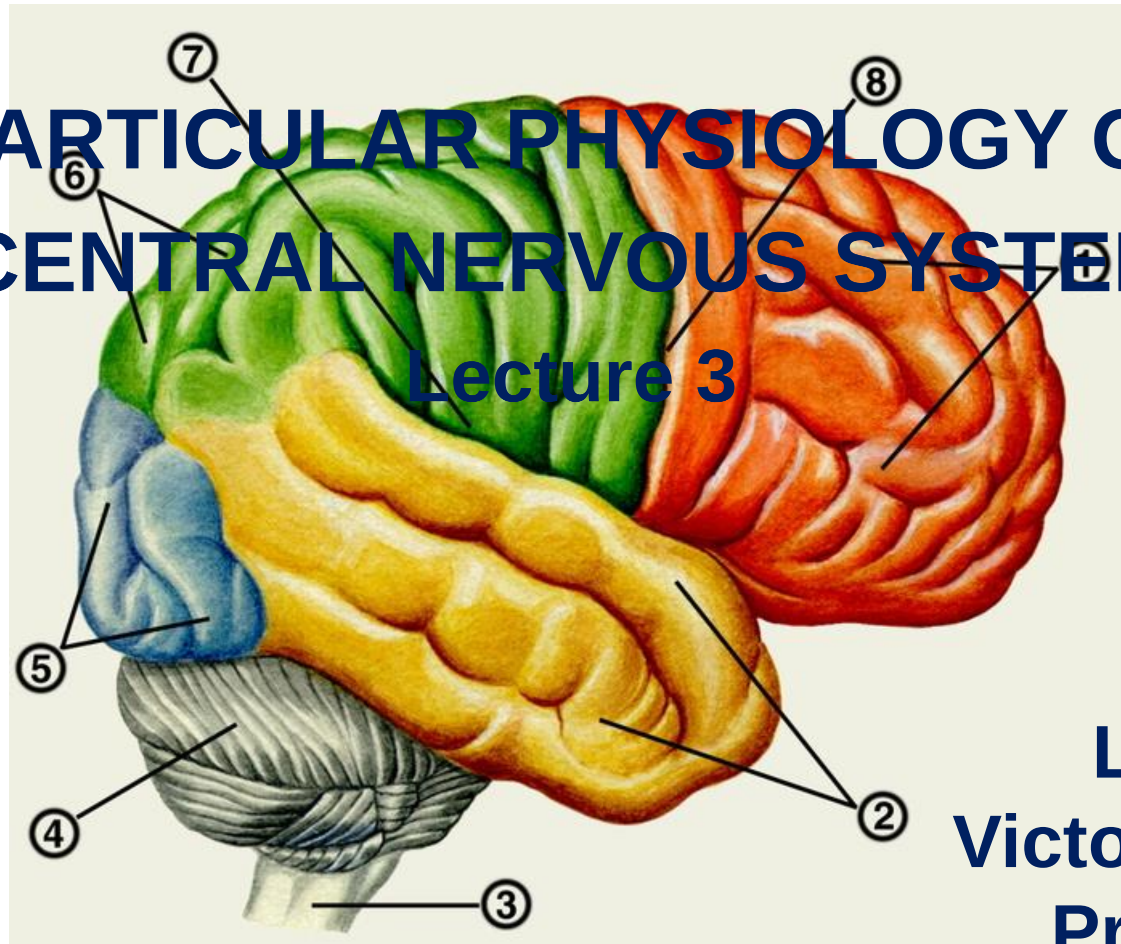
GOMEL STATE MEDICAL UNIVERSITY

Normal and Pathological Physiology Department



PARTICULAR PHYSIOLOGY OF CENTRAL NERVOUS SYSTEM

Lecture 3

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Lecture plan:

1. Physiology of the cerebral cortex:

- Morpho-functional characteristics of the cerebral cortex.
- Main regions of the cortex. Communication of the peripheral formations with the cortex.
- Electrical activity of the cortex of the cerebrum.
- Functional asymmetry of the cortex.

2. Autonomic (vegetative) nervous system:

- Morpho-functional characteristics of the vegetative nervous system.
- Classification of the vegetative ganglia.
- Vegetative reflexes.
- Levels of the regulation of the vegetative functions.

Physiology of the cerebral cortex (CC)

Morpho-functional characteristics of the CC

The cerebral cortex is the most recent structure regarding its evolutionary development. **The cortex is 1.3–4.5 mm thick.** It contains **10–18 billion nervous** cells. The area of the ***cortex surface is 2,200 cm²***. The basic cells of the cortex are *pyramidal, stellate, and fusiform*. All the cells of the cortex contain information and if they are not overloaded with it, they die.

As per the phylogenetic development, the cortex consists of:

1. *The archicortex,* which consists of the *rhinencephalon*.

2. *The paleocortex,* which consists of the *cingular gyrus, hippocampus, amygdaloid body*.

3. *The neocortex,* which has typical 6-layer structure (1st layer — molecular, 2nd layer — external granular, 3rd — external pyramidal, 4rd layer — internal granular, 5th layer — internal pyramidal, 6th layer — polymorphic).

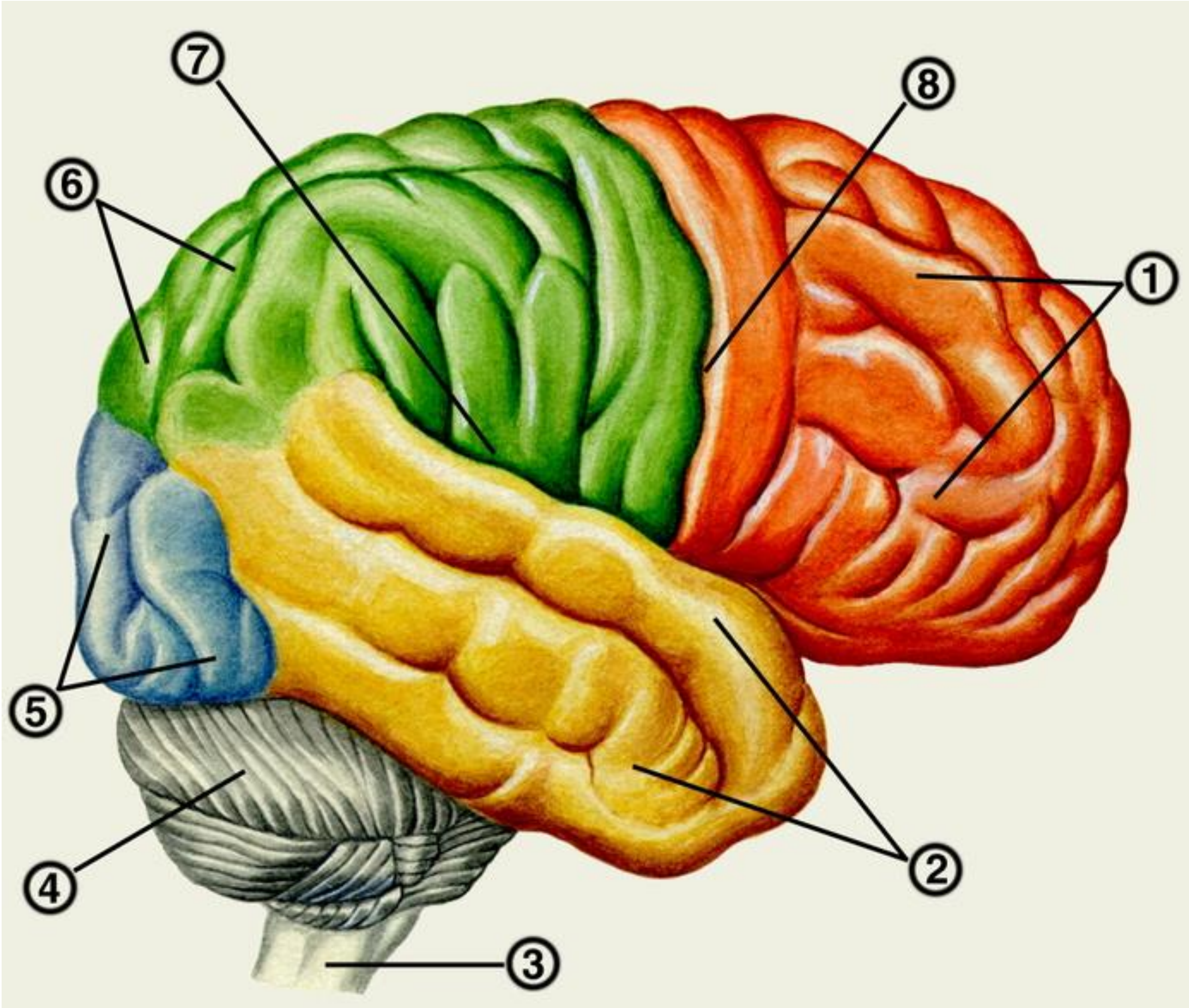


Figure — Cortex of cerebrum

The **main efferents** from the neocortex start from the cells of the 5^{th} layer (pyramidal cells) and stretch outside the cortex forming the pyramidal tract.

The **main afferents** come to the cortex along the fibers of the thalamocortical tract.

The cerebral cortex is characterized by numerous interneuronic contacts whose amount intensively increases till the age of 18. **The final development of the cortex ends by 22–23.**

By the location, density, and form of neurons, Brodman divided the cortex into **53 cytoarchitectonic fields.**

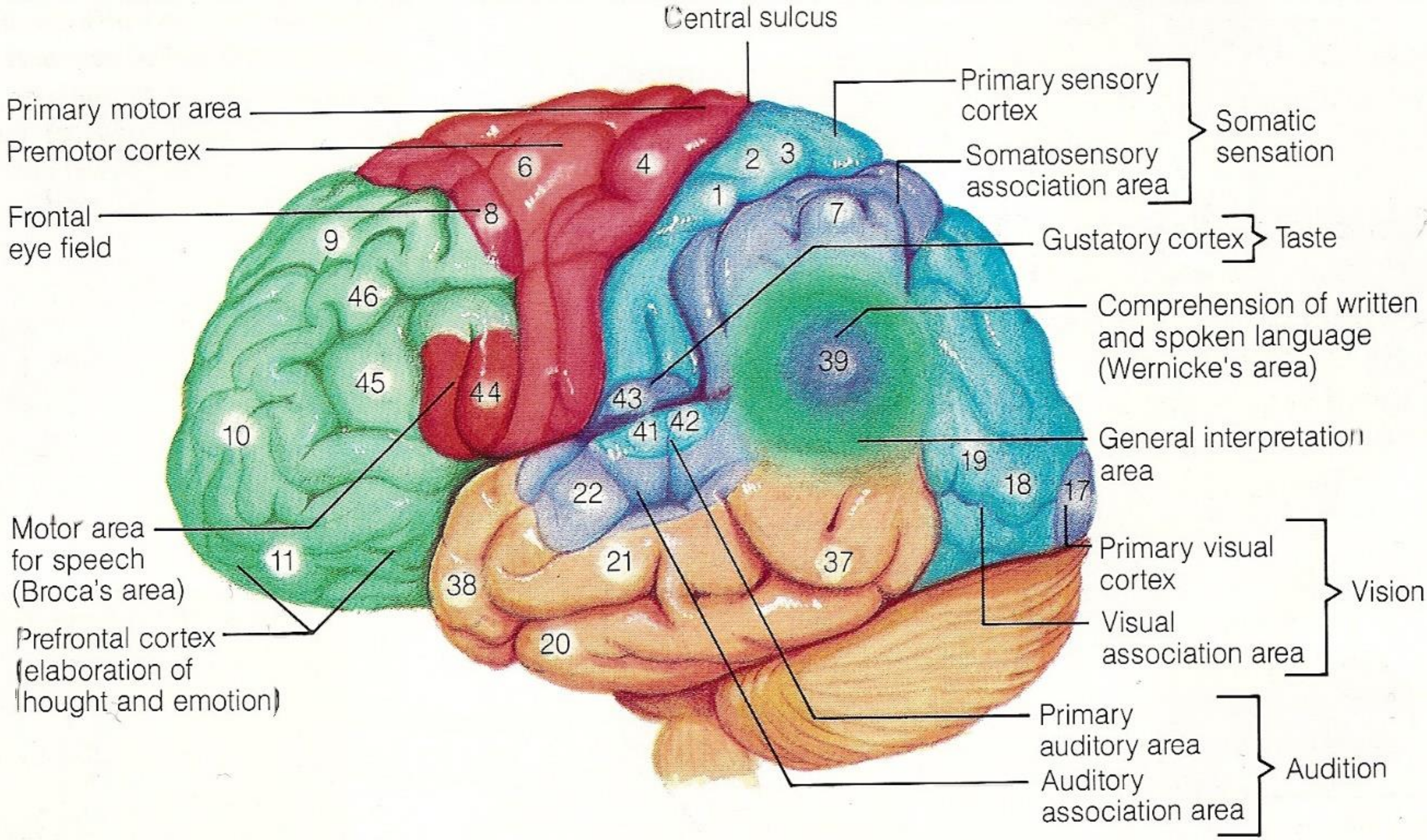


Figure — Functional areas of the left cerebral cortex. **The numbers indicate the regions plotted by the Brodman system**

The functional unit of the cortex is the ***vertical column***, which performs a certain function. It consists of large pyramidal cells with above-and under-located neurons which organize functional unification. All the neurons of the column respond to the stimulation of the same receptor with identical reactions and together create the efferent response. Signal conduction from one column to the next one is limited by lateral inhibition. For example, each column of the somatosensory cortex innervates only one spinal motoneuron. Under the activation of the column this motoneuron is excited and induces contractions of muscles connected with this motoneuron.

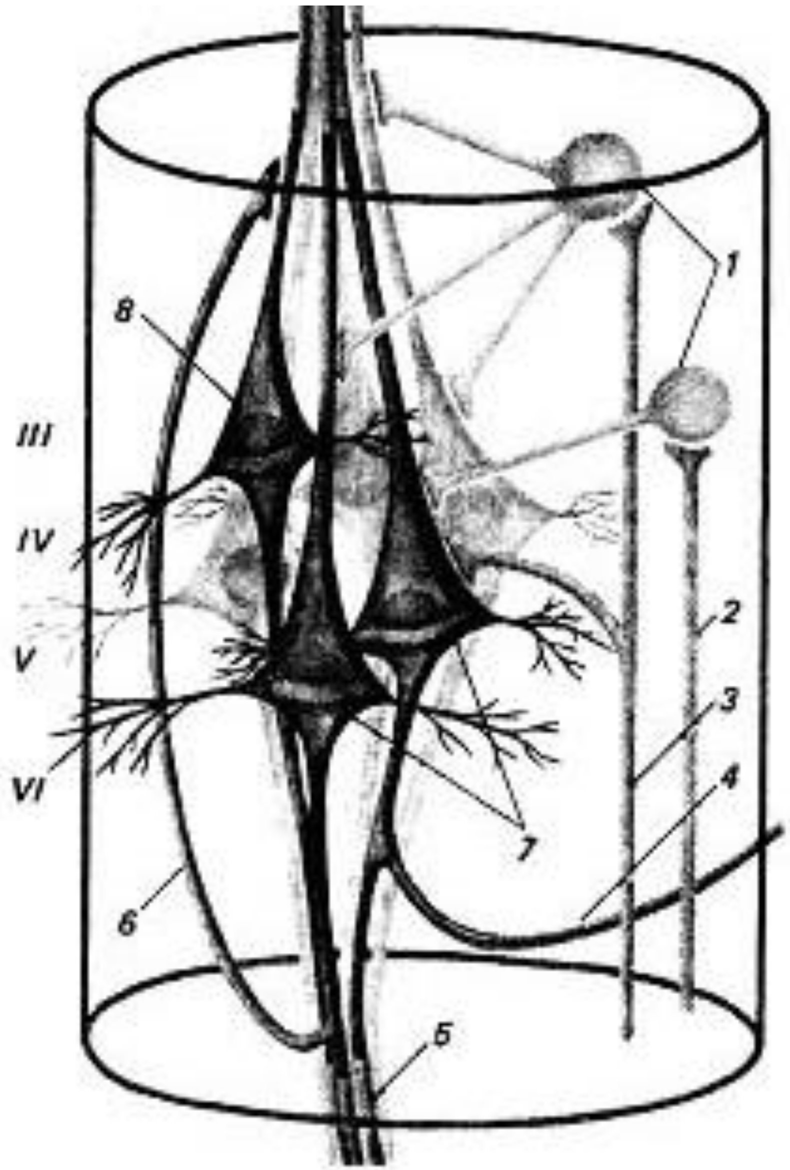


Figure — Vertical column

Main regions of the cortex. Communication of the peripheral formations with the cortex

It has been revealed that removal of certain fields of the cortex results in termination of some functions, whereas stimulation of the cortex with electric shock results in their appearance. Thus, each region of the cortex is responsible for the performance of a definite function. Regarding this, the cortex has **several regions** (Figure):

1. *Sensory regions.* Specific afferent impulses come here from periphery receptors.

2. *Motor regions.* Once stimulated, various movements appear.

3. *Associative regions*. They receive information from various receptor areas of the cortex.

