

An example of a misnomer in medicine: Choice of the term basal ganglia for the basal nuclei

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Abstract

In modern literature, a group of neurons in the peripheral nervous system is called a 'ganglion', while this in the central nervous system is called a 'nucleus'. For the plurality of these structures, ganglia and nuclei are used, respectively. Such terminological distinction was probably not in the mind of early scientists, and the name of the basal ganglion became a misnomer frequently used by modern scientists to name subcortical nuclei involved in the control of movement. All this is far from explaining why this misnomer continues. It is not known whether it will change in the future, but it is certain that this will not happen in the near future. Knowing that it is used with a misnomer and the fact that these structures are actually basal nuclei appears in the minds of scientists and students is an important victory.

Keywords: Basal nuclei; basal ganglia; misnomer; medicine; physiology

Functional anatomy of basal nuclei

Basal nuclei, called basal ganglia, are the general name of movement-related neuron clusters that symmetrically distribute in the subcortical areas of the brain in the telencephalon, diencephalon, and mesencephalon. These clusters of neurons include the substantia nigra, putamen, globus pallidus, caudate nucleus and subthalamic nucleus (Figure 1). Among these, the caudate nucleus, putamen and globus pallidus are in the telencephalon area, the subthalamic nucleus is in the diencephalon, and the substantia nigra is located in the mesencephalon (1). Although the subthalamic nucleus and substantia nigra are distant to the basal nuclei in the telencephalon, they are functionally recognized as important members of this family. The nucleus caudatus and putamen are named striatum (2), which together form the largest structure of the basal nuclei (3), while the putamen and globus pallidus are named nucleus lentiformis (2). The neostriatum area is usually named as the striatum. The structure including the nucleus caudate and the lentiform nucleus is also known as the corpus striatum (3). In the old classification, the amygdala and claustrum were accepted as members of the basal nuclei instead of substantia nigra and nucleus subthalamicus (4). However, the amygdala is now considered to be a member of the limbic system.

The claustrum has reciprocal connections with the cerebral cortex (5). Considering the functional integrity of the basal ganglia, the amygdala and also hippocampus cooperate with the basal nuclei to control the psychomotor movement.

In the control of movement, the basal nuclei are important members of the motor system, similar to the cerebellum, which generally does not function alone, and are in constant close relationship with the corticospinal motor system and the cerebral cortex. In fact, the basal nuclei receive all the input signals from the cortex and return the output signals almost entirely to the cortex. Almost all motor and sensory nerve fibers that connect the cerebral cortex to the spinal cord pass between the caudate nucleus and putamen, the main circuits of the basal nuclei (6).

Physiological roles of basal nuclei

Performing learned movement spontaneously: Putamen circuit

The putamen circuit of the basal nuclei plays a major role in facilitating learned movements spontaneously. One of the basic roles of the basal nuclei in motor control is to control complex models of motor activity with the corticospinal system. Writing is one of the examples of these roles.

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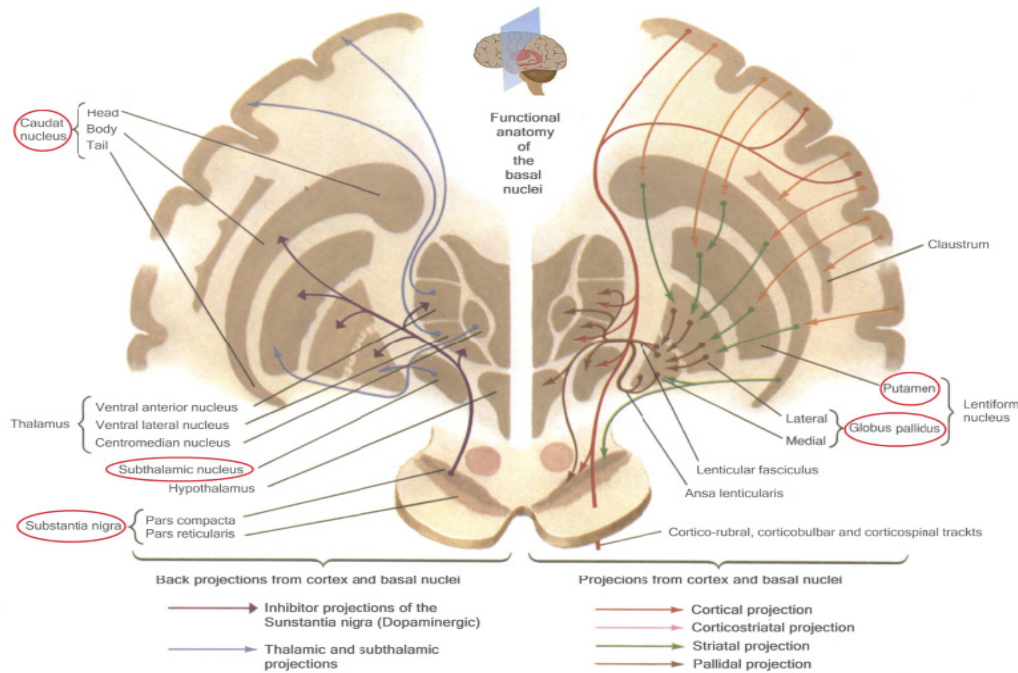


