Anatomy. — *The Connection of the Cortex with the Neostriatum and Palaeostriatum in rabbits.* By Dr. L. COENEN. (Communicated by Dr. C. U. ARIËNS KAPPERS and Prof. B. BROUWER).

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The question if there are tracts, which connect the cortex and neostriatum (putamen and nucleus caudatus) or palaeostriatum (globus pallidus) has again recently stimulated many neurologists. Formerly it was generally believed, that a fibre-connection between cortex and striatum did not exist. In 1872 VON GUDEN mentioned as a result of his experiments that cortical lesions have no influence upon the corpus striatum. Also FLECHSIG (1876) and later WERNICKE emphasised that the corpus striatum is independent of the cortex and has no connections with it.

KINNIER WILSON (1914) after extensive investigation of experimental lesions of the neostriatum on monkeys found no degenerated fibres to the cortex, and concluded that a connection between striatum and cortex does not exist. The few degenerated fibres that he found he considered to be fibres which only passed the nucleus caudatus to reach the capsula interna.

As late as 1919 C. and O. VOGT deny the existance of connections between cortex and striatum (nucleus caudatus and nucleus lentiformis). They regard the fibres which seem to establish such connections as fibres which pass the striatum to join the capsula interna.

There were, however, some neurologists who believed such connections to exist. Among these were BIANCHI and D'ABUNDO (1886) who had removed the cortex from a dog and had found a reduction of volume of the globus pallidus and proliferation of the neuroglia in the nucleus caudatus and lentiformis; and MARINESCU who in 1895 after removal of the lobus frontalis, found with the Marchi method degenerated fibres running from this lobe along the frontal segment of the capsula interna to the nucleus caudatus in which they disappeared. RAMON J. CAJAL (1895), though granting that there were no direct fibres from the cortex to the striatum, found in rodentia (rat and mouse) that the fibres from the pyramidal cells of the cortex, which run to the capsula interna, send out collaterals to the striatum. DEJERINE, LONG and DEJERINE (1898) believed, that in cortical lesions in man no degenerated fibres could be demonstrated in the nucleus caudatus and the putamen but found in cortical and subcortical lesions a slight degeneration in the globus pallidus. In 1918 ECONOMO described as the result of a primary lesion of the corpus striatum degenerated fibres running to the cortex.

Especially however VON MONAKOW and MINKOWSKY gave us a clearer formulation of these vague conceptions.

VON MONAKOW (1925) found after extirpation of the cortex in a dog a distinct atrophy of the corpus striatum. His collaborator MINKOWSKY removed several parts of the cortex in monkeys and got the following results:

From the gyrus praerolandus fibres run to the nucleus caudatus and from the lobus frontalis to the nucleus caudatus as well as to the globus pallidus. He also confirmed the presence of pallido-frontal fibres, which had first been observed by VON MONAKOW.

Recently KODAMA studying the development of the globus pallidus and corpus striatum in embryos found that the striatum subcallosum establishes an association between cortex and nucleus caudatus; and that in a fetus of 6 months myelinated fibres occur in the globus pallidus (oral part) which pass in the capsula interna and partly disappear in the corona radiata. KODAMA does not believe, that these are simply fibres which pass the striatum because they are caudally no where visible in the peduncules. He believes that they disappear in the globus pallidus.

For my experiments I used rabbits. The left side of the skull was opened and with a sharp spoon a part of the cortex was removed, a different area in each rabbit. As rigid asepsis as possible was maintained so that no suppuration should affect the site of the lesion and thus

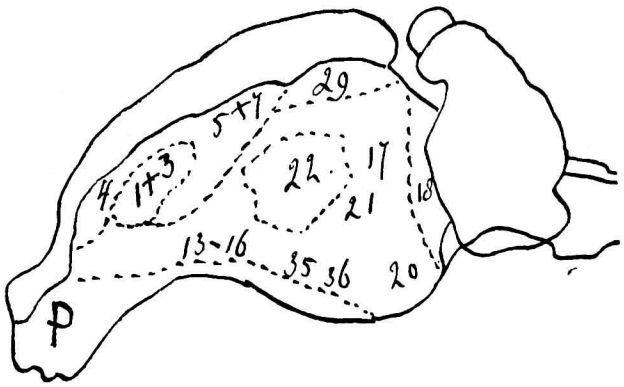

Fig. 1.

cause complications in the degeneration. The rabbits were allowed to live 18 days, when they were hanged and the brains treated after the Marchi method.