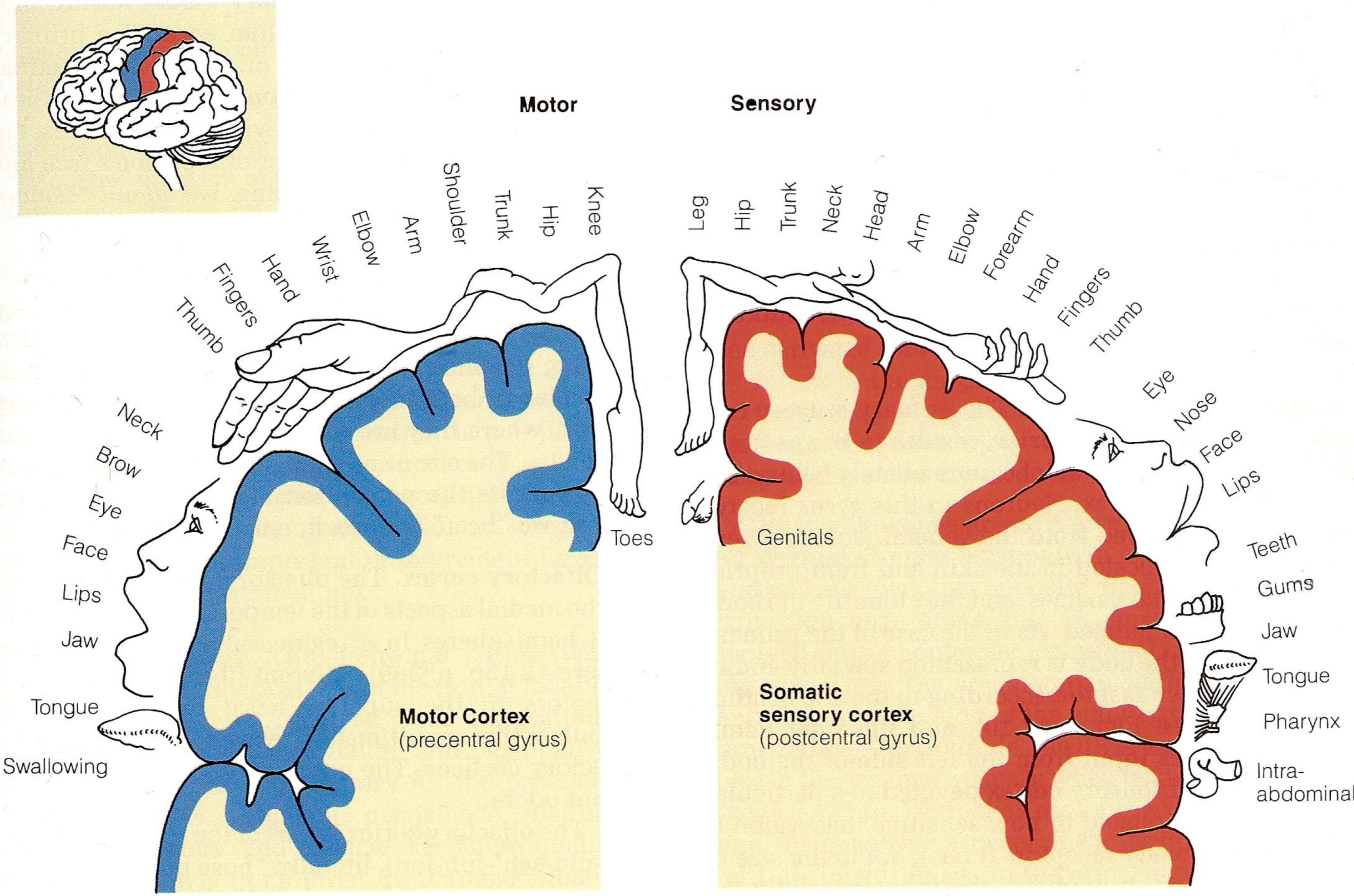


Figure — Sensory and motor areas of the cerebral cortex

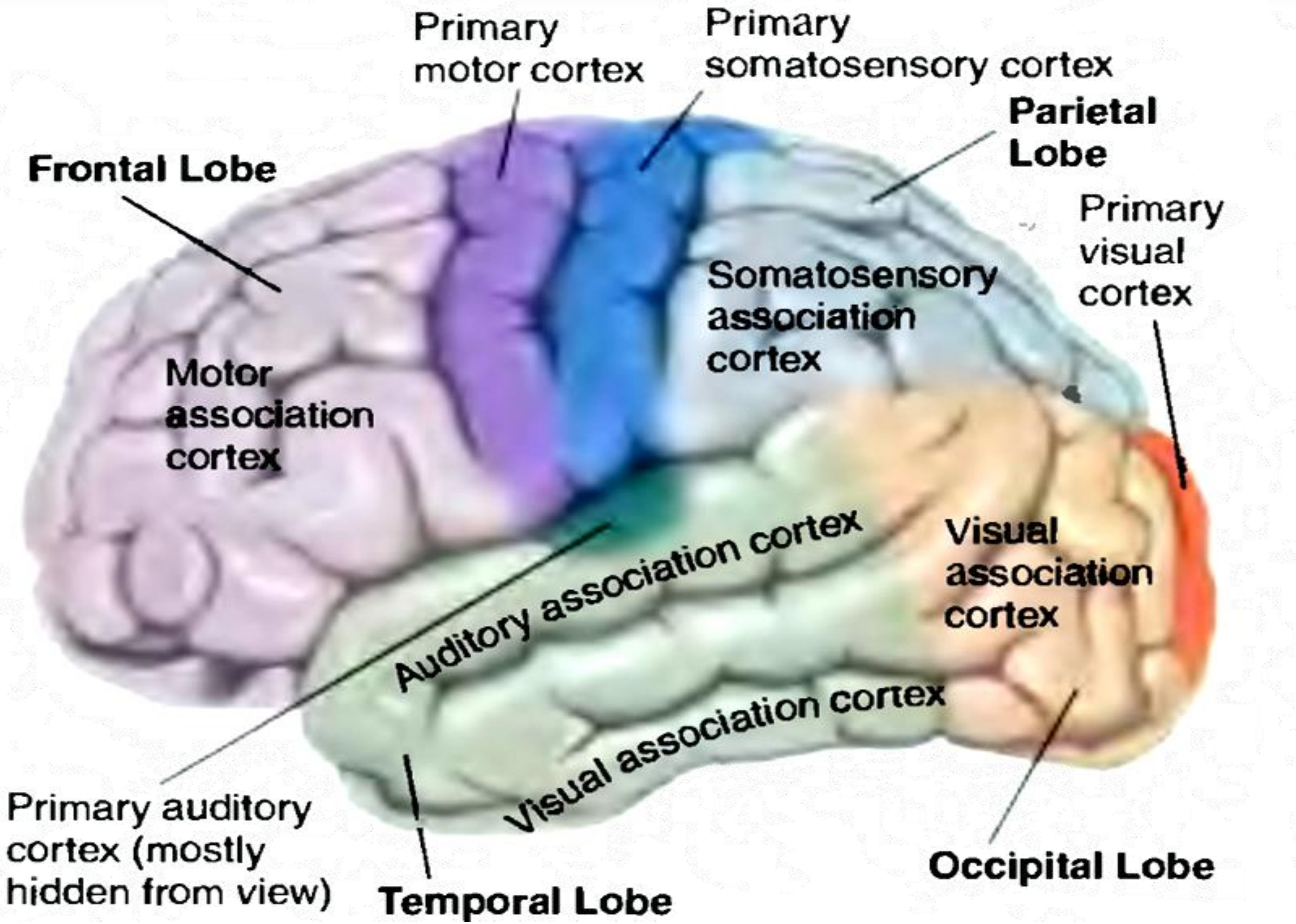


Figure — Main functional areas of the cerebral cortex

The cortex has regions with less definite functions. A significant part of the frontal lobes, especially on the right, can be removed without visible disorders. However, removal of both the frontal lobes causes serious mental disorders.

The presence of structurally various areas in the cortex assumes their different functional value.

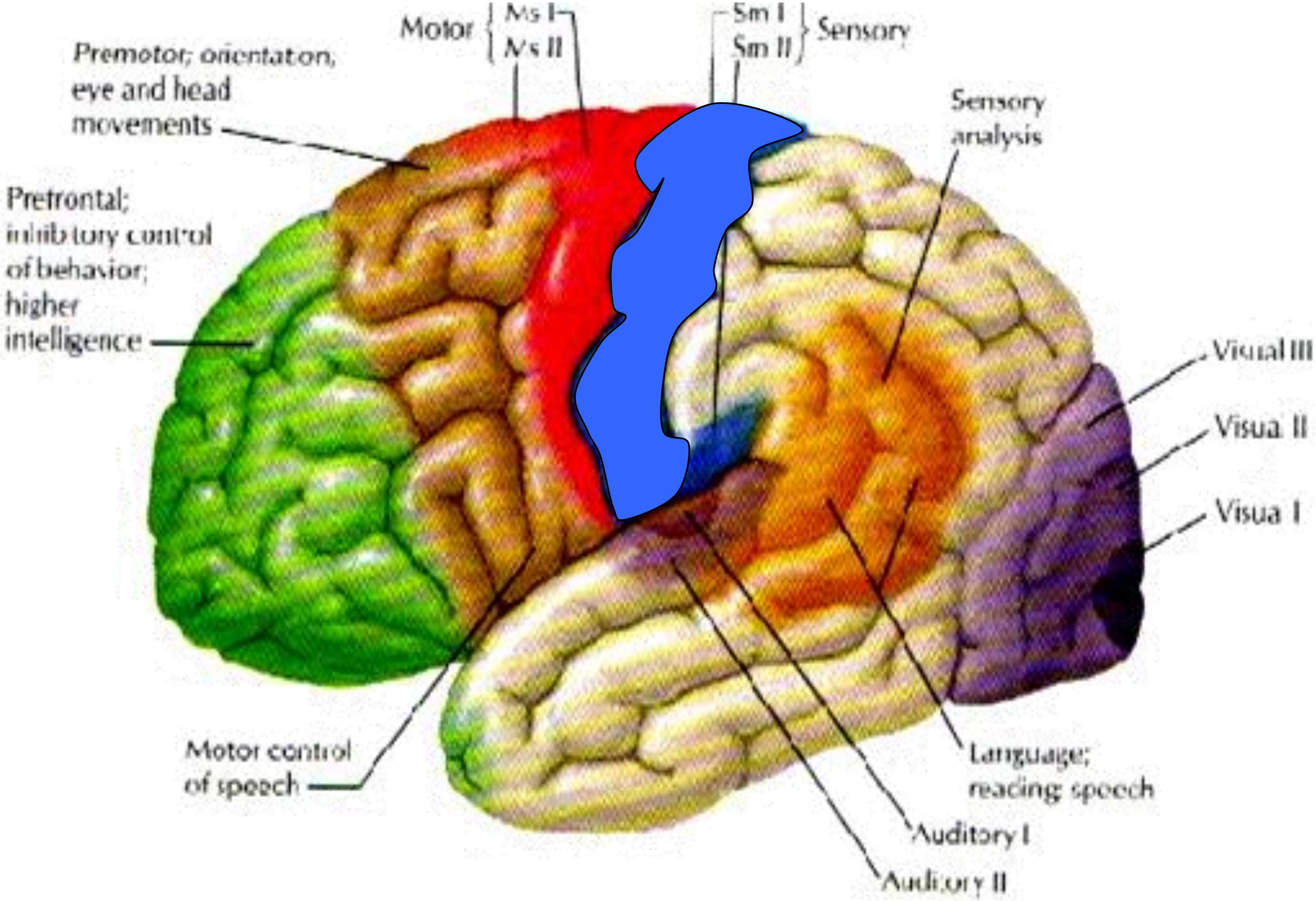
Sensory regions. Each hemisphere has two sensory regions:

1. *Somatic* (dermal, muscular, joint sensitivity).

2*. Visceral* (impulses from the internal organs come here).

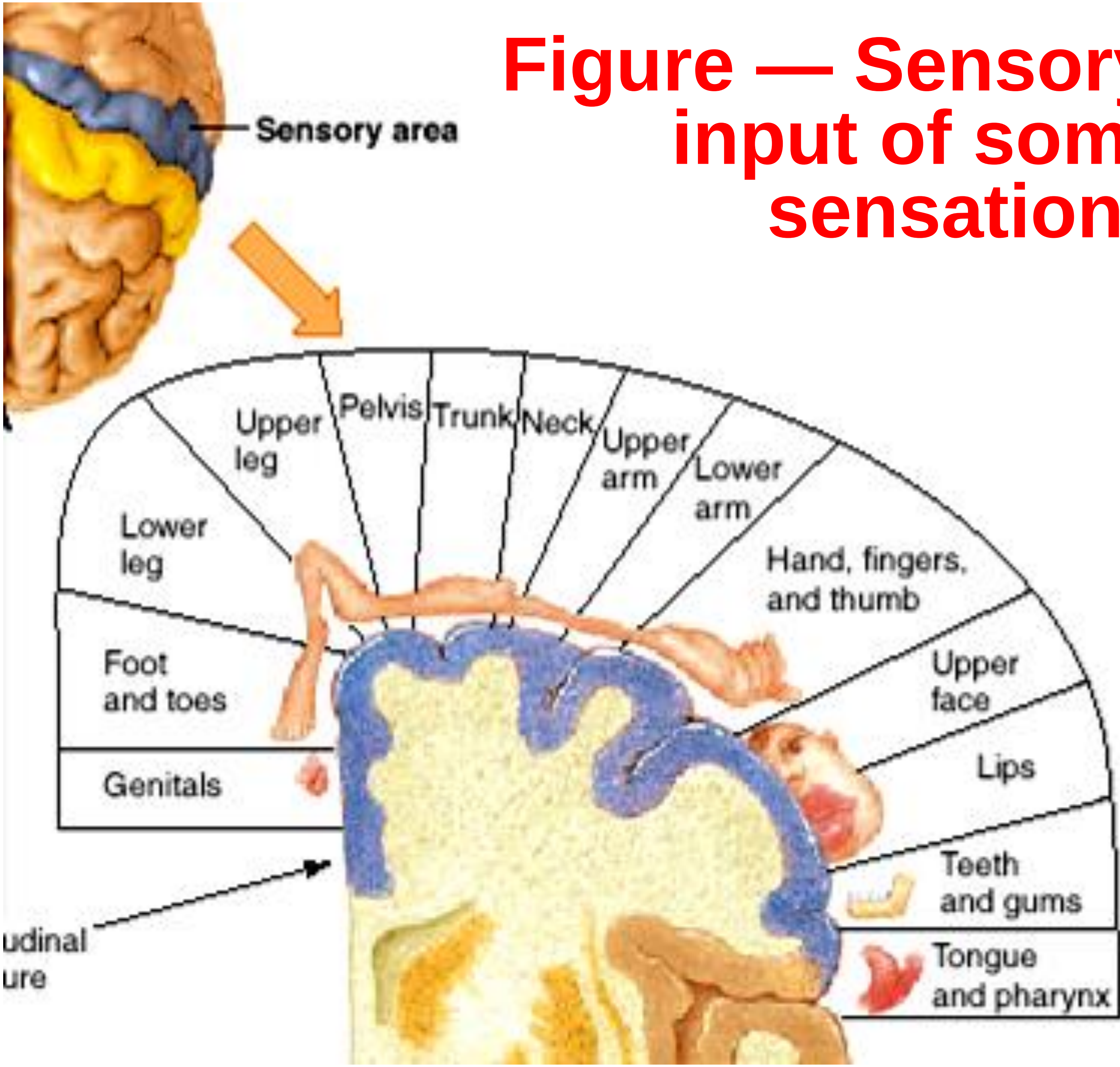
The somatic region is located in the area of the ***postcentral gyrus***. Information from the skin and organs of the locomotor system comes here from the specific nuclei of the thalamus. The dermal receptor system is projected to the posterior central gyrus.

Figure — The somatosensory area: postcentral gyrus



The receptive fields of the skin of the lower extremities are projected to the superior parts of this gyrus, receptive fields of the body — to the medium parts, and those of the hand and head — to the lower fields. Removal of certain fields of this region results in a loss of sensitivity of the corresponding organ. The area of the somatic cortex which is responsible for the work of the finger muscles, facial mimic muscles, vocal apparatus occupy the larger part than that responsible for the work of the muscles of the hips, legs, and trunk since they have less receptors.

Figure — Sensory cortex: input of somatic sensations



The second somatosensory region is localized in the ***zone of the sylvian sulcus***. In this region integration and critical assessment of information from the specific nuclei of the thalamus take place. For example, the visual area is localized in the occipital lobe within the area of the calcarine sulcus. The acoustic system is projected to the transverse temporal gyruses (Heschl’s gyrus).

