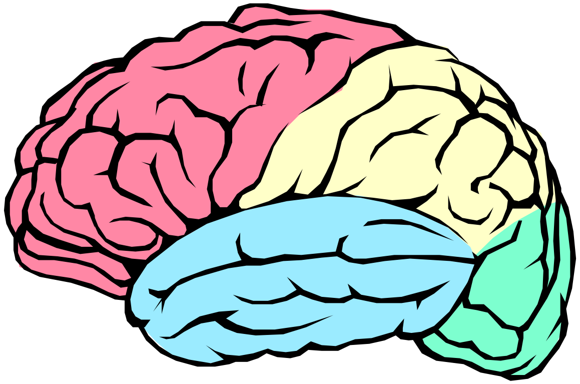
GOMEL STATE MEDICAL UNIVERSITY
Normal and Pathological Physiology Department

PARTICULAR PHYSIOLOGY OF CENTRAL NERVOUS SYSTEM

Lecture 1



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Lecture plan:

1. Spinal cord. Reflex activity of the spinal cord. Conductive function of the spinal cord.

2. Afterbrain: medulla, pons varolii. Functions of the medulla and pons varolii.

3. Midbrain.

1. Reflex activity of the spinal cord

The spinal cord is the most ancient structure of the CNS, which is proved by its segmentary structure. The segments are regions of the spinal cord with two pairs of dorsal and ventral roots growing from it.

Along the spinal cord there are 31 pairs of roots (ventral and dorsal). The ventral (anterior) roots contain efferents through which the axons of the following neurons pass: α-motoneurons to skeletal muscles, gamma-motoneurons to the muscle proprioreceptors, preganglionic fibers of the vegetative nervous system, etc.

The dorsal (posterior) roots represent the processes of neurons whose bodies are in the spinal ganglia. The ventral roots carry out motor functions, and the dorsal — sensitive ones.

The gray matter of the spinal cord contain the ventral and dorsal horns and also the intermediate region. The thoracal segments of the spinal cord have the lateral horns, too. Here, in the gray matter, there are many interneurons and Renshaw cells. The lateral and anterior horns contain preganglionic vegetative neurons, whose axons go to the corresponding vegetative ganglia. The top of the dorsal horn (also known as the posterior horn) creates an initial sensory region, as the fibers from exteroreceptors come here. Several ascending tracts originate from here.

In the anterior horns, motoneurons are concentrated and form motor nuclei. Segments with sensitive fibers of one pair of the dorsal roots form the metamere. The axons of one muscle go within the structure of several ventral roots, which provides stable functioning of muscles if any of the axons is damaged.

The spinal cord executes *two basic functions* (Figure):

1. ***Reflex activity*.**

2. ***Conductive function*** (innervates all musculation except for the head muscles).

Functions of spinal cord

- Reflex activity of spinal cord
  - Vegetative reflexes:
    1. Reflexes of urogenital system.
    2. Reflexes of intestine.
    3. Reflexes of vascular system.
    4. Body temperature.
    5. Respiratory movement, etc
  - Motor reflexes
    - Monosynaptic reflexes
    - Polysynaptic reflexes
      - Rhythmic reflexes: walking in human
      - Cervical reflexes
      - Posture reflexes
- Conductive function of spinal cord

Reflex activity of the spinal cord

The functions which are carried out by the spinal cord are vital, as it takes part in the regulation of:

1. All motor reflexes (except for head movements).

2. Reflexes of the urogenital system.

3. Reflexes of the intestines.

4. Reflexes of the vascular system.

5. Body temperature.

6. Respiratory movements, etc.

The simplest reflexes of the spinal cord are ***tendon reflexes***, or ***myotatic reflexes.*** The reflex arc of these reflexes does not contain interneurons, therefore, such reflexes are called ***monosynaptic***. These reflexes are of a great value in neurology, as they are easily invoked by the impact of the neurologic hammer by tendons and as result, muscle contractions occur. In clinical practice these reflexes are called *T-reflexes*. They are clearly marked in muscles-extensors. For example, the knee reflex, Achilles reflex, elbow reflex, etc.

