

## CEREBRAL CORTEX, SENSATIONS AND MOVEMENTS

STRATON ALEXANDRU<sup>1</sup>, GIDU DIANA<sup>1</sup>, ENE VOICULESCU CARMEN<sup>1</sup>, STRATON CORINA<sup>2</sup>

### Abstract

The links of cerebral cortex areas still presents many unknowns regarding interpretation of sensations and generation of movement. The role of motor cortex in learning and execution of movements is well known, but there is a deep understanding of motor cortex function which still eludes us. In the literature, there is still a controversy regarding what the motor cortex codes: the spatial aspects (kinematics) of motor output (direction, velocity and position) or the muscle control and forces (kinetics). Therefore, this study is mainly focused on the understanding of how the movement is generated by the functional association (or inter-relations) of cerebral cortex areas.

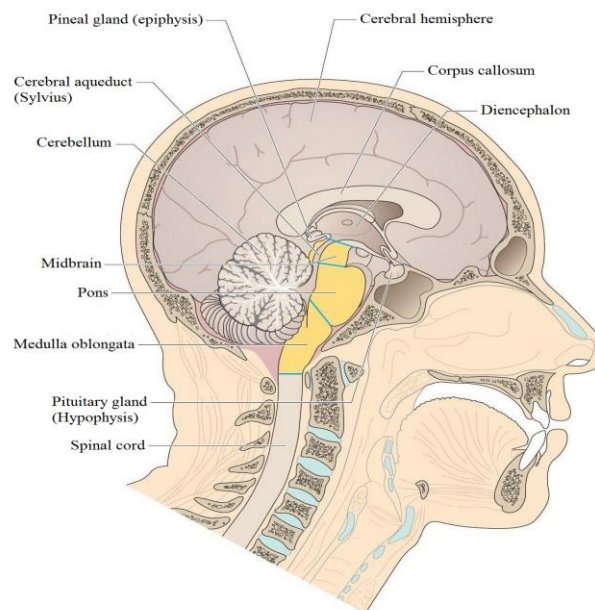
**Key words:** cerebral cortex, Brodmann areas, sensations, movements.

### Introduction

The brain is a part of the CNS (Central Nervous System) and is divided into four parties, namely: large brain (cerebrum), diencephalon, cerebellum and brainstem (G. Davies, 1998) (fig. 1.).

The brain controls voluntary movement through its intrinsic and extrinsic nervous connections. One of the most important part of the brain which controls movement is cerebral cortex. It is well known that the

connections of cerebral cortex areas produce movement, but how the involvement of nervous circuitry of these areas produce movement its not well understood. Therefore, a better understanding of cerebral cortex functions related to sensations and movements may lead to an explanation of how the movement is generated by cerebral cortex areas and how these areas are connected (colaborate) to produce movement.



**Fig. 1. Nervous structures components topography of the central nervous system.** (adapted with permission from A. Faller et al., 2004)

### Anatomical view of cerebrum

*Cerebrum* (which comprise about 80% of the brain) is consisted of right hemisphere and left hemisphere, which are divided by the longitudinal cerebral fissure and functionally linked together by a large tract of nerve fibers (axons) (about 200 million), which form corpus callosum. Cerebrum includes in its

composition, the cerebral cortex (with a thickness between 2mm and 4mm), which is composed of gray matter (composed of local networks of neurons with dendrites and short unmyelinated axons), being located on the surface and covering the white matter (composed of very long myelinated axons which realize global and rapid nervous communication; it contains association fibers, which conduct nerve

<sup>1</sup> Ovidius University of Constanta, Faculty of Physical Education And Sport, Constanta, ROMANIA

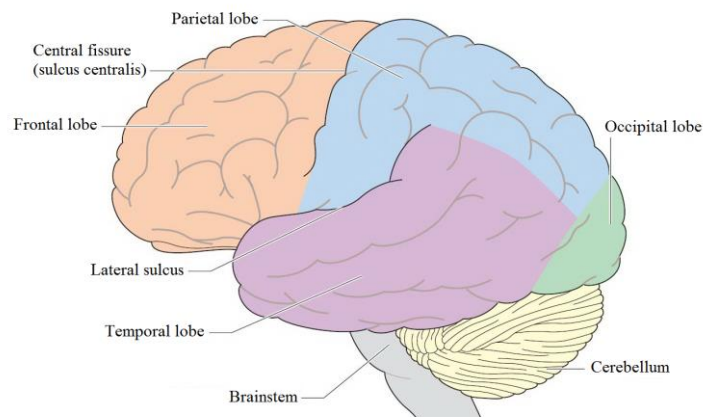
<sup>2</sup> Mihai Viteazul School From Constanta, ROMANIA