Figure — The visual sensory cortex area

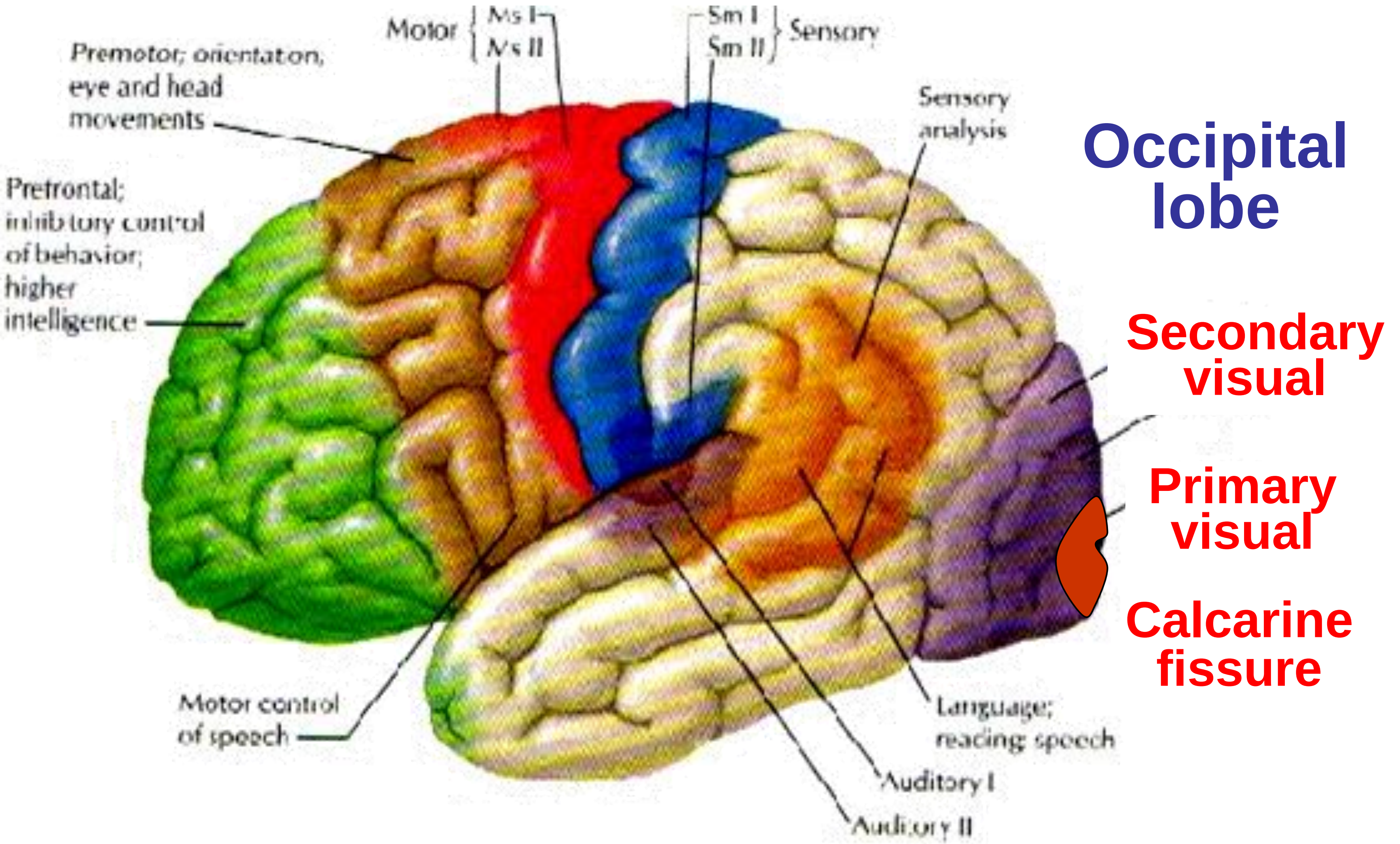
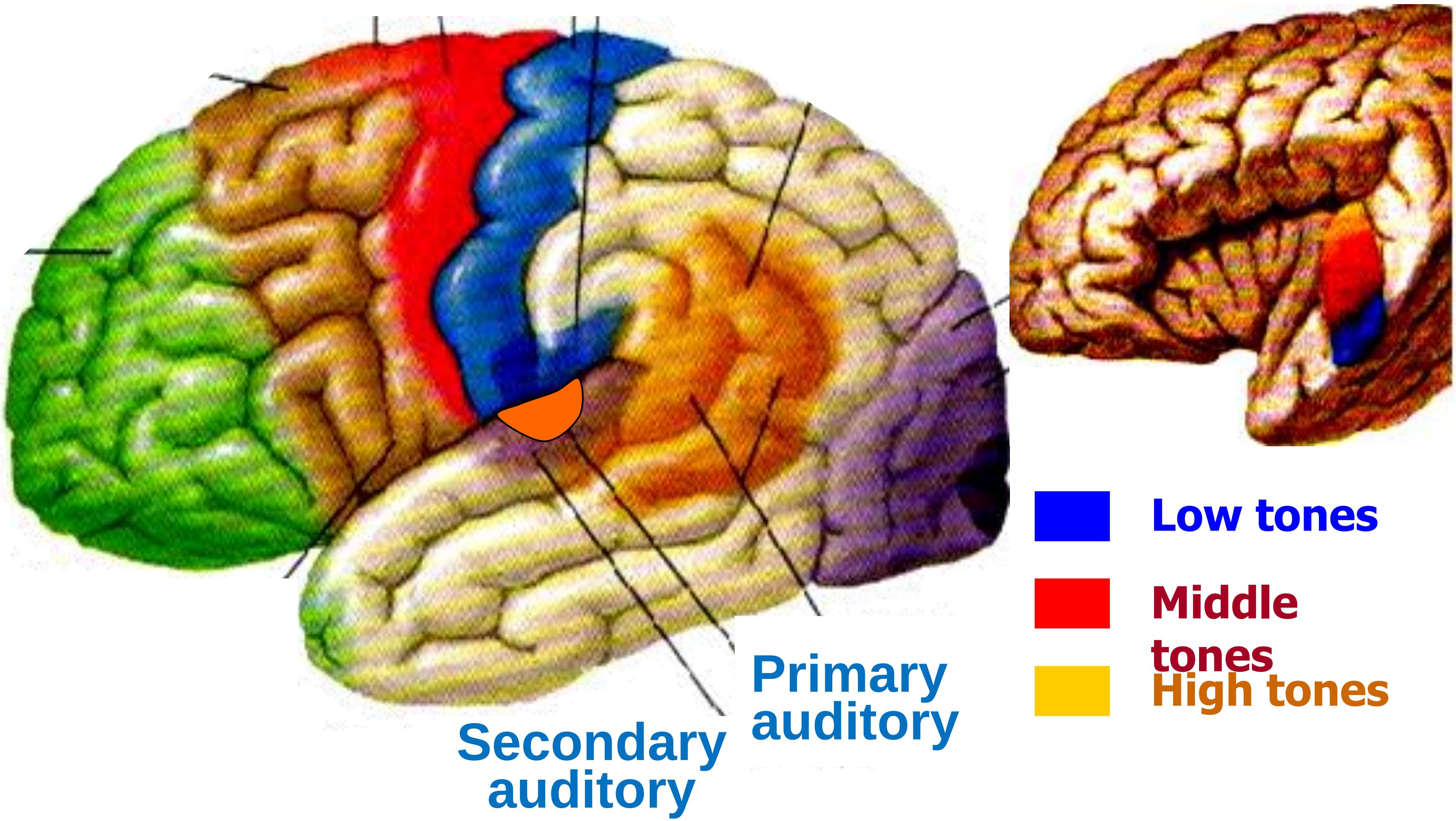


Figure — The auditory sensory cortex area: *superior temporal gyrus*



The cortex contains the ***projective regions of analyzers***. By the structure and functional value, they are divided into 3 basic groups of areas:

1. ***Primary areas*** (nuclear regions of analyzers).
2. ***Secondary areas*.**
3. ***Tertiary areas*.**

The primary *areas* are connected with the organs of sense and motions. They develop first. Pavlov called them the nuclear regions of analyzers. They perform the initial analysis of separate signals which come to the cortex. **If the primary areas to which information comes from the organs of vision or audition are affected, there comes cortical blindness or deafness.**

The secondary areas are the peripheral regions of the analyzers. They are localized near the primary areas and connected with the sense organs through the primary areas. In these areas generalization and further processing of information take place. **If the secondary areas are affected, a person can see, hear, but is not able to understand the meaning of signals.**

The tertiary areas are the regions where analyzers are overlapped. They are located on the borders of the parietal, temporal, and occipital regions and also in the region of the frontal lobes. In the process of ontogenesis they develop after the primary and secondary areas. The development of the tertiary areas is connected with speech. These areas ensure balanced work of both the cerebral hemispheres. Here, ***the highest analysis and synthesis of information, task and problem solution take place.*** The tertiary areas have major communications.

The motor area of the cortex is located in the ***anterior central gyrus***. The pyramidal tract originates here. Damage to this area of the cortex results in imbalanced voluntary movements. Through the associative pathways the motor area is connected with other sensory zones of the opposite hemisphere.

Figure — The motor area: precentral gyrus

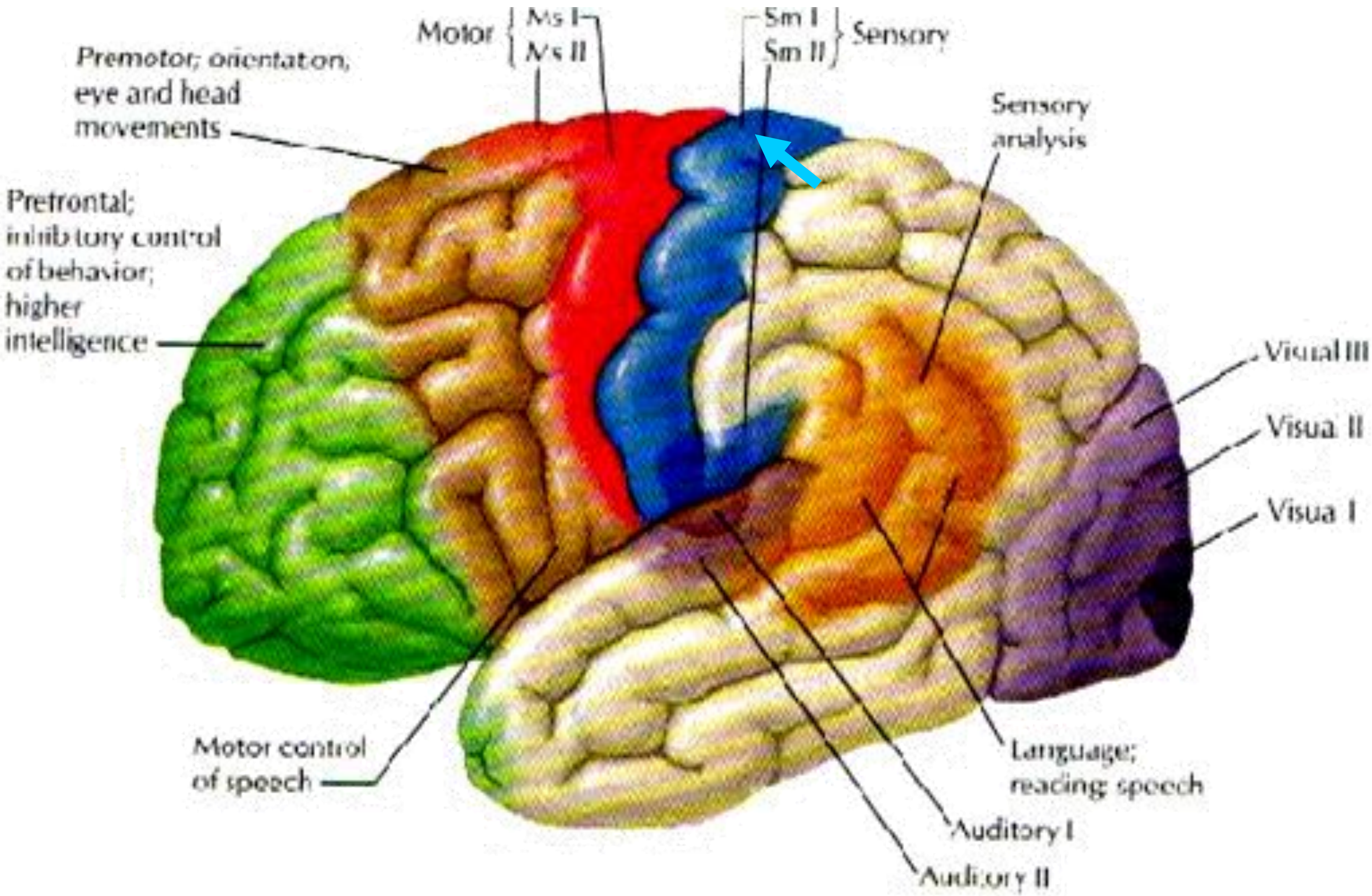
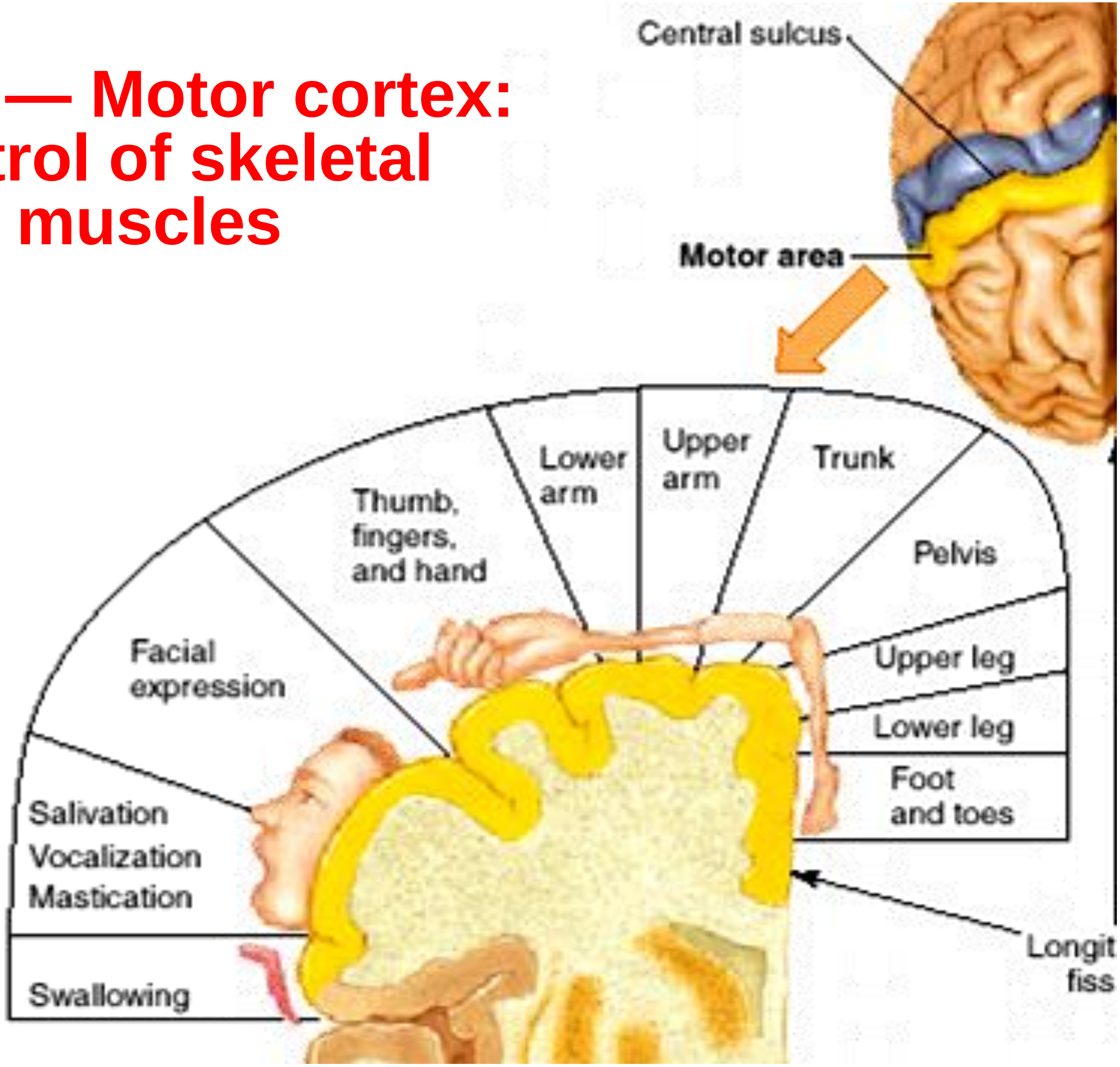
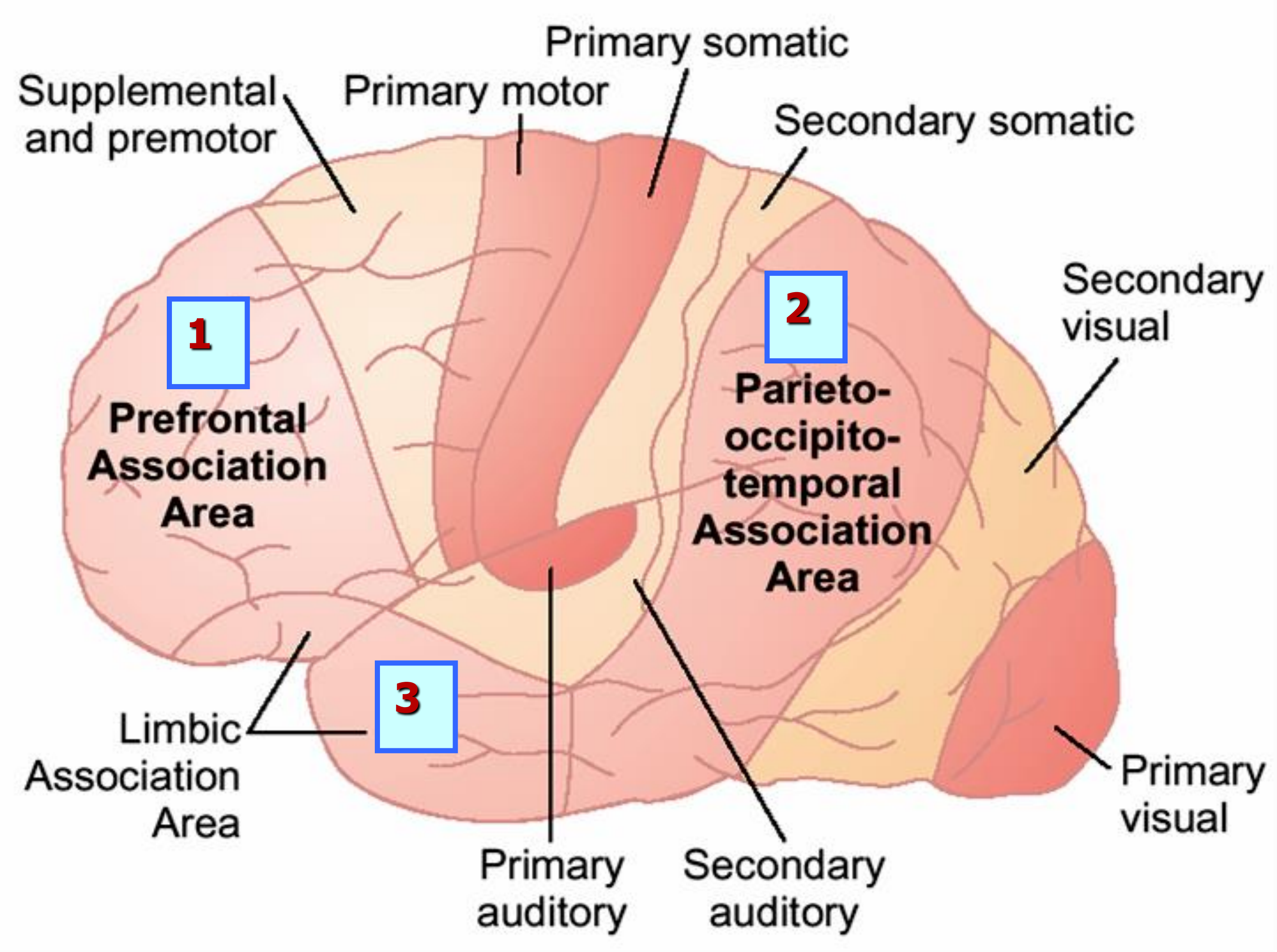


