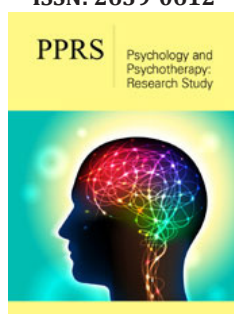


Morpho Functional Organization of the Rat Cerebellum

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Abstract

During embryonic development, the anterior part of the neural tube first forms three cerebral vesicles, which give rise to the cerebrum and related structures: forebrain (prosencephalon), midbrain (mesencephalon), hindbrain (rhombencephalon). The hindbrain subsequently divides into the metencephalon (pons) and the medulla oblongata (lower). The cerebellum develops from the metencephalon. Thus, the cerebellum and the cerebral cortex are connected by numerous neural pathways. Through these pathways, the cerebellum receives information from the cortex, in particular, copies of the motor programs of upcoming movements, and mainly through the dentate-thalamic pathways influences the motor commands sent by the cerebral cortex to the stem motor centers and to the spinal cord.

Keywords: Morpho functional organization; Rat; Cerebellum

Introduction

During embryonic development, the anterior part of the neural tube first forms three cerebral vesicles, which give rise to the cerebrum and related structures:

- a) forebrain (prosencephalon)
- b) midbrain (mesencephalon)
- c) hindbrain (rhombencephalon)

The hindbrain subsequently divides into the metencephalon (pons) and the medulla oblongata (lower). The cerebellum develops from metencephalon. The cerebellum is located at the back of the brain, immediately below the temporal and occipital lobes, and within the posterior cranial fossa. It is separated from these lobes by the cerebellum, which is represented by a strong layer of the dura mater. It is located at the same level and posterior to the pons, from which it is in turn separated by the fourth ventricle. The cerebellum is connected to other parts of the brain through nerve fibers that form thickenings called peduncles: the upper peduncles connect the cerebellum to the midbrain, the middle ones to the pons, and the lower ones to the medulla oblongata. The spinal tracts of Fleshing, fibers from the Gaulte and Burdach nuclei located in the medulla oblongata, fibers from the vestibular nucleus pass through the lower legs. These fibers carry impulses from proprio- and vestibulo receptors. Fibers carrying impulses from the cerebral cortex (from the precentral gyrus) enter the cerebellum through the middle legs to the cerebellum. The dorsal cerebellar pathways of Gowers and fibers from the anterior colliculus of the quadrigemina enter the cerebellum through the superior peduncles [1].

The cerebellum consists of two hemispheres that are connected by the vermis, a narrow median region. Like other structures of the central nervous system, the cerebellum consists of gray and white matter: Gray matter-located on the surface of the cerebellum, forming the cerebellar cortex. It forms folds-furrows and convolutions. White matter is located under the gray matter. There are four nuclei of the cerebellum in the white matter: dentate, emboloid, spherical and fastigial. The cerebellum can be divided in three ways: into anatomical lobes,

zones, and functional divisions [2]. There are three anatomical lobes in the cerebellum: anterior lobe, posterior lobe, and flocculonodular lobe. These lobes are separated by two sulci, the primary sulcus and the posterolateral fissure [1,2]. There are also three zones of the cerebellum. The vermis is located in the midline of the cerebellum. Either side of the worm is an intermediate zone, and lateral to the intermediate zone are the lateral hemispheres. Cortical-nuclear projection zones

