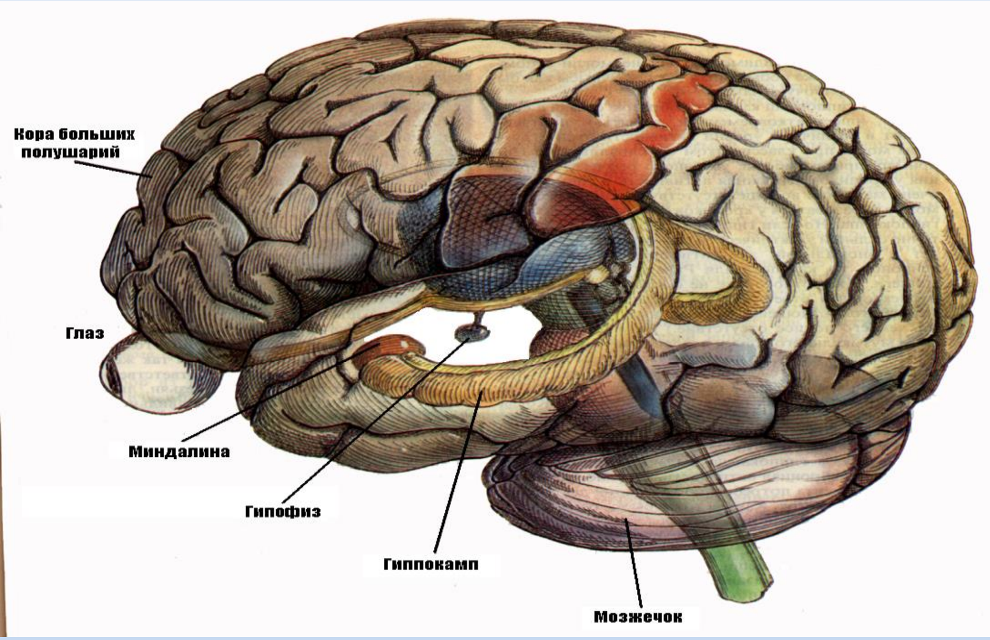
GOMEL STATE MEDICAL UNIVERSITY

Normal and Pathological Physiology Department

PARTICULAR PHYSIOLOGY OF CENTRAL NERVOUS SYSTEM

Lecture 2



Lecturer:
Victor Melnik
Professor, Doctor of Biological Sciences

Lecture plan:

1. **Cerebellum.**
2. **Reticular formation of brain stem.**
3. **Diencephalon: thalamus and hypothalamus.**
4. **Limbic system of brain.**
5. **Basal ganglions.**

1. Cerebellum

The cerebellum is a part of the extrapyramidal system and consists of two hemispheres: vermis cerebelli and lateral lobes. **The gray matter forms the trilaminar cerebellar cortex (Figure):**

1. ***Molecular layer*.** This layer consists of basket and stellate cells and nerve fibers.

2. ***Ganglionic layer*** consists of Purkinje's cells (piriform cells).

3. ***Granular layer*** consists of granule cells (grains cells) and Golgi neurons.

In the white matter neurons form nuclei: ***dentate, emboliform, globose, and fastigial***.