Figure 1. Functional anatomy of the basal nuclei (5)

When severe damage to the basal ganglia occurs, the cortical system of motor control cannot produce this movement. The person's writing becomes corrupted as if someone just learned to write. Basal nuclei are needed to cut something with scissors, walk or run, use cycling, many aspects of vocalization, controlled movements of the eyes and all other movements that require dexterity. Most of this is performed in an unconscious form. Dysfunction in the putamen circuit may lead to pathologies such as athetosis, hemiballismus, and chorea (6).

Role of basal nuclei in the cognitive control of sequential motor movements: Caudate nucleus circuit

Most of our motor movements arise from the thoughts we have created in our minds, and this process is called cognitive control of motor activities. The caudate nucleus plays the main role in cognitive control of motor activity. A good example of this is that, when a person sees a big predator approaching him, he suddenly and automatically responds (I) away from the predator, (II) starts running and (III) even tries to climb a tree. Without cognitive functions, the individual may not have the necessary instinctive knowledge to respond quickly and appropriately without too much thought (6).

Parkinson's disease

In Parkinson's disease, also known as paralysis agitans or shaking palsy, there is widespread destruction of the subcomponent nigra of the pars compacta, which sends dopamine-secreting nerve fibers to the striatum area such as the caudate nucleus and putamen.

Parkinson's disease involves (I) rigidity in the majority of the muscles in the body, (II) involuntary tremor at

a constant frequency of 3-6 per second, even during rest in the related areas (III) severe difficulty in starting movements, (IV) weakness caused by postural reflexes, (V) dysphagia (difficulty swallowing), speech disorder, gait disturbances and other motor symptoms including fatigue (6).

Why the basal nuclei are called basal ganglia?

The nomenclature of structures associated with the basal nuclei in the brain, which began to emerge in the Middle Ages, was characterized by Mondino de' Liuzzi (Mondinus, c. 1270-1326), a Bolognese anatomist. He was boldly searching for new knowledge from direct dissection of the human body through a procedure that had been forbidden from that time since Alexandrian period in the 3rd century BC (7). Mondinus first referred to an appellation of the basal nuclei as anachae (haunches) in *Anathomia*, a short letter he wrote for his students in 1316. This letter, which went through many printed editions, called this part as Anachae (Haunches) and guided European anatomists for more than 200 years (8). Another researcher, Jacopo Berengario da Carpi (c.1460-1530), one of the first anatomists to integrate talented painter artists to enrich their work, used the Latin term *nates* (buttocks) to define the same structures (9). After the Renaissance, a rough but clearer description of the basal nuclei was published by Andreas Vesalius (1514-1564) in his book series 'De humani corporis fabrica libri septem (On the Fabric of the Human Body in Seven Books, Vesalius, 1543). The 7th book of his work contains an extremely detailed outline of some basal nuclei components, probably drawn by Jan van Calcar, a painter. Unfortunately, Vesalius did not give a name to these structures in the figure label or anywhere

else in the text, and nor did he explain their possible functions. However, in the book of Vesalius, there are some essential brain areas that may be described as the putamen, caudate nucleus, pallidum and even thalamus (7).

In the 17th century, Thomas Willis decided to dissect the brain from a different perspective. He is recognized as a pioneer of the modern era of neurology (10), because he was one of the first to use the word 'neurology' in his classic book 'Cerebri Anatome' (11). The new dissection method allowed typical lines of gray and white matter to be seen on the top of the brainstem and identified the corpus striatum (streaked or chamfered structure) in humans and some animals. In his famous *Cerebri Anatome*, published in 1664, Willis explained the topographic position and general morphological appearance of the corpus striatum: 'The corpus striatum or apex of the medulla oblongata stands as two lens-like prominences in the anterior cerebral ventricles (Latin original text: Corpus striatum seu medullae oblongatae apices, sunt duo prominentiae

lentiformes, quae intra piores cerebri ventriculos (12). Willis also defined an arterial pattern at the base of the brain (known as circle of Willis) and a classification of the cranial nerves (10). In his work, Willis profited from the artistic talent of Christopher Wren, a designer, geometer and architect, to provide striking representations of the corpus striatum that are still valid today (Figure 2). Following the 17th century, Raymond Vieussens (1641-1715) referred to the basal nuclei as *le grand ganglion cerebral* (the great cerebral ganglion) (13).