Figure — Motor cortex: control of skeletal muscles

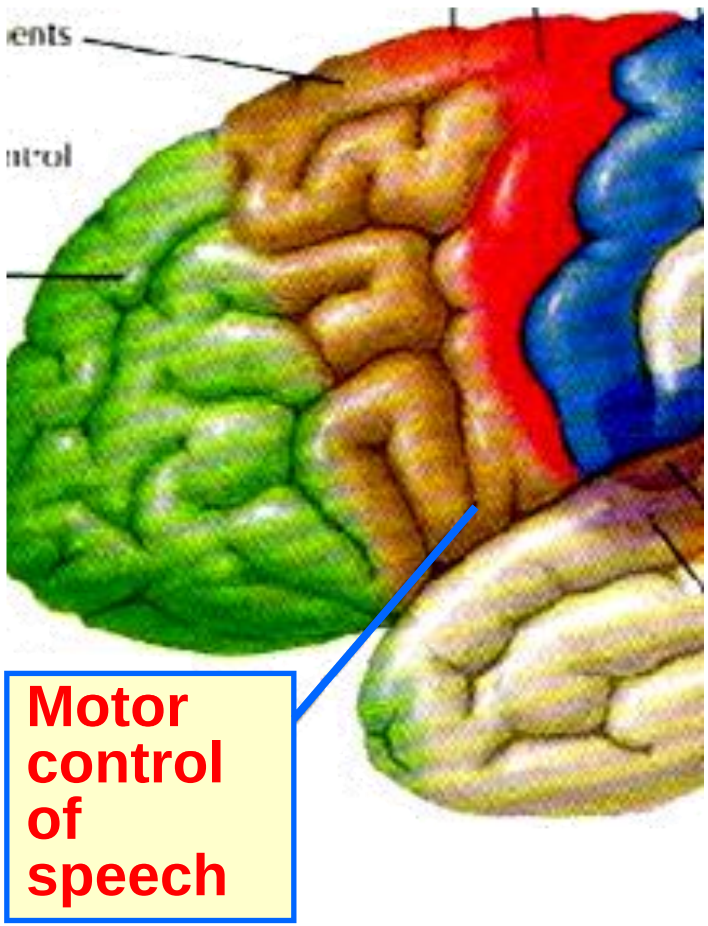


All the sensory and motor areas occupy less than 20 % of the cortex surface. The rest of the cortex organizes the **associative area**. Each associative area of the cortex is connected with several projective regions. The associative area of the cortex includes some part of the parietal, frontal and temporal lobes. The borders of the associative area are not clear. Its neurons participate in integration of diverse information. The highest analysis and synthesis of stimuli take place here thus resulting in the formation of complex elements of consciousness. The parietal part of the cortex participates in the assessment of the biological value of information and space perception.

Figure — The associative cortex areas

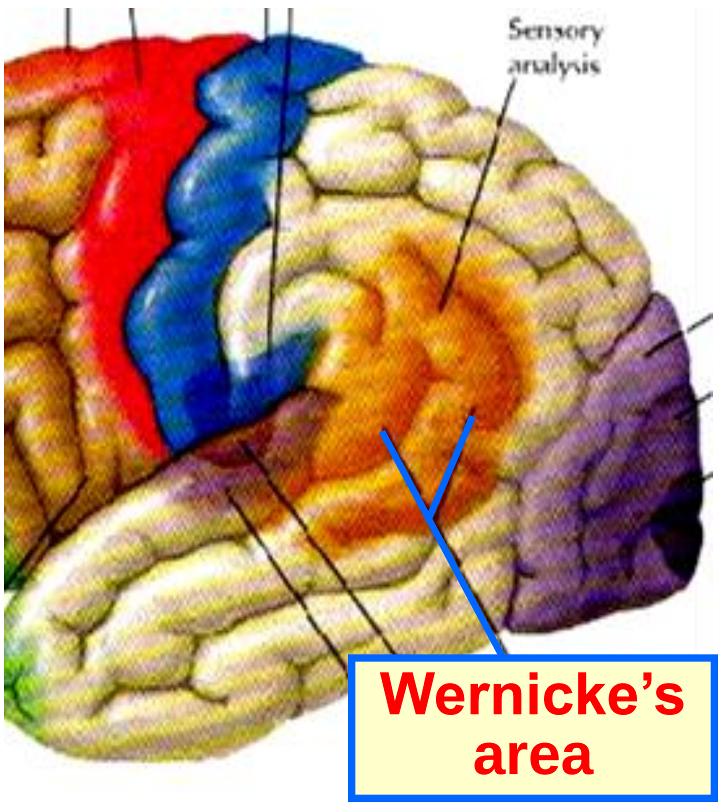


Functions of the prefrontal associative area



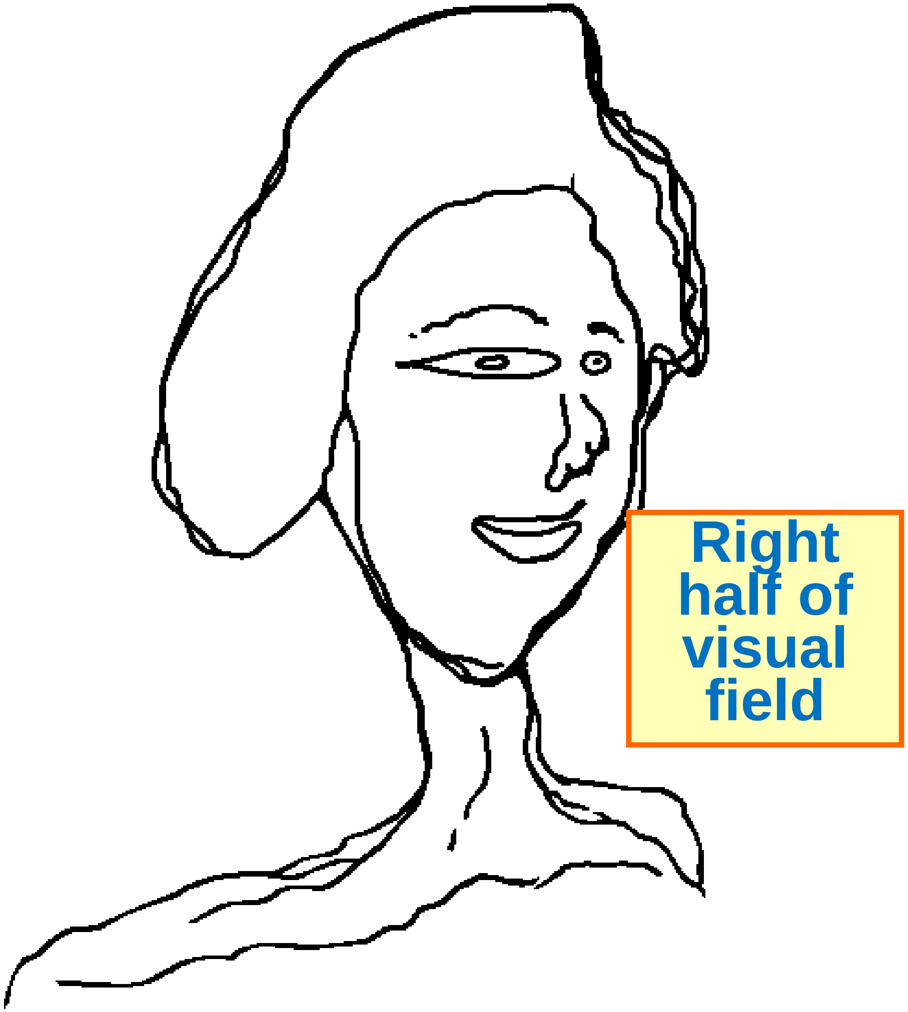
- Planning of complex movements.
- Elaboration of thoughts.
- Planning and decision making.
- Working memory.
- Motor control of speech.
- Inhibitory control of behavior.

Functions of the parieto-occipito-temporal associative area



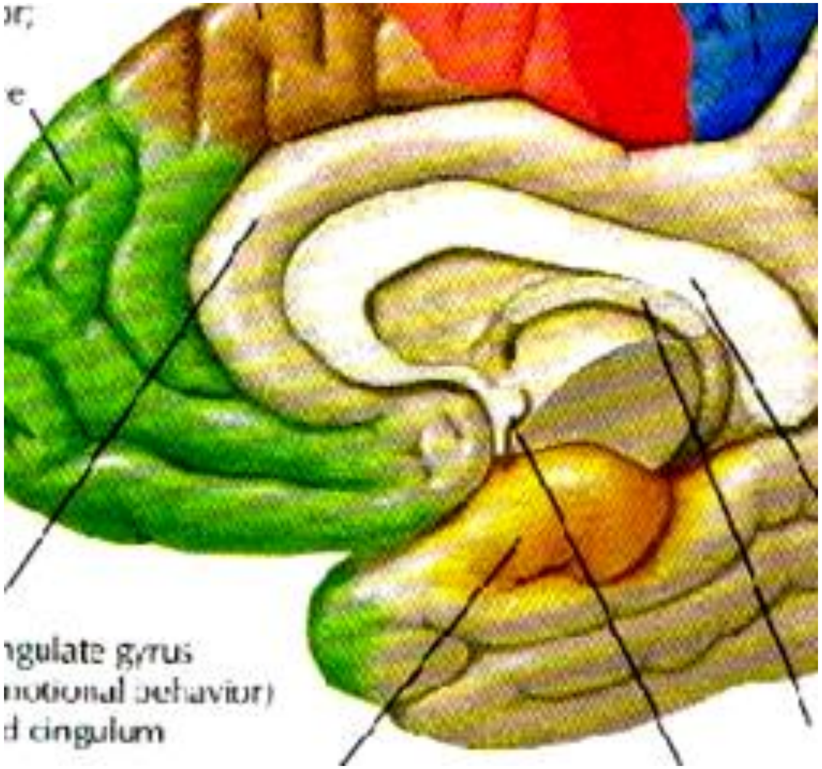
- **Integration of sensory information**
- **Posterior part of the superior temporal gyrus:**
  the sensory center of speech
- **Posterior parietal area:**
  spatial coordinates of body and surroundings;
  visual processing of words
- **Inferior temporal area:**
  images of objects and their naming

Parietal cortex damage: example of consequences



Typical drawing that might be made by a person who has severe damage of the left parietal cortex where the spatial coordinates of the right half of visual field are stored.

Functions of the limbic associative area



- Behavior control
- Emotions
- Motivations

Speech centers of the cortex

Speech is used by humans as the second signaling system.

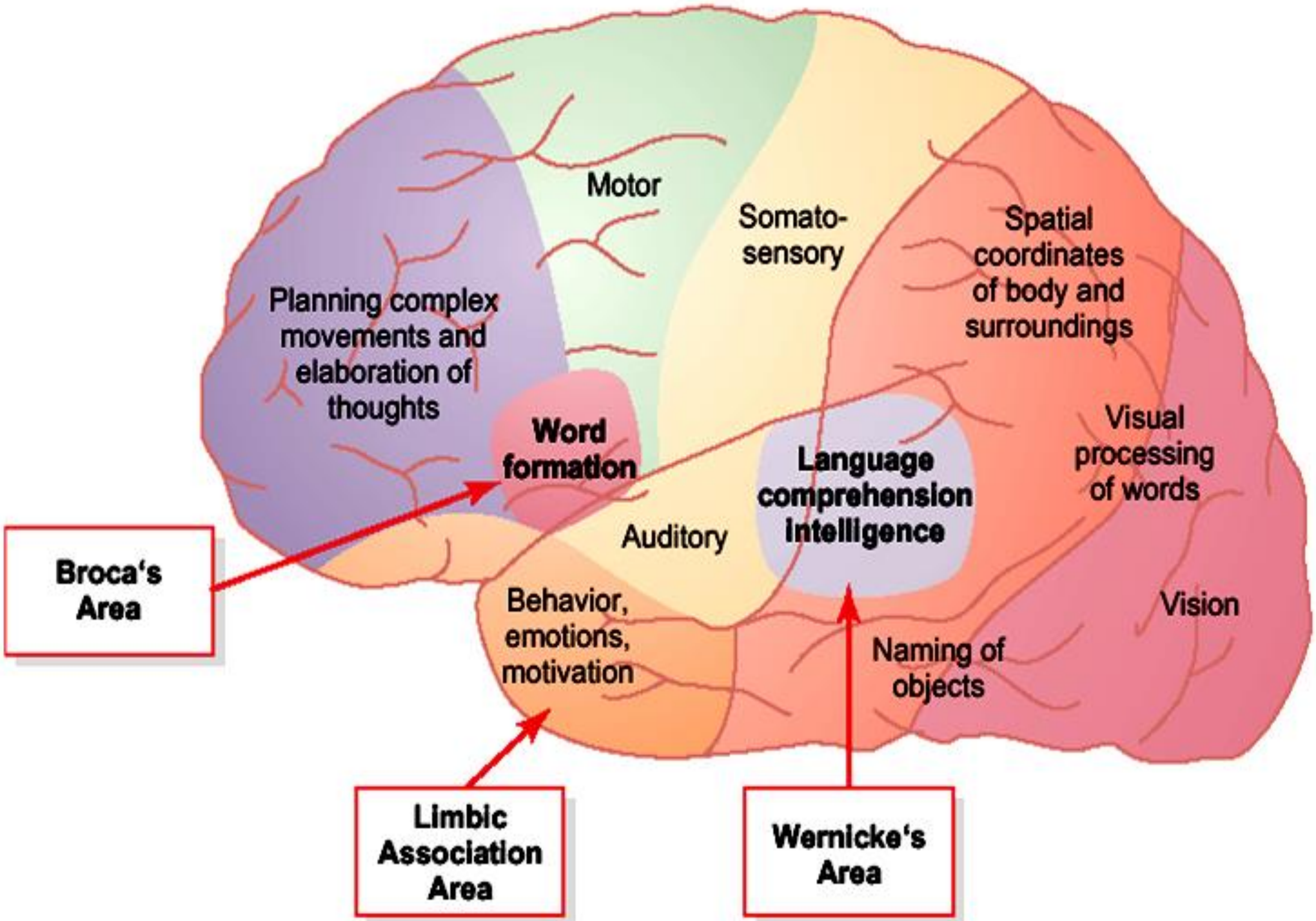
Speech and language functions are connected with both the motor and sensory areas. The functions of the sensory and motor speech areas are usually much more highly developed in one cerebral hemisphere than in the other**. In 95 % people the centers of speech are located in the left hemisphere of the brain.**

Broca's area (the motor center of spoken speech) is located in the posterior part of the inferior frontal gyrus and controls the motor functions involved in speech production and language comprehension. Damage to Broca's area causes motor aphasia. In this type of aphasia a person may understand speech and know what they want to say but cannot make the vocal system emit words.

Wernicke's area (the sensory center of speech) is located in the posterior superior temporal gyrus. It provides auditory comprehension of speech. Damage to Wernicke's area causes sensory aphasia. In this type of aphasia a person has difficulty understanding language and is unable to arrange words into a coherent thought.

The angular gyrus is associated with the processing of visually perceived words (reading).

