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PERENITY OF THE NEW ANATOMIC CONCEPT "*VENTRAL STRIATOPALLIDAL SYSTEM*". PSYCHOPATHOLOGICAL IMPLICATIONS

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Abstract: Diversification of research microanatomic methods of subcortical neuron structures has led to the re-structuring of the classical concept of basal ganglia and the working out of a new anatomic concept of ventral striatopallidal system. Macroanatomic visualization and evaluation of subsystems and structures of this new system are pioneering issues in the description and topography of the basal forebrain. The authors' aim – based on our macroanatomic experience – is at debating several issues associated to the progress in deciphering subcortical neuronal structures which generated dilemmas regarding their naming and evaluation. We based our study on post-mortem human biological samples, with the observation of the ethics and deontology of research. The study was carried out on four human brains free from acute or chronic lesions, that were taken from two men and two women aged between 55 and 65. They were analyzed after pre-fixation in solution 10% formaldehyde for 10 days and post-fixation in solution 5% formaldehyde for 6 months. Evaluation of location and subsystems' relations within the structures of the ventral striatopallidal system were based on the macroscopic anatomic analysis of serial sections carried out both on the brain and forebrain. We noticed several issues associated to: choosing the references for serial sections on the brain and forebrain; identification of the delimitations of subsystems from the dorsal striatum and the ventral striatum on the one hand and the structures in the ventral pallidum, on the other; the paths and the relations of the "extensions" originating in the dorsal striatum and in the amygdaloid body; anatomic and/or functional criteria of grouping the structure in the basal nuclei. The new concept of "ventral striatopallidal system" implies extra information on the integration of neuronal structure within the Limbic – Motor Interface.

Key words: Ventral Striatum, Ventral Pallidum, Innominata Substance, Sublenticular Extended Amygdala, Limbic – Motor Interface.

INTRODUCTION

The anatomic concept of "the ventral striatopallidal system" has appeared quite recently. It is based on studies that required the functional and anatomic restructuring of the basal nuclei (the basal ganglia) (Heimer L:1972 [1]; Heimer L, Wilson RD:1975 [2]; Heimer L:1976 [3]; Heimer L, *et al.*: 1982 [4]; Heimer L, *et al.*:1991 [5]. The structures of this new system are, currently, part of the basal forebrain (TNA Latin: Pars Basalis Telencephali, 2016).

Visualizing, naming and evaluating of connexions and deciding on the neuronal structures to the ventral striatopallidal system proved to be rather difficult in the course of history (Table 1).

Vesalius, Andreas (1543)[6] was the first anatomist to draw attention on the existence of subcortical neuronal structures, without naming them or evaluating their functional role. Willis Thomas (1644) [7] introduced the term corpus striatum in which, later on, Burdach, Karl Friedrich (1819)[8] visualized and termed two structures: the caudate nucleus and the putamen. In 1872 Meynert, Theodor Herman [9] described a nucleus in the vicinity of septum verum, which he named the nucleus accumbens septi, as well as a group of neurons that belonged to the ganglion of the ansa peduncularis. Further on, Kölliker, Rudolf Albert von (1896)[10] termed the neuronal group the basal ganglion of Meyner (Synonym: the basal nucleus of Meynert). In 1809 Reil, Johann Christian [11] identified a new group of neurons in the basal forebrain area; he named the former "medulla incognita". In 1859

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Table 1. Strucures of the dorsal striatopallidal system and the ventral striatopallidal system

SYSTEMS	PHYLOGENETICALLY SYSTEMS	ONTOGENETICALLY STRUCTURES	THE BASAL NUCLEI
THE DORSAL STRIATO-PALLIDAL SYSTEM	***THE NEOSTRIATUM***	**The Dorsal Striatum** *(TNA Latin: Striatum Dorsale,2016)*	**a). The Caudate Nucleus** (*Burdach,KF:1819)* **b). The Putamen** *(Burdach,KF:1819)*
	THE PALEOSTRIATUM	**The Dorsal Pallidum** *(TNA Latin: Pallidum Dorsale,2016)*	**The Globus Pallidus** *(Burdach,KF:1822)* Synonym: ***The Pallidum*** *(Foix,CE and Nicolesco, J: 1926)*
THE VENTRAL STRIATO-PALLIDAL SYSTEM *(Heimer,L; Wilson,RD:1975 Heimer,L:1978; Heimer,L., et al.:1982)* **Noteworthy:** ***The Ventral expansion of the basal ganglia and expansion of the cortical output apparatus*** *Heimer et al., 2008)*	***THE NEOSTRIATUM***	**The Ventral Striatum** *(Heimer,L; Wilson,RD:1975; Heimer, L:1978; Heimer, L., et al:1982) (TNA Latin: Striatum Ventrale, 2016)*	**The Fundus Striati** *(The Ventral Part of the Caudate nucleus and the Putamen; TNA: 2016)* ***a*) The Nucleus Accumbens:** *(Meynert,T:1872; Heimer, L et al.: 1997)* ***1.The Central part or The Core Region*** *(TNA Latin: Pars Centralis; Synonym: Region Nuclearis.* ***2. The Medial part or Shell Region*** *(TNA Latin:Pars Medialis; Synonym: Regio Tegens)* **b) The Striatal Areas of the Olfactory Tubercle** *(The Ventral Extention of the Ventral Medial part of the Fundus Striati). (Kölliker, A. 1896; Heimer, L,2003)*
	THE PALEOSTRIATUM	**The Ventral Pallidum** *(Heimer,L:1972; Heimer, L;Wilson, RD; 1975; Heimer, L., et al:1982) (TNA Latin: Pallidum Ventrale,2016)* **Paradigma "The innominate substance"** *(The Neurologist's Equivalent of the Cartographer's „Terra Incognita" (Heimer, L et al.:1997; 2008)* **1).The Subcommissural Substantia Innominata** *(Miodonski, R:1967). {The Subcommissural part of the Ventral Pallidum: Groenewegen, HJ:2007)}* ***a)The Ventral Extention of the globus pallidus*** ***b)The Basal nucleus***	**a). The Pallidal Areas of the Olfactory Tubercle** *(The Ventral Extention of the Globus Pallidus)* Synonym: *The Rostral part of the innominate substance (Heimer,L:;1982;2003)* **b).The Basal Nucleus** *(Meynert,T:1872;TNA Latin:Nucleus basalis,2016).* Synonym:*Nucleus basalis of the Magnocellular basal forebrain).* Eponyms: *a).Basal nucleus of Meynert (1872) b). Basal Ganglia of Meynert (Kölliker, RA:1896)*
	THE ARHISTRIATUM	**2).The Sublenticular Substantia Innominata** *(Johnston, JB:1923; de Olmos JS,1969;1972; Schwaber, 1982):* ***a)The Centromedial Amygdaloid Complex*** ***b)The Bed Nucleus of the Stria Terminalis.*** Synonyms : --**The extended amygdala** *(De Olmos JS, Ingram RW:1972; Alheid,GF, Heimer, L:1988; de Olmos, JS, Heimer, L:1999) (TNA Latin: Amygdala extenda, 2016)* ---**The Sublenticular Extended Amygdala** *(Alheid, GF; Heimer, L. 1988)(TNA Latin: Pars sublenticularis Amygdalae, 2016)*	**c). The centromedial Amygdaloid Complex** *(Johnston,JB:1923; de Olmos JS,1969;1972; Schwaber,1982):* **d).The Bed Nucleus of Stria Terminalis** *(Johnston, JB:1923; de Olmos, J:1972) (TNA Latin: Nucleus Striae Terminalis, 2016*