It is known from a rabbit study that the corticonuclear projection is not strictly transected and that the cerebellar vermis is associated with the medial cerebellar nucleus and the hemisphere with the intermediate and lateral nuclei of the cerebellum. Cortical-vestibular fibers depart from the worm and shreds. Information on the lobular organization of the corticonuclear process in rats is quite extensive, but, as some authors point out, localization in the corticonuclear process is more pronounced in the mediolateral direction than in the rostro caudal direction. Therefore, it is necessary to pay attention to the presence in the cerebellar cortex of longitudinal zones with a specific projection to the central cerebellar or vestibular nuclei. The subdivision of the cerebellar cortex into the medial (vermal), intermediate, and lateral zones, projecting respectively onto the medial, intermediate, and lateral nuclei of the cerebellum, was introduced by some authors and applied to the rat cerebellum. The position of the boundaries between these three cortical zones depended on the position of arbitrary boundaries between the medial, intermediate, and lateral nuclei, and not on specific landmarks in the cortex itself. One scientist studied the projection of the inferior olive by retrograde cellular degeneration in animals and concluded that specific lobules receive olivocerebellar fibers from specific divisions of the contralateral nucleus of the olive. Other scientists have shown that each division of the lower olive projects onto a specific longitudinal strip of the cortex, which can be traced through a series of successive lobules. According to the data, the olive-cerebellar fibers reach the Purkinje cells of these striae through the same myeloarchitectonic compartments that contain the projections of these Purkinje cells to the central nuclei of the cerebellum. The scientist came to the conclusion that the organization of the olivo-cerebellar projection and the organization of the cortical-nuclear projection are essentially similar [1-3].

Functional Divisions

There are three functional areas of the cerebellum: cerebellar, spinocerebellar, and precerebellin [4]. Since the cerebellum is the largest part formed by the lateral hemispheres, it is involved in movement planning and motor learning. It receives afferent fibers from the cerebral cortex and pontine nuclei and sends data back to the thalamus and red nucleus. This area also regulates the coordination of muscle activation and plays an important role in visually guided movements. Spino cerebellum-consists of the vermis and the intermediate zone of the cerebellar hemispheres. It is involved in the regulation of body movements, allowing you to correct mistakes. It also receives proprioceptive information [1,4]. The vestibulo cerebellum is the functional equivalent of the flocculonodular lobe. It is involved in the management of balance

and eye reflexes, is fixed on the main goal. It receives afferent fibers from the vestibular system and sends output back to the vestibular nuclei [4].

Cerebellar nuclei and their efferent pathways

According to electrophysiological, morphological and biochemical properties, several types of neurons of the cerebellar nuclei are distinguished:

- a) Large glutamatergic neurons project to different parts of the brain; this is the main type of neurons, on the bodies and dendrites of which Purkinje cells establish synaptic contacts [5].
- b) Small GABAergic projection neurons provide signal output to the inferior olive [1,5].
- c) Large glycinergic projection neurons that provide an efferent inhibitory effect from the cerebellar nuclei to the cerebellar cortex and from the rostral part of the fastigial nucleus ipsilaterally to the neurons of the vestibular nuclei [1,3,5].
- d) Small GABA-glycinergic interneurons, whose axons terminate on neighboring neurons and provide integration within the nucleus [5].
- e) Small non-GABAergic interneurons, because they do not express GAD-67, have been described in the fastigial nucleus [1,5].

Cerebellar Nuclei

Some authors have divided the nuclei of the cerebellum into two groups of interconnected nuclei. The caudal group consists of the medial cerebellar or fastigial nucleus and the posterior intercalary nucleus. The rostral group consists of the anterior intercalary nucleus and the lateral cerebellar or dentate nucleus. Myelin fibers occupy the space between the two nuclear groups. The boundary between two nuclei within a group is often extremely difficult to define. The scientist applied this subdivision to the nuclei of the cerebellum of a rat. Its description takes into account the presence of certain subnuclei characteristic of rats. The accessory nuclei of the cerebellum, which should be considered as separate structures, are the «groups of interstitial cells» located between the caudal medial and posterior intermediate nuclei, and the basal interstitial nucleus. The latter is a group of small acetylcholinesterase-positive neurons that extend from the white matter of the flocculus, in the roof of the fourth ventricle, next to the cerebellar nuclei, to the white matter of the nodule [1,6].