In this way ten rabbits were operated and the following fields (after the map of WINKLER and POTTER) were removed. Fig. 1:

1. field 4, 1 + 3 (area prae- and postcentralis).
2. field 4, 1 + 3, 5 + 7 (area prae- and postcentralis and parietalis).
3. field 4, 1 + 3, 5 + 7 (area prae- and postcentralis and parietalis).

4. field 4, 1 + 3. 5 + 7,22 (area prae- and postcentralis, parietalis, temporalis superior).
5. field 4, 1 + 3, 5 + 7,17 [1]), 18 [1]), 29 (area prae- and postcentralis, parietalis, striata, occipitalis, retrosplenialis).
6. field 1 + 3, 5 + 7, (area postcentralis, and parietalis).
7. field 1 + 3, 5 + 7, 22, (area occipitalis, parietalis, temporalis superior).
8. field 17, 21, 22 (area occipitalis, temporalis media and superior).
9. field 20, 21, 22 (area temporalis inferior, media superior).
10. field 20, 21 (area temporalis inferior and media).

Of these series I shall treat only the degenerations in the principal ones and after that give my conclusions.

1. *Serie 1. B. 205.* Removed field 4, 1 + 3 (area prea- and postcentralis).

The intention was to remove the left frontal pole. At the operation it was first thought that we were dealing with an anomaly of the left skull, and we therefore passed over to the right skull. Here, however, the same condition was found, so that now again the left side was further operated upon. Hence by this operation we cut the left as well as the right frontal pole. There was slight bleeding. The rabbit was killed after 18 days. The left as well as the right pole appeared to have been cut. As a result of the bleeding there was much infiltration at both poles.

It may be stated that field 4 (area praecentralis, field 1 + 3 in part, (area postcentralis), and a very small piece of 5 + 7 (area parietalis) (according to the map of WINKLER and POTTER) had been removed. Fig. 2 gives a sketch of the lesion. In section 18 we observed the corpus

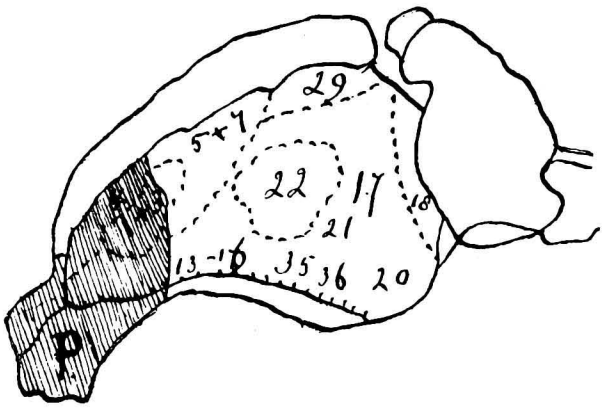

Fig. 2.

[1]) I believe it better to call area 17 "area striata" and area 18 "area occipitalis", after BRODMANN.

callosum on both sides full of degenerative granulae, more on the right side than on the left.

The centrum semiovale as well was more involved by this process on the right than on the left. Further, over the dorsal part of the nucleus caudatus a long line of degenerative granulae runs which inclines slightly to the side of the ventricular surface of the striatum (capsula intima PŘECECHTĚL. [1]) From this line on the right side long lines of degenerative granulae were observed to radiate (fig. 3) which were not visible on the left side.

The line at the dorsal side of the nucleus caudatus was also much smaller in extent on this side.

Section 24. As well on the left side as on the right many degenerative granulae are seen at the side of the capsula interna which borders the nucleus caudatus, These form a long line of small islands, where the granulae are most numerous and whence strips of degenerative granules run to the nucleus caudatus (fig. 4).

Serie 4 B. 176. Removed field 4 in part (area praecentralis), 1 + 3 in part (area postcentralis) 5 + 7 in part (area parietalis) and 22 nearly entirely (area temporalis superior). A sketch of the *lesion* in fig. 5.

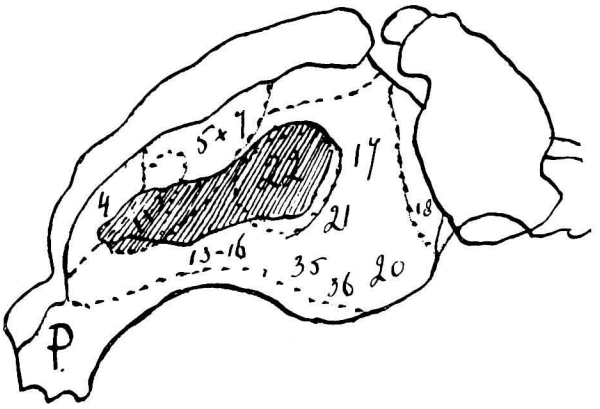

Fig. 5.