Reichert, Karl Bogislaus [12] re-named this neuronal group the innominate substance for which later eponyms were used, i.e. "substantia innominata of Reil" and "substances of Reichert".

The Innominate substance was called "Terra Incognita" by neuro-anatomists (Heimer *et al.*:1972) [1]. It was defined as a mass of neurons situated in the substriatal part of telencephalon, ventrally to the putamen and separated from globus pallidus by the anterior commissure. The term of basal nucleus of Meynert was used in clinical literature as a synonym of innominate substance.

In 1819 Burdach, Karl Friedrich[8] discovered, at macroscopic level, in the medial part of the temporal lobe, a structure looking like an amygdala, which he named as such, the amygdala. In 1923 Johnston JB [13] formally divided the amygdala into two components, i. e. the centromedial amygdaloid nucleus and the latero-basal-cortical complex. He noticed that the centromedial amygdaloid nucleus penetrates the innominate substance where it connects to the bed nucleus of the stria terminalis. In 1972 De Olmos JS and Ingram RW[14] advanced the hypothesis that the bed nucleus of stria terminalisis part of a new formation which they termed the extended amygdala. In 1988, Alheid GF and Heimer L [15] were sure that it was a very important functional anatomic entity in the organization of the basal forebrain.

Based on personal experience, the authors' aim is to present the progress that has been made in the understanding of subcortical neuronal structures, with impact on naming and evaluating them.

Our objectives are vizualisation and macroanatomic evaluation of the location of the structures within "the ventral striatopallidal system" on one hand, and of the reley - stations that enable their integration in the extra pyramidal System and behavioral functions, on the other.

MATERIALS, METHODS, TERMINOLOGY

Materials

The macro anatomic study was carried out on human biological samples taken post mortem in the Dissection Laboratories from the Department of Morphology, Faculty of General Medicine, University of Medicine and Pharmacy of Craiova. The research norms of ethics and deontology were strictly observed. We used 4 human brains (TNA Latin: Encephalon,2016) free from acute or chronic lesions taken from 2 men and 2 women aged between 55 and 65. The samples were pre-fixed in 10% formaldehyde solution for 10 days and post-fixed in 5% formaldehyde solution for 6 months.

METHODS

Visualization of structures in the ventral striatopallidal system was carried out on macro anatomic sections in the following spatial planes, i.e. horizontal, through the forebrain (TNA Latin: Prosencephalon, 2016); oblique to the horizontal through the cerebral hemisphere of the human forebrain; oblique to the coronal plane through the cerebral hemisphere of the human brain and paramedian sagittal through the human brain.

In a first stage of dissection we removed the leptomeninx and the blood vessels from the surface of the brain. In the second stage we isolated the forebrain from the brain. We managed that after removing the hindbrain (TNA Latin: Rhombencephalon,2016) by bilaterally cutting the cerebral peduncle. In the third stage serial sections through the brain and the forebrain were performed:

1) Horizontal serial sections were done on the human forebrain, at 10 mm distance through: the trunk of the corpus callosum ; the fornix ; the head of the caudate nucleus; the thalamus and the hippocampus (Fig.1).

2) Brissaud oblique sections through the cerebral hemisphere of the forebrain was performed following Edouard Brissaud's (1852-1909) approach,i.e. an oblique plane crossing two commisural anatomic marks: the anterior commissure and the posterior commissure. The section was obliquelly oriented, from medial to lateral, caudal to posterior so as it may cut through the head of the caudate nuclei and the thalamus (Fig. 2).

3) Oblique serial sections in coronal plane (Synonym: frontal) were carried out on the medial face of the cerebral hemisphere of the brain by sectioning the human brain in medial sagittal plane. They were done in parallel oblique planes to the central sulcus on the superolateral face of the cerebral hemisphere and crossing the rostrum of the corporis callosi (Fig. 3A); the interventricular foramen and the anterior commissura (Fig. 3B) as well as through the cerebral peduncle (Fig. 3C).

4) Paramedian sagittal plane sections were carried out on the basal surface of the brain through two points, i.e. the optic tract (Fig. 4) and through the parahippocampal gyrus (Fig. 5).