Email: axelcorro@yahoo.com

Received 11.05.2012 / Accepted 02.08.2012

impulses between neurons corresponding to the same cerebral hemispheres - commissural fibers that connect neurons and gyri, between hemispheres and - projection fibers which forms ascending and descending tracts necessary for the transmission of nerve impulses from the cerebrum into the other parts of the brain and/or spinal cord and vice versa). The cerebral cortex is characterized by numerous creases (including gyri (bumps) and sulci (sulcus sg.) (ditches))

which are called circumvolutions. Each cerebral hemisphere is divided by deeper sulci (grooves) called fissures into five lobes, four located on the surface - frontal lobe (the faces of the hemispheres), parietal lobe (central parts of the cerebral hemispheres), temporal lobe (external and lateral parts of the cerebral hemispheres) and occipital lobe (posterior parts of the cerebral hemispheres) - and one located centrally - the island (fig. 2.).



**Fig. 2. Topography of the four lobes and two sulci (deeper fissures) of the brain;** are represented, also, the position of cerebellum and brain stem; left lateral view. (adapted with permission from A. Faller et al., 2004)

### Functional aspects of cerebral cortex lobes and areas

The frontal lobe contains the primary somatomotor cortex (primary motor cortex area) (Brodmann area 4) (fig. 3. and fig. 4), located in the precentral gyrus and anterior paracentral gyrus. Precentral gyrus (located immediately to the central sulcus), covers much of the primary somatomotor cortex and anterior paracentral gyrus covers the medial continuity of primary somatomotor cortex, both being involved in motor control, because they contain neurons (giant pyramidal neurons – of Betz's - belonging to layer V) involved in muscle control. Primary motor cortex area of one of the cerebral hemispheres includes cortical nerve centers which controls all muscles or muscle groups belonging to contralateral side of the body.

The face is represented in the first one third of the lateral precentral gyrus, the upper extremity (arm, forearm and hand especially), is represented in the second third of the lateral precentral gyrus, and the trunk is represented in the third third (medial) of the precentral gyrus; the hip is represented in the place where precentral gyrus is continuing with paracentral gyrus and the lower limb (thigh, leg and foot), is represented in anterior paracentral gyrus (fig. 5. and fig. 6.). Damage to the primary motor cortex area of one of the cerebral hemisphere, is leading to muscle

weakness or paralysis of contralateral body parts (D. E. Haines, 2006; I. Petroveanu and N. Cozma, 1989).

It seems that the activity of corticospinal neurons corresponding to primary somatomotor cortex may change during the execution of a movement. Under certain conditions the corticospinal neurons corresponding to primary somatomotor cortex are activated slightly before performing a movement, showing no function for the coding of movement, but rather presenting function in the assessment of force necessary to perform a movement. Other populations of neurons corresponding to primary somatomotor cortex may encode the direction of movement (J. P. Donoghue and J. N. Sanes, 1994). P. D. Chaney (1985), showed that the execution of a movement is the main function of the primary motor cortex, which translates programmed instructions of movement to other parts of the brain in nerve signals which, in turn, encode movement variables such as force, contraction time and muscle to be contracted.

Also, on the surface of the frontal lobe there are Brodmann areas 6 and 8<sup>1</sup> with major motor functions (Brodmann area 8 shows only motor function), produced by nerve connections with the striatum and

<sup>1</sup> Brodmann area 6 can be decomposed into Brodmann areas 6 $\alpha$  and 6 $\beta$  and Brodmann area 8 can be decomposed into Brodmann areas 8 $\alpha$ , 8 $\beta$ , 8 $\gamma$  and 8 $\delta$ .



other nuclei of the extra-pyramidal system (red nucleus, substantia nigra, etc.). In Brodmann area 8 there are nerve centers (part of the oculocephalographic area) that control combined eye and head movements; so, the nerve center of the right hemisphere produce simultaneous head and eyes left turns and vice versa.

Premotor area is located above Brodmann area 4 (at the base of precentral gyrus), which presents role in the preparation (arbitrary coupling of cues in motor acts) (J. P. Donoghue and J. N. Sanes, 1994) and initiation of motor response made by Brodmann area 4. It seems that the corresponding neurons of premotor area are active during the interval between movement presentation and start signal of movement beginning. In other words, premotor cortex is activated for body (or body segments) orientation (position) in space to achieve a movement. P. D. Chaney (1985), concluded that premotor area participate in the assembly of new motor programs.