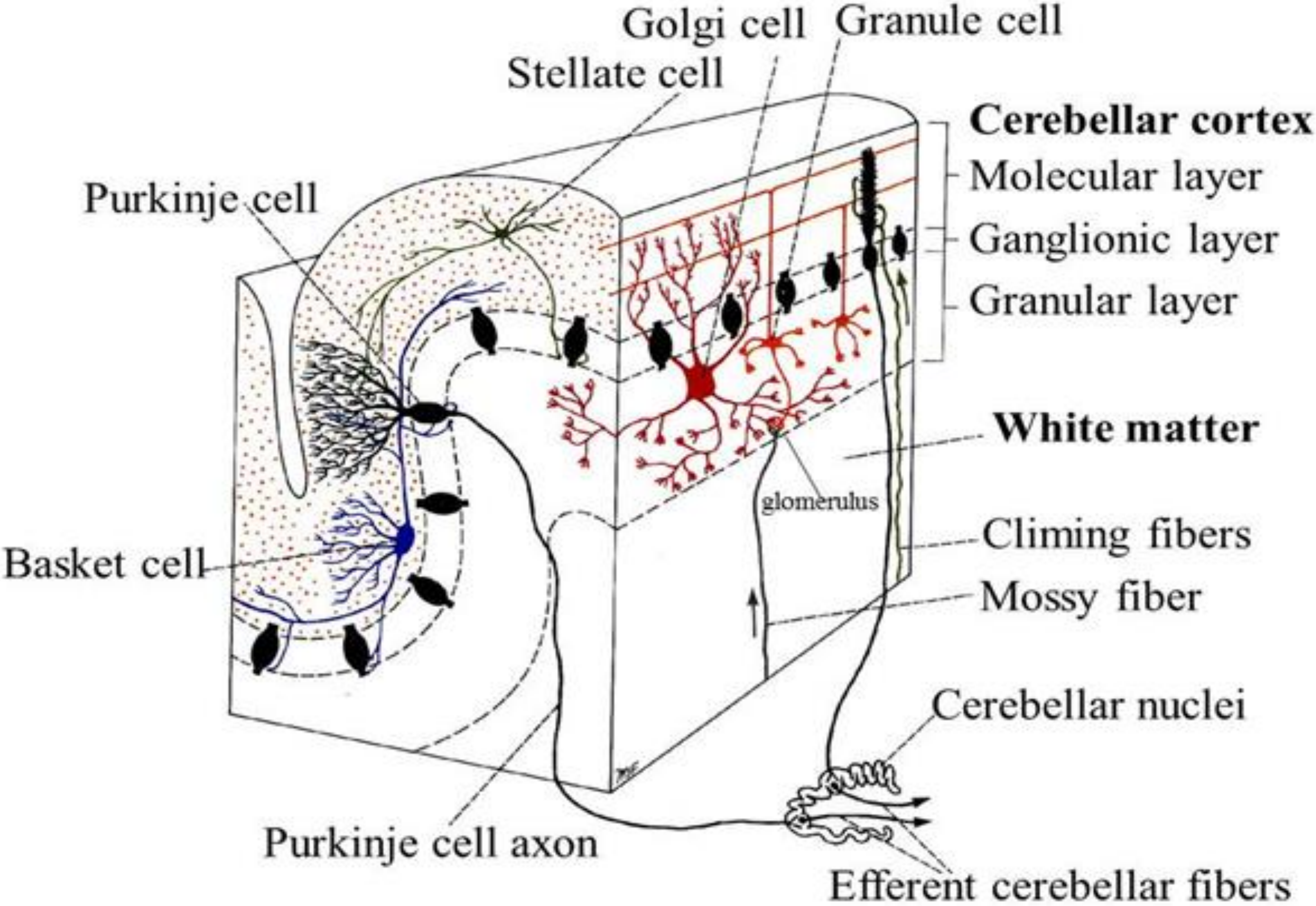


Figure — Cerebellar cortex

The cerebellum has no direct connection with the organs. It is connected with the receptors of the skin, muscles, and tendons along the spinocerebellar tract. It receives signals from the medulla about the state of the vestibular apparatus, and visual and acoustic information from the midbrain.

The cerebellum is connected with the cerebellar cortex by means of the cortex-cerebellar path. The cerebellum has big representation in the cortex. These regions of the cortex of the cerebrum are connected with the relevant fields of the cerebellum, thus providing coordinated activity of these structures of the brain in the control over its functions.

The cerebellum takes part in the regulation of motor activity, in the change and redistribution of muscle tone, i. e. together with the medulla it provides static and statokinetic reflexes.

Sensory influences come to the cerebellum along *climbing fibers*, *mossy fibers and from the neurons of the blue nucleus*. Contacts formed by these fibers are excitant. The climbing fibers come from the inferior olives of the medulla. Each climbing fiber contacts one Purkinje's cell. The nuclei of the pons varolii send afferent signals to the cerebellum along the mossy fibers. The cells of the mossy fibers form synapses on the great amount of inserted neurons; its fibers contact basket cells which form inhibiting synapses on Purkinje's cells. Also the mossy cells form synapses with Golgi cells and stellate cells, which are inhibiting cells.

Apart from grain cells, *all the neurons of the cortex of the cerebellum are inhibiting neurons*. No other part of the CNS contains such an amount of inhibiting cells.

The cortex of the cerebellum receives several types of nerve fibers, and only one pathway gets out — the axons of Purkinje's cells. All synapses which form these fibers are inhibiting and exert inhibiting influences on the nuclei of the cerebellum.

The cerebellum gives rise to the vestibulospinal tract and therefore controls basic commands coming to the spinal cord through the descending tracts.

Removal of the cerebellum or its anterior lobe in animals results in increased tone of the muscles of extensors, and the stimulation of the anterior lobe results in decreased tone.

Table — Characteristics of cerebellar deficiency

Type of disorder	Characteristics
Asthenia	Increased fatigability of muscles, decreased force of muscle contractions
Astasia	Inability to stand due to a limitation or absence of muscular coordination (constant tremor of the head).
Dystonia	Involuntary increase or decrease of muscle tone
Tremor	Small by amplitude shaking movements arising synchronously in different parts of the body
Dysmetria	Inaccuracy in voluntary movements
Hypermetria	A form of dysmetria resulting in movements that overreach the intended goals (movement of the arm or hand beyond the object)
Hypometria	A form of dysmetria resulting in movements that fall short to the intended goals (movement of the arm or hand before the object)
Dysarthria	Disturbance of speech
Atony	Decreased muscle tone and deficiency of posture maintenance
Ataxy	Inability to coordinate voluntary muscle movements (their speed, orientation, and smoothness)
Adiadochokinesia	Inability to perform rapidly alternating muscle movements, as flexion