Figure — Localization of functions in cortex areas



The two speech cortex areas

Sensory center of speech Wernicke's area	Speech comprehension and abstract thinking
Motor center of speech Broca's area	Words formation and control of vocalization

Figure — Transfer of sensory information from primary sensory to associative cortex areas and finally to **Wernicke's area**

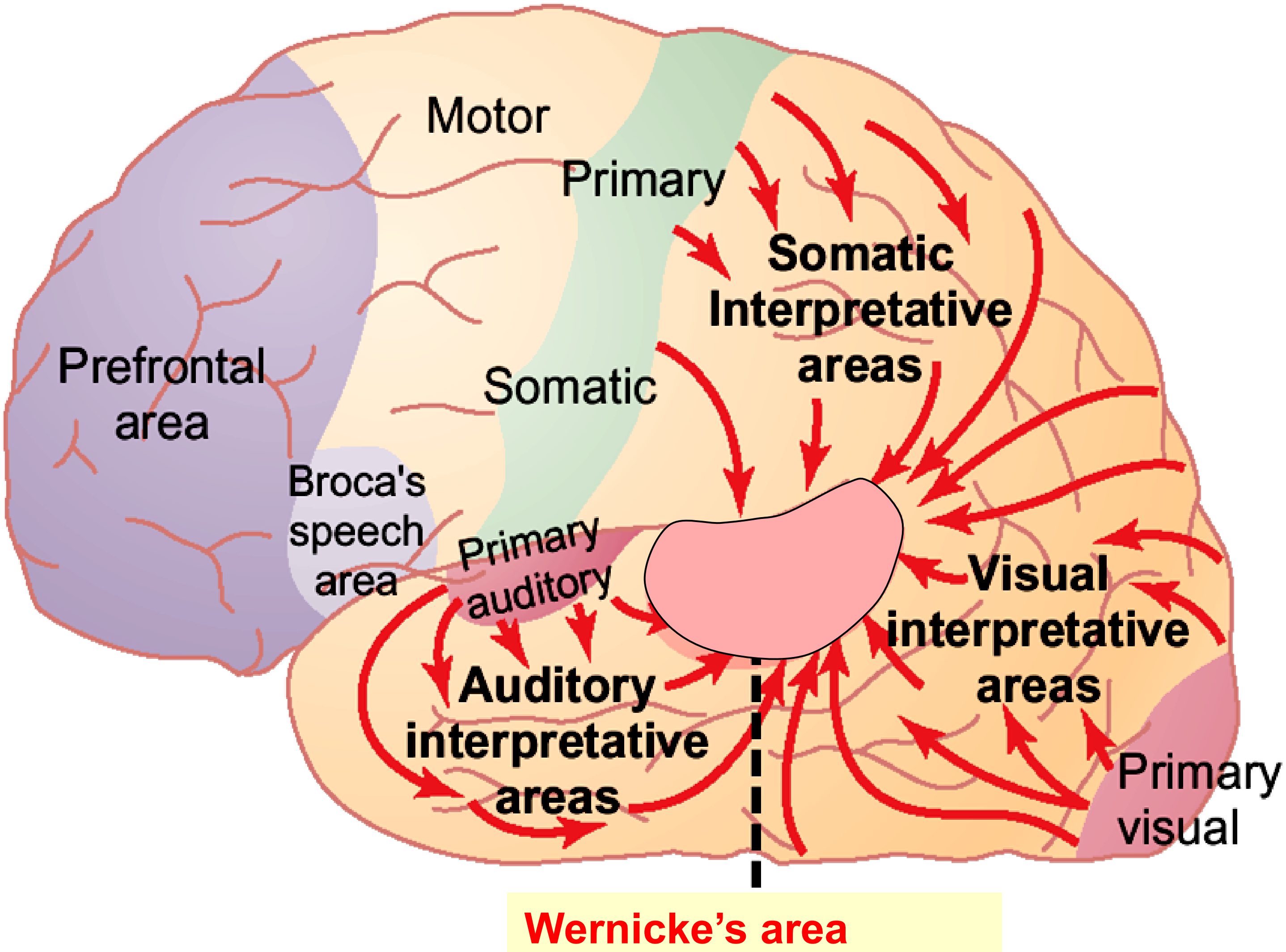


Figure — Brain pathways for auditory perceiving a word and then speaking it

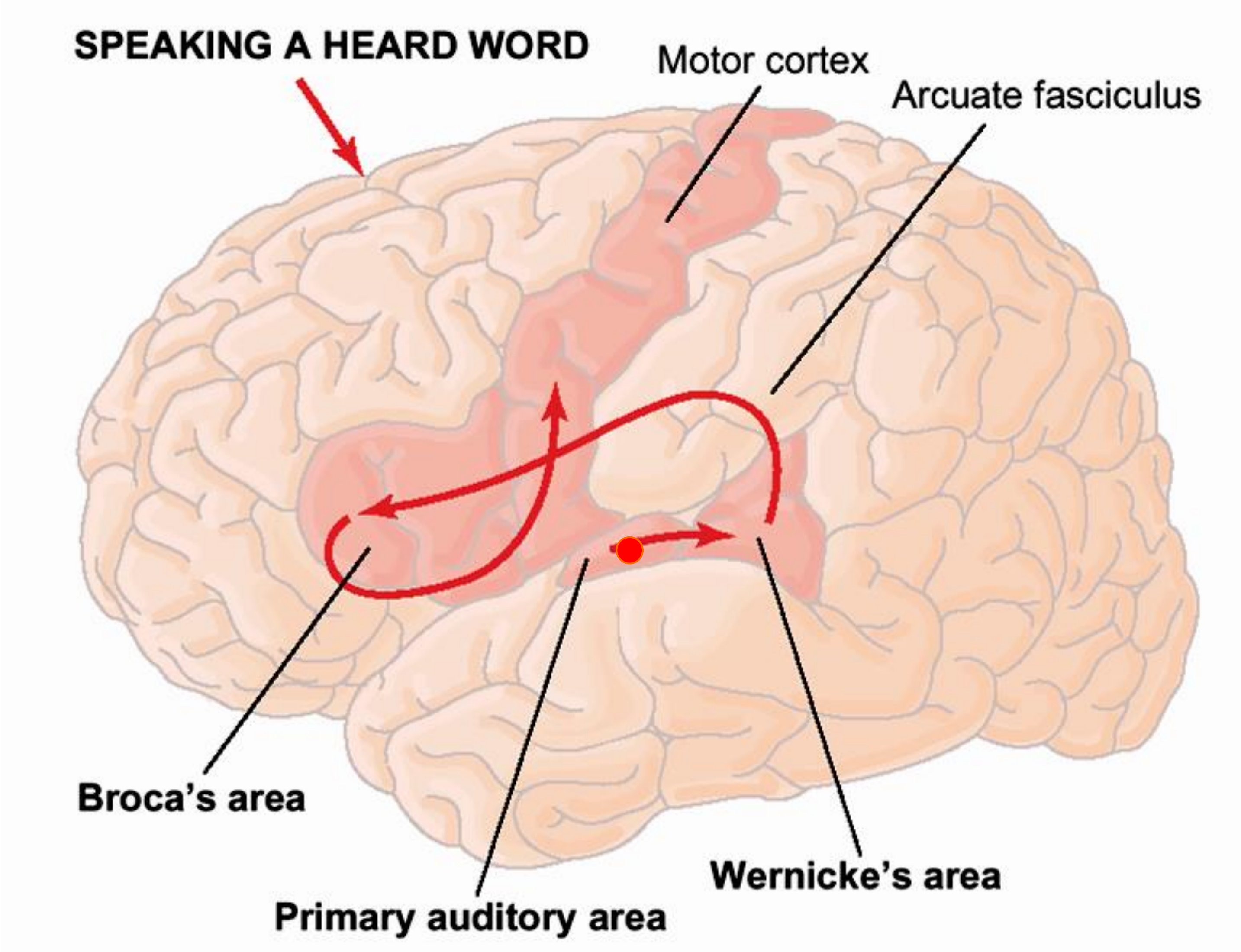
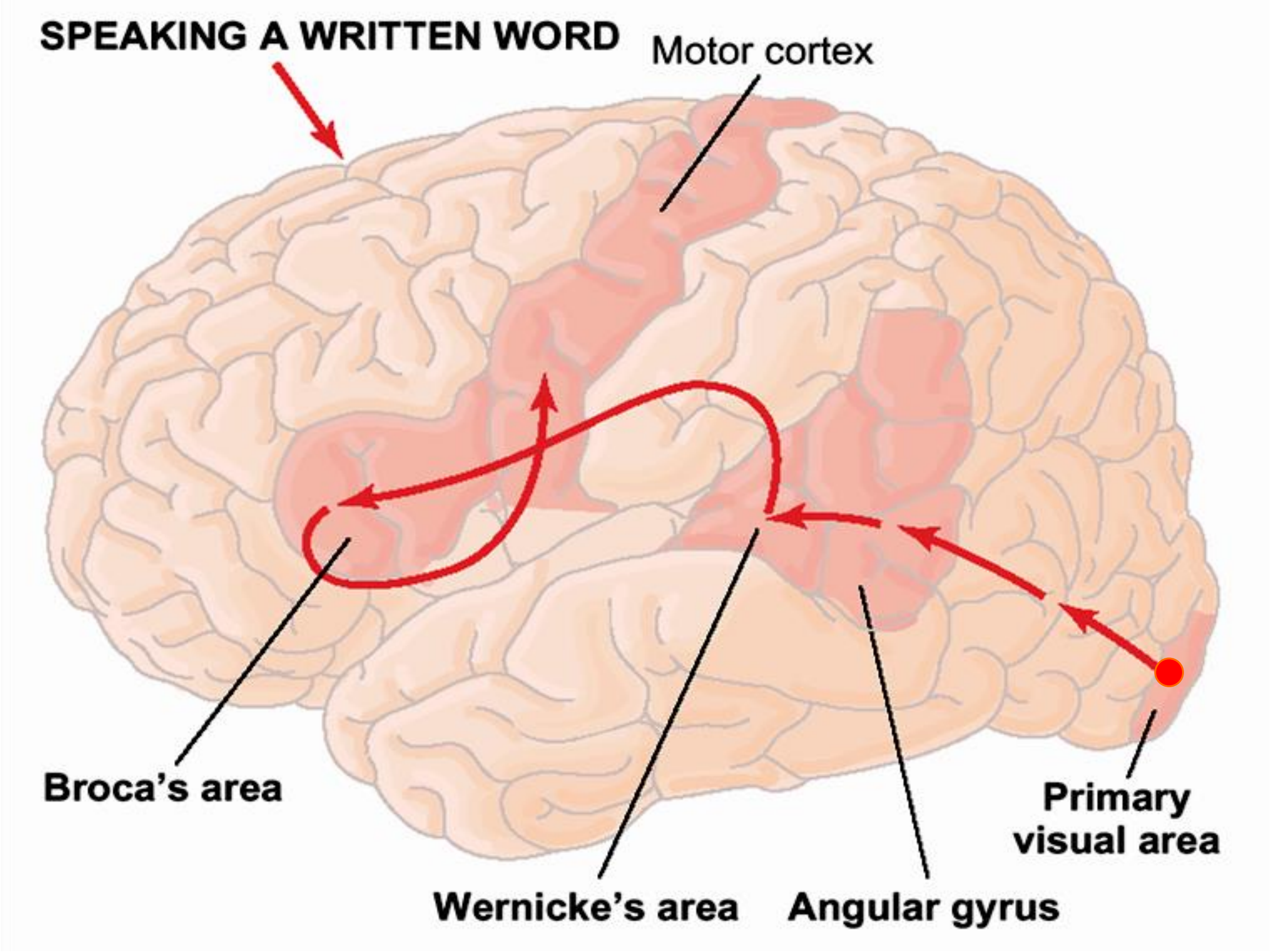


Figure — Brain pathways for visual perceiving a word and then speaking it



The aphasias

Broca's aphasia (motor)

- Halting speech.
- Disordered syntax and grammar.
- Normal comprehension

Wernicke's aphasia (sensory)

- Fluent speech.
- Adequate syntax and grammar.
- Impaired comprehension

Electrical activity of the cortex of the cerebrum

Changes in the functional state of the cortex influence its biological potentials. Spontaneous electrical fluctuations which have certain periodicity are called ***electroencephalography (EEG).***

In 1924, Berger succeeded in recording the first human electroencephalogram. An electrode which registers the total activity of the cortex and subcortical structures is applied to certain points of the skin surface in the frontal, parietal, occipital fields. EEG is widely used in clinical practice, as it allows to determine the state of the cortex, ***to obtain information about the depth of narcosis and localization of a pathological process***.

There are following EEG rhythms (Figure):

Alpha-rhythm — frequency of 8–13 Hz, voltage — 50 mV. This rhythm is registered at rest and is fully present only when a person is mentally inactive, with eyes closed.

Beta-rhythm — frequency of 14–30 Hz, voltage — 25 mV. This rhythm is observed in a person upon sensory stimulation, especially with light, or when they are engaged in purposeful mental activity and indicates desynchronization of the cortex.

Theta-rhythm — frequency of 4–7 Hz, voltage — 100–300 mV. It is observed during various states of light sleep or arousal.

Delta-rhythm — frequency of 3–5 Hz, voltage — 100–300 mV. It is registered during deep sleep, loss of consciousness, narcosis. In people who do not sleep the delta-rhythm is not registered, however it is typical for the hippocampus even in an active state.

EEG does not evaluate human mental capabilities.

Figure — EEG registration

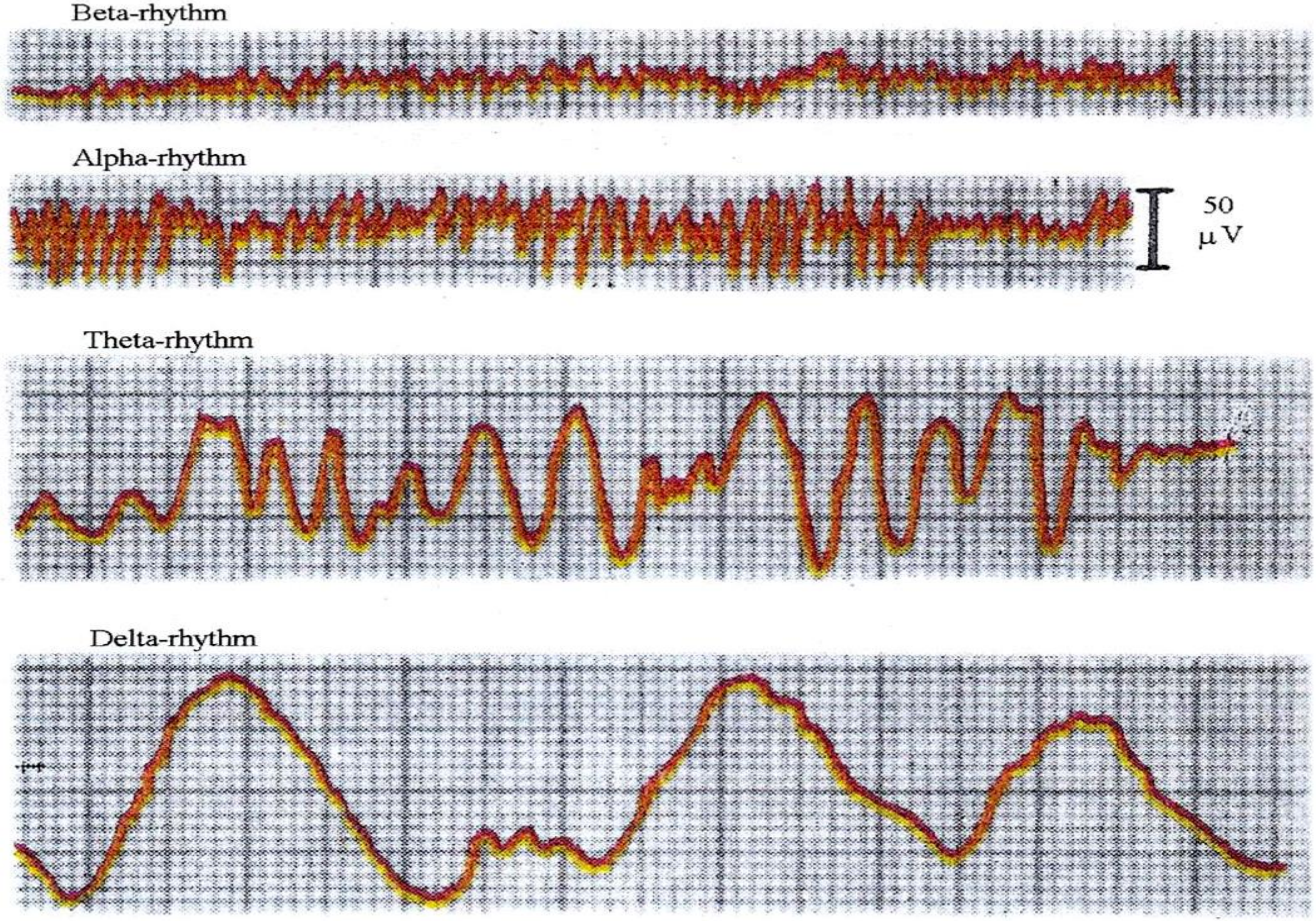


Figure — The EEG rhythms

Functional asymmetry of the cortex

The functional asymmetry of the cortex or cerebral asymmetry refers to anatomical, physiological, or behavioral differences between the two cerebral hemispheres.

There are 3 kinds of asymmetry:

1. ***Motor*** — unequal motor activity of the muscles of the right and the left halves of the body. For example, in people who tend to do everything with their left hand, the functional activity of the right hemisphere of the cortex dominates, and vice versa.

2. ***Sensory*** — unequal perception of information by the right and the left hemispheres of the cortex.

3. ***Mental***. People with the *dominant left hemisphere* are logical, analytical in nature and more academically inclined, purposeful and capable to make predictions.

People with the *dominant right hemisphere prefer* certain kinds of activity, are slow, intuitive, thoughtful, sentimental.

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People with the *dominant right hemisphere prefer* certain kinds of activity, are slow, intuitive, thoughtful, sentimental.

Recently, the concept of the mutual influence of both the hemispheres of the cortex has been accepted. It means that domination of either hemisphere can be expressed only in one kind of activity.