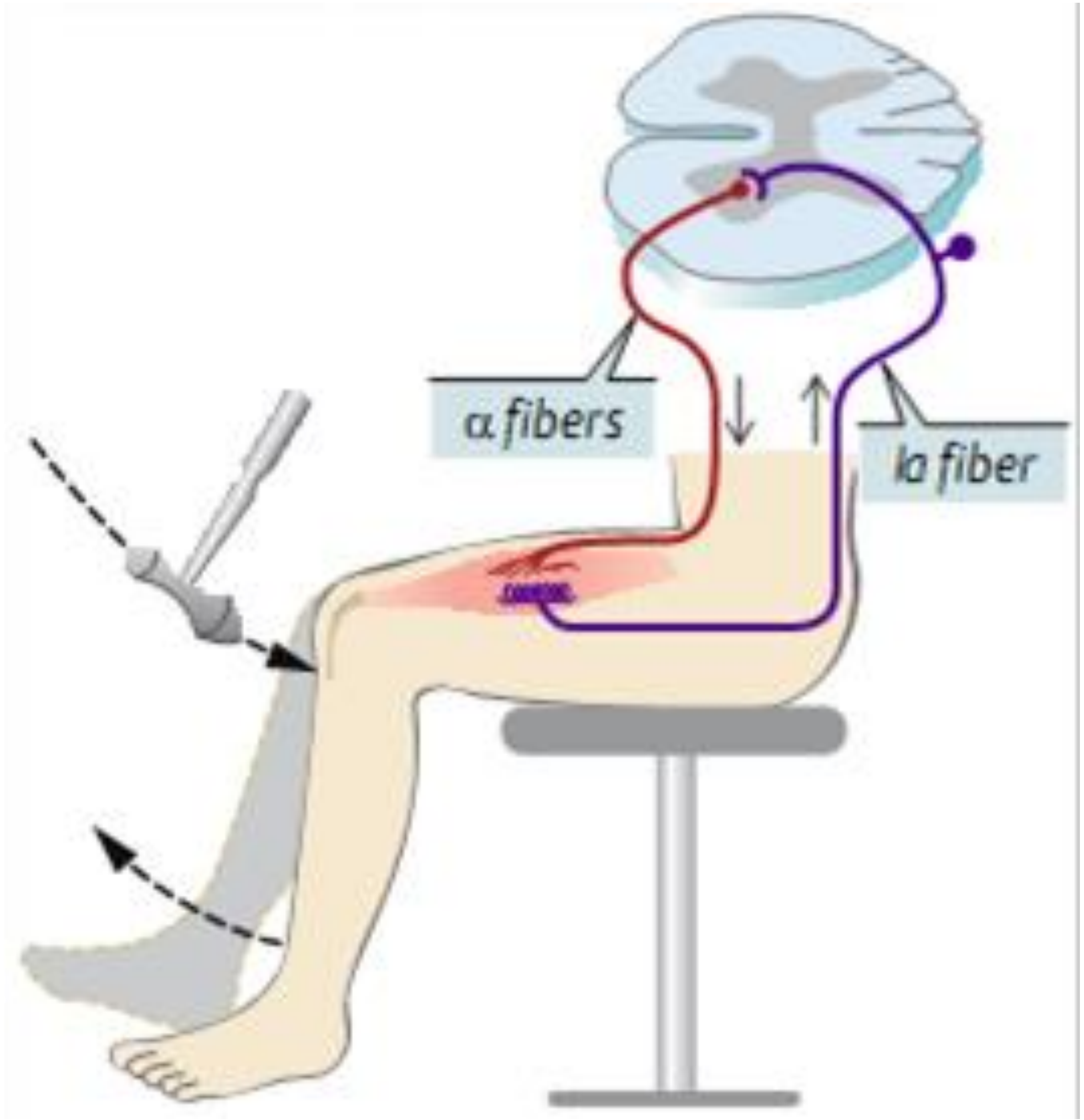

Figure — Monosynaptic stretch reflex

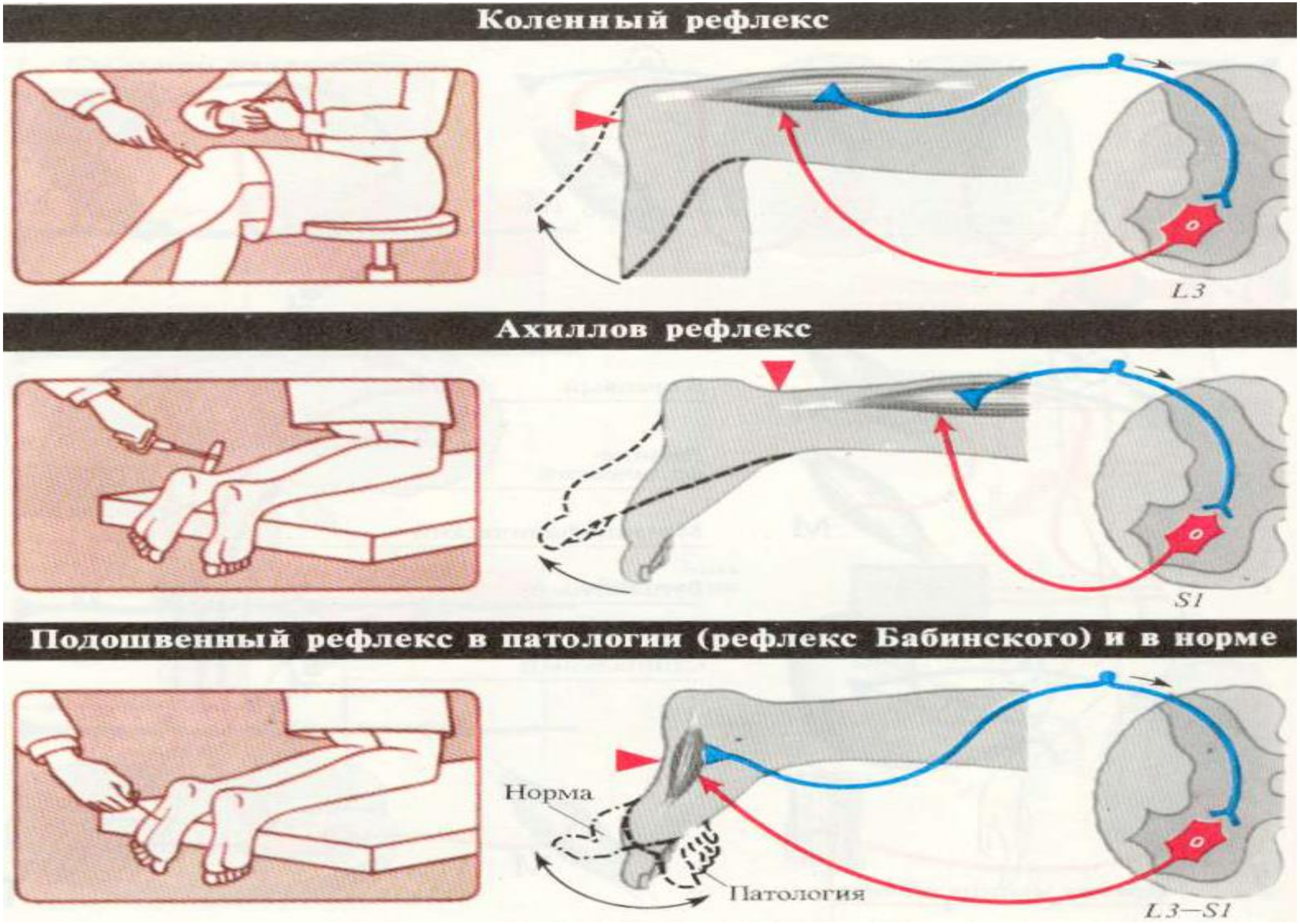

Figure — Monosynaptic stretch reflex

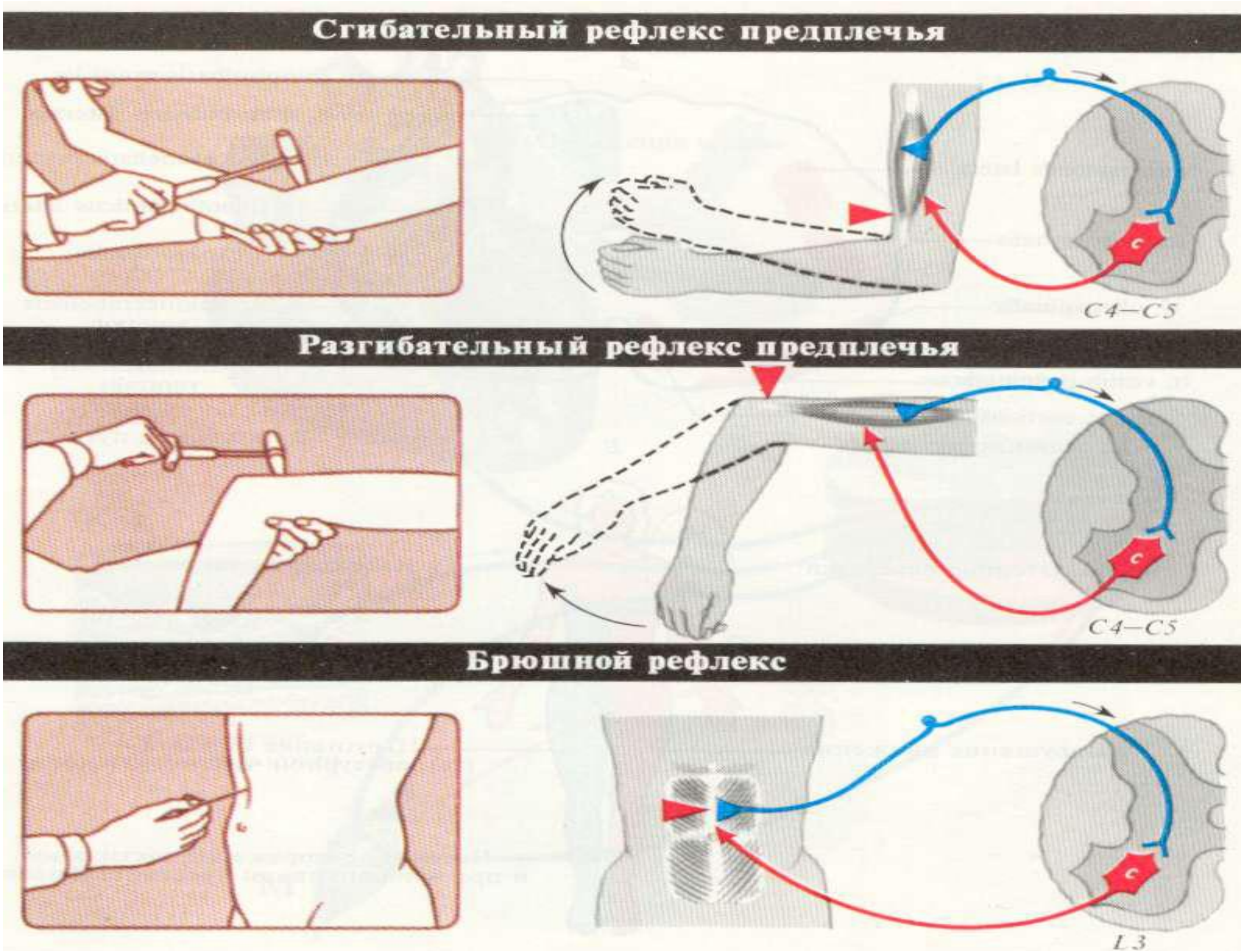

Figure — Monosynaptic stretch reflex

The examination of these reflexes in clinical practice helps to determine:

1. At what *level of the spinal cord a pathological process is localized*. Thus, if to carry out tendon reflexes starting from the plantar and to rise gradually upwards and know at what level the motoneurons of this reflex are localized, it is possible to determine the level of damage.