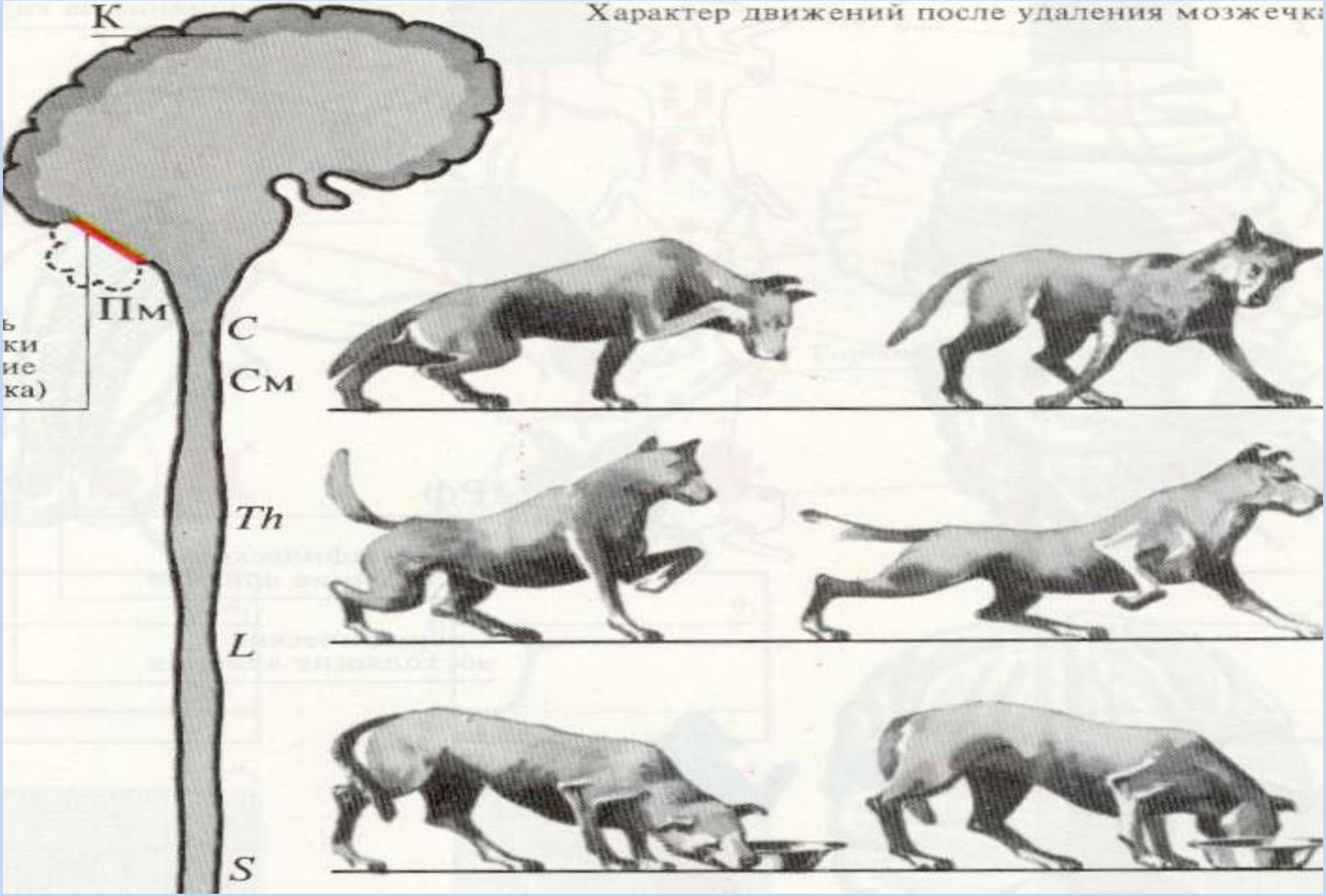


Figure — Movement disorders after cerebellar removal

It is very difficult to diagnose cerebellar damage, since its failure can be compensated by other parts of the CNS, i. e. other regions of the brain can perform functions of the cerebellum in its dysfunction.

The cerebellum affects a number of the ***vegetative functions,*** as it is connected to the reticular formation. For example, it changes the work of the *gastrointestinal tract, the level of blood pressure,* the *composition of blood*. The activity of the cerebellum is controlled by the cortex of the cerebrum.

2. Reticular formation of the brain stem

The central part of the brain stem contains diffuse accumulation of cells interlaced by a set of fibers stretching in all directions. Under the microscope this formation represents a network, that is why the scientist ***Deuters*** called it ***the reticular formation (network formation)***.

The reticular formation <u>begins in the spinal cord and continues to the cortex of the cerebrum</u>. The fibers of the reticular formation extend to the cortex of the cerebrum through the thalamus and form nonspecific pathways which sustain the activity of all the parts of the CNS. <u>Through the descending</u> reticular-spinal tracts the reticular formation <u>can activate and inhibit the reflexes of the spinal cord</u>.

<u>Along the ascending</u> nerve pathways the reticular formation <u>activates the cortex of the cerebrum</u> and maintains its wakeful state. Influenced by the reticular formation, <u>reflexes become stronger and more precise</u>.

