ACTA THERIOLOGICA
Vol. 32, 7: 95—104, 1987

Topography and Structure of Corpus striatum in Insectivora

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Szteyn St., Gawrońska B. & Szatkowski E., 1987: Topography and structure of *corpus striatum* in *Insectivora*. Acta theriol., 32, 7: 95—104 [With Plates III—IV].

The telencephalon was studied in three species of *Insectivora: Sorex araneus, Neomys fodiens* and *Talpa europaea*. The material was fixed in formalin, dehydrated in ethyl alcohol, embedded in paraffin and cut into transverse sections 15 μm thick. The sections were stained by the methods of Nissl and Klüver and Barrera. The *corpus striatum* of *Insectivora* is divided into the *striatum*, the *nucleus accumbens* and the *globus pallidus*. In *S. araneus* and *N. fodiens* the *striatum* is a homogenous band of cells. Only in the middle part the fascicles of the fibres of the internal capsule separate partly the central part of the *striatum* into a lateral and medial part. In *T. europaea* the *striatum* is divided into the *nucleus caudatus* and *putamen and* only in the anterior and posterior parts both nuclei are fused. The *nucleus accumbens* and the *globus pallidus* in *Insectivora* show no significant species-specific differences. As compared with higher mammals the septal part of the *nucleus accumbens* is relatively poorly developed in *Insectivora*.

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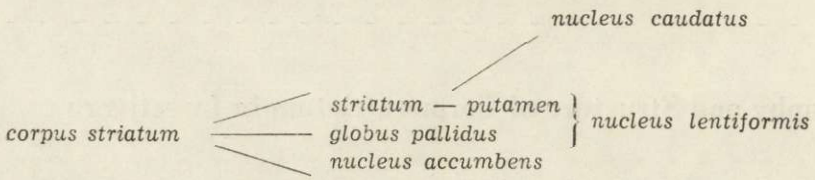
1. INTRODUCTION

The purpose of the study was to gain an insight into the situation, structure and cells forms of the *corpus striatum* in certain mammals from the order *Insectivora*. The structure of the central nervous system in these animals shows numerous primitive features which are interesting from the standpoint of comparative anatomy. In view of this a study was undertaken on the *corpus striatum* in certain species from this order of mammals.

2. MATERIAL AND METHOD

The study was carried out on the brains of three species from the *Insectivora* order: mole (*Talpa europaea* Linnaeus, 1758), common shrew (*Sorex araneus* Linnaeus, 1758) and water shrew (*Neomys fodiens* Pennat, 1771). The material for the investigations was fixed in formalin, dehydrated in graded ethyl alcohol, and embedded in paraffin cutting it then into transverse sections 15 μm thick. The sections were stained by the methods of Nssl and Klüver-Barrera.

The following division of the *corpus striatum* was accepted:



3. RESULTS

Striatum (St). The *striatum* in *S. araneus* (*St*-Fig. 1, 2, Plate III) lies in the subcortical part of the telencephalic hemisphere dorsally to the other subcortical structures of the telencephalon. It is not divided into the *nucleus caudatus* and the *putamen,* but is formed by a homogenous band of cells sharply delineated from the *globus pallidus* which lies in the middle part of *St*. The anterior pole of the *St* lies about 600 μm posteriorly to the anterior end of the frontal horn of the lateral ventricle. The posterior pole lies about 300 μm from the posterior end of the *nucleus amygdalae*. The *St* is about 1.67 mm long.

On the transverse sections the anterior part of the *St* appears as an oval group of cells situated on the ventrolateral aspect of the lateral ventricle. This group of cells increases in size posteriorly filling the space between the wall of the lateral ventricle and the external capsule which forms the boundary of the *St* on the lateral and ventral sides. About 700 μm from the anterior pole of the *St* delicate fascicles of fibres begin to penetrate between the cells of the *St*, and they fan out in the lateral direction. Some of them reach the external capsule. At the level of the anterior pole of the *globus pallidus* the *St* assumes on the transverse cross-sections the shape of a bean, with its convex surface pointing laterally. At a distance of about 400 μm from the posterior pole the fan-like fascicles of fibres are no longer visible, and the *St* decreases gradually in size and shifts laterally. The terminal part of the *St* is a narrow group of cells adjacent to the external capsule. In the dorsal part of the *St* delicate fascicles of the fibres of the internal capsule appear between its cells. Their arrangement is irregular and they form no larger aggregates.