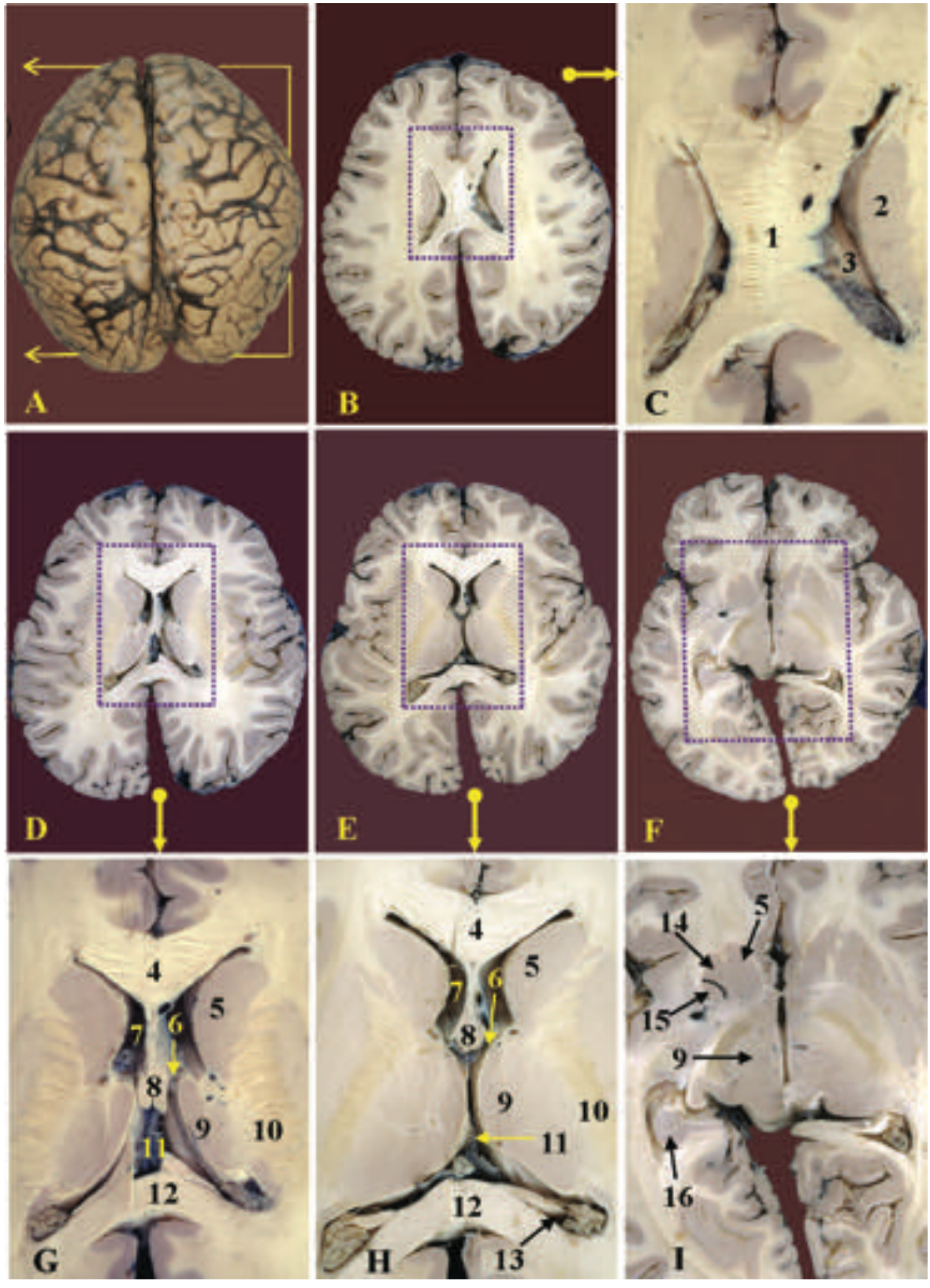

Figure 1. Horizontal serial sections through the human forebrain. A: Orientation of the horizontal plane. B and C: Horizontal section through the body of the corpus callosum (1); the body of the caudate nucleus (2); the central part of the lateral ventricle (3). D and G; E and H: Horizontal sections through the genu of the corpus callosum (4); the head of the caudate nucleus (5), the interventricular foramen (6), the cornu anterius of ventriculus lateralis (7); the fornix (8); the thalamus (9); the internal capsule (10); the third ventricle (11); the splenium of corpus callosum (12); the posterior horn of lateral ventricle (13); F and I: Horizontal through: the putamen (14); the nucleus accumbens (15); and the hippocampal formation (16).