Section 12. The corpus callosum on the right side is full of degenerative granules; on the left side there are none at all. Here are also many in the capsula interna on the right. Again over the dorsal side of the nucleus caudatus (capsula intima) a long strip of degenerative granulae is seen to run from the beginning of the capsula interna (fig. 6 and 7).

Section 16. Here also a degenerative tract is seen from the centrum semiovale and the fasciculus subcallosus along the dorsal edge of the

[1]) The fibrelayer, which covers the corpus striatum (specially the nucleus caudatus) on the ventri-cular side. This capsula intima is specially strong in the Elephant where it was first described by PŘECECHTĚL (1925).

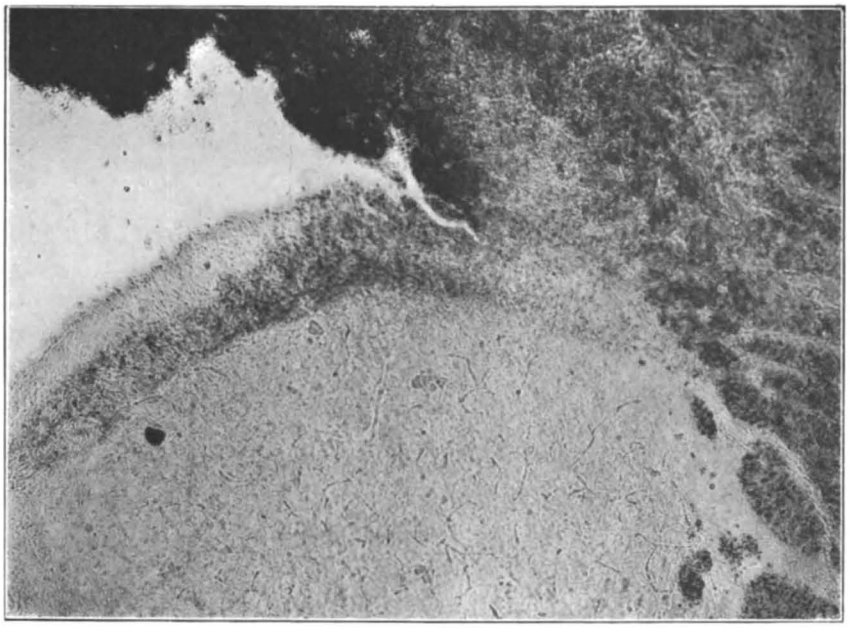

Fig. 3. Degeneration in the capsula intima. Serie I. B. 205. (section 18).

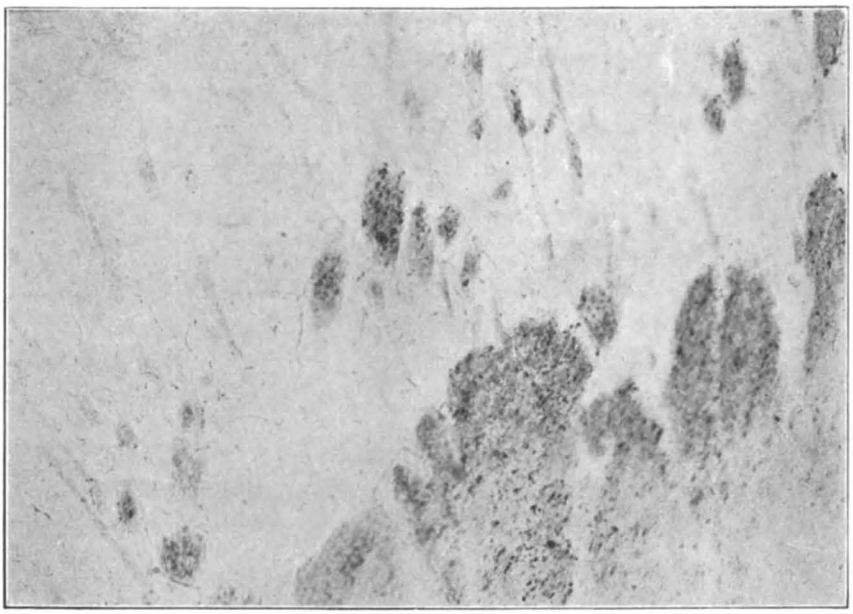

Fig. 4. Degenerated granules from the capsula interna to the nucleus caudatus. Serie I. B. 205 (section 24).

nucleus caudatus (fig. 6 and 7). At the dorsal side of the capsula interna one sees again an edge of degenerative granules, interrupted here and there. From here degenerative granules radiate to the centre of the nucleus caudatus (fig. 6 and 8). Further on from the capsula interna tracts filled with degenerative granulae run to the centre of the globus pallidus (fig. 9).