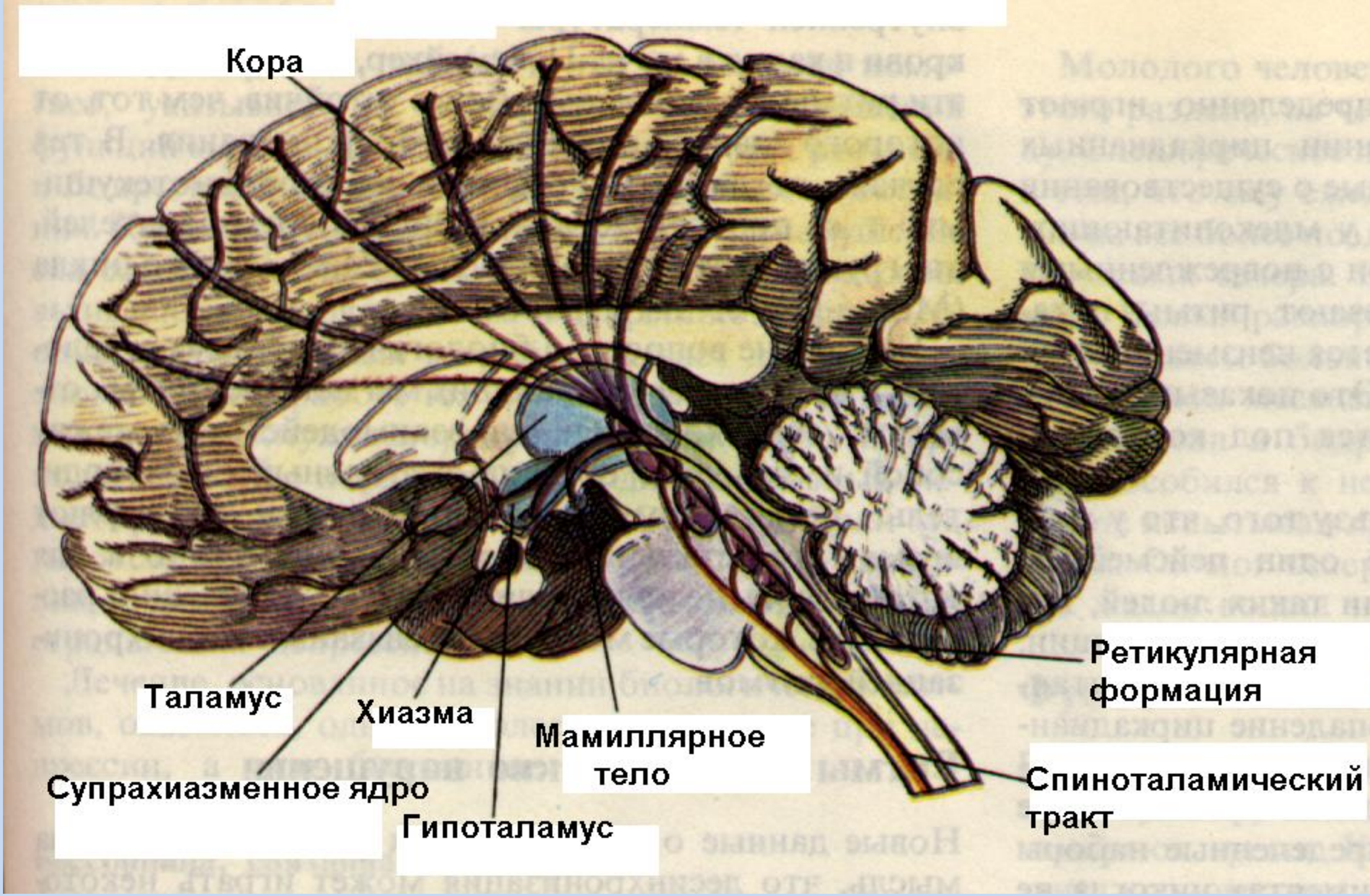


Figure — Reticular formation of the brain stem

The **reticular formation** acts as a filter and ***transmits only new and important information*** to the upper parts of the CNS.

The activity of the reticular formation is maintained constantly at a high level since signals from all receptors are transmitted through it.

The neurons of the **reticular formation** are ***very sensitive to the action of hormones and drugs*** which are capable to decrease its activity (aminazine, reserpin, serpasil, etc.).

The reticular formation receives signals from the cortex of the cerebellum, descending and ascending signals interact in its neurons. These signals constantly circulate in the chains of the neurons of the reticular formation and keep it in an active state, which is necessary to maintain the CNS tone and its readiness for work.

After introducing a microelectrode into the reticular formation with its subsequent stimulation with electric signals it was defined that the <u>stimulation of this region</u> of the brain <u>induces the electrical activity of the brain, which is typical for awakening and waking states.</u>

<u>In lesions of the reticular formation</u> and, in particular, its superior parts, an <u>animal falls deeply asleep</u> though afferent signals come into the cortex of the cerebrum along other nerve pathways. Animals with disorders of the reticular formation are <u>constantly asleep and do not respond to any stimuli.</u>

Thus, normal functioning of the cortex of the cerebrum to a greater extent depends on the influences of the reticular formation.

The majority of the neurons of the reticular formation are polysensoric, i. e. excitation may be induced in them by any stimulus (light, sound, tactile stimuli, etc.).

The reticular formation influences the tone of skeletal muscles, and elimination of this influence is one of the reasons for the appearance of the spinal shock followed by hyporeflexia. The activity of the reticular formation is controlled by the cortex of the cerebrum.

3. Thalamus

The neurons of the thalamus form nuclei which, ***by their anatomical features***, are divided into several basic groups:

1. **Anterior.**
2. **Posterior.**
3. **Middle.**
4. **Lateral.**
5. **Central.**
6. **Ventral.**
7. **Intra-laminar.**

***By their physiology*, **all the nuclei of the thalamus can be divided into:

1. **Nonspecific.**
2. **Specific.**
3. **Associative.**

The nonspecific nuclei represent continuation of the reticular formation. They send their signals through the axons to the whole cortex of the cerebrum. First, the signals are distributed from the nonspecific nuclei to the subcortical structures, and then go in parallel to all the regions of the cortex of the cerebrum, since axons organize a set of collaterals. The nonspecific nuclei represent more ancient structures which include some part of the anterior nuclei, middle and intra-laminar nuclei.

The specific nuclei send their signals through the axons only to the cells of a certain area of the cortex of the cerebrum (for example, visual or acoustic areas). The fibers from all the ascending pathways end at the neurons of the specific nuclei. Then nerve signals along direct monosynaptic connections go to the sensory and associative areas of the cortex of the cerebrum.

Some nuclei of the thalamus receive signals from the receptors of the skin, proprioreceptive system.

Some specific nuclei included into the posterior group of the thalamus form the ***medial*** and ***lateral geniculate bodies***. The neurons of the medial geniculate body receive signals from the acoustic nuclei of the medulla and posterior colliculi of the quadrigeminal plate, and visual afferents end at the neurons of the lateral geniculate bodies. In this connection, the <u>medial geniculate bodies</u> are called the subcortical <u>center of audition</u>, and the <u>lateral</u> — <u>subcortical center of vision.</u>

The axons of the specific nuclei do not practically organize collaterals. All sensory information (except for the olfactory system) comes to the cerebellar cortex through the thalamus.

Inhibiting influences from the cortex of the cerebrum and other subcortical structures grab new important information, since the cortex of the cerebrum cannot accept all information at once.

The neurons of the nonspecific nuclei of the thalamus are effectively activated by pain signals, therefore it is assumed that the ***thalamus is the supreme center of pain sensitivity***. Damage to the thalamus is accompanied with unbearable pain and even its insignificant stimulation produces acute pain. Also, damage to a portion of the nonspecific nuclei of the thalamus results in a loss of consciousness. It means that signals from these nuclei maintain the necessary level of the activity of the cortex of the cerebrum necessary to maintain consciousness.

The associative nuclei of the thalamus (mediodorsal, lateral, etc.) receive impulses from other nerve centers of the thalamus. For example, a neuron can receive impulses of different modalities from the centers providing visual, tactile and painful sensitivity. The neurons of the associative nuclei are polysensory and provide an opportunity of integrated processes as a result of which the signals transferred into the associative zones of the cortex of the cerebrum are formed. These impulses provide manifestation of such <u>mental processes, as recognition of subjects, coordination of speech, visual and motor functions, formation of concept about the pose and position of the body</u>.

With the participation of the nuclei of the thalamus, conditioned reflexes may be formed without participation of the cortex of cerebrum.

Hypothalamus

The structure of the hypothalamus includes a group of nuclei situated at the base of the brain close to the hypophysis (Figure). These nuclei are the superior subcortical centers of the autonomous nervous system and all the vital body functions.