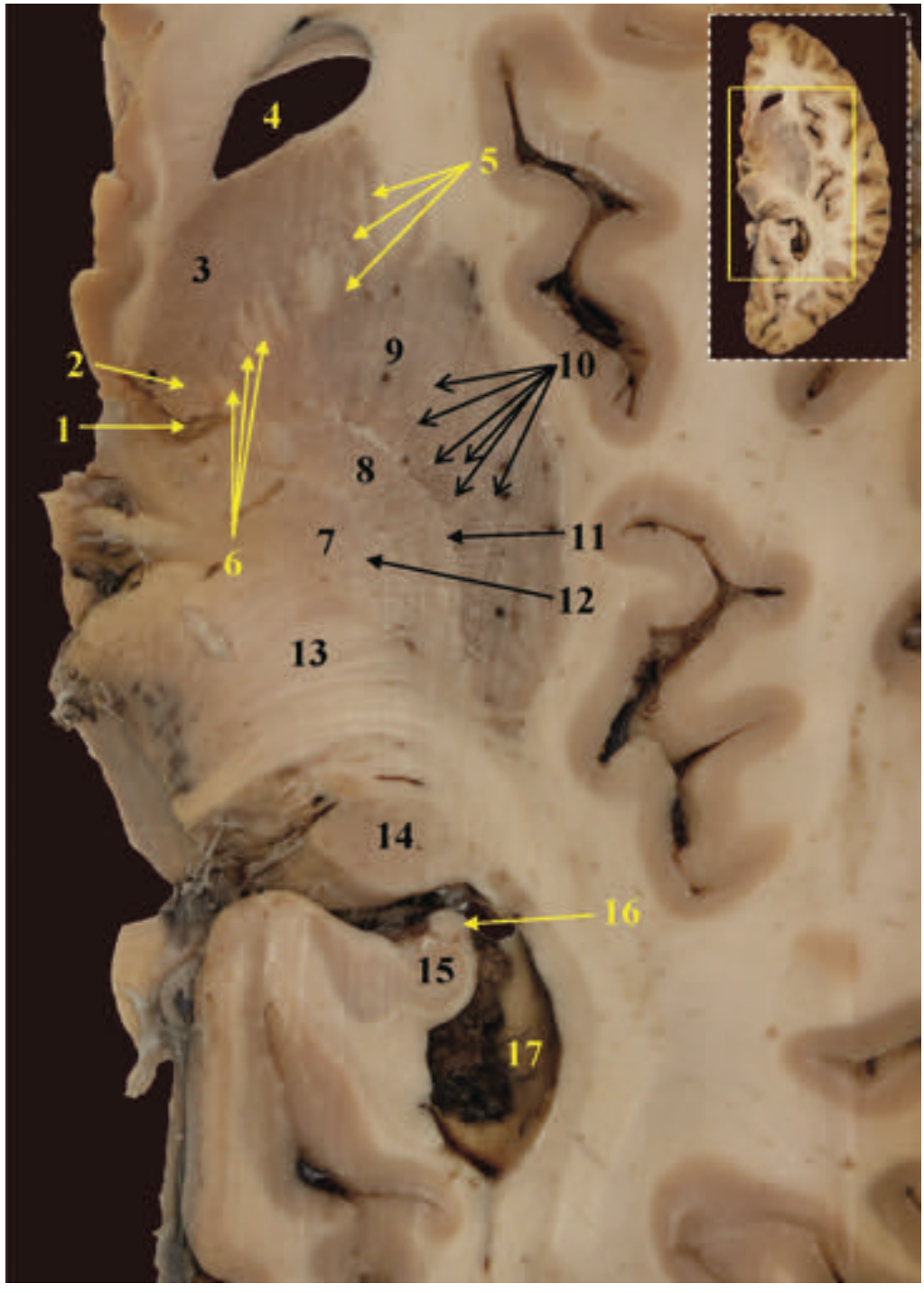

Figure 2. Oblique section (Brissaud) through the cerebral hemisphere of the human forebrain 1. The third ventricle (TNA Latin: Ventriculus tertius). 2. The nucleus accumbens (TNA Latin: Nucleus accumbens). 3. The head of the caudate nucleus (TNA Latin: Caput nuclei caudate). 4. The frontal or anterior horn of the lateral ventricle (TNA Latin: Ventriculus lateralis – cornu frontale;Latin synonym: cornu anterius). 5. The caudolenticular gray bridges (Synonym: the transcapsular gray bridges) (TNA Latin: Pontes grisei caudolenticular; Synonym:Pontes grisei transcapsulares). 6. The fiber bundles in the anterior limb of the internal capsule. 7. The medial or internal segment of the globus pallidus (TNA Latin: Globus pallidus medialis; Latin synonym: Globus pallidus internus). 8. The lateral or external segment of the globus pallidus (TNA Latin: Globus pallidus lateralis . Latin synonym: Globus pallidus externus). 9. The putamen (TNA Latin: Putamen). 10. The striatopallidal fibers (TNA Latin: Fibrae striatopallidal; Eponym: Pencil bundles of Wilson). 11. The lateral or external medullary lamina of globus pallidus (TNA Latin: Lamina medullaris lateralis; Latin synonym: Lamina medullaris externa). 12. The medial or internal medullary lamina of the globus pallidus (TNA Latin: Lamina medullaris medialis; Latin synonym: Lamina medullaris interna).13. The cerebral peduncle (TNA Latin: Pedunculus cerebri; Latin synonym: Crus cerebri). 14. The pulvinar nuclei (TNA Latin: Nuclei pulvinares). 15. The hippocampus proper or the Ammon's horn (TNA Latin: Hippocampus proprius; Latin synonym: Cornu ammonis). 16. The fimbria of hippocampi (TNA Latin: Fimbria hippocampi). 17. The temporal or inferior horn of the lateral ventricle (TNA Latin: Ventriculus latralis- cornu temporal; Latin synonym: Cornu inferius).