In *S. araneus* the *St* is formed of densely crowded rounded and multipolar cells 10—20 μm in diameter, with poorly discernible nucleus and intensively staining nucleolus. The tigroid is present in a form of small granules (Fig. 5, Plate IV).

The situation and the shape of the *St* in *N. fodiens* are not different from those in *S. araneus,* and similarly as in *S. araneus* it is not divided into the caudate nucleus and the *putamen*. The anterior pole of the *St*

in *N. fodiens* lies about 360 μm posteriorly from the anterior end of the lateral ventricle, and the posterior pole is situated about 200 μm behind the posterior pole of the *nucleus amygdalae*. The length of the *St* is about 2.8 mm. The *St* in *N. fodiens* is formed by cells very similar to those in the *St* in *S. araneus*, but they are arranged much more densely (Fig. 7, Plate IV).

In *T. europaea* the *St* shows an evident division into the *nucleus caudatus* and the *putamen* which are fused only near both poles. The *nucleus caudatus* in *T. europaea* (*Nc*-Fig. 3, 4, Plate III) lies in the subcortical part of the telencephalic hemispheres, closely adjacent to the lateral wall of the anterior horn of the lateral ventricle. The anterior pole of the *nucleus caudatus* lies about 1.4 mm posteriorly to the anterior pole of the lateral ventricle, and the posterior pole lies about 600 μm anteriorly to the posterior pole of the amygdaloid nucleus. The length of the *nucleus caudatus* is about 4.3 mm.

The anterior pole of the *nucleus caudatus* and the *putamen* is formed by an oval group of cells adjacent to the lateral wall of the lateral ventricle. About 360 μm posteriorly to the anterior pole numerous fibres of the internal capsule appear and separate the medially situated *nucleus caudatus* from the laterally lying *putamen*. The *nucleus caudatus* assumes the shape of a vertical oval. On the medial side it is limited by the lateral wall of the lateral ventricle, on the lateral side by the internal capsule, and dorsally by the *corpus callosum*. Below, the caudate nucleus meets the anterior comissure. At a distance of about 1.7 mm posteriorly from the anterior pole the *nucleus caudatus* assumes the shape of a club with its broader part adjacent to the *corpus callosum*, tapering off posteriorly and assuming the shape of a triangle with its base adjacent to the *corpus callosum*. The number of the fibres from the internal capsule increases, and the *nucleus caudatus* is connected to the *putamen* only with a narrow bridge of cells. About 2.8 mm posteriorly to the anterior pole the *nucleus caudatus* is completely separated from *putamen* by the fibres of the internal capsule and the *nucleus caudatus* has an oval shape. About 50 μm anteriorly from the posterior pole the caudate nucleus and the putamen are again connected by bridges of cells, and about 200 μm from the posterior pole both these nuclei are completely fused. The group of cells forming the posterior part of these nuclei tapers off and disappears completely.

In the mole the caudate nucleus is formed by multipolar and rounded cells 10—20 μm in size. They contain a light-staining nucleus with an intensely staining nucleolus, and microgranular tigroid (Fig. 9, Plate III).

The *putamen* of the mole (*Pt*-Fig. 3, 4) lies in the subcortical part of the telencephalic hemisphere, laterally to the other nuclei in this

region. The anterior and posterior poles are common to both these nuclei, and the length of *Pt* and *Nc* is also common. At the site of *St* division into two nuclei the *Pt* lies laterally to the caudate nucleus. In this place the *putamen* has the shape of a vertical oval. The lateral boundary of the nucleus is formed by the external capsule, the medial one by the internal capsule, and dorsally the nucleus is limited by the *corpus callosum*. The ventromedial part of the *Pt* lies in close vicinity to the anterior commissure. About 500 μm from the anterior pole the *nucleus accumbens* appears on the ventral side of the *putamen*. In view of the similarity in the cellular arrangement of both it is very difficult to establish an exact boundary between them. After the appearance of the *globus pallidus* the *putamen* assumes the shape of a bean with the *globus pallidus* situated in its *hilus*. The dorsal part of the *putamen* is divided by the fibres running fan-like to the *corpus callosum* and internal capsule. In the posterior part these fibres divide also the middle part on the *putamen*, and they are absent only in the ventral part. The *putamen* and the *nucleus caudatus* are bound again by isolated cell bridges at first, and at a distance of about 300 μm from the posterior pole they are fused forming one cell mass, which tapers of gradually and disappears as an oval group of cells. The *putamen* in the mole is composed of the same cells as the caudate nucleus.