Section 17. N°. 8. Fig. 6 and 7 show a tract filled with granules, which runs over the dorsal ventricular lining (capsula intima) of the nucleus caudatus. Further on the capsula interna shows at its dorsal side a darker part, filled with granules, here and there interrupted, whence degenerated tracts radiate into the nucleus caudatus (fig. 8).

One observes as well rows of granules, running from the capsula interna to the globus pallidus (fig. 9). Fig. 7, 8, 9 show some of these degenerations enlarged. Fig. 7 shows the tract, which runs from the fasciculus subcallosus in the dorsal lining of the nucleus caudatus, and whence numerous degenerated strips continually run into the above named nucleus.

Fig. 8. Shows strips of degenerated tracts running from the dorsal part of the capsula interna into the nucleus caudatus and finally fig. 9 shows the tracts which run from the capsula interna into the globus pallidus.

Serie IX. B. 209. Removed field 22 (temporalis superior) 21 (temporalis media) 20 (part of temporalis inferior). Fig. 10 shows the lesion.

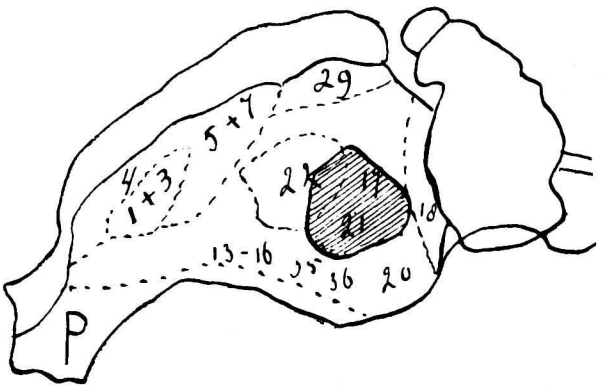

Fig 10.

Section 21. 1. Fibres at the dorsal side of the capsula interna running in the nucleus caudatus (fig. 11).

Section 23. Fibres from the capsula interna to the globus pallidus (fig. 12).

Resume of personal investigations.

Serie 1. B. 205. Removed area prae- and postcentralis.

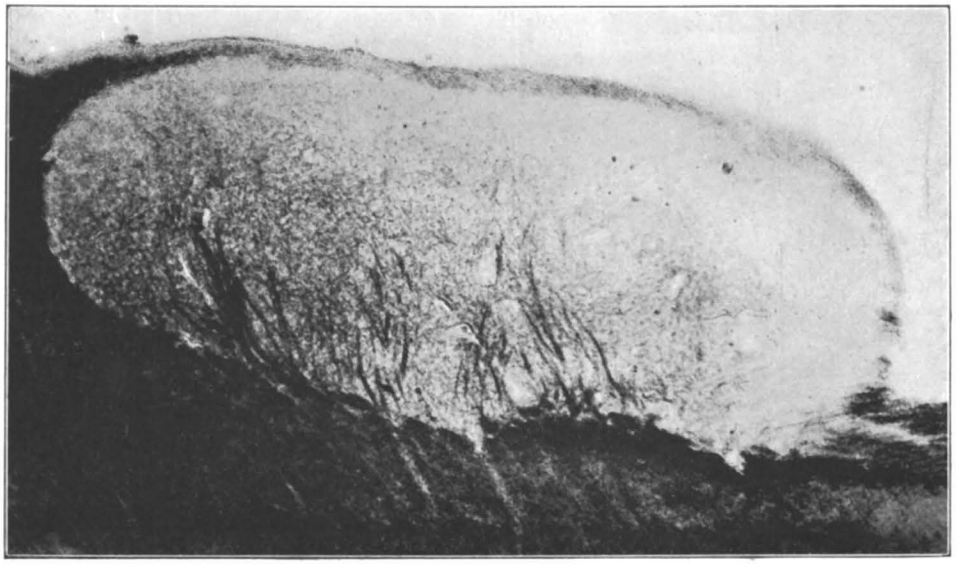

Fig. 6. Degenerations on the dorsal side of the capsula interna.
Serie IV. B. 176.