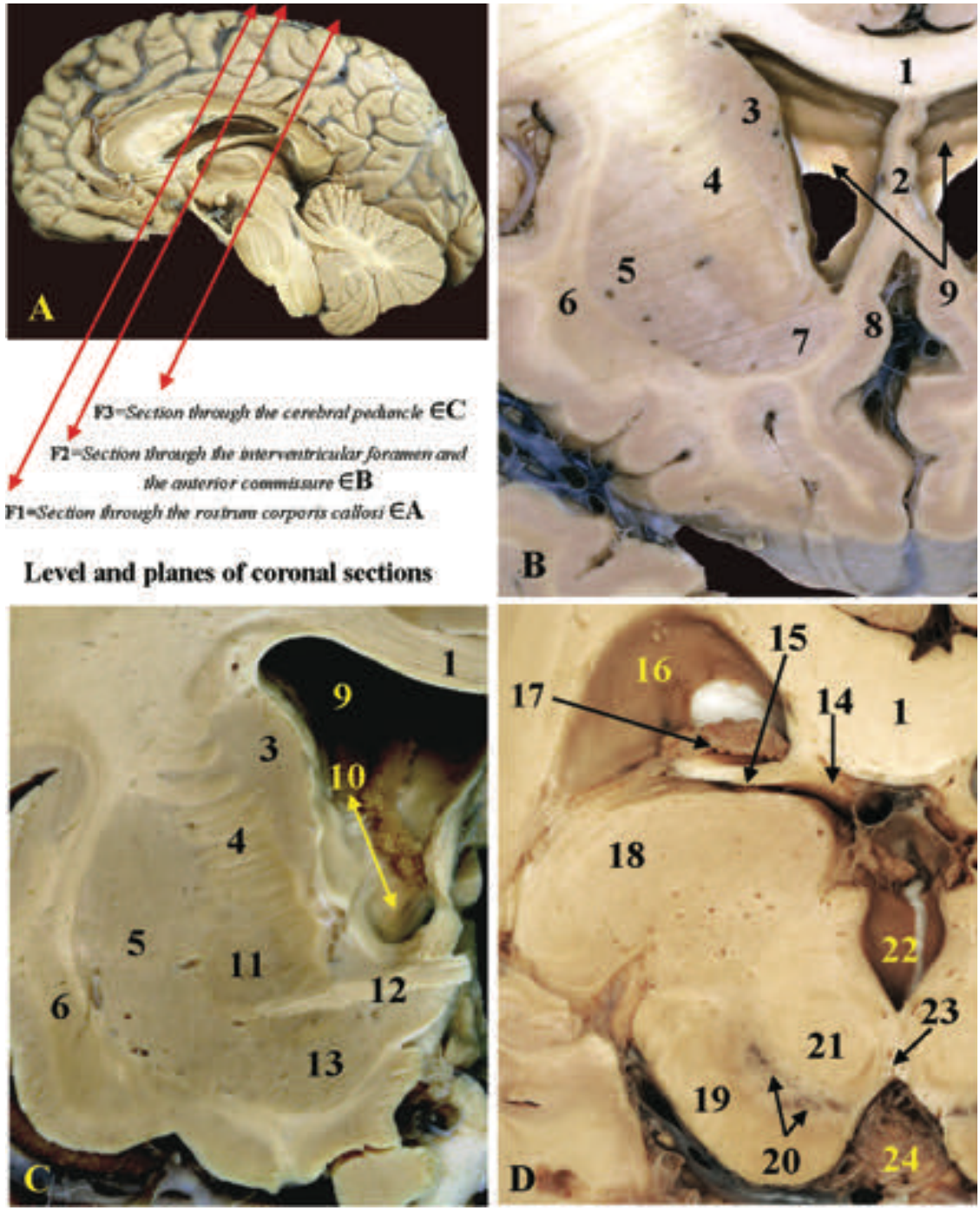

Figure 3. Coronal oblique serial sections through the cerebral hemisphere of the human brain. 1. The trunk of the corpus callosum (TNA Latin: Corpus callosum – truncus; Latin synonym: corpus). 2. The septum pellucid (TNA Latin: The septum pellucidum (TNA Latin: Septum pellucidum). 3. The head of the caudate nucleus (TNA Latin: Caput nuclei caudati). 4. The anterior limb of the internal capsule with the transcapsular gray bridge(TNA Latin: Capsula interna – crus anterius). 5. The putamen (TNA Latin: Putamen). 6. The external capsule (TNA Latin: Capsula externa). 7. The nucleus accumbens (TNA Latin: Nucleus accumbens). 8. The septum verum (TNA Latin: Septum verum). 9. The frontal, or anterior horn, of the lateral ventricle (TNA Latin: Ventriculus lateralis – cornu frontale or cornu anterius).10. The interventricular foramen (TNA Latin: Foramen interventriculare; eponym: foramen of Monro). 11. The globus pallidus (TNA Latin: Globus pallidus). 12. The anterior commissure (TNA Latin: Commissura anterior). 13. The innominate substance (TNA Latin: Substantia innominata; Eponym: Substance of Reichert)). 14. The body of the fornix (TNA latin: Corpus fornicis). 15. The crus of the fornix or the posterior pillar (TNA Latin: Crus fornicis). 16. The central part, or body, of the lateral ventricle (TNA Latin: Ventriculus lateralis - pars centralis). 17. The choroid plexus of the lateral ventricle (TNA Latin: Plexus choroideus ventriculi lateralis). 18. The thalamus (TNA Latin: Thalamus). 19. The cerebral peduncle (TNA Latin: pedunculus cerebri. Latin synonym: crus cerebri). 20. The substantia nigra (TNA latin Substantia nigra; eponym: substance of von Soemmerring). 21. The red nucleus (TNA Latin: Nucleus ruber). 22. The third ventricle (TNA Latin: ventriculus tertius). 23. The ventral tegmental nuclei (TNA Latin: Nuclei tegmentalis ventralis; eponym: ventral tegmental area of Tsai). 24. The interpeduncular fossa (TNA Latin: Fossa interpeduncularis; eponym: fossa of Taron).

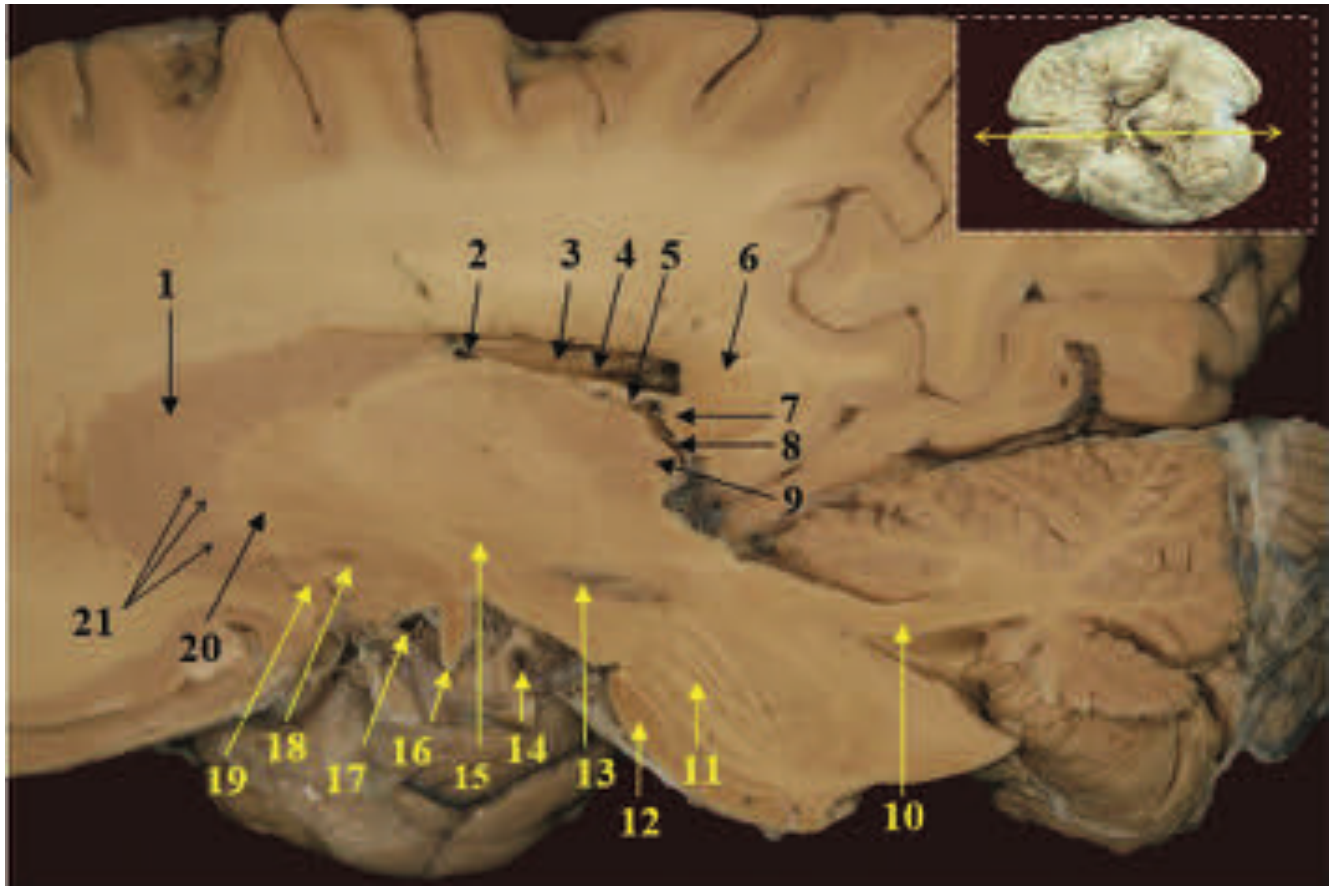

Figure 4. The human brain. Paramedian sagittal section through the optic tract.1. The head of the caudate nucleus (TNA Latin: Nucleus caudatus-caput). 2. The superior thalamostriate vein (TNA Latin: Vena thalamostriata superior; Latin synonym: vena terminalis). 3. The central part or body of the lateral ventricle (TNA Latin: Ventriculus lateralis - pars centralis; Latin synonym: Corpus). 4. The choroid plexus of the lateral ventricle (TNA Latin; Plexus choroideus ventriculi lateralis). 5. The crus of the fornix or the posterior pillar (TNA Latin: Crus fornicis). 6. The splenium of the corpus callosum (TNA Latin: Corpus callosum - splenium). 7. The fasciolar gyrus (TNA Latin: Gyrus fasciolaris). 8. The temporal horn, or inferior horn, of the lateral ventricle (TNA Latin: Ventriculus lateralis – cornu temporal; Latin synonym: cornu inferius). 9. The pulvinar (TNA Latin: Pulvinar). 10. The superior cerebellar peduncle (TNA Latin: Pedunculus cerebellaris superior). 11.The Longitudinal pontine fibres - Corticospinal fibres (TNA Latin: Fibrae pontis longitudinales – Fibrae corticospinales). 12. The pons (TNA Latin: Pons; Eponym: pons Varoli). 13.The substantia nigra (TNA Latin: Substantia nigra; eponym: substance of von Soemmerring). 14. The posterior cerebral artery (TNA Latin: Arteria cerebri posterior).15. The subthalamic nucleus (TNA Latin: Nucleus subthalamicus; Eponym: Nucleus or Corpus Luys). 16. The optic tract (TNA Latin: Tractus opticus). 17. The anterior cerebral artery (TNA Latin: Arteria cerebri anterior). 18. The anterior commissure (TNA Latin: Commissura anterior). 19. The ventral striatum (TNA Latin: Striatum ventral; Latin synonym: Corpus striatum ventrale). 20. The anterior limb of the internal capsule (TNA Latin: Capsula interna – crus anterius). 21. The caudolenticular grey bridge; synonym: The transcapsular grey bridge (TNA Latin: Pontes grisei caudolenticulares).