Nucleus accumbens (Na). The *nucleus accumbens* in *S. araneus (Na, Nas*-Fig. 1) lies in the subcortical part of the telencephalic hemispheres, ventrally to the remaining structures of the *corpus striatum*. The anterior pole of the *Na* lies about 50 μm posteriorly to the anterior pole of the striatum. The posterior pole of this nucleus is situated about 900 μm anteriorly from the posterior pole of the *St*. The length of the *Na* is about 700 μm.

The anterior pole of the *nucleus accumbens* is formed by an oval group of cells separated from the ventral surface of the *St* by a horizontal band of fibres. Posteriorly, the nucleus increases in size in the ventromedial direction. At a distance of about 90 μm from the anterior pole the *Na* encircles the anterior commissure on the ventromedial side, and with a narrow band of cells it is connected to the inferior surface of the striatum. This band is adjacent on the medial side to the *septum pellucidum*, and is called the septal part of the *nucleus accumbens* (*Nas*). At this level the boundary between the *St* and the remaining part of the *Na* becomes less well visible. The lateral surface of the *Na* is limited by the external capsule. At a distance of about 200 μm posteriorly from the anterior pole the anterior commissure meets the floor of the lateral ventricle which causes that the *Nas* and the *St* become separated. The septal part of the *Na* lying on the medial side of the anterior commissure

disappears gradually. At half the length of the *Na* the anterior commissure of the left side meets that of the right side and the *Nas* disappears there. About 400 μm posteriorly from the anterior pole of the *Na* between this nucleus and the *St* fibres of the posterior part of the anterior commissure penetrate there and divide both these nuclei. The Na assumes the shape of the letter "U" with widely spread arms meeting the posterior part of the anterior commissure, and without changing this shape it tapers off and disappears. The *Na* in *S. araneus* is composed of the same cells as the striatum.

In *N. fodiens* the *Na* lies ventrally to the remaining structures of the corpus striatum. The anterior pole of the *Na* is situated at a distance of about 150 μm posteriorly from the anterior pole, and the posterior pole lies 1.4 mm anteriorly to the posterior pole of the striatum. The length of the *nucleus accumbens* is about 1.2 mm.

The anterior pole of the *Na* is formed by an oval group of cells on the ventral surface of the *St*. The boundary between the *Na* and the striatum is not distinct. It is formed by few very thin fascicles of fibres coursing horizontally from the anterior commissure towards the external capsule. Posteriorly, the *Na* increases in size rapidly in the ventromedial direction. At a distance of about 120 μm posteriorly from the anterior pole medially from the anterior commissure a small cell group appears. This group increases in size and joins the ventral surface of the *Na* and *nucleus caudatus*. The lateral boundary of the *Na* is formed by the external capsule, while the medial one is the *septum pellucidum* to which the septal part of the *Na* is adjacent. About 240 μm posteriorly from the anterior pole the anterior commissure meets the floor of the lateral ventricle. This leads to separation of the septal part of the *Na* from the *St*. In the posterior direction the septal part disappears gradually. At a distance of about 750 μm posteriorly from the anterior pole the anterior commissure of both hemispheres meet. The *nucleus accumbens* assumes the shape of the letter "U" and its arms adjacent to the posterior part of the anterior commissure. The *Na* disappears as a small group of cells closely adjacent to the posterior part of the anterior commissure. In *N. fodiens* the *Na* is formed of the same morfologically cells as the *St* which are somewhat more densely arranged (Fig. 8, Plate IV).