In the late 18th century, the French anatomist Fe'lix Vicq d'Azyr (1748-1794) provided a remarkably accurate description of the basal nuclei in *Traite' d'anatomie et de physiologie* (14). His work contains several plates in which the various members of the basal nuclei, including the putamen, the caudate nucleus and the pallidum, are clearly delineated from one another. Unfortunately, like Vicq d'Azyr, Vesalius did not name these structures separately.

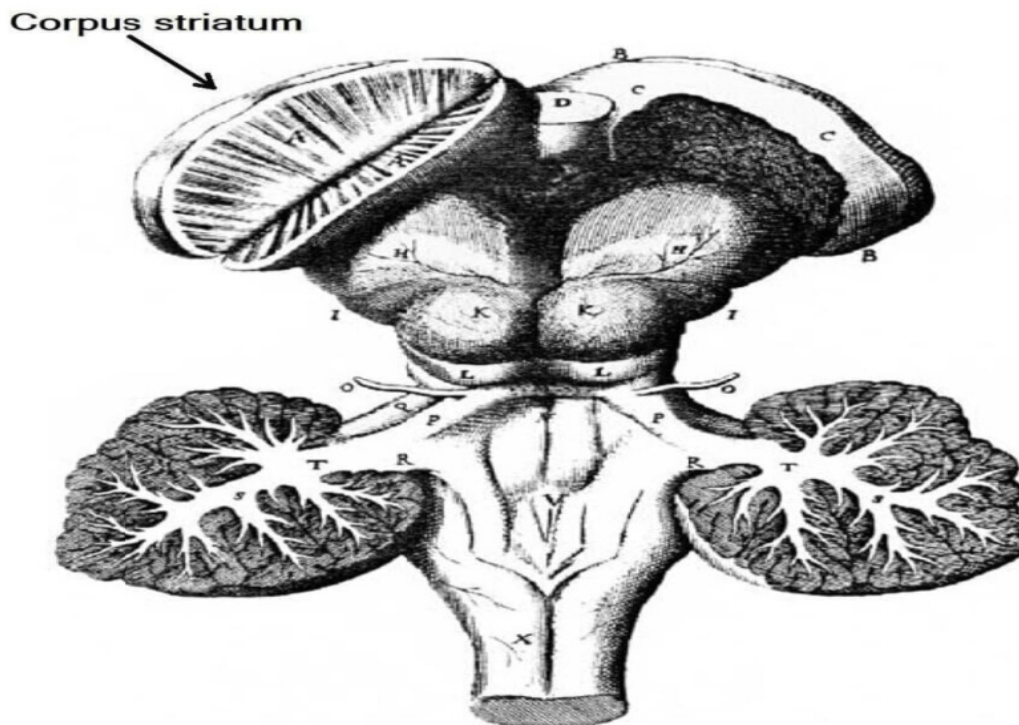


Figure 2. Drawing of the basal nuclei in Thomas Willis' book 'Cerebri Anatome' (12). This drawing shows a dorsal view of the basal ganglia and the brainstem in a sheep. The corpus striatum, which is indicated by an arrow (also the letter A), appears to be its characteristic striations

After a certain period of time, Reil, Gall and Spurzheim provided considerable contributions to the anatomy of the brain in general and of the basal nuclei in particular (15). Reil, called the first two divisions as the great cerebral nucleus, with an anterior part (Willis's corpus striatum) and a posterior part (thalamus) (16). Afterwards, Gall and Spurzheim named the same features as the great cerebral ganglion (*le grand ganglion cerebral*) with its anterior and

posterior parts (17). Solly (1836) used the nomenclature 'hemispheric ganglion' to call the cerebral cortex, in an effort to provide a complement to the term 'great cerebral ganglion' of Gall and Spurzheim (18). In 1876, David Ferrier evaluated the set of subcortical structures in his book 'Functions of the Brain' (19). Ferrier considered these structures as the great cerebral nucleus or ganglion. In his book, the basal nuclei were described as the basal

ganglia (the basal ganglia-the corpora striata and optic thalami) (11).