2. To determine the hypoexcitability or hyperexcitability of *excitation in the nerve centers.*

3. To determine the *side of the damage to the spinal cord*, i.e. if to define reflexes on the right and the left body sides, and if they are absent, it means this side is damaged.

There is a second group of reflexes carried out with the participation of the spinal cord which are more complex, as they include many interneurons and, therefore, are called ***polysynaptic***. There are three groups of these reflexes:

1. ***Rhythmic*** (for example, the scratch reflex in animals and walking in humans).

2. ***Posture*** (maintenance of posture).

3. ***Cervical or tonic reflexes***. They arise in the turning and nodding movements of the head resulting in the relocation of the muscle tone of the whole body.

Apart from somatic reflexes, the spinal cord carries out a set of the vegetative functions (vasomotor, urogenital functions, motility of the gastrointestinal tract, etc.) in the performance of which the vegetative ganglia located in the spinal cord take part.

Conductive function of the spinal cord

The conductive function of the spinal cord is connected with the transmission of excitation to and from the brain along the white matter consisting of fibers. The group of fibers of general constitution carrying out the general function organizes ***pathways***:

1. Associative (connect various segments of the spinal cord on one side).

2. Commissural (connect the right and left parts of the spinal cord at one level).

3. Projective (connect the lower parts of the CNS with the upper parts, and vice versa):

a) Ascending (sensory) tract.

b) Descending (motor) tract.

Table — The basic conductive pathways

Conductive tracts	Columns of the spinal cord	Physiological importance
I. Ascending (sensory) tracts		
1. Tract of Goll	Posterior	Touch sensibility, sense of body position and passive movements, sense of vibration
2. Wedge-shaped fascicle of Burdach	-//-	-//-
3. Dorsolateral tract	Lateral	Tracts of pain and temperature sensitivity
4. Dorsal spinocerebellar tract of Flexig	-//-	Impulses from muscle proprioceptors, receptors of ligaments and tendons
5. Ventral spinocerebellar tract of Govers	-//-	-//-
6. Dorsal spinothalamic tract	-//-	Pain and temperature sensitivity
7. Spinotectal tract	-//-	Sensory tract of visual motor reflexes and pain sensitivity
8. Ventral spinothalamic tract	Front	Tactile sensitivity

Table — The basic conductive pathways

II. Descending (motor) tracts		
1. Lateral corticospinal tract (pyramidal)	Lateral	Impulses to skeletal muscles Arbitrary movements.
2. Rubrospinal tract	-//-	Impulses supporting the tone of skeletal muscles.
3. Dorsal vestibulospinal tract	-//-	Impulses providing the maintenance of posture and body equilibrium.
4. Olivospinal tract	-//-	Unknown function
5. Reticulospinal tract	Front	Impulses support the tone of skeletal muscles, regulate the condition of the spinal vegetative centers and sensitivity of muscle spindles
6. Ventral vestibulospinal tract	-//-	Impulses providing the maintenance of posture and body equilibrium
7. Tectospinal tract	-//-	Impulses provide optic and acoustic reflexes
8. Ventral corticospinal tract (pyramidal)	Front	Impulses to skeletal muscles Arbitrary movements

The ascending tracts of the spinal cord are:

1. ***Tract of Goll***.

2. ***Wedge-shaped fascicle of Burdach***. The primary efferents of both the fascicles, without interruption, go to the medulla to the appropriate nuclei and are conductors of dermal and mechanical sensitivity.

3. ***The spinothalamic*** tract conducts impulses from dermal receptors.

4**. The *spinocerebellar*** tract:

a) Dorsal.

b) Ventral. These tracts conduct impulses to the cerebellar cortex from the skin and muscles.

5. The tract of ***pain sensitivity*** is located in the ventral columns of the spinal cord.

***The descending tracts* of the spinal cord are:**

1. ***The pyramidal (corticospinal) tract*** begins in the motor region of the cerebellar cortex. Some part of these fibers of the tract go to the medulla, where they are cross-directed and go to the lateral columns (lateral tract) of the spinal cord. The other part go directly and reach the corresponding segment of the spinal cord (direct pyramidal tract).

2. ***The rubrospinal tract*** is formed by the axons of the red nucleus of the midbrain. Some part of fibers go to the cerebellum and reticular formation, and the other — to the spinal cord, where they control muscle tone.

3. ***The vestibulospinal tract*** is formed by the axons of the neurons of Deuter's nucleus (lateral vestibular nucleus). It regulates muscle tone and coordinates movements, participates in the maintenance of equilibrium.

4. ***The reticulospinal tract*** begins from the reticular formation of the afterbrain, regulates the processes of movement coordination.