In the mole the *Na* (*Na, Nac*-Fig. 3) is situated ventrally to the caudate nucleus and *putamen*. The anterior pole of this nucleus lies at a distance of about 480 μm posteriorly to the anterior pole of the *putamen*, and the posterior pole lies at a distance of 1.74 mm anteriorly to the posterior pole of the *putamen*. The length of the *Na* is about 2.0 mm. On the transverse cross-sections the anterior pole of the *Na*

is formed by an oval group of cells situated on the ventral aspect of the *putamen*. The boundary between the *putamen* and the *Na* are not numerous fascicles of fibres running horizontally from the anterior commissure to the external capsule. At this level the cells of the ventral part of the caudate nucleus penetrate into the space between the lateral ventricle and the anterior commissure forming the caudate part of the *nucleus accumbens* (*Nac*). At a distance of about 250 μm posteriorly to the anterior pole, in the space between the *Nac* and *Na* an oval group of cells appears fuses posteriorly with the dorsal surface of the *Na* and ventral surface of the *Nac*. This group forms in *T. europaea* the septal part of the *nucleus accumbens (Nac)*. At this site also the *Na* is best developed. Its lateral boundary is the internal capsule, and the medial one is the *septum pellucidum*. The boundary between the caudate nucleus and the *Nac* is indistinct in view of the similarity in the arrangement of cells. The anterior commissure reaches the floor of the lateral ventricle at a distance of about 480 μm posteriorly to the anterior pole of the *Na* and the *Nac* disappears at this level. The cells of the *Na* encircle the anterior commissure on the lateral, ventral and medial sides. In the posterior direction the posterior direction the *Nas* decreases in size and disappears from the dorsal side. At a distance of about 1.4 mm posteriorly to the anterior pole of the *Na* the right and left anterior commissures meet and at this site the *Nas* disappears. The posterior part of the anterior commissure separates the *Na* from the *putamen*. The *Na* disappears as a group of cells in the shape of the letter "U" whose arms are adjacent to the posterior part of the anterior commissure. In the mole the *Na* is formed by the same morphologically cells as the caudate nucleus and putamen.

Globus pallidus (*Gp*). In *S. araneus* the *globus pallidus* (*Gp*-Fig. 2) has a central position among the nuclei of the *corpus striatum*. It extends from a transverse plane lying at a distance of about 720 μm posteriorly to the anterior pole of the *St* to a transverse plane passing at a distance of about 300 μm anteriorly from the posterior pole of the *St*. The lenght of the *Gp* is about 300 μm. The anterior pole of the *Gp* is formed by a small oval group of cells lying in a hollow in the medial surface of the *St*. In the posterior direction this cell group increases rapidly in size and its inferior border lies below the ventral surface of the *St*. At a distance of about 120 μm from the anterior pole the *Gp* assumes at a short distance the shape of the letter "L", and increases in size in the lateral direction returning them to an oval shape. On the dorsal, lateral and partly on the ventral sides the *Gp* is adjacent to the *St*, and the medial side meets the internal capsule. At a distance of about 350 μm posteriorly to the anterior pole the *globus pallidus* tapers off

and assumes the shape of a horizontally situated letter "U" whose arms are adjacent to the medial surface of the *St.* This shape changes rapidly and the *Gp* ends as a narrow band of cells adjacent to the striatum.

The *globus pallidus* is formed by multipolar and fusiform cells from 15 to 25 μm in diameter lying loosely between the fibres of the internal capsule. These cells contain a poorly staining nucleus with a strongly staining nucleolus and microgranular tigroid (Fig. 6, Plate IV).

In *N. fodiens* the *globus pallidus* has the shape and position very similar to those in *S. araneus.* Its anterior pole lies at a distance of about 1.45 mm posteriorly to the anterior pole of the *St,* and its posterior pole about 400 μm anteriorly to the posterior pole of the *St.* The length of the *Gp* is about 950 μm. The *globus pallidus* in *N. fodiens* is composed of the same cells as the *Gp* in *S. araneus.*

In the mole the *globus pallidus* (*Gp*-Fig. 4) lies between the caudate nucleus and the *putamen.* The anterior pole is about 2.5 mm posteriorly from the anterior pole of the *St,* and the posterior pole about 450 μm anteriorly from the posterior pole of the *St.* The length of the *Gp* is about 1.3 mm.