Supplementary motor area is located on the internal face of cerebral hemisphere between Brodmann areas 4 and 6a, having a role in controlling basic (elementary) movements ordered by Brodmann area 4, in controlling of automatic movements associated with speech and in controlling postural complex movements. J. M. Orgogozo and B. Larsen, (1979), concluded that the supplementary motor area presents a major role in initiating and controlling, at least, of certain voluntary movements. The basic function of supplementary motor cortex is for organizing and planning the muscle activation sequences necessary in the execution of movements (J. P. Donoghue and J. N. Sanes, 1994), reported to primary motor cortex which presents mainly function in the execution of movement. Some authors suggest that supplementary motor area is a specialized zone in programming motor subroutines and in this area are temporally ordered motor commands before motor actions will be executed by the primary motor cortex (P. E. Roland et al., 1980). Also, supplementary motor area is involved in planning complex sequences of discrete movements performed rapidly (ex. finger movements while playing the piano) (P. D. Chaney, 1985).

All these issues involving the motor cortex suggest that, it has a role in learning and execution of muscles voluntary actions.

There are an extensive number of studies which states that cells which correspond to the motor cortex are strongly correlated with upper limb movement direction in space. Even if the motor cortex may encode static kinematic<sup>2</sup> relative parameters as movement direction, it seems that also may reflect (but with a weaker influence) kinematic parameters that change continuously during dynamic movements performed in a straight line (in the same plane or 2D) as position, velocity and acceleration (J. Ashe and A.P.

Georgopoulos, 1994). Thus, direction and speed of movement, which can vary continuously, is strongly reflected in the motor cortex. Also, a large number of studies have shown relationships between motor cortex and the magnitude, direction and rate of force changes (kinetics<sup>3</sup>). Thus, there is clear evidence that, movement is primarily represented in kinematic form and the beginning of the actual movement is produced by activating the appropriate muscle groups (kinetics). Assumptions underlying these successive coordinate transformations are that, the different motor areas (including some areas of the parietal cortex) are involved in various stages of this transformation from kinematics to kinetics. However, closer to the truth, the motor cortex, may be involved in the final stage of transformation from kinematics to kinetics or may implement kinetics based on instructions offered by lateral premotor cortex or supplementary motor area. However, motor cortex involvement in the transformation from kinematics to kinetics is not yet clear. The conclusion proposed by A. Riehle and E. Vaadia, (2005), shows that, even if the motor cortex controls muscles and movement, it seems that it is focused mainly on spatial aspects. In other words, the primary motor cortex encodes most relevant aspects of spatial motor response, both in dynamic motion and in purely isometric behavior.

<sup>2</sup> study of body movement (characteristics of motion), independent of their masses and the causes that produce movement (forces).

<sup>3</sup> relationship between the motion of bodies and causes of these movements (forces).

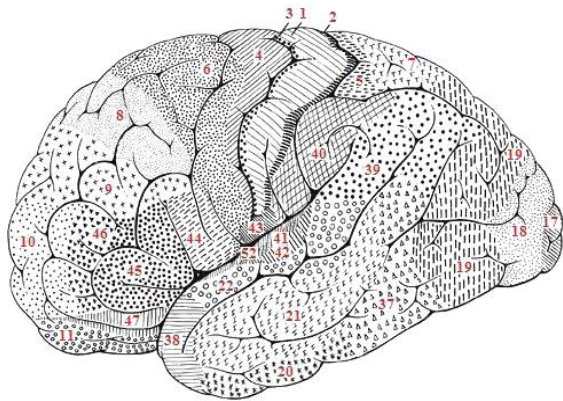


Fig. 3. Brodmann areas topography (seen from the side of the left hemisphere) (adapted with permission from P. W. Brazis et al., 2007).