The neurons of the cerebellar nuclei are a mixed population of cells of all shapes and sizes. A number of authors have noticed a binomial distribution of cell sizes in the cerebellar nuclei. This distribution can be explained by the presence of a population of small inhibitory GABAergic neurons and a population of excitatory, presumably glutaminergic, neurons of different sizes for rat cerebellar nuclei. Excitatory neurons give rise to highly branched axons with collaterals that can descend to the spinal cord and ascend

to the thalamus. Small GABAergic neurons project predominantly to the inferior olive. GABAergic nuclear cells with projections to the cerebellar cortex were found by a number of authors. However, most nuclear-cortical fibers originate as collaterals from putative glutaminergic relay cells in the cerebellar nuclei and terminate as mossy fibers in the cerebellar cortex. Nuclear-cortical projection in rats has been studied by a number of scientists. They found in rats a population of small glycinergic cerebellar interneuron nuclei, some of which co-localize GABA. Their glycine content distinguishes these cells from the GABAergic neurons that project onto the olive. The appearance of parvalbumin-expressing neurons in the cerebellar nuclei in some mice is associated with the activity of glycinergic and GABAergic interneurons, which cause increased inhibition of nuclear neurons and compensate for the loss of inhibition by Purkinje cells. Scientists have described the division of the superior cerebellar peduncle, which contains the ascending fibers of several nuclei, into a smaller medial part and a larger lateral part in most mammals studied. The medial third of the superior cerebellar peduncle contains fibers from the medial cerebellar and posterior intermediate nuclei. The lateral two-thirds of the peduncle contains efferent fibers from the anterior intercalary and lateral nuclei of the cerebellum. A small-caliber GABAergic nucleolar-liviar tract connects the lateral and intermediate nuclei with the contralateral inferior olive. These fibers gather in the lateral corner of the fourth ventricle and ascend into a bundle located ventral to the superior cerebellar peduncles until they cross [4,6].

Medial (Fastigial) Nucleus of the Cerebellum

The medial nucleus receives its corticonuclear projection from the vermis

The medial nucleus of the rat cerebellum is characterized by a prominent dorsolateral prominence, a group of large neurons extending far dorsally into the white matter of the posterior lobe. The medial nucleus was divided into middle and caudomedial parts. The caudomedial division is the most distinct, but most of its cells are small. The caudomedial subdivision of the medial nucleus is located at the base of the nodule and uvula. Dorsally, it remains separated from the rest of the nucleus by myelinated fibers, and ventrally, where it lines the roof of the fourth ventricle, it fuses with the middle portion of the medial nucleus. The middle section is distinguished by a high content of myelinated fibers, which belong to two groups. The uncinat tract exits the nucleus and crosses it on its way to the cerebellar commissure. Smaller, so-called «perforating fibers» cross its caudal part, medial to the dorsolateral ridge, on their way to the vestibular nuclei. These fibers originate from the Purkinje cells of the anterior part of the worm. The unique shape of the dorsolateral prominence and its afferent corticonuclear connections from the posterior hemisphere set it apart from the rest of the medial nucleus, which receives its corticonuclear projection from the vermis [7].

Cyto- and myeloarchitectonics

The uncinat tract originates from the entire medial nucleus, including the dorsolateral prominence. Contralaterally, uncinat fibers run rostral to and through the hilum of the medial nucleus.

The tract curves dorsally to the superior cerebellar peduncle, immediately rostral to the anterior intercalated nucleus, to join the inferior cerebellar peduncle along its course lateral to the vestibular nuclei. Part of the fibers of the uncinat tract joins the medial part of the upper leg in the form of a crossed ascending knee. For most of their intracerebellar course, the efferent fibers of the hamate and superior cerebellar peduncle remain separated from the spinal- and reticulo-cerebellar fibers of the inferior cerebellar peduncle by a layer of thin olive-cerebellar fibers. The uncrossed fastigiobulbar fibers originate from the middle and caudomedial portions of the fastigial nucleus, but the dorsolateral protrusion appears to be of little importance. The main projections of the rostro medial part of the nucleus are bilateral and include the vestibular nuclei (mainly the macro cellular part and the more caudal ventral and lateral regions of the medial vestibular nucleus, the spinal vestibular nucleus and the para solitary nucleus) and the bulbar reticular formation. Rostrally, this projection extends to the ipsilateral reticular formation of the pons with small targets in the midbrain and diencephalon [5,8].