The anterior pole of the *Gp* is formed by scant cells scattered between the internal capsule and the posterior part of the anterior commissure. In the posterior direction the number of cells increases and the *Gp* assumes an oval shape. About 360 μm posteriorly from the anterior pole the ventral border of the *Gp* reaches below the inferior surface of the *putamen.* Then the *Gp* shifts dorsally and fills the hollow in the medial part of the *Pt* which limits the *Gp* on the dorsolateral and ventrolateral side. About 350 μm from the posterior pole the *globus pallidus* decreases gradually in size assuming the shape of the narrow vertical cell band which disappears slowly. In *T. europaea* the *Gp* is compared of the same cells as in *S. araneus* and *N. fodiens.*

4. DISCUSSION

In the studied species of *Insectivora* the *corpus striatum* shows a distinct differentiation into two types: the primitive type with regressive features, represented by *S. araneus* and *N. fodiens,* and the progressive type present in *T. europaea.* These differences are particularly evident in the development of the *striatum.*

In both representatives of *Soricidae,* similary as in the rat (Graybiel & Ragsdale 1979) and the mouse (Iwahori & Mizuno 1981) the absence of *striatum* division into *putamen* and *nucleus caudatus* is due to poor development of the internal capsule whose main component are the fibres of the corticospinal tract. This may suggest that the cerebral cortex of these animals has a more primitive structure than that in

T. europaea in which, similarly as in *Tadarida mexicana* (Humphrey 1936), the *striatum* is divided into two centres. However, in the caudate nucleus in *T. europaea* the head, corpus and tail cannot be discerned, while this division is evident in the higher *Placentalia* (*Tamandua tetradactyla*, Smith, 1930; rabbit, Younng, 1936; horse, Barone & Reut, 1955; goat, sheep and cow, Szteyn, 1966; and man, Hewitt, 1958). The *putamen* in *T. europaea* is shaped as in the bat *Tadarida mexicana* (Humphrey, 1936) and much less developed than in *Tamandua tetradactyla* (Smith, 1930), rabbit (Young, 1936), horse (Barone & Reut, 1955) and domestic ruminants (Szteyn, 1966).

The arrangement of cells in the *striatum* in *Insectivora* is not significantly different from that of other mammals such as *Tadarida mexicana* (Humphrey, 1936), rabbit (Young, 1936), domestic ruminants (Szteyn, 1966), cat and primates (Graybiel & Ragsdale, 1978).

The *nucleus accumbens* is regarded by certain authors as a part of the caudate nucleus lying in the region of the *septum pellucidum*. This definition lacks precision. In *S. araneus* and *N. fodiens* two parts of the *nucleus accumbens* can be discerned: the main part lying below the *striatum*, and the part occupying a small segment called the septal part of the *nucleus accumbens*. In the mole, besides the main part of the *Na* which lies below the ventral border of the *putamen*, two cell aggregates are found. Thus evident differences are present in the development of the *Na* of various species of *Insectivora*. In the dog (Miodoński, 1962) the *Na* is composed by two cell groups: the septal *nucleus accumbens* and the caudate *nucleus accumbens*. Szteyn (1966) discerned in domestic ruminants also two groups of cells which he called: the septal and the caudate part of the *nucleus accumbens*. However, in contrast to the dog, in the ruminants both these cells groups are present together only at a short distance. The cell pattern of the *nucleus accumbens* in *Insectivora* is not significantly different from that of other mammals.

The position and shape of the *globus pallidus* in the studied species of *Insectivora* are similar. The nucleus is a homogenous band of cells situated on the medial part of the *striatum*. A similar structure and location of the *globus pallidus* are observed in other mammals studied as yet, with the exception of *Primates*. It man Riley (quoted by Szteyn, 1966) isolated two parts: lateral and medial. Graybiel and Ragsdale (1979) divided it in *Primates* into an external and an internal part. These authors believed that the internal part of the human *globus pallidus* is secondarily divided into a lateral and a medial part. They regarded also that the *globus pallidus* in *Carnivora* and *Rodentia* was also divided into two cell groups, but this division was not so evident as in *Primates*.