The term basal ganglia remained prominent for the majority of the 20th century for scientists to qualify the term basal nuclei to its original meaning, corpora striata (the corpus striatum of Willis), that is, the basal nuclei of the cerebral hemisphere (11). At the beginning of the 20th century, the basal nuclei were thought to be associated with movement, as lesions in these areas were often associated with motor dysfunction in humans (15). Samuel Alexander Kinnier Wilson (1912) introduced the term "extrapyramidal" to neurology and focused attention upon the function of the basal nuclei. In 1925, Wilson also referred to the basal nuclei as 'the dark basement of the brain' (20). Structures composing the basal nuclei were reported by M. B. Carpenter to be the globus pallidus, putamen, caudate nucleus and amygdaloid nuclear complex (4).

Since the nomenclature basal nuclei refers to the subcortical telencephalic nuclei, neurologists have considered that it is more practical to use the term extrapyramidal system to classify together the corpus striatum and certain related brain stem nuclei (the substantia nigra, subthalamic nuclei, brain stem reticular formation and red nucleus), considered to subserve somatic motor functions (15). Although there have been some disapprovals to the use of the extrapyramidal system that was coined but not described by Wilson, it has been widely used for more than half a century (4). It should be mentioned, however, that the term extrapyramidal was used well before Wilson. For example, the 'Extrapyramidenbahnen' nomenclature for the extrapyramidal tracts was commonly employed by Theodor Meynert (1833-1892) at the end of the nineteenth century (21). Although it is still used in some clinical sciences today, the concept of the extrapyramidal system has gradually lost its didactic value especially in the physiology and neuroscience society.

In terms of physiology or neurophysiology, the current internationally published essential physiology textbook has been researched with special interest in the nomenclature of the basal nuclei or basal ganglia. Our survey revealed that some books only contain the phrase "basal ganglia" (Berne and Levy Physiology: 6th Edition. Bruce M. Koeppen and Bruce A. Stanton, 2010; Medical Physiology: A Systems Approach, Michael Levitzky and Hershel Raff, 2011; Medical Physiology. Walter F. Boron, Emile L. Boulpaep. Edition 3. 2017; Medical Physiology: Principles for Clinical Medicine. Rodney A. Rhoades and David R. Bell, Fourth Edition 2013; Textbook of Medical Physiology. Guyton AC and Hall JE, 13th edition, 2017; Physiology. Linda Costanzo 5th Edition 2013), some books refer to the basal nuclei (Human Physiology: From Cells to Systems, Lauralee Sherwood, 7e, 2010, Principles of human physiology, Cindy L. Stanfield, 5th ed. 2013), and some books include both of the terms 'basal ganglia and

basal nuclei' (Ganong's Review of Medical Physiology. Kim E. Barrett, Susan M. Barman, Scott Boitano, Heddwen Brooks, 25th Edition, 2016; Human physiology: Stuart Ira Fox, Fourteenth edition, 2016, Lippincott Illustrated Reviews: Physiology Richard A. Harvey, Robin R. Preston, Thad E. Wilson, 2018). Interestingly, in a national physiology book (Klinik Anlatımlı Tibbi Fizyoloji, Halis Koylu, 2nd edition, 2016), it was observed that the terminological sensitivity of our article was complied with in the section on the basal nuclei. In the book, it is emphasized that the subcortical nuclei of the basal nuclei should be named as nucleus rather than ganglion as they are located in the central nervous system. After this important reminder, it is stated that these structures are mentioned as basal ganglia in the book in order to comply with general usage. Despite this positive example, it has been disappointing to witness that the same sensitivity is not found in famous international physiology books.

It is seen that, in most international and famous physiology books, the basal nuclei are still referred to as the basal ganglia. This misnomer example appears to be long-term, as it exists, both in written documents and in laboratory and clinical routines. The best way for this change is to explain the correct terminology in lessons to students and assistants. Currently, there is an increase in neurodegenerative diseases due to lifestyle changes and prolongation of life. Parkinson's is one of these diseases. Dopaminergic dysregulation due to degeneration of the basal nuclei has an important role in the pathophysiology of Parkinson's disease. Therefore, in relation to this common neurodegenerative disease, the basal nuclei are often referred to as the basal ganglia in written works and orally. It is known as a general rule that a cluster of neurons in the central nervous system is called as nucleus and in plural as nuclei. This terminological nuance is known, but it is clear that calling the basal ganglion the basal nuclei is a habit. It should not be forgotten that habits or taboos are difficult to break down, but not impossible.

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