The dorsolateral prominence gives rise to a large protrusion of the contralateral bulbar medial reticular formation extending into the pons in the area bordering the trigeminal nuclei and including the parabrachial nuclei. The mesencephalon endings include the deep mesencephalic nucleus and the adjacent central gray nucleus. Collateralization of the bulbar reticular formation and thalamus was observed. The efferent fibers of the caudomedial medial nucleus focus on the contralateral paramedian reticular formation of the pons with strong projections into the pararubral region, the deep mesencephalic nucleus, the deep layers of the superior colliculus, and the areas adjacent to the oculomotor nuclei and the retro flexive bundle. Thalamic targets include the para fascicular, ventromedial, and ventrolateral nuclei. Collaterals of the same neuron may terminate in the spinal cord, bulbar reticular formation, roof of the brain, and thalamus [5,7,8].

Posterior Interstitial Nucleus and Groups of Interstitial Cells

The posterior intercalated nucleus is the smallest of the rat central nuclei, but it has a very high cell density and also contains fairly large cells. Small cells are located more ventrally. The group of cells located between the posterior intercalated nucleus and the fastigial nucleus, which was previously part of the posterior intercalated nucleus, was considered as an independent nucleus of the cerebellum. Since it serves as a target nucleus for one of the corticonuclear projection zones of the anterior lobe (X-zone), it is known as the group of interstitial cells [7,9].

Cyto- and myeloarchitectonics

The efferent connections of the posterior intermediate nucleus of the rat cross in the dorsal part of the decussation of the superior cerebellar peduncles and terminate along the medial edge of the red nucleus, the central gray matter, the deep mesencephalic nucleus, the deep layers of the superior tubercles, the Dark shevich nucleus, and the sub para fascicular nucleus. Their thalamic targets

include the ventromedial, ventrolateral, and intralaminar nuclei. In rats, the posterior intercalary nucleus does not give fibers to the pontine nuclei. Small-caliber fibers descend dorsolaterally from the pyramidal tract to the level of the inferior olive, where they end at the rostral part of the medial accessory olive and the ventral plate of the main olive. A number of studies with retrograde labeling in rats have found no difference between the anterior and posterior intermediate nuclei. Cells projecting into the spinal cord were most numerous in the region of the interstitial cell group. They are located collateral to the superior colliculus, thalamus, and medial reticular formation [7-9].

Rostral group

The anterior intercalated nucleus of the cerebellum includes the dorsomedial crest and dorsolateral prominence, which have been described by scientists as small cells superimposed on the posterior intercalated nucleus. The fibers of the nucleus enter the brainstem and descend into the lateral reticular formation. The lateral (dentate) nucleus of the rat cerebellum consists of a dorsolateral magnocellular part and a ventromedial parvocellular part. A group of interstitial cells is also isolated, located between the anterior interstitial and lateral nuclei (Langer's basal interstitial nucleus). The lateral (lateral) nuclei of the cerebellum of rats are bilateral structures, each of which has the shape of a bean, with a medial depression. The lateral nucleus of the rat cerebellum is a compact bean-shaped mass of large and small neurons that are organized into heterogeneous groups. A segment with large spindle-shaped cells is also revealed, starting from the caudolateral margin and protruding in the center. The remaining ventral third of the lateral nucleus, the rostral and caudal poles, and a thin dorsal margin are represented by rounded cells [7,9].

Lateral (dentate) nucleus of the cerebellum

The function of the dentate nucleus of the cerebellum is to ensure the smoothness and accuracy of movements, the coordination of cognitive functions. In addition, the dentate nucleus has a connection with the thalamus, the center of the autonomic nervous system that controls reparative processes. In case of injury, nerve impulses are transmitted through the afferent anterior spinal cerebellar tract (Gowers tract) [10].

Cyto- and myeloarchitectonics

The first neuron of this pathway originates from the proprioceptors of the muscles, joints, tendons, and periosteum and is located in the spinal ganglion. The second neuron is represented by cells of the posterior horn of the spinal cord, the axons of which pass to the opposite side and rise up in the anterior part of the lateral column, pass the medulla oblongata, the pons, then cross again and through the upper legs enter the cortex of the cerebellar hemispheres, and then into the dentate nucleus. The efferent cerebellar-thalamic pathway begins in the dentate nucleus, passes through the superior cerebellar peduncle, and ends in the ventral nuclei of the thalamus. A study by some scientists confirmed the connection of the lateral macro cellular part of the lateral nucleus with the thalamus [6,8,10].