The cell pattern in the *globus pallidus* of *Insectivora* shows no significant species specific differences and differences from other mammals. Only few exceptions are known. For example, Iwahori and Mizuno (1981) observed that in mice the *Gp* was composed of large and medium-sized fusiform cells. The large cells were present in the central part of the *globus pallidus*, and the medium-sized ones were lying peripherally. Difiglia, Pasik and Pasik (1982) observed in the *Gp* of *Macaca mulatta* large fusiform cells up to 50 μm in size, and small ones, about 12 μm in size which they regarded as interneurons.

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Received, December 20, 1985. Accepted, October 23, 1986.

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TOPOGRAFIA I BUDOWA *CORPUS STRIATUM* OWADOŻERNYCH

Streszczenie

Zbadano kresomózgowia trzech gatunków owadożernych: *Sorex araneus, Neomys fodiens* i *Talpa europaea*. Materiał do badań utrwalono w parafinie i krojono na skrawki poprzeczne grubości 15 μm. Skrawki barwiono metodami Nissla i Klüvera — Barrery. *Corpus striatum* owadożernych dzieli się na *striatum, nucleus ac-*

cumbens i *globus pallidus*. *Striatum S. araneus* i *N. fodiens* (*St*-Ryc. 1, 2, 5, 6, 7, 8) jest jednolitym pasmem komórek. Jedynie w środkowym odcinku pęczki włókien *capsula interna* rozdzielają częściowo centralną okolicę *St* na część boczną i przyśrodkową. U kreta *striatum* (*Nc*, *Pt*-Ryc. 3, 4, 9) jest podzielone na *nucleus caudatus* i *putamen*. Tylko w przednim i tylnym odcinku oba jądra są ze sobą zespolone. *Nucleus accumbens* i *globus pallidus* u owadożernych nie wykazują istotnych różnic gatunkowych. W porównaniu ze ssakami wyższymi u owadożernych stosunkowo słabo wykształcona jest część przyśrodkowa *nucleus accumbens* (*nucleus accumbens pars septalis*).

EXPLANATION OF PLATES III—IV

Plate III

Fig. 1. Cross section of the telencephalon of *S. araneus* at the level of the middle part of the *nucleus accumbens*.

Fig. 2. Cross section of the telencephalon of *S. araneus* at the level of the middle part of the *globus pallidus*.

Fig. 3. Cross section of the telencephalon of *T. europaea* at the level of the anterior part of the *nucleus accumbens*.

Fig. 4. Cross section of the telencephalon of *T. europaea* at the anterior pole of the *globus pallidus*.

Plate IV

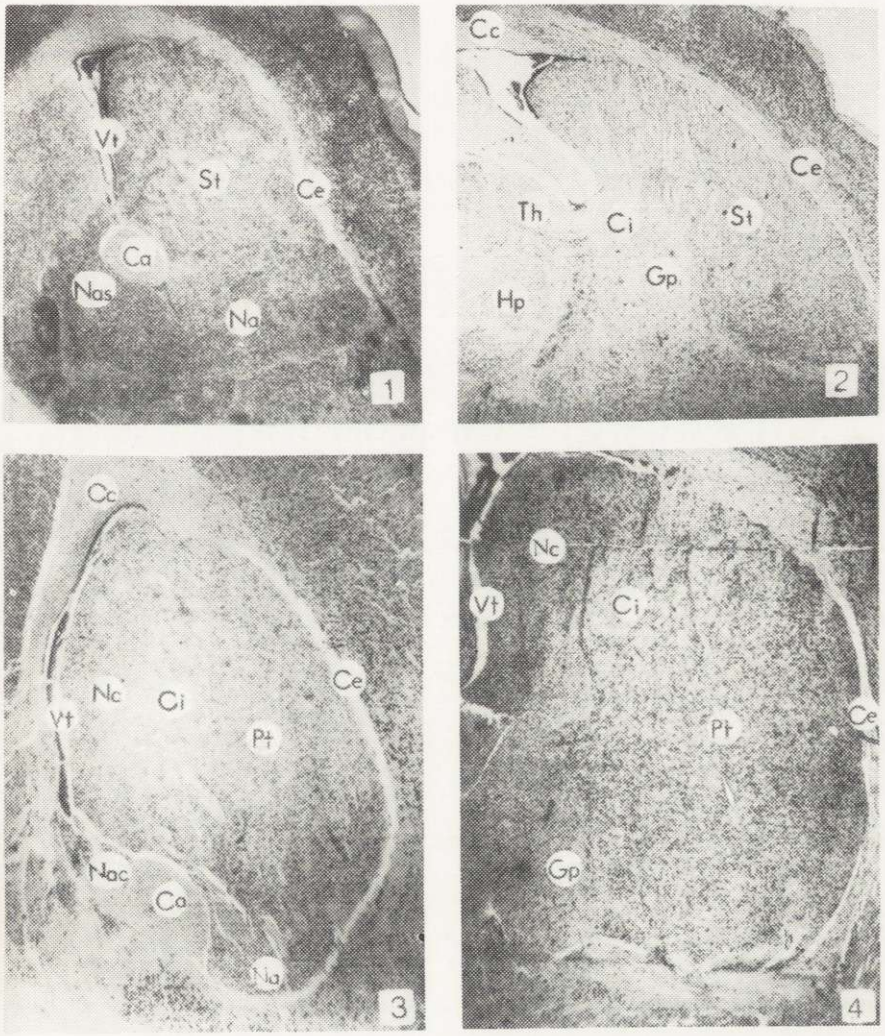
Fig. 5. Cells of the *striatum* in *S. araneus*.