The nuclei of the hypothalamus are divided into some basic groups:

1. Anterior group (supraoptic and paraventricular nuclei).

2. Middle group.

3. Posterior group.

4. External group.

5. Preoptic group.

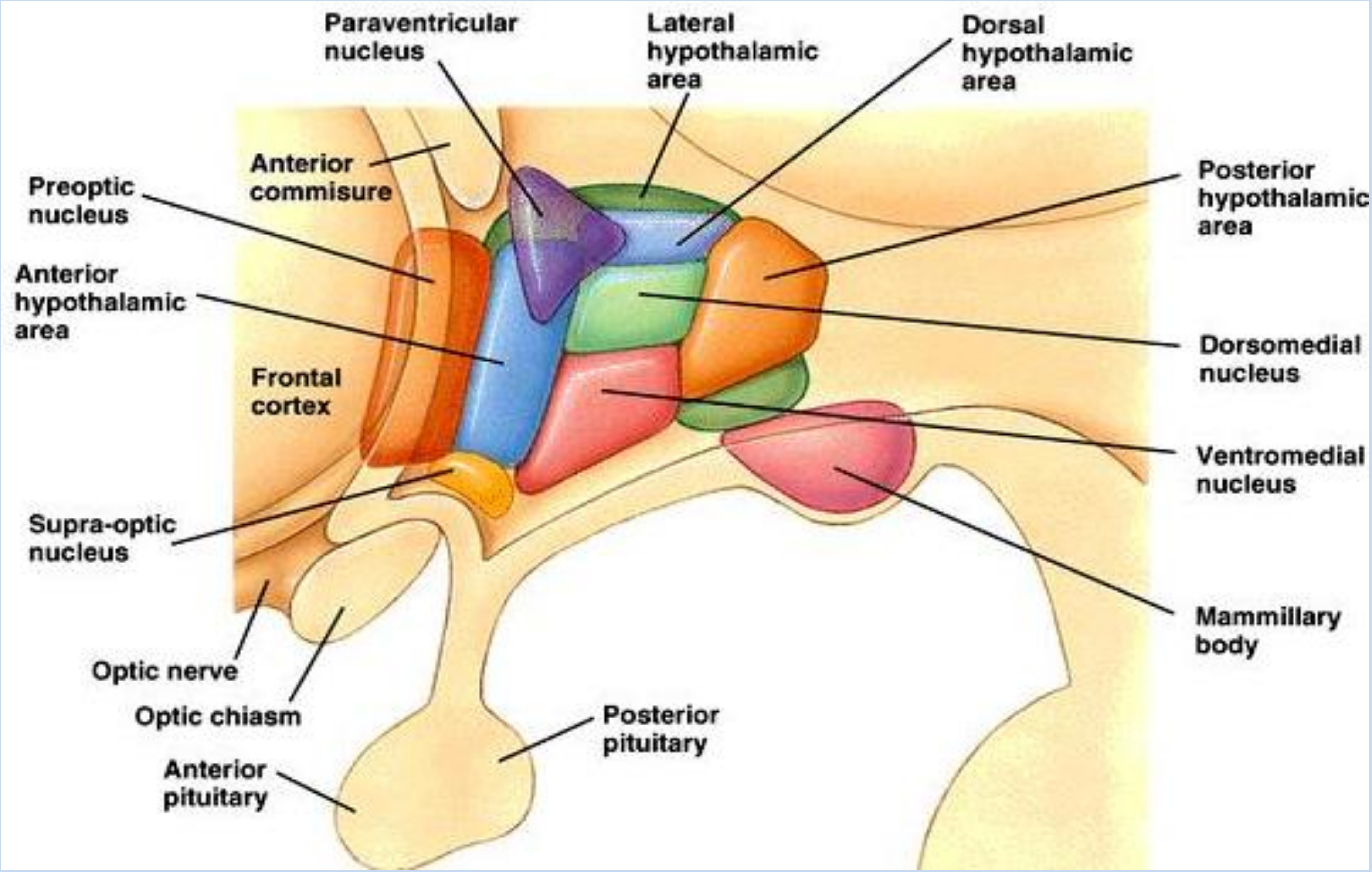


Figure — The nuclei of the hypothalamus

These nuclei have complex afferent and efferent connections. *Afferent* signals come to the hypothalamus *from the cortex of the cerebrum, basal ganglia, and thalamus*, and *efferent* signals go from the hypothalamus to the *midbrain, thalamus, and other subcortical structures*.

The supraoptic and paraventricular nuclei of the hypothalamus are connected with the hypophysis with a special system of fibers which conduct electrical impulses and neurosecretion products of the neurons of these nuclei.

The majority of the hypothalamic nuclei have no borders (except the supraoptic and paraventricular nuclei), that is why other nuclei of the hypothalamus are divided into regions depending on their functional value.

There are the three regions of the hypothalamus:

1. *The hypophysotropical region* includes the preoptic and anterior groups of nuclei whose neurons produce *liberins (stimulators)* and *statins (inhibitors),* thus regulating the activity of the adenohypophysis.

2. *The medial region* includes the middle group of nuclei and contains neurons which react to *changes of the body temperature, water-electrolytic composition of blood, the amount of hormones in the blood, and also controls the activity of the hypophysis*.

3. *The lateral region* is a denuclearized region where nerve fibers are located.

On the whole, the **hypothalamus** **is an integrative *center of the vegetative, somatic and endocrine functions* of the organism.**

The ***posterior part*** of the hypothalamus ***regulates heat production***. Stimulation of this part results is intensified metabolism, increased heart rate, appearance of shivering, which altogether leads to increased thermogenesis. If the posterior part of the hypothalamus is damaged, an animal cannot stand low temperature.

The ***anterior part*** of the hypothalamus (paraventricular nucleus) is responsible for ***heat loss***. If to stimulate this region of the hypothalamus, the skin vessels are dilated, sweat release increases. If the anterior part of the hypothalamus is affected, an animal cannot stand hot temperature.