The macro anatomic images were performed by prof. dr. Gheorghe S. Drăgoi by means of a Digital Camera Canon Eos 1Ds Mark II with Macro Ultrasonic Lens EF 100 mm, f/2,8.

Terminology

Official anatomic nomenclature that lies at the basis of current medical terminology was created by the Federative Committee on Anatomical Terminology (FCAT) and published in July 1998 under the name of The International Anatomical Terminology (IAT)[16]. The terminology has been revised and updated by the Federative International Programme for Anatomical Terminology (FIPAT) (Istanbul, Turkey, August 31 – September 1, 2015) for the structures of neuronal biosystem. Further on, the International Federation of Associations of Anatomist (IFAA) validated and called this revised version The Terminologia Neuroanatomica (TNA) (Göttingen, Germany, September, 24 , 2016) [17]. This is the terminology the authors use in the present paper.

RESULTS

The evaluation of the location and relations of structures in the ventral striatopallidal system was

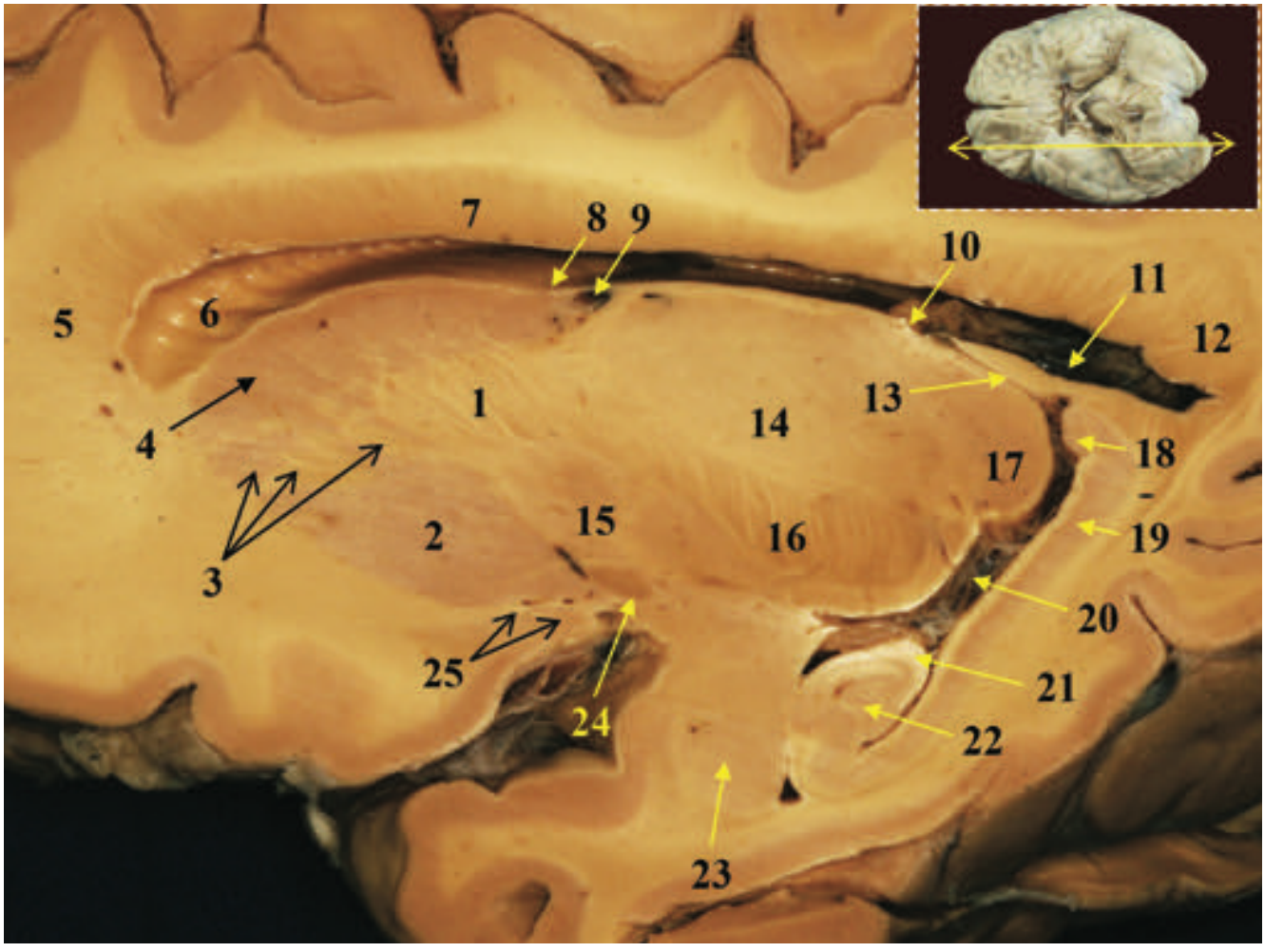

Figure 5. The human brain. Paramedian sagittal section through the parahippocampal gyrus. 1. The anterior limb of the internal capsule (TNA Latin: Capsula interna). 2. The putamen (TNA Latin: Putamen). 3. The caudolenticular grey bridge, synonym: The transcapsular grey bridge (TNA Latin: Pontes grisei caudolenticulares). 4. The head of the caudate nucleus (TNA Latin: Caput nuclei caudati). 5. The genu of the corpus callosum (TNA Latin: Corpus callosum – genu). 6. The frontal or anterior horn of the lateral ventricle (TNA Latin: Ventriculus lateralis- cornu frontalis; Latin synonim: cornu anterius). 7. The trunk, or body, of the corpus callosum (TNA Latin: Corpus callosum – truncus or corpus). 8. The central part, or body, of the lateral ventricle (TNA Latin: Ventriculus lateralis-pars centralis). 9. The superior thalamostriate vein (TNA Latin:vena thalamostriata superior; Latin synonim: v.terminalis). 10. The choroid plexus of the lateral ventricle (TNA Latin: Plexus choroideus ventriculi lateralis). 11. The occipital horn, or posterior horn, of the lateral ventricle (TNA Latin:Ventriculus lateralis-cornu occipitale; Latin synonim: cornu posterius). 12. The splenium of the corpus callosum (TNA Latin: Corpus callosum – splenium). 13. The crus of the fornix (TNA Latin: Crus fornicis). 14. The thalamus (TNA Latin: Thalamus). 15. The globus pallidus (TNA Latin: Globus pallidus). 16. The cerebral peduncle (TNA Latin: Pedunculus cerebri). 17. The pulvinar (TNA Latin: Pulvimar). 18. The fasciolar gyrus (TNA Latin: Gyrus fasciolaris). 19. The parahippocampal gyrus (TNA Latin: Gyrus parahippocampalis). 20. The temporal horn, or inferior horn, of the lateral ventricle (TNA Latin: Lateral ventriculus cornu temporal; Latin synonim: cornu inferius). 21. The fimbria (TNA Latin: Fimbria hippocampi). 22. The hippocampus proper or the Ammon's horn (TNA Latin: Hippocampus proprius; Latin synonim: Cornu ammonis). 23. The amygdaloid body or amygdaloid complex or simply amygdala (TNA Latin: Corpus amygdaloideum; Latin synonim: Complexus amygdaloideus). 24. The anterior commissure (TNA Latin: Commissura anterior). 25. The lenticulostriate arteries - distal lateral striate branches; or anterolateral central arteries (TNA Latin: Aa. centrales anterolaterales - Rr. Distales lateralis striati).

based on the macroscopic anatomic analysis, the serial sections through the brain and the forebrain.

A. Macroscopic Analysis Of Horizontal Plane Serial Sections

The macro anatomic analysis was carried out on four horizontal sections selected from the eight serial sections performed through the forebrain, spaced at 10 mm. The first horizontal section rendered evident the trunk of the corpus callosum (Fig. 1C, no. 1), the central part of the lateral ventricle (Fig. 1C, no. 3) and the body of the caudate nucleus (Fig. 1C, no. 2). The following two horizontal sections enabled the visualization of the genu of the corpus callosum (Fig. 1G and H, no. 4), the

head of the caudate nucleus (Fig. 1G and H, no. 5), the interventricular foramen (Fig. 1G and H, no. 6), the thalamus (Fig. 1G and H, no. 9) and the splenium of the corpus calosum (Fig. 1G and H, no. 12). The fourth horizontal section visualizes the nucleus accumbens (Fig.1 I, no. 15) at the junction between the head of the caudate nucleus (Fig.1 I, no. 5) and the putamen (Fig.1 I, no. 14) called "the fundus striati" (Synonym: The ventral parts of the caudate nucleus and putamen. TNA Latin – unlicensed).