All areas of the cortex that are targeted by the dentate project back to the cerebellum via efferent fibers to the pontine nuclei, and the area of the cortex that does not project to the cerebellum is not targeted by the serrated output. The motor area in the dorsal dentate contains output channels that control both generation and control of movement, as well as neurons that innervate premotor areas in the frontal lobe. The non-motor area contains output channels involved in cognition and visuospatial function, and projections to the prefrontal and posterior parietal cortex areas in this area are grouped into separate areas with little overlap. These areas are activated during tasks related to short-term working memory, rule-based learning, and higher executive function planning [10].

The dentate nucleus is highly convoluted, with gyri (ridges on the cerebral cortex) and sulci (furrows or grooves on the cerebral cortex). Its formation coincides with the critical period of extensive growth of the dentate of the fetus. The dentate nucleus becomes visible in the white matter of the cerebellum as early as 11-12 weeks of gestation and contains only smooth lateral (toward the side(s) or away from the midline) and medial (toward the midline) surfaces. At this time, the neurons of the dentate nucleus are similar in shape, they are mainly bipolar cells [8,10]. The nucleus receives afferent fibers from the premotor cortex and supplementary motor cortex via the pontocerebellar system. Efferent, or outgoing, signals pass through the superior cerebellar peduncle through the red nucleus to the opposite side-the ventro-anterior/ventrolateral part of the thalamus. The lateral nucleus is involved in the crossing of the ascending and descending branches of the superior cerebellar peduncles.

Globular nucleus

The neurons of the spherical nucleus have synaptic connections with the field of the prefrontal cortex of the brain through the thalamus, therefore, they can participate in the regulation of behavior. In addition, these nuclei are involved in sequential finger movements in humans, the perception of intense pain, in the control of voluntary and automatic movements, and play an important role in cognitive processes [11]. The globular nucleus is a paired formation located in the right and left hemispheres of the cerebellum ventrally from the anterior edge of the emboloid nucleus and is covered by 1-3 convolutions of the dentate nucleus on the dorsal surface. The nucleus extends in the ventral and lateral directions in the thickness of the white matter of the gate of the dentate nucleus, the shape varies from sinuous from ribbon-like to sigmoid-oval, depending on its part. On a series of stained sections of the cerebellum, the boundaries of the spherical nucleus are clearly differentiated. The plate of its gray matter has small spherical sinuous teeth in the form of a wavy line. In the ventral-lateral part, it connects with the anterior-ventral part of the emboloid nucleus with a thin bundle of gray matter [6,11].

Fastigial nucleus

Purkinje cells of the cerebellar cortex project into the deep nuclei of the cerebellum and inhibit the excitatory output system via GABAergic synapses. The fastigial nucleus receives information from the Purkinje cells of the worm. Most of its efferent connections

pass through the inferior cerebellar peduncles to the vestibular nuclei, which are located at the junction of the pons and the medulla oblongata [12]. The fastigial nucleus sends excitatory projections outside the cerebellum. Probable neurotransmitters of the axons of the fastigial nucleus are glutamate and aspartate.

Rostral fastigial nucleus

The rostral fastigial nucleus is associated with the vestibular system. It is projected from the vestibular nuclei and promotes the activity of vestibular neurons. This core interprets the movement of the body and moves it to spatial to evaluate the movement in space. This applies to antigravity muscle groups and other synergies associated with standing and walking (in addition to the muscles of the lower limb, the antigravity muscles include the muscles of the back, which, by their tension, allow a person to maintain a vertical position of the body, these muscles are also called postural) [6,12].