The degree of the integration of the functions of the spinal cord with those of the brain is so strong, that impaired communication of the spinal cord with the brain results in spinal reflex disorders ***(the phenomenon of spinal shock)***, i. e. the excitability of the nerve centers sharply disappears below the damaged level. In spinal shock, the motor and vegetative reflexes are inhibited, which can be recovered within a long period of time.

The spinal shock is the loss of spinal reflexes after an injury of the spinal cord that appears in the muscles innervated by the cord segments situated below the site of the lesion.

The majority of reflexes which regulate the movements and tone of skeletal muscles disappear, and the vegetative functions, acts of urination and defecation are disturbed. The blood pressure decreases, but comparatively earlier than other vegetative functions it starts to rise together with the restoration of some reflexes which regulate the blood redistribution between the vascular areas. If damage occurs above the 3rd cervical segment, it is accompanied by arrest of respiration and leads to death, if below the cervical segments — breath can be kept due to the contraction of the diaphragm. In modern clinical practice it is possible to preserve life of these patients.

2. Afterbrain

The afterbrain consists of the medulla and pons varolii.

Medulla oblongata (medulla)

In the medulla, the grey matter is broken up into nuclei that are separated by nerve fibers. The white matter represents conducting tracts which connect the spinal cord with the upper regions of the CNS, and vice versa. The nuclei of the 5^{th}–12^{th} pairs of the cranial nerves are located in the medulla.

12^{th} pair — ***sublingual nerve***. It is motor, innervates the tongue muscles.

11^{th} pair — ***auxiliary nerve***. It is motor, innervates the neck muscles.

10th pair — ***vagus nerve***. It is mixed (both motor and sensory). It has 3 nuclei:

1. *Vegetative nucleus* innervating the larynx, gastrointestinal tract, heart, etc.

2. *Viscerosensory nucleus*. On this nucleus, fibers from the internal organs end and form a solitary tract (single).

3. *Somatomotor nucleus*. The neurons of this nucleus regulate the sequence of the muscle contractions of the pharynx and larynx.

9th pair — ***glossopharyngeal nerve***. It is mixed. Its motor fibers innervate the muscles of the bottom of the pharynx, and sensory fibers go from the gustatory receptors of the oral cavity. Vegetative fibers go to the parasympathetic ganglia and from them to the salivary glands.

8th pair — ***acoustic nerve***. It is sensory and has two branches: vestibular and acoustic. The vestibular branch begins from the semicircular canals of the internal ear and ends on the vestibular nuclei of the medulla (Deuter’s and Schwalbe’s nuclei). The acoustic branch is organized by the afferents going from Corti's organ and ends on the ventral and dorsal acoustic nuclei.

In the center of the medulla, there is the reticular formation, which begins in the spinal cord and proceeds in the pons varolii and medulla. It is assumed that the reticular formation reaches the cortex of the cerebrum.