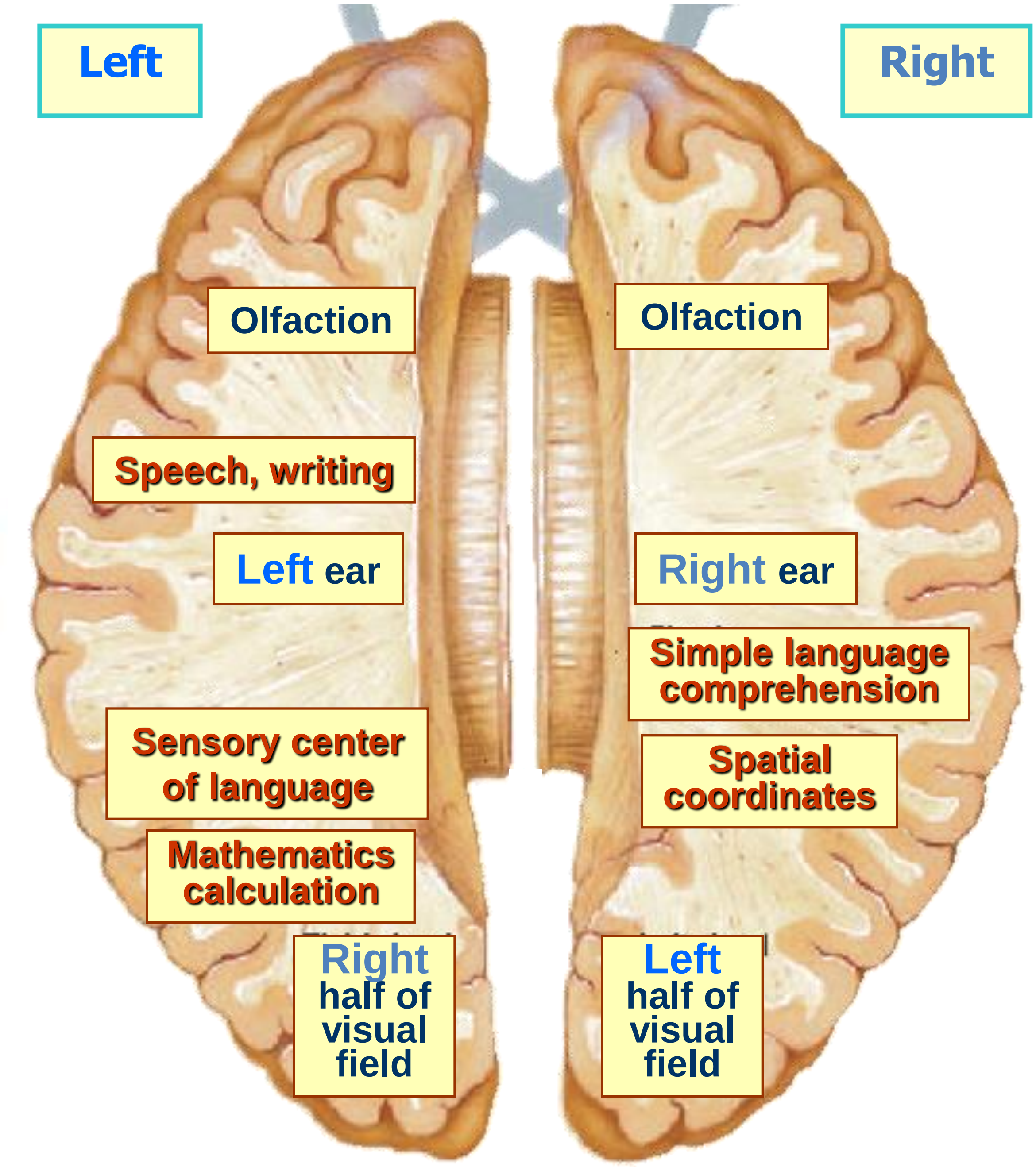


Figure — Functions of right and left brain hemispheres: asymmetry and dominance

The division of functions between hemispheres: symmetrical functions

Left hemisphere

- **Analysis of right visual field.**
- **Stereognosis (right hand).**

Right hemisphere

- **Analysis of left visual field.**
- **Stereognosis (left hand).**

The division of functions between hemispheres: asymmetrical functions

Left hemisphere

- Speech.
- Writing.
- Lexical and syntactic language.
- Calculations.

Right hemisphere

- Primitive speech only.
- Emotional coloring of language.
- Spatial abilities.
- Perception of music.
- Recognition of faces.

2. Autonomic (vegetative) nervous system

Morpho-functional characteristics of the vegetative nervous system

By the functional value, the nervous system is divided into:

Somatic —performs the motor and sensory functions.

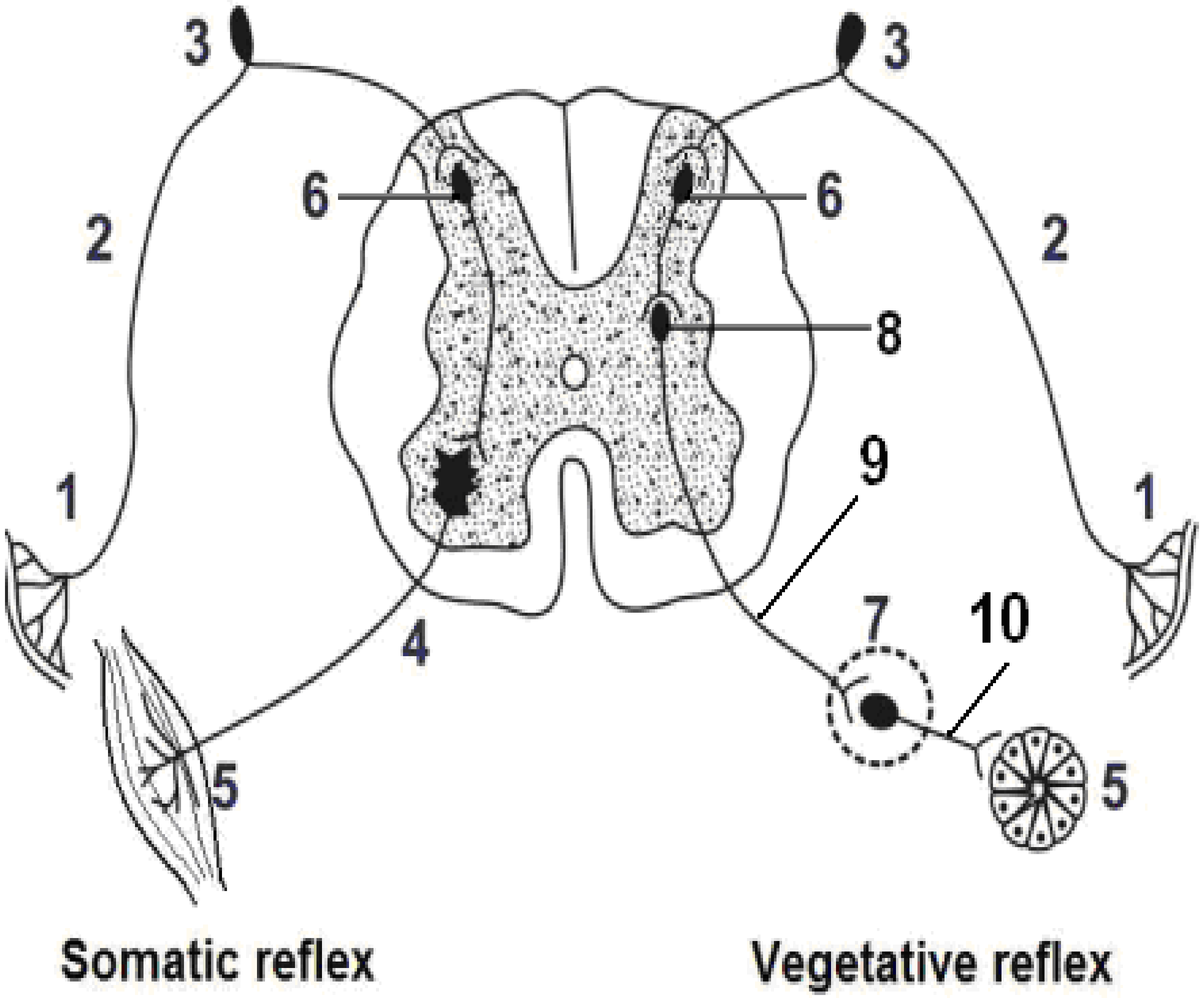
Vegetative — regulates the activity of the internal organs and supply trophicity of skeletal muscles.

The autonomic (vegetative) nervous system (ANS) has 4 differences from the somatic system:

1. *Focal outlet of fibers* from the head and spinal cord.

2. *Absence of segmental distribution of fibers* on the periphery.

3. *Small diameter of fibers*.



4. ***Two-neuron principle*** of the structure of the efferent part of the reflex arc (Figure), i. e. preganglionic fiber forming the axon starts from the body of the ***first efferent neuron (preganglionic neuron)*** located in the CNS.

Figure — Reflex arch

Notes: 1 — receptor; 2 — afferent fiber; 3 — sensory neuron; 4 — motor neuron; 5 — working organ (muscle, gland); 6 — interneuron; 7 — vegetative ganglia; 8 — preganglionic neuron; 9 — preganglionic fiber; 10 — postganglionic fiber

In the ***vegetative ganglia,*** excitation from this neuron is conducted to the ***second efferent neuron***, from which the postganglionic fiber goes to the executing organ. However, there exist one- and three-neuron pathways. For example, the chromophilic cells of the adrenal medulla are innervated by one preganglionic fiber, and in the gastrointestinal tract the postganglionic fiber ends on the parasympathetic ganglia of the walls of the organs.

The vegetative ganglia do not only conduct signals. These are peripherally located reflex centers capable to regulate the functions of the internal organs independently, i. e. without participation of the CNS.

As per the structurally-functional properties, the <u>ANS can be divided into</u>: ***sympathetic (SNS)***, ***parasympathetic (PSNS),*** and ***metasympathetic*** *(located in the microganglia of the internal organs: heart, gastrointestinal tract, etc.).*

The division of the ANS into the sympathetic and parasympathetic parts is based upon the following principles

1. *The localization of the nerve centers* in the brain. The centers of the ***<u>PSNS</u>*** are localized ***in the midbrain and medulla***, and also in the ***sacral segments of the spinal cord***. The centers of the ***<u>SNS</u>*** are localized in ***the thoracal-lumbar segments of the spinal cord.***

2. *Influence on the functions of the organs*. The sympathetic and parasympathetic parts of the ANS more often act as functional antagonists.

3. *The location of the ganglia* in which nerve pathways terminate.

4. *The secreted mediator.*

All the parts of the ANS are controlled by the superior subcortical center of the regulation of the vegetative functions, – ***hypothalamus***. The hypothalamus is controlled by the cortex.

The efferent fibers of the ***SNS*** are accumulated in the ganglia connected to one another and forming the symmetric **paravertebral chain** (Figure).

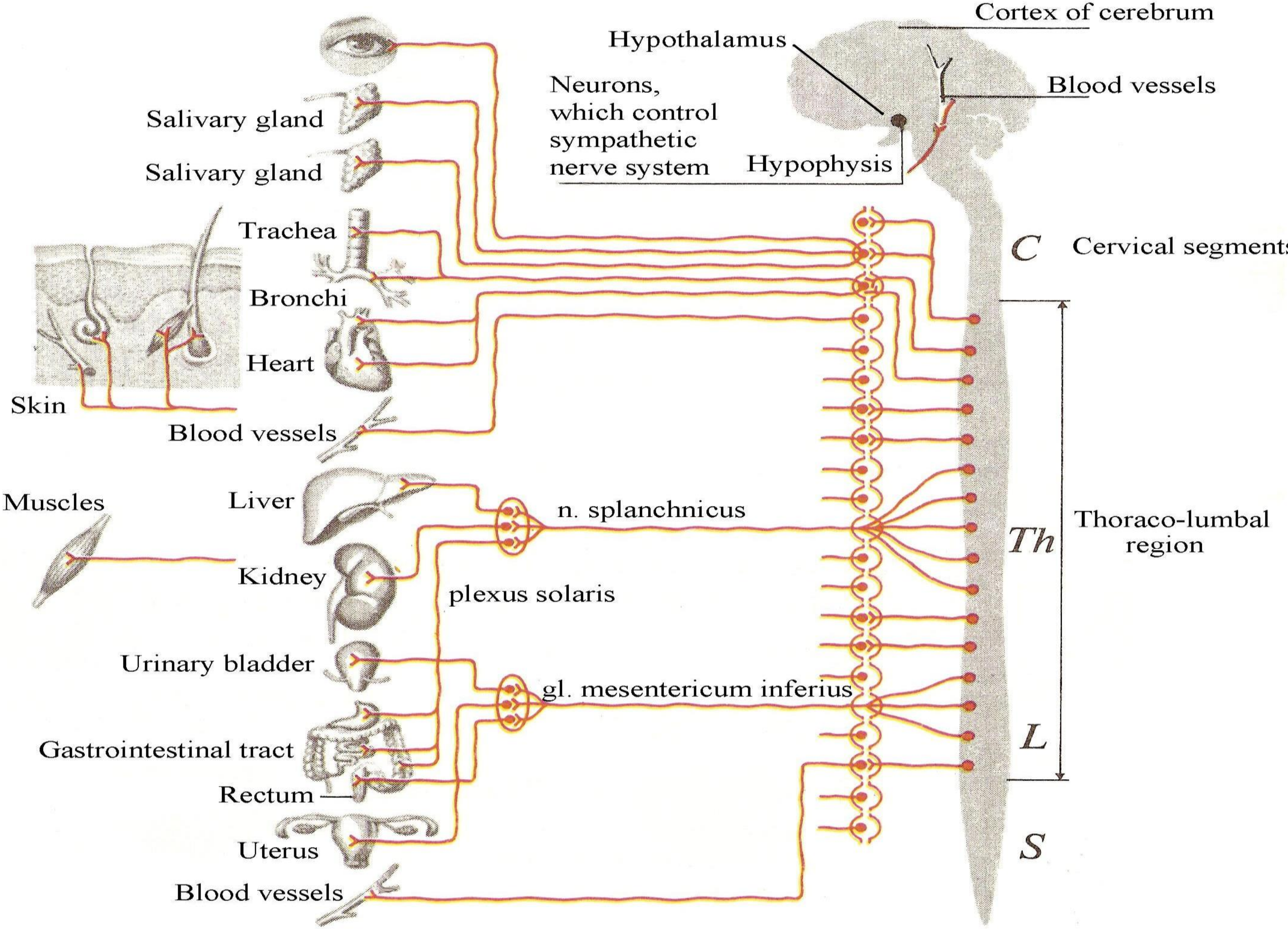


Figure — General structure of the sympathetic nervous system

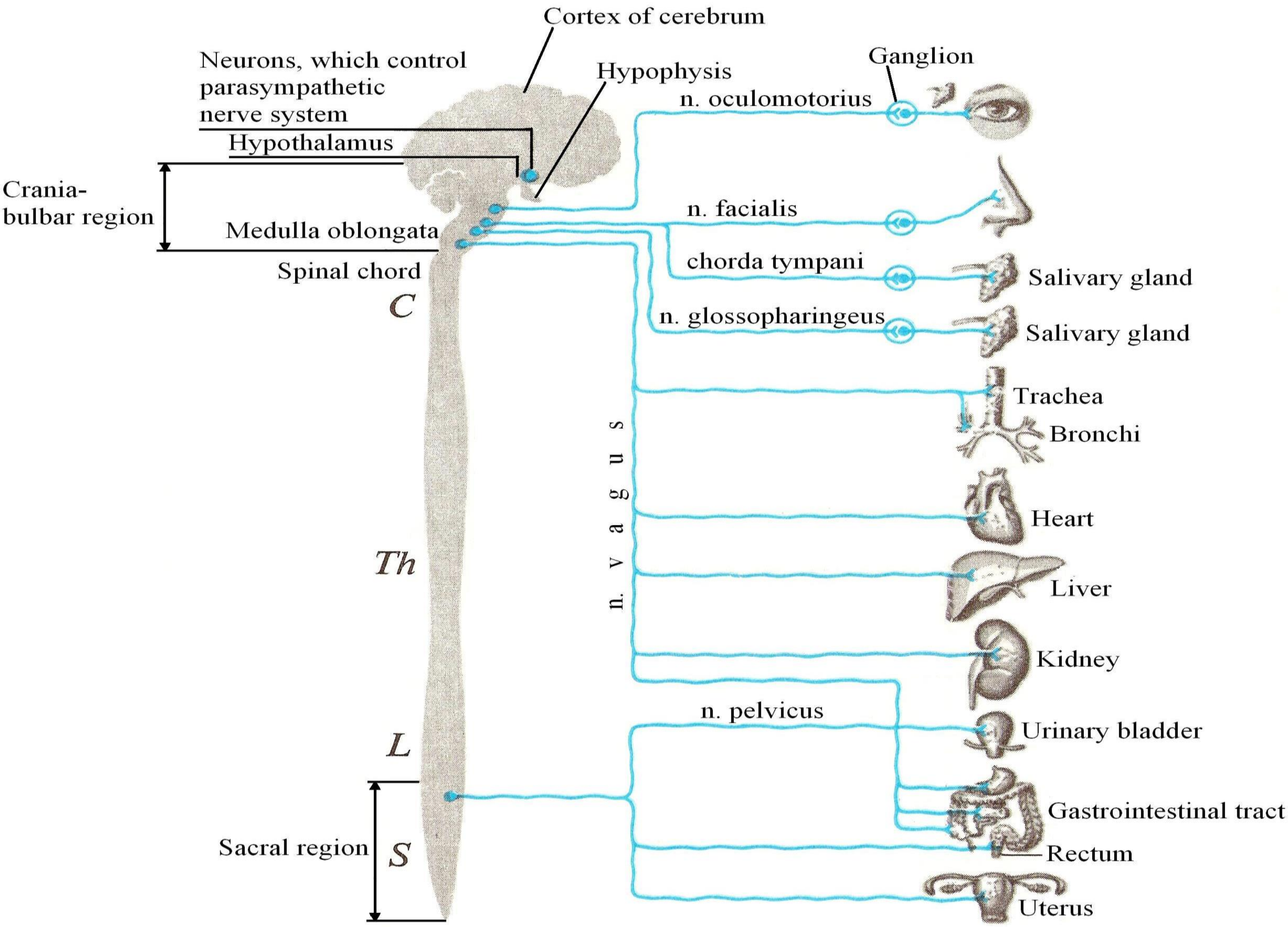


Figure — General structure of the parasympathetic nervous system

That is why the SNS acts as a whole, its stimulation goes simultaneously with changes of the functions of various organs. The neurons of the PSNS are localized in several parts of the CNS and are not connected with one another, therefore they influence the organs selectively (Figure).