In the region of the **middle and lateral nuclei**, there are the ***centers of hunger and satiety, thirst, centers regulating sexual behavior, aggression***. These regions of the hypothalamus take part in the ***change of the phases of sleep and wakefulness***, and their damage makes a person fall into lethargic sleep.

The secretory cells of the **supraoptic and paraventricular nuclei** produce ***vasopressin*** and ***oxytocin***. These hormones come through axons into the neurohypophysis.

The hypothalamus produces ***enkephalins*** and ***endorphins*, **which possess morphine-like action, and thus take part in the regulation of behavior, and also regulate the vegetative functions. The hypothalamus produces a number of other biologically active substances. The activity of the hypothalamus is regulated by the cortex of the cerebrum.

4. Limbic system of the brain

The limbic system is a functional set of the brain structures participating in the ***organization of emotion and motivated behavior***, such as alimentary, sexual, defensive instincts. This system takes part in the organization of the ***wakefulness-sleep cycle***.

The limbic system influences the cortex of the cerebrum and subcortical structures establishing necessary conformity of their activity.

The limbic system includes (Figure):

1. ***The ancient cortex,*** which includes the *rhinencephalon*.

2. ***The old cortex*** including the *hippocampus and cingulate gyrus*.

3. ***The subcortical structures*** (*amygdaloid complex, anterior thalamic nucleus, mamillary bodies*).

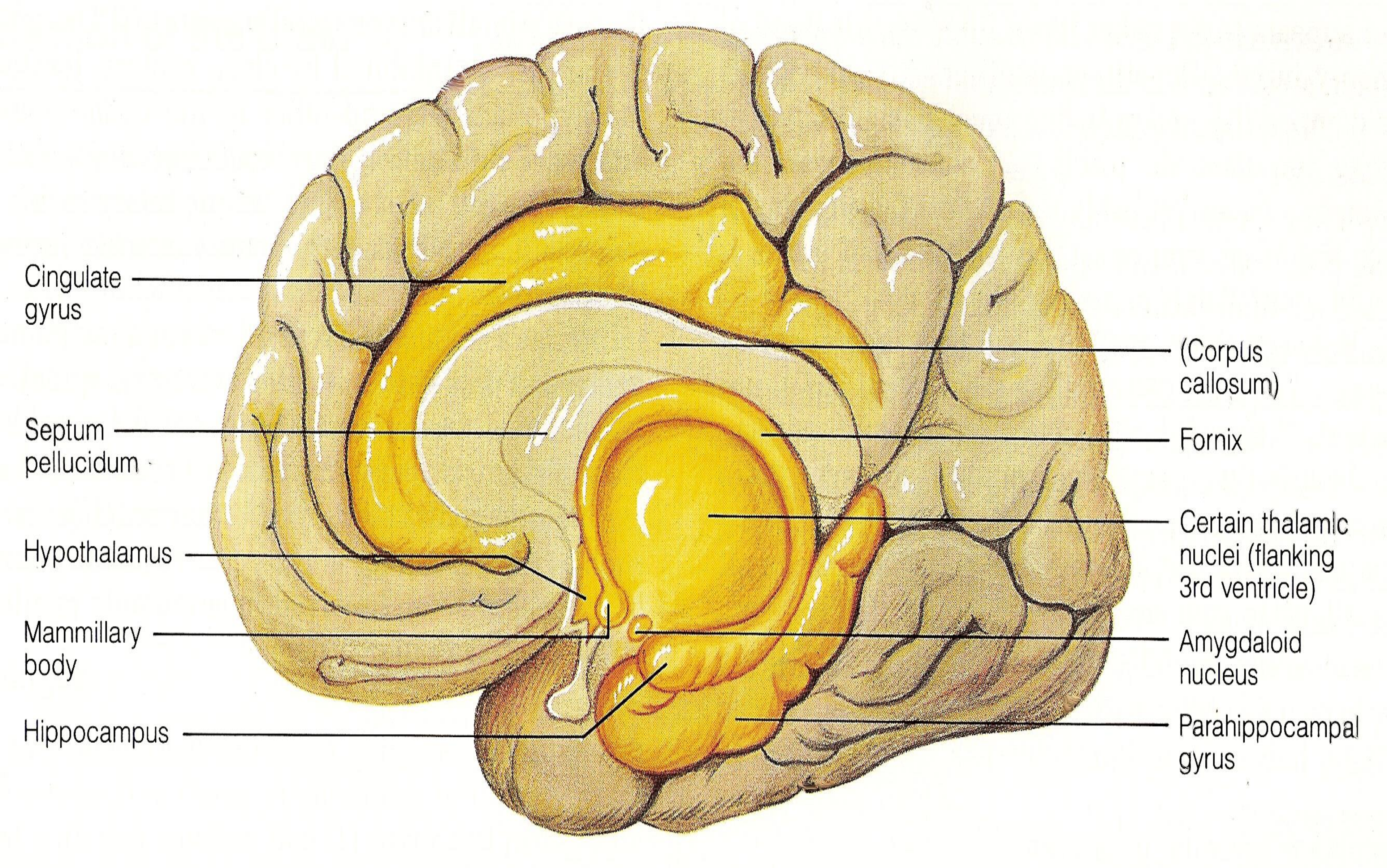


Figure — The main structures of the limbic system

The limbic system is a ring-like structure which surrounds the base of the forebrain and is the border between the neocortex and brain stem. The limbic system is characterized by a set of bilateral connections. These connections inside the system and with other parts of the CNS are very complex and complicate the treatment of the diseases of the limbic system.

The connections between the brain structures organizing circuits having functional specificity are well-known nowadays. For example, the ***Papez circuit*** (*hippocampus — mamillary body — anterior nuclei of the thalamus — cortex of the cingulate gyrus — parahippocampal gyrus — hippocampus*). This circuit is connected with memory and leaning processes. Other circuits regulate defense-aggressive behavior.

The participation of the limbic system in the ***regulation of vegetative reactions*** (stimulation or inhibition) is well-defined. The limbic system controls the activity of the internal organs through the lower located parts of the CNS (thalamus and hypothalamus). The limbic system changes the excitability of the nerve centers of these structures and aims the vegetative reactions in a necessary direction.