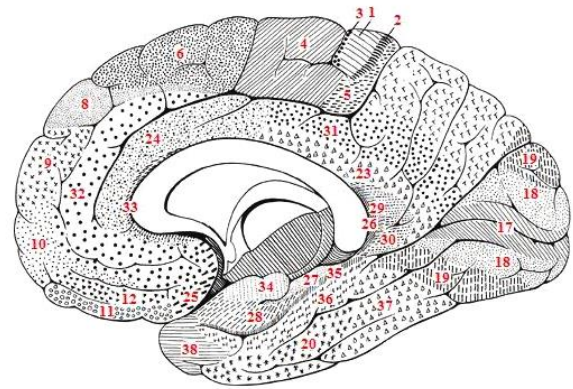
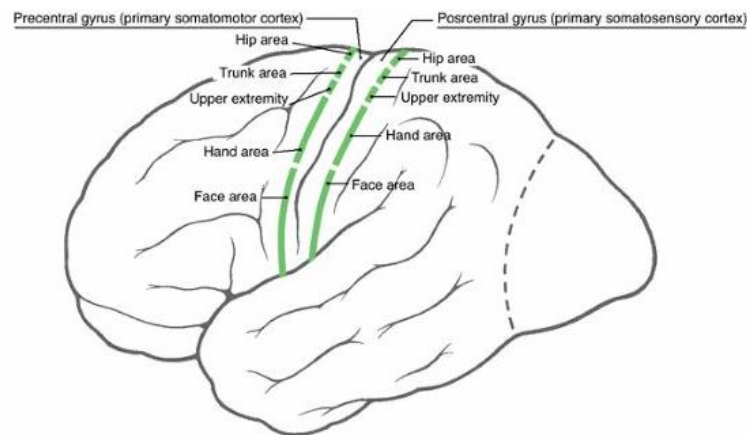


Fig. 4. Brodmann areas topography (medial section view of the left side of the left hemisphere) (adapted with permission from P. W. Brazis et al., 2007).

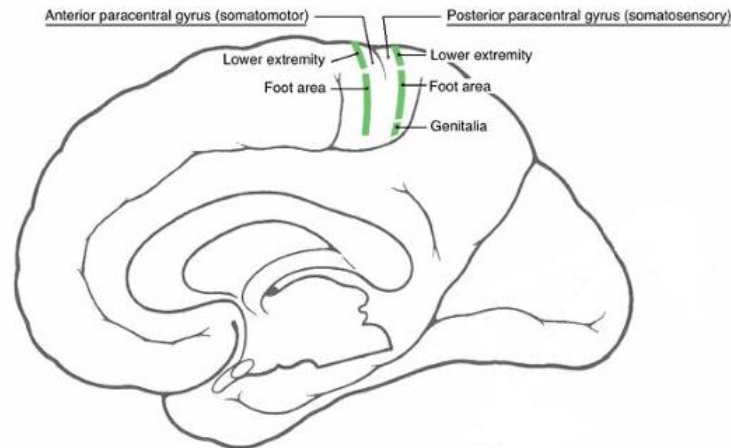


**Fig. 5. Topography of motor and sensory areas located in precentral, respectively, postcentral gyri (side view of the left hemisphere).**

Precentral gyrus (primary somatomotor cortex) - hip area includes the area of hip-femoral joint; upper extremity area consists of the forearm and arm areas (including areas of shoulder, elbow and hand joints); hand area consists of palm, thumb, index, middle finger, ring finger and little finger areas; face area consists of neck, brow, eyelid, eye, facial expression, mouth, chin, tongue, swallowing, saliva secretion, mastication and phonation areas.

Postcentral gyrus (primary somatosensory cortex) - hip area of the postcentral gyrus is formed by hip (including hip-femoral joint area) and leg areas (including knee joint area); trunk area includes areas of the head and neck; upper extremity area consists of the forearm and arm areas (including areas of joint shoulder, elbow and hand); hand area consists of palm, thumb, index, middle finger, ring finger and little finger areas; face area consists of eye, nose, face, lip, lip, lower lip, teeth, gums, jaw, tongue, pharynx and intra-abdominal areas. (adapted with permission from D. E. Haines, 2008).





**Fig. 6. Topography of motor and sensory areas located in anterior paracentral and, respectively, posterior paracentral gyri (medial section view of the left side of the left hemisphere).**

Anterior paracentral gyrus (primary somatomotor cortex) - lower extremity area consists of thigh and calf areas (including the area of the knee joint); foot area includes the area of the ankle joint.

Posterior paracentral gyrus (primary somatosensory cortex) - lower extremity area consists only of the calf area; the leg area includes ankle joint area. (adapted with permission from D. E. Haines, 2008).

