Anatomy. — *The double projection-system of the human corpus striatum.* By C. WINKLER.

(Communicated at the meeting of June 27, 1931).

Prominent investigators of a past generation as VON GUDDEN, FLECHSIG, WERNICKE, independant of each other, considered the striatum as a specific organ, without connections with the cortex cerebri, with a function "sui generis".

VON GUDDEN founded this conclusion on the fact, that extirpation of the cortex cerebri in rabbits caused no alteration of the striatum.

FLECHSIG derived at the same conclusion from his myelogenetic studies and WERNICKE from the anatomical aspects of the striatum in the human brain.

The scrupulous experiments of KINNIER WILSON on apes seemed to confirm this opinion. No MARCHI-degeneration of cortical fibres was found after lesions in the nucleus caudatus, putamen or nucleus pallidus.

OSCAR and CÉCILE VOGT, in their book on the striatum, adopted the same conclusion. Moreover they separated a neo-striatum, i.e. the nucleus caudatus and the putamen from a palaio-striatum or the globus pallidus. Both nuclei of the neo-striatum have the same, small-cellular structure with a few large cells between the small ones. The palaio-striatum is an efferent nucleus with large cells.

The distinction between a neo-striatum and a palaio-striatum was the fruit of comparative anatomy. This distinction, first prepared by EDINGER, afterwards founded by ARIËNS KAPPERS, was chiefly supported by the comparison of the brains of reptiles and birds with those of mammalians.

RAMSAY HUNT's discovery, that the nucleus pallidus contained mostly large (efferent) cells, which are scarcely found in the parvo-cellular nucleus caudatus and putamen, again confirmed this distinction.

Nevertheless many investigators had their doubts that such a simple conception of the striatum could be true.

Their arguments were the following :

1. *Fibres connecting the cortex cerebri with the striatum were certainly present.*

a. First of all VON MONAKOW defended the *existence of a projection-system* from the cortex cerebri to the nucleus pallidus. Though admitting, that neither nucleus caudatus nor putamen were altered after cortex-exstirpation, he found however, that the nucleus pallidus was affected. Local cortical lesions affected different sectors of this nucleus.

COENEN demonstrated the existence of such projection-fibres. Post-frontal lesions of the cortex cerebri in rabbits brought MARCHI-degeneration in fibres of the nucleus pallidus, a fact, not in contradiction with KINNIER WILSON's experiments.

b. The existence of fibres with the character of an association-system, mostly from the frontal cortex, must also be admitted.

MINKOWSKI as well as KODAMA had defended them and again COENEN demonstrated them in rabbits, after frontal cortical operations.

In these cases MARCHI-degenerated fibres, *following the stratum subcallosum,* were seen taking their course into the nucleus caudatus.

2. *The nucleus caudatus and the putamen have not at all the same cellular structure.*

Dr. GUREWITSCH, comparing the cellstructure of the frontal end of the nucleus caudatus and putamen in mammalia and in men, was able to distinguish four separate cell-layers in the caput nuclei caudati and three in the putamen. Differences in form, size and arrangement of the large cells (effectors), as well as in the arrangement of the small cells (receptors), made it obvious, that those cell-layers had to be compared to different cell-territoria, which were found in the cortex cerebri. They differ from each other as much as two cell-fields in the cortex cerebri.

My own researches touch those of Dr. GUREWITSCH and add a new fact to the structural aspect of the striatum.

3. *The frontal and the occipital part of the striatum have each a separate projection-system towards the nervous system caudally from it.*

In 1930 I demonstrated in Paris, how in the fifth foetal month the occipital part of the human striatum is ready to begin with its myelinisation. At that time the frontal part of the striatum, the caput nuclei caudati and the frontal enlargment of the putamen, is not yet differentiated and is covered by its matrix, a large ependymal cell-layer.

KODAMA has shown, that the first myelinisation occurs at the end of the fifth foetal month in the fibres of EDINGER's "Kamsystem" towards the nucleus subthalamicus, whereas the myelinisation in the pedunculus inferior thalami begins in the 8^{th} or 9^{th} fotal month.

And it is easy to demonstrate in the brain of a child of 4 months, that "Kamsystem" and pedunculus inferior thalami are independent and strictly separated systems.

I will show you 5 sections following each other in occipito-frontal direction through such a brain.

In fig. I (N^0. 355 of the series) is seen a drawing of a section through the middle of the nucleus subthalamicus, occipital of the corpus mammilare. The strong myelinisated fibres of "EDINGER's Kamsystem" are crossing the amyelinisated medial part of the pes pedunculi.