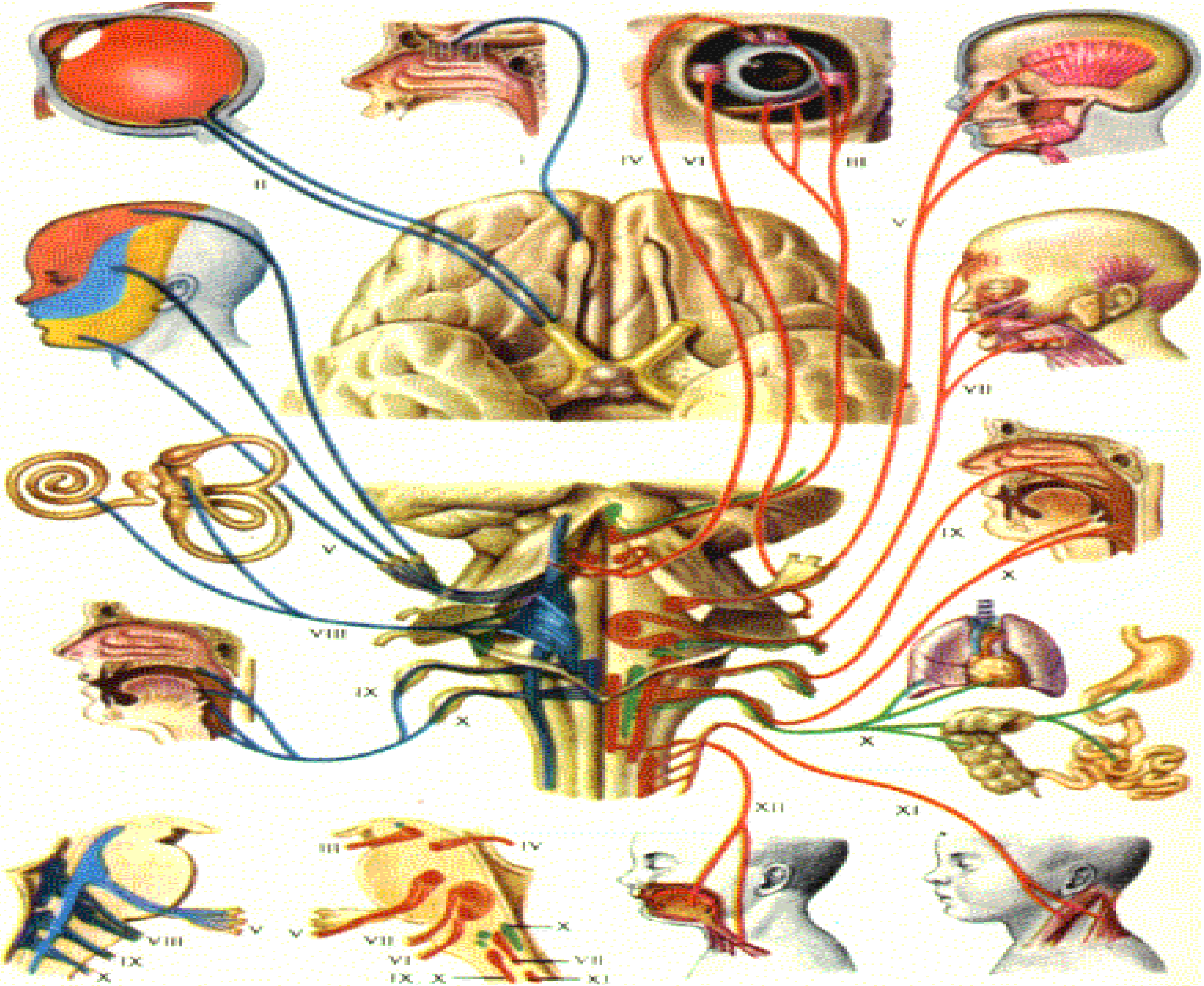

Figure — Cranial nerve

Table — Functional characteristics of cranial nerves

Name of cranial nerves	Effect of action	Function
XII n. hypoglossus	Motor	Innervates the tongue muscles
XI n. accessorius	Motor	Innervates the neck muscles
X n. vagus	Mixed	Afferent information goes from the internal organs Innervates the muscles of the gullet and larynx, internal organs, heart
IX n. glossopharyngeus	Mixed	Innervates the muscles of the gullet
VIII n. vestibulocochlearis	Sensory	Afferent information goes from the vestibular and auditory apparatus
VII n. facialis	Mixed	Afferent information goes from the gustatory receptors of the tongue Innervates the mimic muscles
VI n. abducens	Motor	Innervates eye muscles
V n. trigeminus	Mixed	Afferent information goes from the mucous membrane of the nose, teeth, tongue Innervates the masticatory muscles and muscles stressing the tympanic membrane
IV n. trochlearis	Motor	Innervates the eye muscles
III n.oculomotorius	Motor	Innervates the eye muscles
II n. opticus	Sensory	Innervates the retina
I n. olfactorii	Sensory	Innervates the mucous membrane of the nose

Pons varolii

The pons varolii contains nuclei of three pairs of cranial nerves.

7th pair — ***facial nerve***. It is mixed. Afferents go to it from the gustatory receptors of the tongue, and efferents send signals to the facial mimic muscles.

6th pair — ***abducent nerve***. It is motor, and innervates the lateral rectus muscle of the eye.

5th pair — ***trigeminal.*** It is mixed. It contains sensory nuclei which occupy all the pons varolii, percepts toothache, receives impulses from the mucosa of the nose and tongue. The motor nucleus sends signals to the masticatory muscles and also to the muscles exerting the tympanic membrane.

Functions of the medulla and pons varolii

The afterbrain carries out the *reflex* and *conduction functions*. It is responsible for the reflexes connected with the maintenance of posture and execution of chain reflexes, and also percepts stimulation from the receptors of the skin, muscles, and internal organs.

There are two groups of reflexes connected to the **maintenance of posture:**

1**. Static reflexes**:

a) ***postural reflexes***. These reflexes provide redistribution of muscle tone when the position of the body is changed in space (inclinations, flexions);

b) ***reflexes of straightening***. These reflexes are connected with redistribution of muscle tone during regeneration of natural posture after it has been changed. For example, a person gets up from bed in a certain sequence (first, the head and only then the trunk and legs are raised).

2. **Statokinetic reflexes**. These reflexes are related to the maintenance of posture and orientation in space if the speed of movements is changed. These reflexes are characterized by a great force and a high rate of response. The execution of these reflexes involves all musculation, especially the muscles of the eye. Besides, a large number of vegetative centers are activated. For example, the vagus nerve controls respiration, cardiac work, the tone of the blood vessels.

Except for somatic reflexes, the ***medulla*** takes part in the ***regulation of the organism`s vegetative functions***. On the bottom of the fourth ventricle, there are the neurons of the *respiratory center, vasculomotor center*. The nuclei of the medulla take part in the *mastication process and swallowing of food*.

The medulla contains centers responsible for ***protective reflexes*** (*vomiting, cough, sneezing*).

The centers of the medulla ***regulate the activity of the organs of the thoracal and abdominal cavities***.

Damage to the structure of the medulla results in death.

3. Midbrain

The midbrain belongs to the brain stem. Its dorsal portions are represented with the tectum of the brain, and ventral — cerebral crus. The accumulation of neurons in the midbrain forms the **following nuclei**: ***quadrigeminal plate, red nucleus, reticular formation, black substance, blue nucleus*** (Figure). ***The superior colliculi of the quadrigeminal plate*** are the initial visual centers, and ***the inferior*** ones — initial acoustic. At the level of the superior colliculi, there is the ***nucleus of the oculomotor nerve (III cranial)***, and at the level of the inferior colliculi — ***IV cranial (trochlear nerve)***. The oculomotor nerve innervates several eye muscles: superior rectus, inferior rectus, medial rectus, and inferior oblique muscles. The trochlear nerve innervates the superior oblique eye muscle.