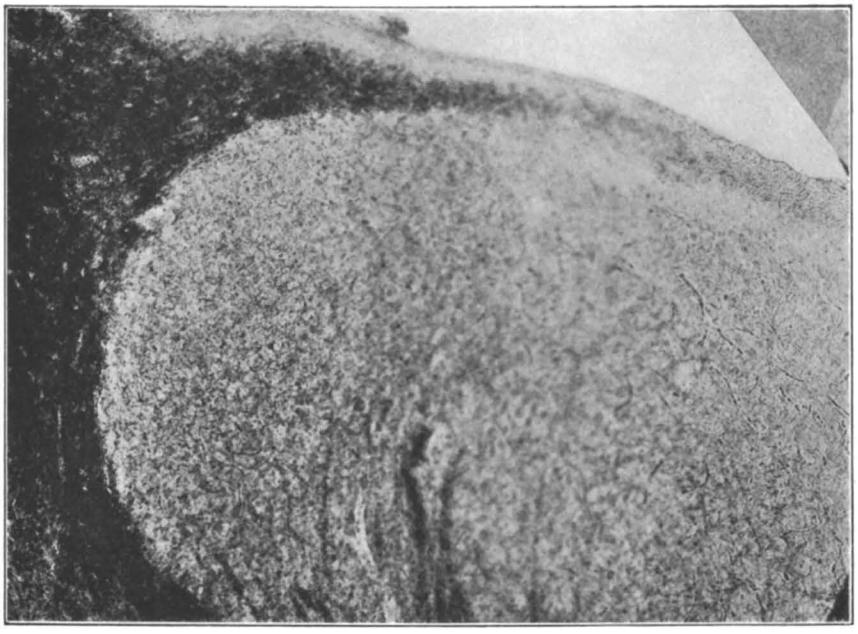

Fig. 7. Degeneration in the capsula intima. Serie IV. B. 176.

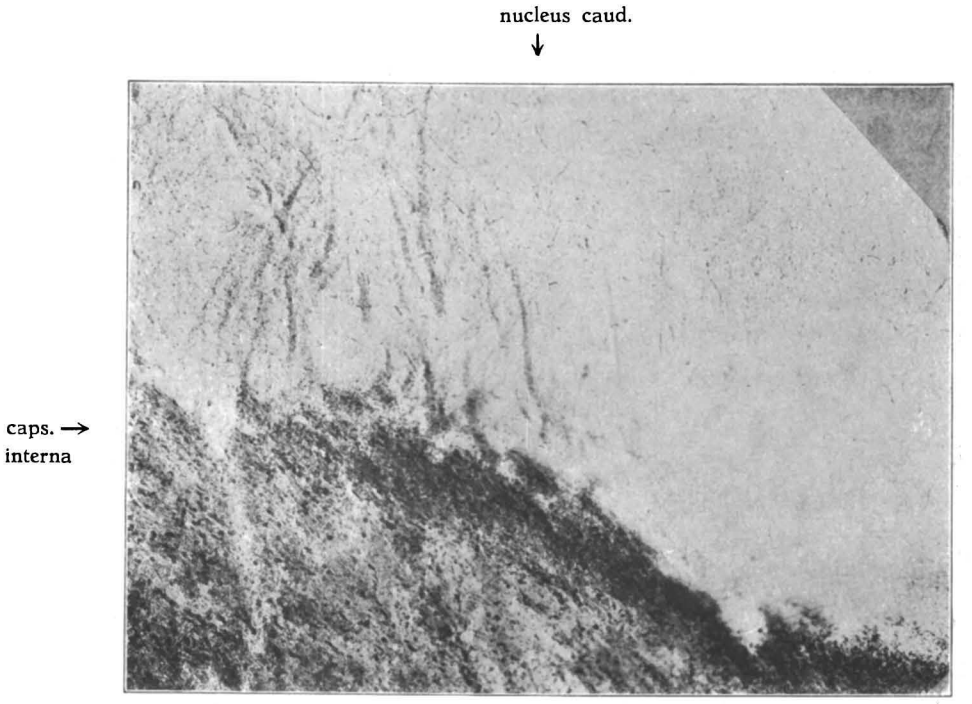

Fig. 8. Degenerated granules from the capsula interna to the nucleus caudatus. Serie IV. B. 176 (section 17).