Sympathetic nerve fibers are major in the human body and innervate almost all the organs. Some organs ***have only sympathetic innervation*** (*adrenals, skeletal muscles, organs of sense, CNS*), other organs have double innervation (heart, intestinal and salivary glands). If an organ is innervated only by one part of the ANS, the regulation of its functions is ensured by weakening or intensifying of the activity of this part of the ANS. In double innervation nerves provide the inverse effect and in norm these influences are balanced.

On the whole, the SNS ensures power supply to the organism. It influences the *blood flow distribution, metabolism intensification, increase of the blood glucose level,* which is necessary for adaptation of the organism to certain conditions (work, emotions, temperature or environmental fluctuations, etc.).

The PSNS constantly *corrects changes occurring in the organism induced by the SNS*, i. e. restores and maintains homeostasis (Figure).

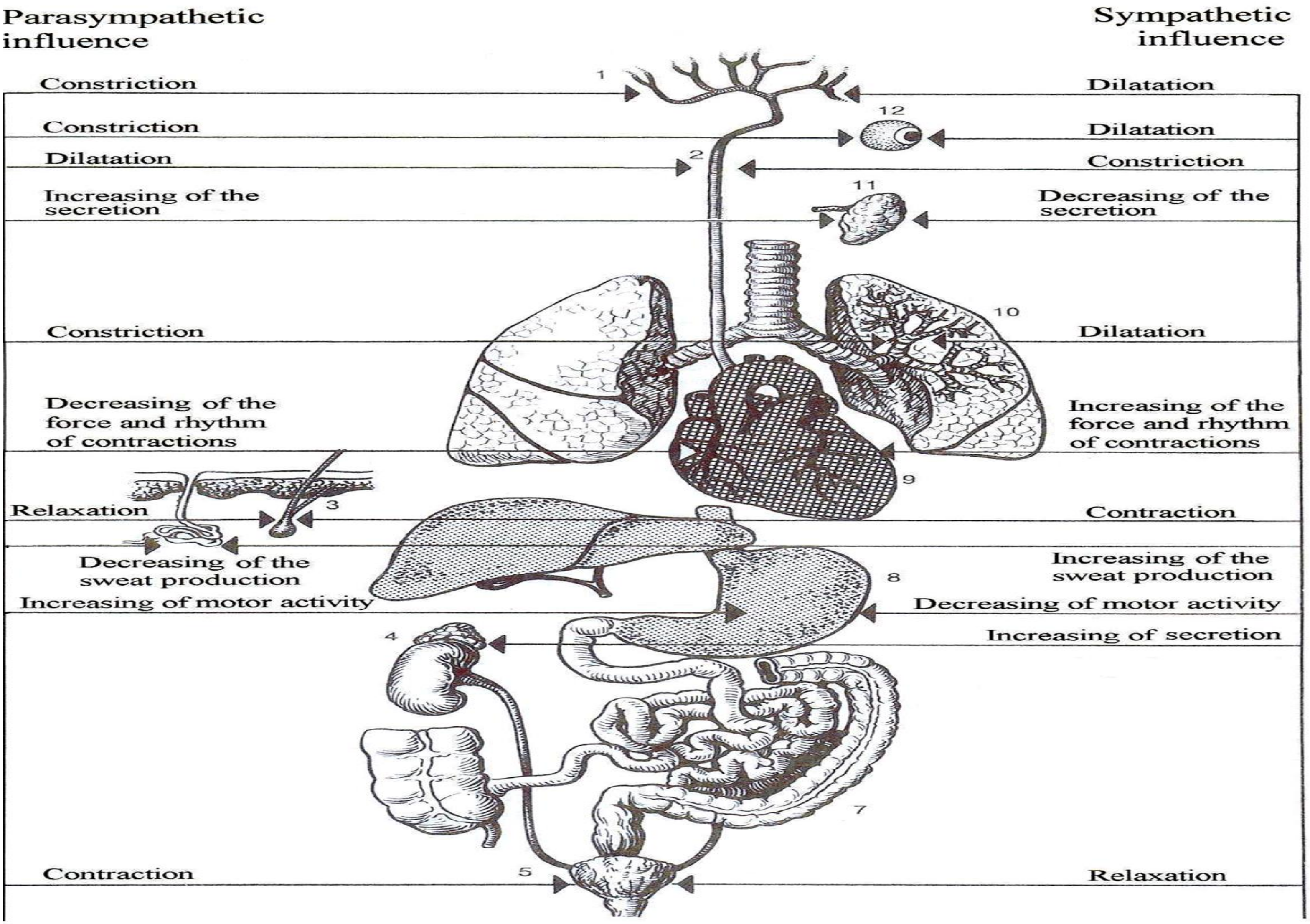


Figure — Changes of the functions of different organs in increased activity of the sympathetic and parasympathetic nerves

Notes: 1 — vessels of the brain; 2 — periphery vessels; 3 — hair muscles; 4 — suprarenal gland; 5 — urinary blander; 7 — intestines; 8 — stomach; 9 — heart; 10 — bronchi; 11 — salivary glands; 12 — pupil

Orbeli and Genetsynsky performed an experience on the frog's gastrocnemius muscle and defined that if was stimulated for a long time, the muscle got tired. After that the tired muscle was innervated with sympathetic fiber. It resulted in increased metabolism in the skeletal muscle and reduced restoration period after tiredness. This phenomenon was called the **adaptive-trophic influence of the SNS on skeletal muscles** (***Orbeli-Genethsynsky's phenomenon***).

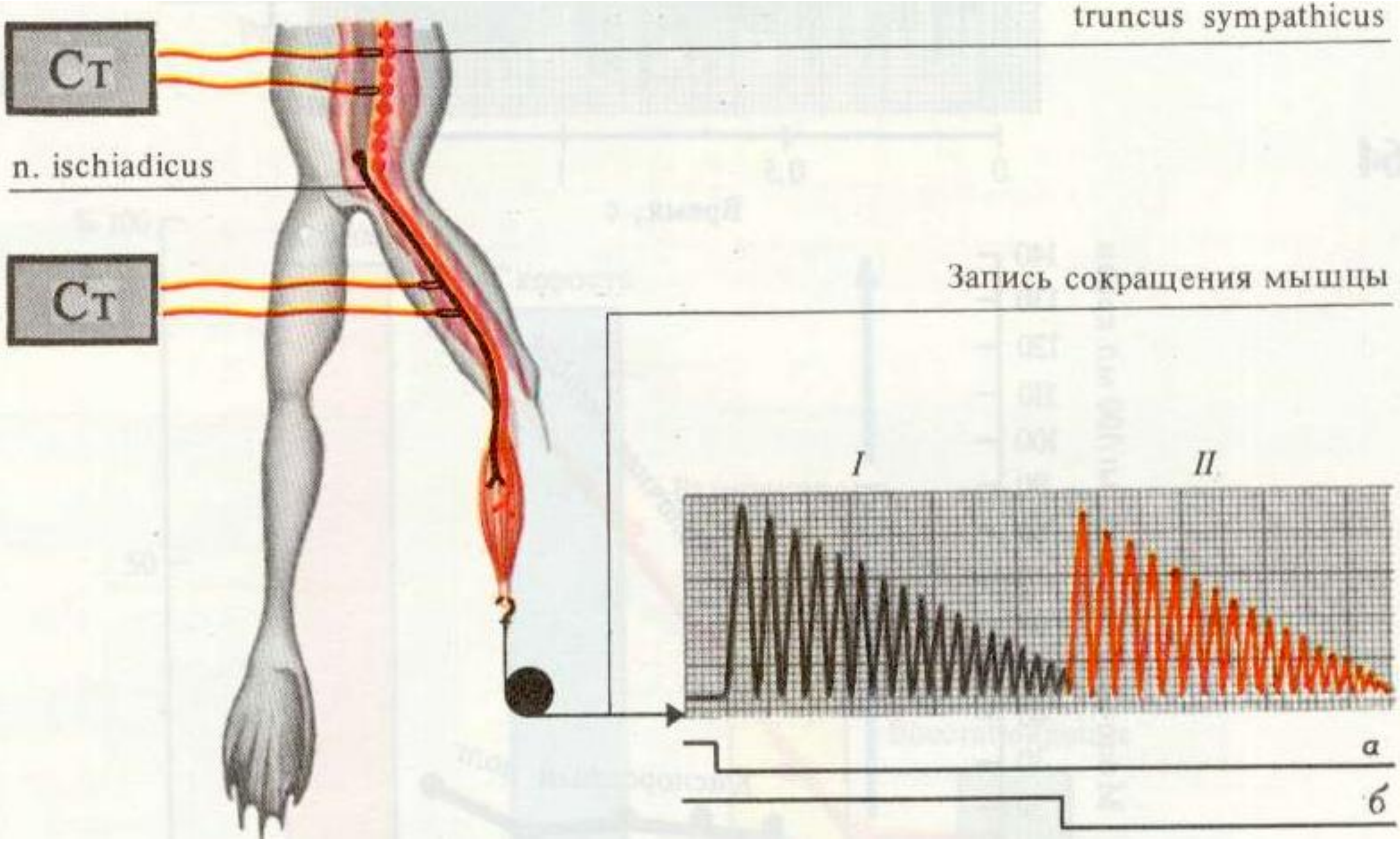


Figure — *Orbeli-Genethsynsky's phenomenon*

Classification of the vegetative ganglia

By their localization, the vegetative ganglia are divided into 3 groups:

1. ***Vertebral (paravertebral) ganglia***, related to the ***SNS*** and stretched like two marginal tubes along the *spinal column* and connected with the spinal cord with white copulative branches (preganglionic fibers). Postganglionic fibers go to the organs either independently or within somatic nerves. The majority of sympathetic fibers terminate in the vertebral ganglia.

2. ***Prevertebral ganglia*** (*solar plexus, superior and inferior mesenteric ganglia*). They are located anterior to the vertebral column and innervate organs. Other ***sympathetic nerve fibers*** terminate in these ganglia.

3. ***Intramural plexuses***. They are localized in the internal organs or close to them. Only ***parasympathetic fibers*** terminate in these ganglia.

Metasympathetic department of the ANS

The metasympathetic department of the ANS is a complex of microganglionic structures forming nervous plexuses and located in the walls of the internal organs (for example in the stomach, intestines, urinary bladder, heart, bronchi). Thus, the metasympathetic department of the intestines includes intermuscular (Auerbah’s) and submucous (Meissner’s) plexuses, which consist of a set of the microganglia and accept impulses from the sympathetic and parasympathetic departments of the ANS and also from their own afferent neurons, which are situated in the microganglia, transfer information from the sensory receptors of the intestinal walls.

The postganglionic fibers of the efferent neurons of the metasympathetic system go to the myocytes and glandular cells of the intestines and control their activity. The influences of the sympathetic and parasympathetic departments have the modulating role. A loss of impulsion from these departments (for example during transplantation of the intestines) does not reduce the activity of the neurons in the replaced plexuses. This activity provides self-control of the functions of the intestines.

The metasympathetic department of the ANS possesses greater independence from the CNS in comparison with other departments of the ANS.

Besides cholinergic and adrenergic neurons in the metasympathetic department of the ANS, there are non-cholinergic and non-adrenergic neurons. As mediators there can be peptides (cholecystokinin, somatostatin), biogenic amines (serotonin, histamine, melatonin), purines (ATP), etc. Some motor neurons can contain up to five various mediators, which is, probably, necessary for better regulation of the work of effector cells (for example, regulation of intestinal motility).

The basic functions of the metasympathetic department of the ANS:

1. It participates in the maintenance of homeostasis.

2. It carries out the role of the peripheral nerve centers and provides constant and continuous control over the work of the internal organs.

3. It participates in the process of information transfer from the sensory receptors of the internal organs to the CNS.

The interaction of the departments of the ANS in the regulation of the vegetative functions. It is realized at two levels: peripheral and central.

The interaction at the peripheral level takes place on effector cells, which receive double (or even triple) vegetative innervation. The basis of this interaction is the antagonistic influence of the parasympathetic and sympathetic departments of the ANS on innervated cells. Thus, stimulation of sympathetic nerves causes strengthening of heart activity, inhibition of intestinal peristalsis, and stimulation of the parasympathetic fibers of the vagus nerve — suppression of the work of the heart, stimulation of intestinal motility. The antagonistic effects of the interaction take place at other levels as well. Excitation transfer in the sympathetic ganglia is inhibited by parasympathetic influences, and in the parasympathetic ganglia — by sympathetic.

The interaction of various departments of the ANS at the central level has a complex, cooperative and intercontrolling character. The functions of the preganglionic neurons of the ANS are controlled by the higher vegetative oversegmental centers located in **various departments of the brain:**

1) ***brain stem: vasomotor center, blue substance, the centre of vomiting;***
2) ***cerebellum;***
3) ***diencephalons: hypothalamus, thalamus;***
4) ***telencephalon: basal ganglia, cortex of the cerebrum.***

The oversegmental formations integrate the human body functions and provide the expedient processes of adaptive activity. **The oversegmental mechanisms regulating the vegetative functions have three important features:**

1) there are no specific vegetative neurons;

2) damage *to the oversegmental centers* can be revealed not only in vegetative disorders, but also in somatic (mental and/or motor) dysfunctions;

3) the oversegmental centers use all the departments of the ANS for organization of adaptive interaction of the work of various departments of the ANS, which is performed by the hypothalamus.

Conduction of excitation in the synapses of the ANS

The pregangllionic fibers of the ANS are group B nerve fibers (thin myelinated fibers, the rate of excitation conduction is 3–18 m/sec). The mediator in the presynaptic terminals of all the preganglionic fibers (both sympathetic and parasympathetic) is ***acetylcholine*** (Figure). On the postsynaptic membranes of all the ganglia synapses **nicotinic cholinoreceptors** are located (they are activated by nicotin, and can be blocked by curare).

Postganglionic fibers are group C fibers (unmyelinated, the rate of excitation conduction is 1–3 m/sec). The mediator released by the terminations of the parasympathetic nerves is acetylcholine, and in sympathetic fibers — noradrenaline (except for sympathetic fibers which innervate the sweat glands, and also fibers which provide dilatation of the vessels of skeletal muscles, as in these fibers the mediator is acetylcholine).

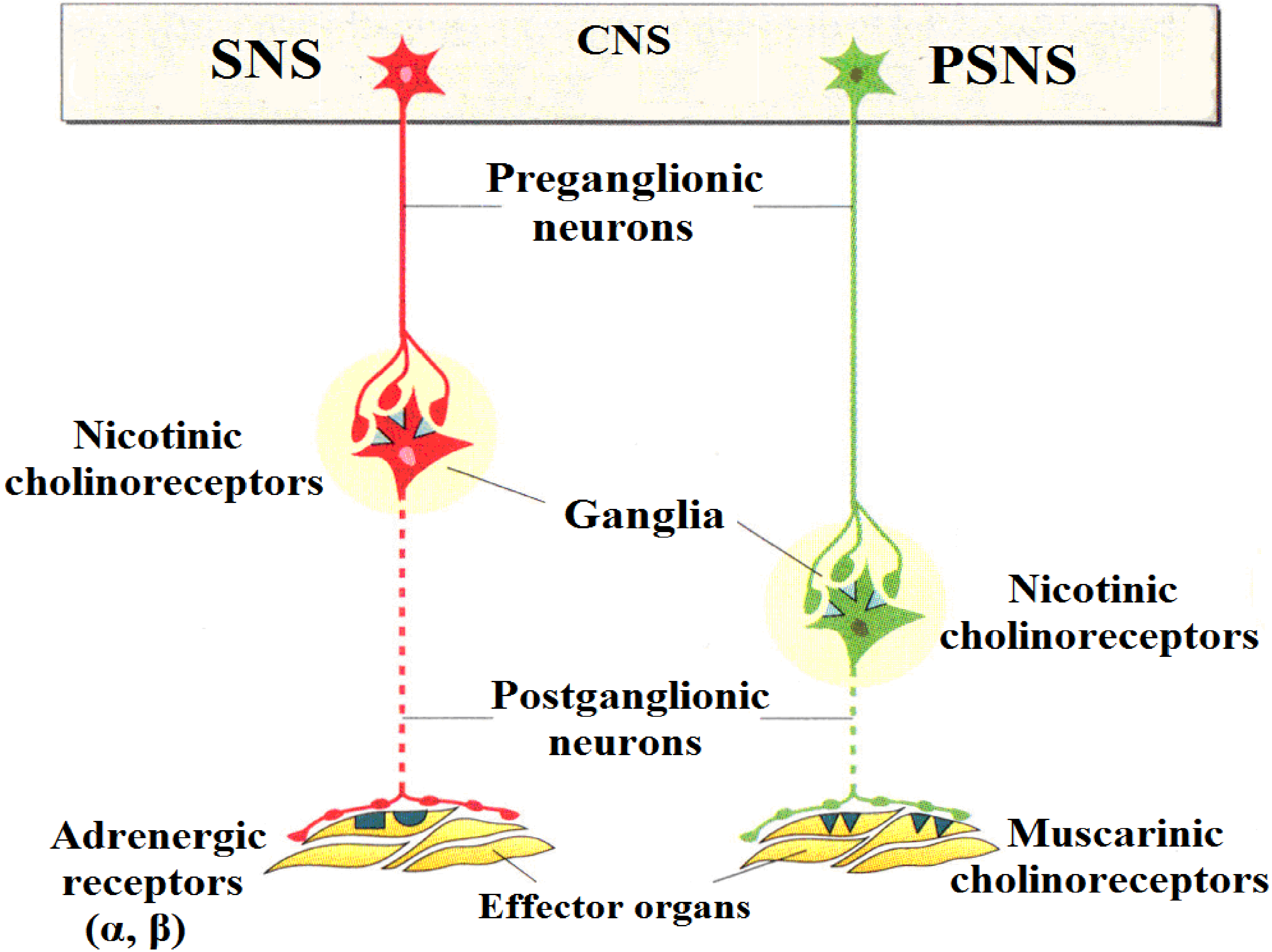


Figure – Excitation conduction in the synapses of the ANS

In the postsynaptic membranes innervated by postganglionic parasymphathetic fibers, **muscarinic cholinoreceptors** are located (they are activated by muscarin, and can be blocked by atropine). In the postsynaptic membranes innervated by postganglionic symphathetic fibers the **adrenergic receptors** are located (α, β).