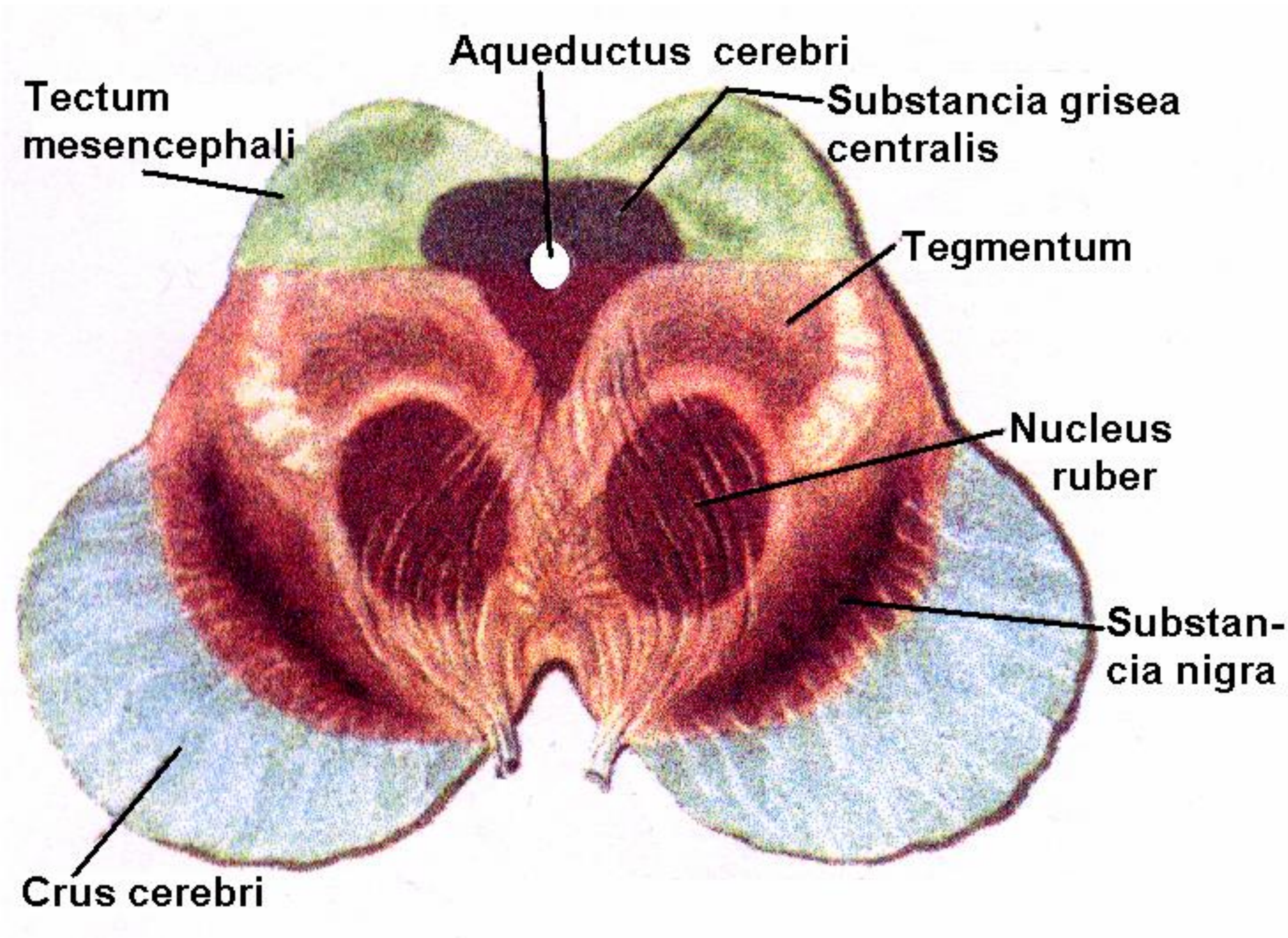

Figure — Midbrain

The **midbrain** takes part in the formation of ***orientative visual and acoustic reflexes***. These reflexes are expressed in turns of the head and body in directions towards sources of light or sound. The nuclei of the quadrigeminal plate take part in the formation of ***watch reflex***, i. e. the tone of flexor muscles increases due to which preparation for response to any new stimulus occurs. For example, high tone of flexor muscles in a cat occurs when there is rustle in silence.

The ***red nucleus*** gives rise to axons that immediately decussate and descend the *rubrospinal tract* and thus **regulates the tone of skeletal musculation.** This nucleus is connected with the cortex of the cerebrum, cerebellum, reticular formation, spinal cord.

The ***black substance*** contains the pigment melanin of dark color, due to which it received its name. This substance is connected with the basal nuclei and reticular formation. It takes part in the **reflexes of mastication, swallowing, regulation of the tone of the finger muscles**. The neurons of the black substance synthesize ***dopamine,*** which is necessary for the control over complex movements. Dopamine enters the basal nuclei, where it performs an inhibiting influence. Damage to the black substance results in impaired function of finger movements, facial mimics (*Parkinson's disease*).