In animals stimulation of the nuclei of the ***amygdaloid complex,*** located in the main temporal gyrus, results in the *appearance of fear, anger, or aggression depending* on where the impulse gets to. The bilaterial removal of the temporal lobe with the amygdaloid complex and hippocampus affects the emotional sphere and causes **psychic blindness**, i. e. the inability to evaluate visual and acoustical information correctly. For example, if an animal has got an electric shock, it will continue moving in the same direction though it will be shocked again.

The limbic system is responsible ***for storage of received information*** i. e. memory formation. The **removal** of the *hippocampus* in humans leads to a **complete loss of short-term memory**. ***Stimulation*** *of the* ***hippocampus*** **recalls the latest events** which a person cannot remember in usual conditions. ***The removal of the hippocampus*** in animals results in affected internal inhibition, i.e. they lose the ability to fade conditioned reflexes which have lost their value for the vital activity of the organism.

The limbic system influences the functioning of the cortex of the cerebrum due to the formation of an emotional background which ***regulates the rate of the formation of conditioned reflexes***.

Thus, the limbic system together with other structures of the brain forms a system coordinating the somatic and vegetative functions of the organism.

5. Basal ganglia

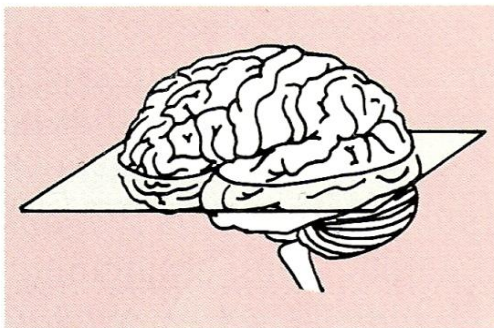
The forebrain includes the basal ganglia and the cortex of cerebrum.

Basal ganglia (Figure)

The basal ganglia are nuclear structures located above the white matter inside the forebrain, mainly in the frontal lobes. They include the ***caudate nucleus, putamen, globus pallidus, and claustrum***. **By functions and phylogenesis, it is divided into:**

1. ***Paleostriatum*** — more ancient structures (*globus pallidus*).

2. ***Neostriatum*** — consists of the *caudate nucleus and putamen*. These two structures are interconnected anatomically and are called the ***corpus striatum***. The axons of its cells go to the globus pallidus and substantia nigra of the midbrain. The corpus striatum is a collector of afferent entries going to the basal ganglia. Impulses reaching the basal ganglia *come from the sensomotor cortex, the substantia nigra, and nonspecific nuclei of the thalamus*.



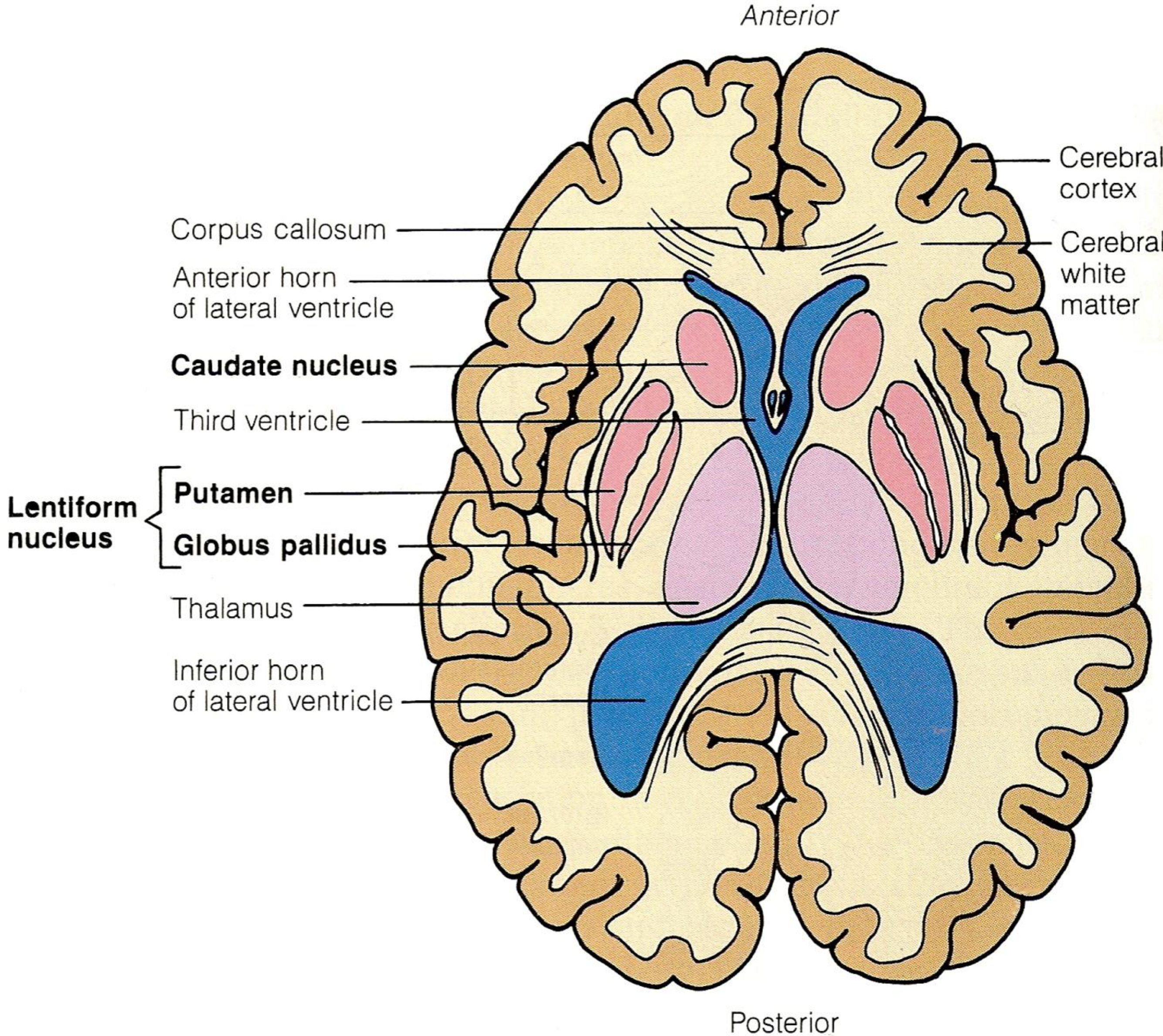


Figure — Basal ganglia
(the relationship of the basal ganglia to the thalamus and the lateral and third ventricles)

The globus pallidus forms efferents from the basal ganglia. Signals from these brain structures go along some efferents *to the diencephalon and red nucleus of the midbrain*. Other efferents go from the globus pallidus to the thalamus, then to the motor cortex of the cerebrum.