Caudal fastigial nucleus

The caudal fastigial nucleus is associated with saccadic eye movements (rapid, strictly coordinated eye movement that occurs in one direction. A deeply located nucleus in the cerebellum, the Shatra nucleus, is involved in controlling the saccadic system. It is believed that the specific contribution of the cerebellum to the work of oculomotor structures is associated with the function of calibration eye movements and a decrease in gaze position instability. The output of the Purkinje cell from the oculomotor worm is transmitted through the nucleus, where the neurons directly associated with saccadic eye movements are located [12].

Anterior intercalary nucleus of the cerebellum

The dorsomedial crest and dorsolateral tubercle have been described as lateral and dorsal protrusions of the undivided intercalated nucleus. The cells of the dorsomedial crest and the adjacent medial part of the anterior intercalary nucleus are smaller than the cells of the lateral part of this nucleus. There is a clear boundary between the small cells of the dorsomedial crest and the larger cells of the posterior intermediate nucleus. The dorsolateral prominence is a ridge of small cells on the rostro lateral and dorsal surfaces of the anterior intermediate nucleus. The scientists included the lateral quarter of the anterior intercalary nucleus in the protrusion. When defined in this way, the prominence includes the large cells of the caudal pole of the anterior intercalary nucleus, which lie between the posterior intercalary and lateral nuclei. The dorsolateral prominence is the main source of the uncrossed descending branch of the superior cerebellar peduncle. It also includes part of the anterior intermediate nucleus ventromedial to the protrusion. The protrusion fibers enter the brainstem between the motor and main sensory nuclei of the trigeminal nerve and descend to the lateral reticular formation, ending here or in the deep layers of the main and spinal trigeminal nucleus. Some fibers project to the spinal cord [13].

Cyto and myeloarchitectonics

The efferent fibers of the anterior intercalary nucleus, including its dorsolateral protrusion, run in the middle part of the superior

cerebellar peduncles. The anterior intercalary nucleus is involved in the crossing of the ascending and descending branches of the superior cerebellar peduncles. Cells projecting to the ventrolateral complex of the contralateral thalamus and the contralateral medial bulbar reticular formation, including the inferior olive, are found throughout the anterior intermediate nucleus. Cells with collateral projections to the thalamus and superior colliculus are located in the lateral part of the nucleus, while cells with double projections to the thalamus and medial bulbar reticular formation extend more laterally into the dorsolateral protuberance. The fibers of the anterior intercalary nucleus do not descend into the spinal cord [11,13].

Cerebellar worm

The cerebellar worm is located in the posterior cranial fossa. It is generally accepted that the worm is part of the «spinocerebellum» and receives somatic sensory signals from the ascending spinal tract. On the contrary, the lateral zone of the cerebellum is part of the «cerebellar-cerebellar», since it is closely connected with the cerebral cortex. The worm is projected onto the medial zone of the cerebellum. The vermis is closely associated with all areas of the cerebellar cortex, which can be divided into three functional components, each of which has different connections with the brain and spinal cord. These areas include the vestibulo-cerebellum, which is primarily responsible for controlling eye movements, and the spino-cerebellum, which is involved in fine movements of the body and limbs. And cerebro cerebellum, which is associated with the planning, initiation and synchronization of movements. Infection of the worm leads to violations of posture and movement of the whole body, while damage to the lateral zone leads to impaired movement of the limbs [14].

Cerebellar cortex

Three layers can be found in the cerebellar cortex during histological examination: the first layer is molecular, it is also called the outer layer, the second is ganglionic (ganglionic), the layer of Purkinje cells, this layer forms the border between the granular and molecular layers, the third is granular or granular layer. These layers are composed of certain types of neurons: the molecular layer - basket and stellate neurons; ganglion layer - pear-shaped neurons, which in turn contain special brain neurons - Purkinje cells; granular layer - granular cells also known as granule cells, large stellate neurons and fusiform horizontal cells. It should also be noted that there are so-called Lugaro cells, which are located in the middle of the outer and granular layers, specifically under the Purkinje cells. Cerebellar granule cells make up more than half of the neurons in the entire brain. These cells extend from mossy fibers and project onto Purkinje cells. Purkinje cells are one of the brightest types of mammalian brain cells. Their apical dendrites branch like a tree in the molecular layer, thousands of small branches with numerous synapses [15].