The ***blue nucleus*** represents dense accumulation of neurons, processes of which form divergent networks with one input. The mediator of the blue nucleus is *noradrenaline*, which **regulates all emotional reactions**. Surplus of this material results in serious stressful conditions, and its lack — in depression. The blue nucleus establishes connections with the cortex of the cerebrum, cerebellum, spinal cord, thalamus, and hypothalamus.

Decerebrate rigidity. If to cut the brainstem in a cat above the medulla so that the red nucleus is remained above the section level, **high tone of extensor muscles is observed**, i. e. decerebrate rigidity develops (Figure). In this case the impairment of the balance between the tone of antagonist muscles develops with the predominance of the tone of extensor muscles. The inhibitory influence of the red nucleus on extensor muscles disappears, but the excitatory influence on these muscles from the reticular and vestibular nuclei remains. After a secondary section of the brainstem at the level of the inferior border of the rhomboidal fossa, rigidity disappears, which is accompanied by the disappearance of the tone of all the muscles.

Decerebrate rigidity in humans results from a lesion of the upper parts of the brainstem and subcortical nuclei without midbrain damage and is manifested by **high tone of flexor muscles and an exaggerated extensor posture of all extremities.**

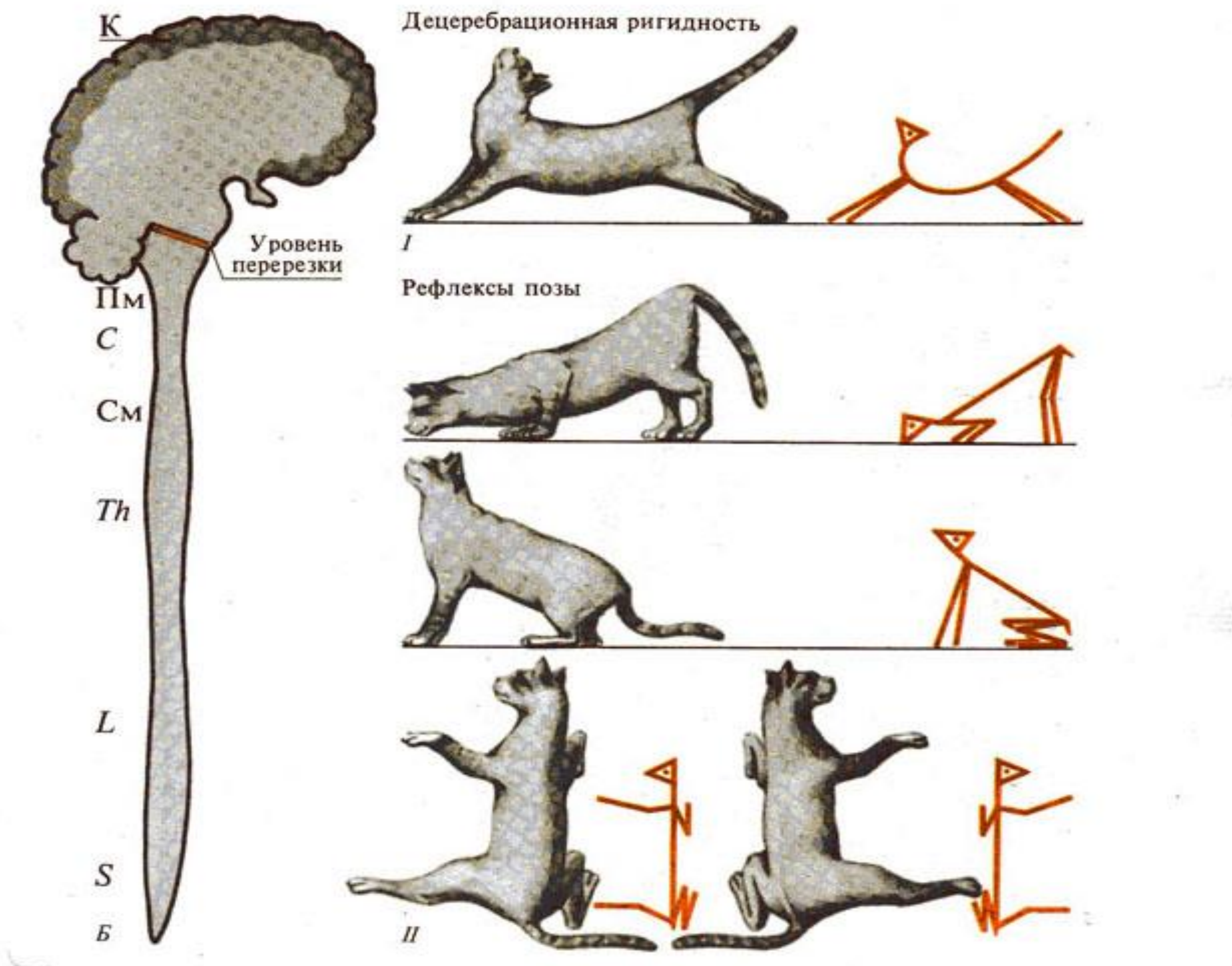

Figure — Decerebrate rigidity