Fig. 6. Cells of the *globus pallidus* in *S. araneus*.

Fig. 7. Cells of the *striatum* in *N. fodiens*.

Fig. 8. Cells of the *nucleus accumbens* in *N. fodiens*.

Fig. 9. Cells of the caudate nucleus in *T. europaea*.



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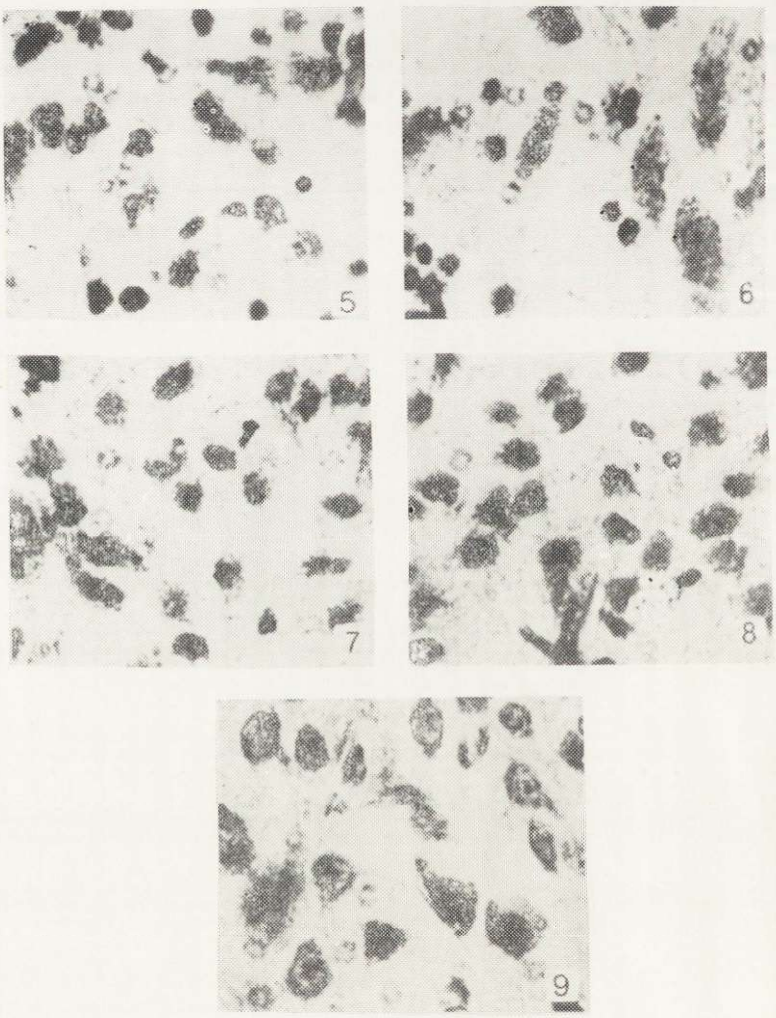

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