Among other things, Purkinje cells are highly differentiated GABAergic neurons. They receive excitatory signals through afferent mossy fibers, through granular neurons. Note that Purkinje cells

also inhibit neurons in the cerebellar nuclei and inhibit granular neurons [8,15]. In addition to the main cell types (granule cells and Purkinje cells), the cerebellar cortex also contains various types of interneurons, including Golgi cells, basket cells, and stellate cells. Information comes to the cerebellar cortex through two types of afferent fibers. Mossy fibers originate in the pontine nuclei, spinal cord, brainstem reticular formation, and vestibular nuclei and project excitatory projections to the cerebellar nuclei and to granule cells in the cerebellar cortex. They are called mossy fibers because of the bundled appearance of their synaptic contacts with granule cells. There is a great deal of divergence in the association of mossy fibers with granule cells, since each mossy fiber innervates hundreds of granule cells. The granule cells guide axons upward to the surface of the cortex. Each axon bifurcates in the molecular layer, sending out collaterals in opposite directions. These fibers, called parallel fibers, run parallel to the folds of the cerebellar cortex, where they form excitatory synapses with Purkinje cells along the way. Two-dimensional dendritic branches of Purkinje cells are oriented perpendicular to parallel fibers. Thus, the arrangement of Purkinje cells and parallel fibers resembles telephone lines running between telephone poles. Each parallel fiber contacts hundreds of Purkinje cells, and due to the high degree of synapse divergence between mossy fibers and granule cells, the excitation of each Purkinje cell can be affected (dysynaptically) by thousands of mossy fibers [16].

Climbing fibers originate exclusively in the inferior olive and make excitatory projections to the cerebellar nuclei and directly to the Purkinje cells of the cerebellar cortex. They are called climbing fibers because their axons climb and wrap around the dendrites of the Purkinje cell like a creeping vine. Each Purkinje cell receives one extremely powerful impulse from one climbing fiber. Unlike mossy and parallel fibers, each climbing fiber contacts on average only 10 Purkinje cells, forming about 300 synapses with each Purkinje cell. Thus, the climbing fiber is a limited but extremely powerful excitatory input to Purkinje cells [8,16,17].

Purkinje cells are the only source of impulses in the cerebellar cortex. It is important to note that Purkinje cells form inhibitory connections with the cerebellar nuclei. Almost all spikes generated by the Purkinje cell are caused by its parallel fibers that form the entrance. This input causes the Purkinje cell to fire at a high resting rate (~70 pulses per second), tonically inhibiting its targets in the cerebellar nucleus. This input from climbing fibers is less frequent (about 1 pulse/sec), so it has little effect on the overall rate of excitation of the Purkinje cell. However, Purkinje cell spikes that are generated by climbing fibers are calcium spikes that allow climbing fibers to initiate a series of calcium-dependent changes in the Purkinje cell. One of the important changes, apparently, is a long-term change in the strength of the inputs of parallel fibers into the Purkinje cell [17].

Functionally, the mediolateral continuity of the cortex depends on the presence of parallel fibers, that is, the molecular layer. In the anterior lobe, the worm's bark continues continuously into the hemispheres. The cortex of lobules 9 (uvula) and 10 (nodule), as well as the secondary and posterolateral fissures, ends in a deep

paramedian groove that separates these lobules from the pyramidal ligament. Laterally, the ligament passes into the para flocculus (shred). The cortex of the para flocculus is a laterally directed loop that continues with the cortex of the patch at the bottom of the hemispheric segment of the posterolateral fissure. The cortex of the patch is interrupted in the center of the loop in the so-called intrapara floccular furrow. These areas where the central white matter comes to the surface are in the caudoventral and rostral parts of the patch. For descriptive purposes, the dorsal and ventral branches of the loop are distinguished as dorsal and ventral para flocculi, but this distinction is secondary to the essential continuity of the leafy chain of the hemisphere. Scientists have found that the lateral expansion of the secondary sulcus separates the dorsal patch from the ventral. There is no such continuity in the rat. The sulci of this part of the cerebellum develop independently in the cortex of the caudal vermis and in the hemisphere and end in the white matter in the paramedian and inter parafloccular sulci that separate the caudal vermis from the para flocculus and flocculus [18].