The fibers going from the cortex of the cerebrum and thalamus form *excitant synapses* on the neurons of the corpus striatum, and the fibers of the substantia nigra form *inhibiting synapses*.

Functions of the basal ganglia*.* The basal ganglia take part in ***coordination of motor activity.*** Damage to the corpus striatum results in ***athetosis*** — slow vermiform movements of the wrist and fingers; ***chorea*** — convulsive movements of mimic muscles and extremities.

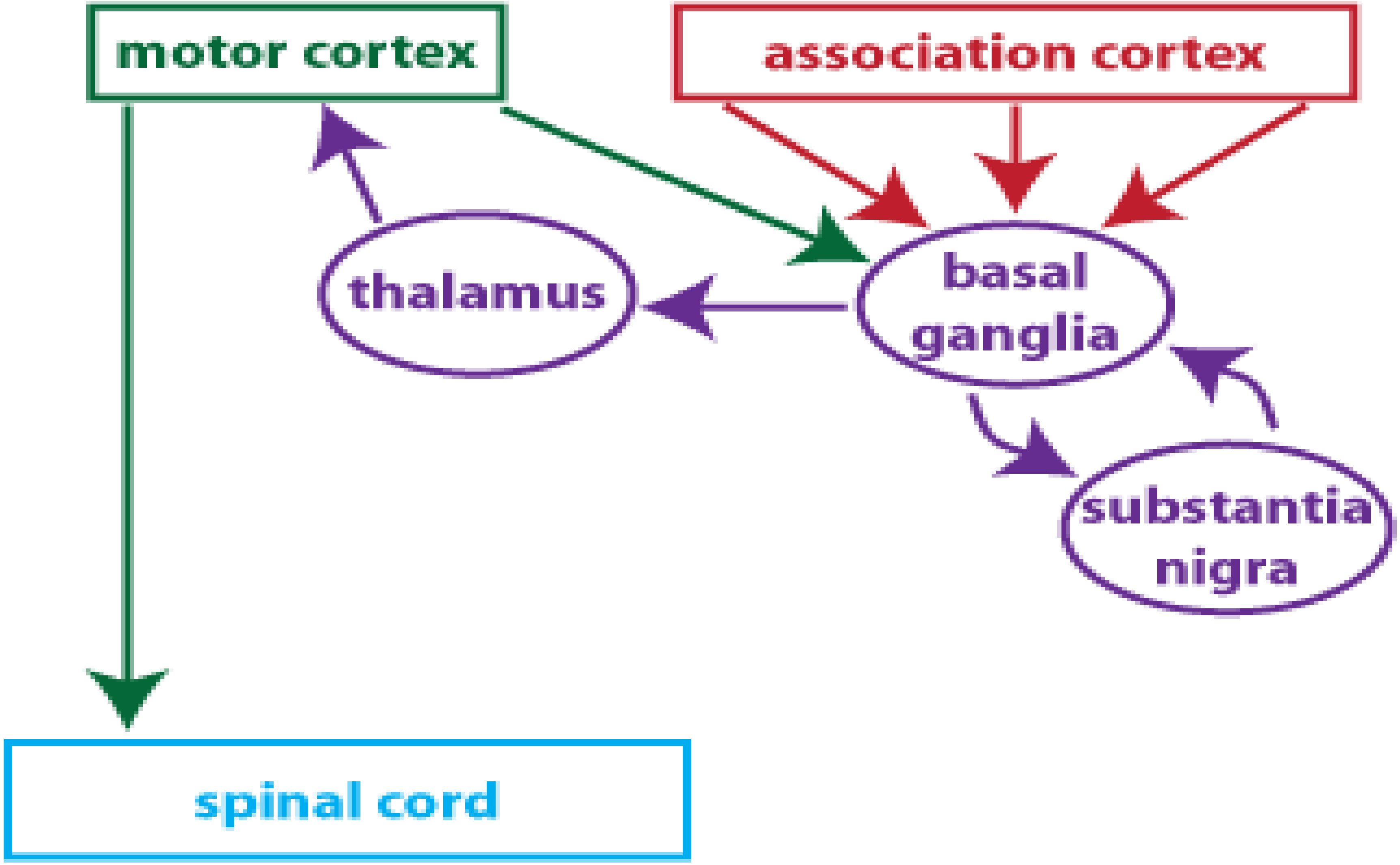


Figure — Basal ganglia
(afferent and efferent connections of the basal ganglia**)**

Damage to the basal ganglia is related with the appearance of ***Parkinson's disease*****,** which is accompanied by the following signs:

1. *Akinesia* — small motility.

2. Wax rigidity — ***hypertonus***.

3. ***Static tremor***, which is observed in the extremities and head.

These signs are connected with increased activity of the basal ganglia output nuclei which appears as a result of the damage of a dopaminergic pathway, i. e. the inhibiting influence from the substantia nigra of the midbrain disappears.

Also, the basal ganglia take part in ***the development of a program of targeted movements***, i.e. they receive information from the cortex of the cerebrum and send it to the forebrain, where it is integrated with information from the cerebellum. After that the information comes to the motor region of the cortex of cerebrum thus resulting in realization of the motor program through the influences on the spinal cord.