B. Macroanatomic Analysis Of Brissaud Oblique Plane Section

In the oblique section to the horizontal (Brissaud) carried out through the cerebral of the human forebrain, at the junction between the anterior commissure and the posterior commissure, we identified and evaluated the special relations between the caudate nucleus (Fig. 2, no. 3), the putamen (Fig. 2, no. 9) and the globus pallidus (Fig. 2, no. 7, 8). It is easily identifiable the presence of fiber bundle connecting the putamen and the globus pallidus approved as the striatopallidal fibers (TNA Latin: 2016) (Fig. 2, no. 10) and the transcapular grey substance bridges between the caudate nucleus and the lentiform nucleus approved as the caudolenticular gray bridge (TNA Latin: Pontes grisei caudolenticular, 2016) (Fig. 2, no. 5). In the medio-caudal part of the Brissaud section we identified the nucleus accumbens (Fig. 2, no. 2) at the border between the head of the caudate nucleus (Fig. 2, no. 3) and the putamen (Fig. 2, no. 9) in the vicinity of the third ventricle (Fig. 2, no. 1).

C. Macroanatomic Analysis Of Coronal Plane Oblique Serial Sections

Coronal plane oblique sections were carried out on the cerebral hemisphere of the brain. They were oriented in parallel to the trajectory of the central sulcus on the superolateral face of the cerebral hemisphere. Three points were selected to carry out the coronal plane sections, i.e. the rostrum corporis callosi; the interventricular foramen and the cerebral peduncle (Fig. 3A).

On the first coronal section through the rostrum corporis callosi the location of the nucleus accumbens (Fig. 3B, no. 7) is seen, and it appears like a basal extension of the caudate nucleus (Fig. 3B, no. 3) in the direction of the putamen (Fig. 3B, no. 5) in a structure called the fundus striati. It is separated from the septum verum (Fig. 3B, no. 8) by a thick band of white substance.

On the second section on the interventricular foramen we easily identified the anterior commissure (Fig. 3C, no. 12). At commissural level the transcapsular gray bridge (Fig. 3C, no. 4) between the head of the caudate nucleus (Fig. 3C, no. 3 and the putamen (Fig. 3C, no. 5) can be seen. At subcommissural level the innominate substance is identified (Fig. 3, no. 13).

On a third coronal section carried out through the cerebral peduncle (Fig. 3D, no. 19) we saw the connections between the fornix (Fig. 3D, no. 15) and the corpus callosum (Fig. 3D, no. 1) on the one hand, and between the substantia nigra (Fig. 3D, no. 20) and the red nucleus (Fig. 3D, no. 21) in the cerebral peduncle (Fig. 3D, no. 19) on the other.

The nucleus accumbens (Fig. 3B, no. 7) situated within the rostral basal forebrain, was defined only with difficulty, the conventional borders being the following structures: the dorsal border through the internal capsule (Fig. 3B, no. 4), the head of the caudate nucleus (Fig. 3B, no. 3) and the putamen (Fig. 3B, no. 5); the medial border through the paramedian sagittal plane that goes through the inferior part of the frontal horn of the lateral ventricle (Fig. 3B, no. 9); the lateral and anterior borders through the rostral border of the internal capsule (Fig. 3B, no. 4) and the ventral border that crosses the plane containing Broca's Diagonal Band towards the medial part, and the anterior hypothalamic nucleus towards the posterior.

D. Macroanatomic Analysis Of Paramedian Sagittal Planes

Two paramedian sagittal planes were taken for the macroanatomic analysis, i.e. the optic tract (Fig. 4, no. 16) and the parahippocampal gyrus (Fig. 5, no. 19). The first section enabled the visualisation of the head of the caudate nucleus (Fig. 4, no. 1), the caudolenticular grey bridge (Fig. 4, no. 21), the anterior commissure (Fig. 4, no. 18), the ventral striatum (Fig. 4, no. 19), the substantia nigra (Fig. 4, no. 13) and the thalamus (Fig. 4, no. 9). The second paramedian sagittal section rendered evident the head of the caudate nucleus (Fig. 5, no. 4), the putamen (Fig. 5, no. 2), the globus pallidus (Fig. 5, no. 15), the caudolenticular grey bridge (Fig. 5, no. 3), the parahippocampal gyrus (Fig. 5, no. 19), the hippocampus proper (Fig. 5, no. 22) and the amygdaloid body (Fig. 5, no. 23).