These fibres run through the stria medullaris limitans and the ansa lenticularis from the nucleus pallidus and proceed towards the field h_2 of FOREL, It seems at if those fibres are forming the teeth of a toothbrush, the handle of which is formed by the field h_2. Hence the name "Kamsystem", as the system has a resemblance to a comb.

Fig. 2 (N^0. 388 of the series), represents a drawing of a section through

the occipital end of the corpus mammillare. The strongly medullated fibres are seen in the same way, crossing the sapsula interna without marrow and ending in the field h_2 of FOREL.

Fig. 3 (N°. 418 of the series), a drawing through the frontal end of the corpus mammillare, gives another aspect. The "Kamsystem" has nearly disappeared and the field h_2 is seen here ending in a ventral point.

At the same time a new system begins. Between the ansa lenticularis and the lamina medullaris limitans passes a new fibre-system, laying here more ventrally from the "Kam-system".

Fig. 4 (N°. 443 of the series) gives a drawing of a section frontally from the corpus mammillare. No more of the "Kam-system" is here to be seen. New fibres appear, surrounding the capsula interna, the "ansa peduncularis". They originate from the nucleus pallidus and the formatio innominata and pass into the pedunculus inferior thalami. They are medullated but not so intensely as those of the "Kam-system". They proceed towards the epithalamus as is seen in fig. 5.

This section (No. 469 of the series) passes through ansa peduncularis and pedunculus inferior thalami, here seen in their full development. In this way two separate projection-systems are found.

From the frontal end of the striatum the ansa peduncularis originates and proceeds through the pedunculus thalami inferior towards the epithalamus.

From its occipital end comes the ansa lenticularis and the lamina medullaris limitans building up the „Kam-system", with a much more complex constitution of fibres.

But the two systems are independent of each other. They begin to obtain marrow at different times. The „Kam-system" in the fifth, the pedunculus inferior thalami in the eight month of foetal life.

The pedunculus thalami inferior only contains connections between striatum and epithalamus.

The "Kam-system" contains not only connections between striatum and the middle part of the thalamus, but as well between striatum and nucleus LUYS, substantia nigra, red neucleus, formatio reticularis lateralis pontis, medullae oblongatae et spinalis and nucleus olivaris inferior.

LETTERS IN THE DRAWINGS.

ansa, ansa lent. = ansa lenticularis.
ans. ped. = ansa peduncularis.
c. ant. = commissura anterior.
c. f. d. = columna fornicis descendens.
c. int. = capsula interna.
c. mam. = corpus mammillare.
hab. = habenula.
h_1 and h_2 = the fields h_1 and h_2 of FOREL.
ka. = Kamsystem.
l. me. li. = lamina medullaris limitans.
n. bas. = nucleus basalis.
n. caud. = nucleus caudatus.
n. ant. th., n. lat. th., n. ret. th. = nucleus anterior, lateralis, reticularis thalami.
n. s. th. = nucleus subthalamicus (LUYS).
p. inf. th. = pedunculus inferior thalami.
s. ni. = substantia nigra
tr. opt. = tractus opticus.
V. d'Az. = fasciculus Vicq d'Azyr.
z. inc. = zona incerta.

DRAWINGS.

5 Sections through the striatum of a child of four months.

Fig. 1. A section through the middle of the nucleus LUYS.
Fig. 2. A section through the occipital end of the corpus mammillare.
Fig. 3. A section through the frontal end of the corpus mammillare.
Fig. 4. A section frontally of the corpus mammillare.
Fig. 5. A section through the chiasma opticum.

LITTERATURE.

B. VON GUDDEN. Gesammelte Abhandlungen. 1889.

C. WERNICKE. Lehrbuch der Gehirnkrankheiten. 1881—1883. Bd. **1**, § 4 und 5, S. 25—44.

P. FLECHSIG. Leitungsbahnen im Gehirn und Rückenmark. Leipzig, 1876. Engelmann.

———— Anatomie des menschlichen Gehirns und Rückenmarkes auf myelogenetischer Grundlage. Bd. **1**. Leipzig, 1920. G. Thieme.

S. A. KINNIER WILSON. An experimental research into the anatomy and physiology of the corpus striatum. Brain, 1913—14. Bd. XXXVI, p. 427—492.

C. VOGT. Quelques considérations générales à propos du syndrome du corps strié. Journal f. Psychologie u. Neur., 1912. Erg. H. Bd. **18**.

