fourth ventricle. Blockade of the aqueduct leads to accumulation of CSF in the lateral and third ventricles and dangerous elevation of intracerebral and intracranial pressure.

Answer to Task 17. This cisternal (suboccipital) puncture allows entry into the posterior cerebellomedullary cistern of the subarachnoid space (the great cistern, cisterna magna) — the widest part. Ventricular CSF enters it through the median aperture (foramen of Magendie) of the roof of the fourth ventricle.

Answer to Task 18. A true anatomical subdural space separating arachnoid and dura is absent; the two membranes are in close apposition but not fused. A space appears only when they are separated by some factor, most often pressure of blood from injured vessels (e.g., the middle meningeal artery in skull fractures). Hence the subdural space is considered "potential."

Answer to Task 19. The midline part of the floor of the anterior cranial fossa is the cribriform plate (lamina cribrosa) of the ethmoid bone. Through its foramina olfactory fila pass from the superior nasal meatus into the cranial cavity. Their rupture in a fracture causes anosmia. Associated meningeal tears here can breach the subarachnoid space and cause CSF rhinorrhea.

Answer to Task 20. Into the subarachnoid space or into the cerebral ventricles — the communicating spaces where CSF circulates.

Answer to Task 21. Closely related to the cavernous sinus, within thin connective-tissue sheaths, pass the oculomotor, trochlear, and abducens nerves. Involvement produces impaired fixation and eye movements (strabismus).

Answer to Task 22. Throughout its course the optic nerve is invested by the three meninges with an intermeningeal slit — a continuation of the subarachnoid space. This allows spread of inflammation to the intracranial subarachnoid space and to the nerve and eye of the opposite side.

Answer to Task 23. With elevated intracranial pressure, rapid removal of CSF during lumbar puncture can cause herniation of the brainstem into the tentorial notch and/or the foramen magnum, often rapidly fatal. To avoid this, the puncture needle should be occluded and CSF released only in very small portions.

Answer to Task 24. As often occurs in young children, the inflammatory process spread along air passages: from the upper respiratory mucosa through the wide, short auditory (Eustachian) tube to the tympanic cavity of the middle ear, and then to the mastoid air cells. The largest (the antrum) develops first and communicates with the tympanic cavity. Mastoiditis threatens severe complications because on the inner surface of the bone lies the sigmoid dural venous sinus; its involvement disrupts cerebral venous drainage and may have many dangerous consequences.

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