There are also two major types of the adrenergic receptors: alpha receptors and beta receptors. The beta receptors in their turn are divided into beta 1, beta 2, and beta 3 receptors, because certain chemicals affect only certain beta receptors. Also, there is the division of the alpha receptors into alpha 1 and alpha 2 receptors. Table gives the distribution of the alpha and beta receptors in some organs.

Table — Adrenergic receptors and their functions

Alpha Receptor	Beta Receptor
Vasoconstriction	Vasodilation (β2)
Iris dilation	Cardiac acceleration (β1)
Intestinal relaxation	Increased myocardial strength (β1)
Intestinal sphincter contraction	Intestinal relaxation (β2) Uterus relaxation (β2)
Pilomotor contraction	Bronchodilation (β2)
Bladder sphincter contraction	Calorigenesis (β2)
Inhibits neurotransmitter release (α2)	Glycogenolysis (β2) Lipolysis (β1) Bladder wall relaxation (β2) Thermogenesis (β3)

When the mediator (acetylcholine or noradrenalin) binds with the receptor on the membrane of the effector cell, this causes a conformational change in the structure of the protein molecule of the receptor. In turn, the altered protein molecule excites or inhibits the cell, **most often by two mechanisms:**

1) causing a change in the cell membrane permeability to one or more ions;

For example, the sodium and/or calcium ion channels open and allow influx of these ions into the cell, usually depolarizing the cell membrane and exciting the cell. If the potassium channels are opened, allowing potassium ions to diffuse out of the cell, this usually inhibits the cell.

2) activating or inactivating an enzyme attached to the other end of the receptor protein, which protrudes into the cell.

For example, the binding of noradrenaline with its receptor on the outside of the cell increases the activity of the enzyme adenylylatcyclase on the inside of the cell, and this causes the formation of cyclic adenosine monophosphate (cAMP). The cAMP can initiate any of many different intracellular actions, the exact effect depending on the function of the effector cell.

Vegetative reflexes

The vegetative reflexes are divided into:

1. ***The viscerovisceral reflex,*** which includes the ways in which excitation appears and ends in the internal organs. For example, an increase or decrease of the pressure in the aorta results in altered heart activity and tone of the blood vessels.

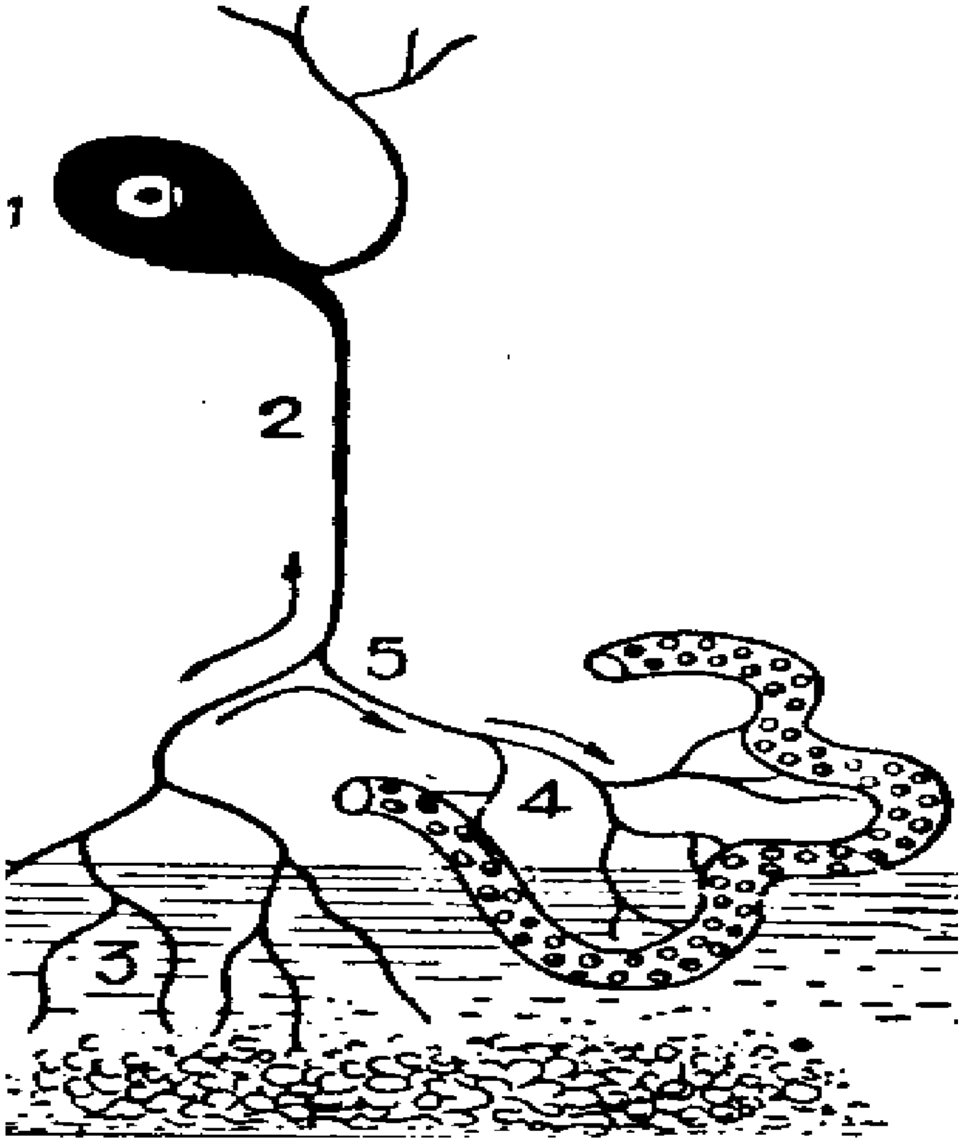


Figure – Axon-reflex

The axon-reflex is a variant of the viscerovisceral reflex. The axon-reflex appears if nerve fiber (axon) generates branching and therefore innervates one organ with one branch, and another organ or part of an organ with another branch. As a result, stimulation from one branch can be transferred to others thus changing the activity in several organs. The axon-reflex illustrates the mechanism of vascular reactions (vasoconstriction or vasodilatation) under stimulation of dermal pain receptors.

2. ***The viscerodermal reflex*** appears under stimulation of the internal organs and manifests itself as changes of sweating, tone of the dermal vessels, increased tactile and pain sensitivity of certain regions of the skin. This pain is called reflected, and the areas of its manifestation — ***Zakharin-Ged's zones***. For example, heart pain irradiates into the left hand, because stimulation from the affected internal organ coming to a certain segment of the spinal cord for a long time results in changes of the neural properties of this segment. Sensory nerves from the skin and muscles come to these segments thus changing the sensitivity of the skin in the regions of its innervation by the given segment.

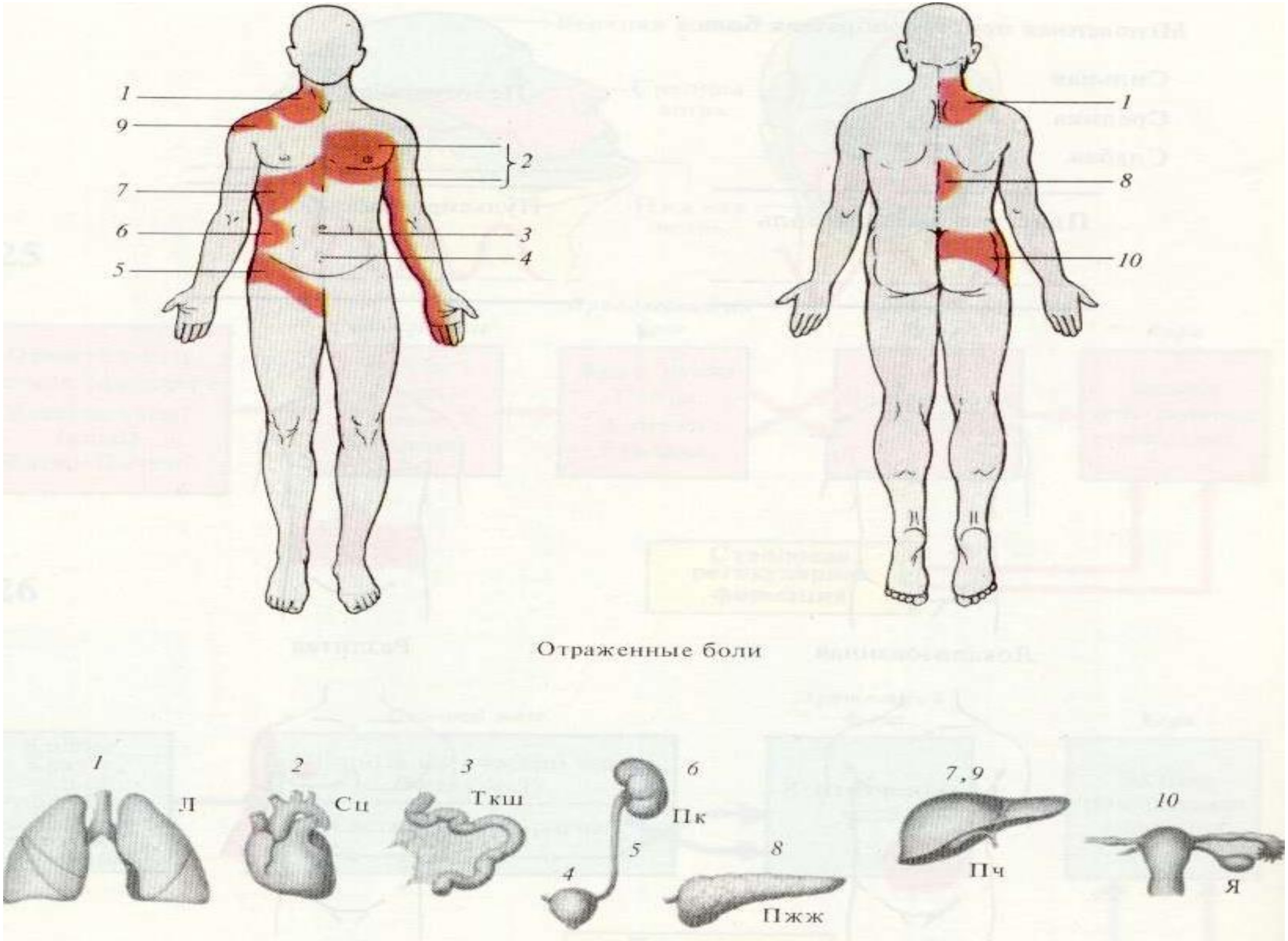


Figure – Zakharin-Ged's zones

3. ***Dermovisceral*.** Stimulation of some regions of the body surface induces vascular reactions and change the functioning of the internal organs. This determines prescription of reflexotherapy (heating, massage, acupuncture, etc.) to the patient.

For the assessment of the state and reactivity of the ANS, different methods are applied in medical practice:

1. Oculocardiac reflex.

2. Respiratory arrhythmia.

3. Orthostatic test, etc.

Levels of the regulation of the vegetative functions

The system regulating the vegetative functions includes several levels which interact among themselves. The influence of the superior levels on the inferior ones is also observed here.

Spinal level

There is the ***spinal ciliary center*** at the level of the last *cervical and two superior thoracal segments* of the spinal cord. Its fibers end at the eye muscles. Stimulation of these neurons results in *mydriasis, which is dilation or widening of the pupil, widening of palpebral fissure and abnormal protrusion of the eyeball (exophthalmia)*. Damage to this segment reveals in *Gornar's symptom — constriction of the pupil (miosis), constriction of palpebral fissure and retraction of the eye (endophthalmia)*.

Five superior segments of the thoracic segments of the spinal cord (***SNS***) send their signals to the heart, bronchi. Damage to separate segments of the thoracic and superior lumbar segments leads to *disappearance of the tone of the blood vessels, sweating*.

The PSNS centers are localized in the ***sacral segments*** of the spinal cord. The reflexes of the *urogenital system, defecation* are regulated with the participation of these segments. Transection of the spinal cord above the sacral segments can terminate these functions.

The medulla and midbrain also have the ***PSNS*** centers. The medulla has the *vasculomotor center,* which coordinates the activity of the sympathetic nerves located in the thoracolumbar segments of the spinal cord. Also the medulla has centers *inhibiting cardiac work and activation of the gastrointestinal glands*.

The midbrain has the centers of the *pupillary light reflex and eye accommodation reflex*.

These parts of the brain are controlled by the superior structures.

The hypothalamus is the ***highest subcortical center regulating all the vegetative functions***. Its *anterior* part activates the activity of the *PSNS*, *posterior* — *SNS.* The hypothalamus regulates the activity of the endocrine glands thus controlling all the vegetative functions.

The reticular formation, cerebellum, basal ganglia participate in the regulation of the vegetative functions**.**

The highest level of the regulation of the ANS activity is the **cortex (frontal lobes)**. The cortex influences the ANS *through the hypothalamus*. The participation of the cortex in the regulation of the activity of the internal organs is proved by the method of conditioned reflexes (for example, salivary secretion in response to inadequate signals (light, sound). Similar effects can arise if influenced by the hypnosis. For example, a person drinks a glass of water and if it is suggested to them that he has drunk a bucket of water; the person will have intensified uropoiesis.

These examples prove the possibility of voluntary control over the vegetative functions after special trainings (Indian yogis).

Thus, the nervous mechanisms of the regulation of the vegetative functions represent a multileveled structure in which the inferior regions are controlled by the superior ones.

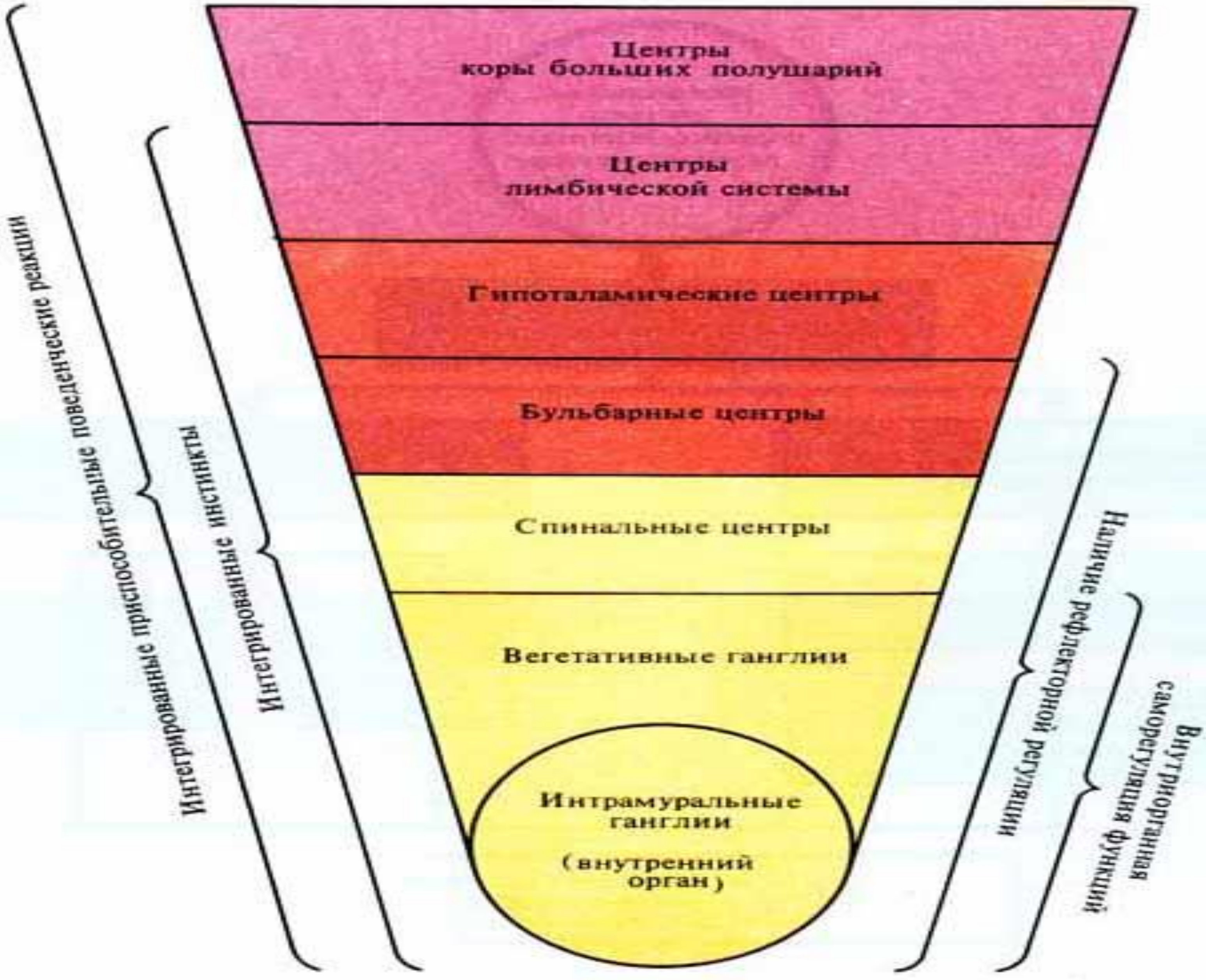


Figure –Levels of the regulation of the vegetative functions