C. u. O. VOGT. Zur Lehre der Erkrankungen des striären Systems. Id. Erg. H. 3, Bd. XXV, 1920.

L. EDINGER. On the importance of the corpus striatum and the basal fore-brain bundle etc. Journ. of nerv. a. ment. disease, 1887, Vol. XIV, p. 674.

———— Vorlesungen. 8e dr. etc. 1911.

C. U. ARIËNS KAPPERS und W. F. THEUNISSEN. Die Phylogenese des Rhinencephalon, des Corpus striatum und der Vorderhirncommissuren. Folia Neurobiologica Bd. **1**, 1908, S. 173.

C. U. ARIËNS KAPPERS. Weitere Mitteilungen über die Phylogenese des Corpus striatum und des Thalamus. Anat. Anzeiger, 1908, Bd. XXXIII, No. 13 u. 14, S. 321.

———— Die vergleichende Anatomie des Nervensystems. Haarlem 1920/21.

J. RAMSAY HUNT. The efferent pallidal system of the corpus striatum etc. 43th Annual meeting of the American Neurological Association, 21 Mai 1917. Journ. of nerv. a. ment. disease. 1917. Vol. **46**, N°. 9, p. 211.

C. VON MONAKOW. Der rothe Kern, die Haube und die Regio hypothalamica..... Wiesbaden, 1910.

———— Sur les connexions du corps strié et du noyau lenticulaire avec les autres parties du cerveau. l'Encéphale. 1925. N°. 6, p. 359.

M. MINKOWSKI. Etude sur les connexions anatomiques des circonvolutions rolandiques, pariétales et frontales. Schweizer Archiv. 1923, Vol. XII, S. 71, S. 227. Schweizer Archiv. 1924, Vol. XIV, S. 255. Vol. XV, S. 97.

S. KODAMA. Ueber die sogenannten Basalganglien.
Schweizer Archiv. 1925. Bd. **18**, H. 2, S. 79.
Schweizer Archiv. 1926. Bd. **19**, H. 1, S. 152.
Schweizer Archiv. 1927. Bd. **20**, H. 2, S. 209.
Schweizer Archiv. 1929. Bd. **23**, H. 1, S. 38 ; H. 2, S. 179.

L. COENEN. The connection of the cortex with the neo-striatum and palaeostriatum in rabbits. K. Akad. v. Wetenschappen 1927. Proceedings Vol. XXX. N°. 7, p. 811.

M. GUREWITSCH. Cytoarchitectonische Gliederung des Neostriatum der Säugethiere. Zeitschr. f. Anatomie u. Entwicklungsgesch. 1930. Bd. **93**, H. 6, S. 723.

C. WINKLER. Sur L'évolution du corps strié. Revue Neurologique 1930. **T. 1**, N°. 6, p. 849.

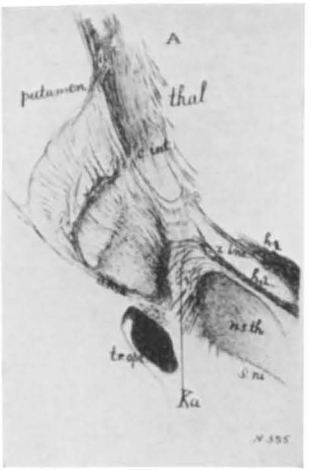

Fig. 1.

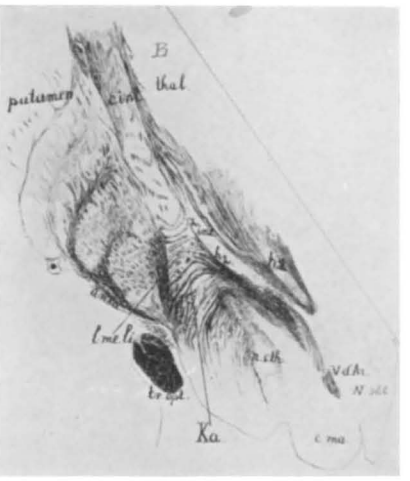

Fig 2.

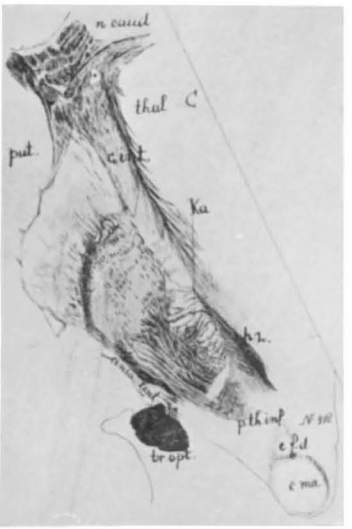

Fig. 3.

Fig. 4.

Fig. 5.