DISCUSSION

The results of our study have highlighted the existence of several problems associated to the selection

of marks for the carrying out of serial sections through the brain and the forebrain; identification of borders delimiting the subsystems within the dorsal striatum and the ventral striatum on the one hand and the structures in the ventral pallidum, on the other; the trail and relations of "extensions" originating in the dorsal striatum and the amygdaloid body; and, last but not least, the anatomic and/or functional criteria of structure grouped within the basal nuclei at the interface between the limbic system and the motor system.

1) Uncertainties in ascertaining terminology, location and boundaries of subsystems and structures in the ventral striatopallidal system.

Neuronal structures and subsystems from the ventral striatopallidal system have been intensely studied in the last 53 years, and the results lie at the basis of the criteria for the macro-anatomic visualization by means of tridimensional dissections; macroanatomic evaluation by histochemistry, immunohistochemistry, immunocytochemistry, neuroanatomical tract-tracing, electrophysiology, pharmacology, as well as their grouping in functional subsystems. In 1975, based on spatial localization criteria, Heimer, L and Wilson, RD[2] described and termed two subsystems of this complex, i.e. the ventral striatum in primate and the ventral pallidum in rat and monkey, without being able to rigorously separate the anatomic limits between them. In 2006, based on philogenesis, O'Rahilly R and Müller F [18] grouped the neuronal structures from the ventral striatopallidal system into three subsystems, i.e. the neostriatum (the nucleus accumbens and the striatal areas of the olfactory tubercle) situated in the ventral striatum; the paleostriatum (the pallidal areas of the olfactory tubercle, and the basal nucleus of Meynert) and the arhistriatum (the centromedial amygdaloid complex şi the bed of stria terminalis) situated in the ventral pallidum on the much controversial innominate substance (Table 1).

The nucleus accumbens visualized and termed in 1872 by Meynert [9] as "the nucleus accumbens septi" was excluded from the septal nuclei in 1942 by Brockhaus, H (1942)[19] who took it as a component of the ventral striatum. Based on ontogenetic criteria it can be aassociated to the medial ventricular eminence (Sidman RL, and Rakic P. 1982)[20], while on histochemical criteria it resembles the structures in the caudate-putamen complex (Brana C *et al.*,1995)[21]. On the basis of connection criteria it is believed that the nucleus accumbens contributes to the transformation of emotion into movement. Mogenson GS *et al.* (1980) [22] suggested that the nucleus accumbens is an interface between the limbic system and the motor system (limbic-motor interface).

The olfactory tubercle remains an ambiguous and enigmatic neurobiological structure (Nieuwenhuys, 2008)[23]. Although topographically it belongs to the anterior perforated substance area, and by structure it is part of the ventral striatopallidal system, functionally it is part of the primary olfactory cortex. It looks like a protuberance along the basal forebrain in the Sylvius' valley in the rostral part of the anterior perforated substance and behind to the bifurcation of the olfactory striae in the medial and lateral stria. Based on the criterion for the origin of neuronal extensions, the olfactory tubercle belongs, structurally, both to the ventral striatum through the ventral extension of the medial part of the fundus striati (synonym: striatal areas of the olfactory tubercle) and to the ventral pallidum through the ventral extension of the globus pallidus (synonym: the pallidal areas of the olfactory tubercle) (Heimer, L, *et al.*: 1982)[4].

The paradigm innominate substance (Reichert KB, 1859)[12] has become a true Terra Incognita within the ventral pallidum subsystem. The absence of anatomic and/or functional criteria has made difficult visualization, evaluation and organization of neuronal structures in time and space.

In 1967 Miodonski, R [24] presented the idea that part of the structures existing in the innominate substance is placed ventrally compared to the anterior commissure and included it into a new subsystem termed the subcommissural substantia innominata. In 2007 Groenewegen HJ [25], renamed this system the subcommissural part of the ventral pallidum in which he included two neuronal structures, i.e. the ventral extention of globus pallidus (synonym: the pallidal areas of the olfactory tubercle) incorporated into the olfactory tubercle and the basal nucleus of Meynert.

In 1972 De Olmos, J [26] worked on rats; he described a new location of the innominate substance which he named sublenticular substantia innominate. The latter includes two neuronal structures, i.e. the centromedial amygdaloid complex and the bed nucleus of stria terminalis. In 1988 Alheid, GF şi Heimer L [15] and then in 1999 De Olmos JS şi Heimer L [27] re-termed this subsystem the sublenticular extendend amygdala *via* the bed nucleus of the stria terminalis.

However, the new information in the research based on macroanatomic approach led to the conclusion that the innominate substance is a well defined anatomic system, integrated in the basal forebrain

(Heimer,L, Zaborszky, L 1989)[28]. We believe that the macroscopic delimitation of these anatomic system structures remains to be solved in the future. In 1997 Heimer, L, Harian RE, Alheid GF, Garcia MM, de Olmos J[29], sustained that the innominate substance is a concept that prevents clinical and anatomic correlations in neuropsychriatry and should be abandoned.

2) Implications in psychopathology

The interest for descriptive, topographic, structural and functional anatomy of the nucleus accumbens has led to the implication of the latter in behavioural processes mediation as an interface between the limbic and motor systems (limbic-motor interface: Mogenson GJ, 1980 and Kelley AE *et al.*,1982) [22, 30]. It seems to be involved in neuropsychiatric pathology, i.e depression, anxiety, Parkinson's Disease, Huntington's Disease on the one hand and certain drug effects, on the other.

CONCLUSIONS

1. The new concept of "ventral striatopallidal system" brings new information regarding the integration of neuronal structures in the subsystems of motor control (the limbic-motor interface) and psychoemotional control (the limbic-emotional motor system).

2. Visualization and evaluation of the structures within the ventral striatopallidal system by means of macro-anatomic methods are still very new in the descriptive and topographic anatomy of basal forebrain. They depend on the identification of anatomic marks so that the researchers could carry out the serial sections, on the one hand, and define the criteria for spatial localization, philogenesis and ontogenesis as well as the reley connections, on the other.

3. The anterior commissure and the lentiform nucleus are two anatomic marks important for the spatial localization of recently termed subsystem in the innominate substance area.

4. The basal nucleus and the ventral extention of the globus pallidus can be identified and evaluated in the in the subcommisural area of the innominate substance.

5. The centromedial amygdaloid complex and the bed nucleus of stria terminalis are situated in the sublenticular area of the innominate substance.

Conflict of interest

The authors declare that they have no conflict of interest.

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