Specific maps of these areas involve higher regions of the cortex devoted to the lower parts of the body (ex. toes) and lower regions of the cortex devoted to the upper body (ex. the head). Therefore, the arrangement of cortical nervous centers is disposed as a motor or sensory homunculus upside down. An interesting aspect of these maps is that the size of cortical areas responsible for different parts of the body isn't directly proportional to the size of the body part being monitored. Thus, body parts with high density of receptors is controlled by the largest area of primary sensory cortex and body parts with the highest number of motor innervations is controlled by the largest area of primary motor cortex. Therefore, hands and face (which has the highest density of sensory receptors, respectively, motor innervations) are controlled by the largest area of precentral gyrus (motor) and postcentral gyrus (sensory). Large territory of the motor area that controls hand movement is due to precise, fine, and diversity of movements which it executes.

*The temporal lobe* contains the auditory centers (primary auditory cortex (Brodmann area 41) belonging to transverse temporal gyrus (of Heschl's), the psycho-auditive area (Brodmann area 42) and the auditory gnosis area (Brodmann area 22) which are involved in memorizing (storing) visual and auditory experiences, in interpretation and combination of visual and auditory information. Primary auditory cortex damage produces difficulties in interpreting sound or location of sound in space. Also, it seems that vestibular sensitivity areas are in the vicinity of auditory centers.

*Occipital lobe* is the primary area responsible for coordination of eye movements; also, is involved in linking visual images with previous visual experience

and other sensory stimuli. Primary visual cortex (Brodmann area 17) is located in cuneus and lingual gyri which is directly adjacent to the calcarin sulcus. Damage to primary visual cortex of one occipital lobe causes the loss of visual stimulus to the contralateral half of the visual field relative to the vertical diameter of each eye (homonymous hemianopia). Image perception and fine analysis of it is done in psycho-visual area (Brodmann area 19), and object recognition, shape and size identification, the concept of space and understanding the significance of the written words is done in the visual-gnosis area (Brodmann area 19); in the same area is the oculocephalographic cortical center that controls visual reflexes (cortical reflex stimulated by light).

*The island* is involved mainly in memory encoding and integration of sensory information (represented mainly by pain) with visceral response and, in particular, is involved in coordinating the cardiovascular responses to stress.

Brodmann areas 8, 5, 7 and 21 of cerebral cortex are cortico-cerebellar areas of coordination, being connected to cerebellum by cortico-ponto-cerebellar nerve fibers. Brodmann areas 5 and 7 (motor areas which correspond to posterior parietal cortex), which occupy large areas of superior parietal lobe, realize certain nerve background connections necessary to achieve movement in space. To achieve such movements in space, these areas need to compare a variety of nerve impulses in sensory systems, in order to create a space map, and at the same time, to calculate a trajectory through which the upper limb may touch a target. Brodmann area 5 receives extensive nerve projections from somatosensory cortex and the vestibular system, and Brodmann area 7,



process visual nervous information, which are related to perception of objects placed in space. Both areas have, mainly, nerve projections to the supplementary motor cortex and premotor cortex, and also have some nerve projections to the spinal cord and brainstem. It seems that Brodmann area 5 neurons are active only when the subject performs a movement of the upper limb to a specific object of interest; these neurons are not active when the same upper limb movement is executed without the object to be present. Thus, Brodmann area 5 neurons are activated only when exploring specific objects of interest (P. D. Cheney, 1985). A specific type of neurons corresponding to Brodmann area 7, which participates in eye-hand coordination, is activated strongly only when eyes and hands fixate a target and the hand reaches this target.

Cingulate motor cortex stimulation produce motor effects, and because of its proximity to the limbic cortex, the region may be involved in movements that have an intense emotional and motivational behavior.

Psychomotor areas of the cerebral cortex is planning and is programming the movement by planning the ideation plan of motric action in Brodmann area 40 (supramarginal gyrus) being transmitted in psychomotor centers which construct the movement engrams (Brodmann areas 6 $\beta$  and 8) and, finally, is being transferred to cerebral hemispheres motor areas of the same or opposite cerebral hemisphere through the corpus callosum.

Association areas of the cerebral cortex have links to other areas of the cerebral cortex, to association and reticulate thalamic nuclei, and from the latter one, to the brainstem reticular formation. These areas have function in physiological activity (as emotion, affection, psychological behavior), in intellectual activity (as prediction, memory, etc.), etc.. Parts of the association areas are found in the frontal lobe of the cerebral hemispheres which is showing functions in the control of apathy, sense of initiative, spontaneity (areas belonging to the external face of prefrontal lobes), euphoria, impulsiveness, bulimia, polidipsy, moral sense (orbital areas of frontal lobes), time and space disorientation, memory disorders (areas belonging to medial faces of frontal lobes), but also, in the temporal lobe of the cerebral hemispheres which has functions in controlling aggressive social behavior, affection, apathy, visual disorientation and visual-constructive disorders. In terms of psycho-motor, Brodmann area 39 contains nerve centers corresponding to the body scheme, where nervous information is associated for acknowledge of spatial position of body segments.