Afferent connections of the cerebellum

Cerebellar neurons receive signals via afferent fibers from various parts of the central nervous system, but their main flow comes from the spinal cord, vestibular system, and cerebral cortex. Through the spinocerebellar pathways, mainly through the lower cerebellar peduncles, it receives information from proprioceptors about the state of activity of the spinal cord motoneurons, the state of the muscles, the tension of the tendons, and the position of the joints. Afferent signals coming to the cerebellum from the vestibular apparatus and the vestibular nuclei of the brain stem bring information about the position of the body and its parts in space (body posture) and the state of balance. Corticocerebellar descending pathways are interrupted on neurons of the nuclei of the pons (cortico pontocerebellar pathway), the red nucleus and the inferior olive (cortico-olivocerebellar pathway), the reticular nuclei (cortico reticulo cerebellar pathway) and the hypothalamic nuclei, and after their processing follow to the neurons of the cerebellum. Through these pathways, the cerebellum receives information about the planning, initiation and execution of movements [18,19].

Afferent signals enter the cerebellum through two types of fibers - mossy and curly (climbing, liana-like). Mossy fibers originate in various areas of the brain, while climbing fibers come from the lower olivary nucleus. The mossy fibers that form acetylcholine diverge widely and end on the dendrites of the granular cells of the cerebellar cortex. Afferent pathways formed by climbing fibers are characterized by low divergence. The synapses they form on Purkinje cells use the excitatory neurotransmitter aspartate [19]. Axons from granule cells travel to Purkinje cells and interneurons, exerting an excitatory effect on them through the release of aspartate. Ultimately, through neuronal connections, mossy fibers (granular cells) and through climbing fibers, excitation of Purkinje cells is achieved. These cells have an excitatory effect on the neurons of the cerebellar cortex, while interneurons have an inhibitory effect (through the release of GABA and taurine).

All types of neurons in the cerebellar cortex are characterized by a high frequency of neural activity at rest. At the same time, the frequency of discharges of Purkinje cells changes in response to the arrival of sensory signals through afferent fibers or from proprioceptors with a change in the activity of motor neurons of the spinal cord. Purkinje cells are efferent neurons of the cerebellar cortex, releasing gamma-aminobutyric acid (GABA), so their effect on neurons in other brain structures is inhibitory. Most of the Purkinje cells send axons to the neurons of the deep (dentate, corky, spherical, tent) nuclei of the cerebellum, and some of them to the neurons of the lateral vestibular nuclei [18,19]. The arrival of excitatory signals to the neurons of the deep nuclei through the collaterals of mossy and climbing fibers maintains a constant tonic activity in them, which is modulated by the inhibitory effects of Purkinje cells.

Efferent pathways of the cerebellum

Subdivided into intracerebellar and extracerebellar. The intracerebellar pathways are represented by the axons of Purkinje cells following the neurons of the deep nuclei. The main number of extracerebellar efferent connections is represented by axons of neurons of the deep nuclei of the cerebellum, emerging as part of the nerve fibers of the cerebellar peduncles and ending in synapses on neurons of the reticular nuclei, the red nucleus, the inferior olives, the thalamus and the hypothalamus. Through the neurons of the stem and thalamic nuclei, the cerebellum can influence the activity of neurons in the motor areas of the cerebral cortex, which form the descending pathways of the medial system: corticospinal, corticobulbar, corticorosticular, etc. In addition, the cerebellum is connected by efferent pathways with neurons in the parietal and temporal associative areas of the cerebral cortex brain [20]. Thus, the cerebellum and the cerebral cortex are connected by numerous neural pathways. Through these pathways, the cerebellum receives information from the cortex, in particular, copies of the motor programs of upcoming movements, and mainly through the dentate-thalamic pathways influences the motor commands sent by the cerebral cortex to the stem motor centers and to the spinal cord.

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