Vegetative areas of the cerebral cortex are still imperfectly located, knowing little about their functions. However, these areas control visceral functions and various psychological symptoms which are accompanied by various autonomic (vegetative) changes. Some believe that Brodmann area 6 controls sympathetic vegetative phenomena, and others believe

that this area only controls gastrointestinal activity. Rate and amplitude of respiration and some vasomotor effects are controlled by Brodmann areas 13 and 14, blood pressure is controlled by Brodmann area 38, and abdominal visceral activity is controlled by nervous centers belonging to the island of Reil lobe cortex. Specialists' assumptions lead to the idea that vegetative areas and motor areas would intersect.

Other specialists have a hypothesis that motor control system is realized by the action of motor control systems consist of descendent parallel cortical nerve projections which is almost linking directly various motor areas of the cerebral cortex and spinal cord motor circuits. This hypothesis is supported by the fact that cortical stimulation of different locations can produce movements involving the same muscles or muscle groups, except that, according to the stimulation site, the characteristics of these movements are different.

From functional point of view all areas of cerebral cortex collaborate to organize cerebral processes. Also, the onset of certain neurological function is due to activation of cortical circuits between cerebral cortex and subcortical nuclei. Penfield, (1954), quoted by I. Petroveanu and N. Cozma, (1989), specifies that centrencephalic system (or midbrain) coordinates nervous activity of both cerebral hemispheres, through a feed-back nervous connection. Thus, the main role of centrencephalic system seems to sort, to organize and to plan the nervous information from the sensory cortical areas, leading to conscious awareness and to integrate and coordinate the development of movement plan which will be sent further to motor cortical areas.

## Conclusions

By controlling the direction, velocity, position and force of movements, motor cortex seems to be primarily involved in space aspects of movements, but only in relations with other areas of the cerebral cortex, especially those who process sensorial stimuli and psychological information.

## References

- ASHE J., GEORGOPOULUS A. P. (1994). *Movement parameters and neural activity in motor cortex and area 5*. Cerebral cortex, 4 (6): 590-600.
- BRAZIS P. W., MASDEU J. C., BILLER J. (2007). *Localization in Clinical Neurology*. 5th ed., Lippincott Williams & Wilkins, Philadelphia, PA..
- CHENEY P. D. (1985). *Role of cerebral cortex in voluntary movements. A review*. Physical Therapy, 65 (5): 624-635.
- DONOGHUE J. P., SANES J. N (1994). *Motor areas of the cerebral cortex*. Journal of clinical neurophysiology: official publication of the American Electroencephalographic Society, 11 (4): 382-396.



- DUMITRU G. (1998).** *Fiziologia Educației Fizice și Sportului*. Ed. Ovidius University Press, Constanța: 13-37.
- FALLER A., SCHÜNKE M., SCHÜNKE G. (2004).** *The Human Body. An introduction to structure and function*. Georg Thieme Verlag, Stuttgart: 536-578.
- HAINES D. E. (2005).** *Fundamental Neuroscience for Basic and Clinical Applications*. 3rd ed., Churchill Livingstone/Elsevier, Philadelphia, PA..
- HAINES D. E. (2008).** *Neuroanatomy. An Atlas of Structures, Sections, and Systems*. 7th ed, Lippincott Williams & Wilkins, Philadelphia, PA..
- JACOBSON J., MARCUS E. M. (2008).** *Neuroanatomy for the neuroscientist*. Springer Science, New York, NY: 293-310.
- ORGONGOZO J. M., LARSEN B. (1979).** *Activation of the supplementary motor area during voluntary movement in man suggests it works as a supramotor area*. Science, 206 (4420): 847-850.
- PETROVEANU I., COZMA N. (1989).** *Anatomia sistemului nervos central*. Ed. I.M.F., Iași: 164-224.
- RIEHLE A., VAADIA E. (2005).** *Motor cortex în voluntary movements. A distributed system for distributed functions*. CRC Press, Boca Raton, FL..
- ROLAND P. E., LARSEN B., LASSEN N. A., SKINHOJ E. (1980).** *Supplementary motor area and other cortical areas in organization of voluntary movements in man*. Journal of neurophysiology, 43 (1): 118-136.