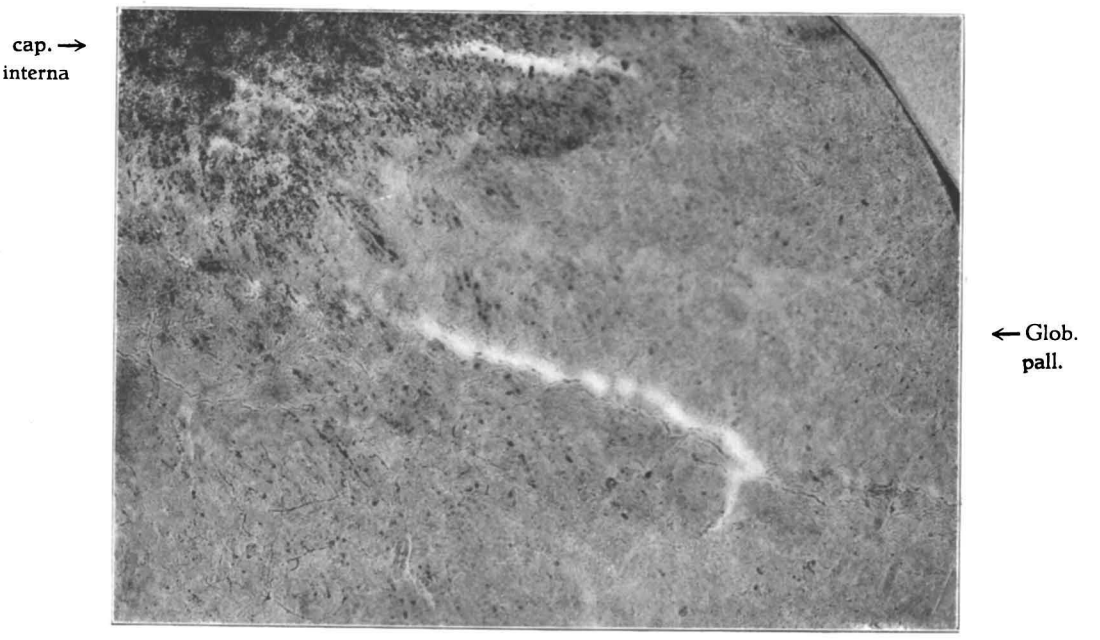

Fig. 9. Degenerated granules from the capsula interna to the palaeostriatum. Serie IV. B. 176 (section 17).

Result: 1. Degenerated fibres from the fasciculus subcallosus run dorsally over the nucleus caudatus and pass into it.

2. Degenerated fibres spread from the dorsal side of the capsula interna into the nucleus caudatus.

Serie IV. B. 176. Removed area prae- and postcentralis (both partially) area parietalis (in part), and area temporalis superior (nearly the whole of this area).

Result: 1. Degenerated fibres from the fasciculus subcallosus run dorsally over the nucleus caudatus and pass into it.

2. Degenerated fibres from the dorsal part of the capsula interna spread in the nucleus caudatus.

3. Degenerated fibres from the capsula interna run into the globus pallidus.

Serie IX. B. 209. Removed field 22 (temporalis superior), 21 (temporalis medius), 20 (temporalis inferior).

Result: 1. Degenerated fibres at the dorsal side of the capsula interna pass over into the nucleus caudatus.

2. Degenerated fibres passing from the capsula interna into the globus pallidus.

In none of these series degenerated fibres can be seen in the *putamen*. There is no direct connection between the cortex and putamen. I found degenerations in the following series as well:

In series V, where field 4 (area praecentralis), 1 + 3 (area postcentralis), 5 + 7 (area parietalis), 29 (area retrosplenialis), 17 (area striata), 18 (area occipitalis) have been removed, degenerated fibres at the dorsal side of the nucleus caudatus are distinctly visible, penetrating into the nucleus caudatus.

In series VIII, where 17 (area striata), 21 (temporalis media) and 22 (temporalis superior) and in series X, where the fields 20 (temporalis inferior) and 21 (temporalis media) have been removed, a distinctly degenerated fasciculus subcallosus and a degeneration in the nucleus caudatus could be observed energing from the dorsal edge of the capsula.

CONCLUSIONS.

In rabbits a connection exists between the cortex and the nucleus caudatus and globus pallidus coming from the following parts of the mantle:

1. There is a connection between the area centralis and temporalis and nucleus caudatus by fibres which run through the fasciculus subcallosus partly under the dorsal ventricular lining of the nucleus caudatus and partly along the dorsal edge of the capsula interna, passing into the anterior part of the nucleus caudatus.

2. There is a connection of the area temporalis with the globus

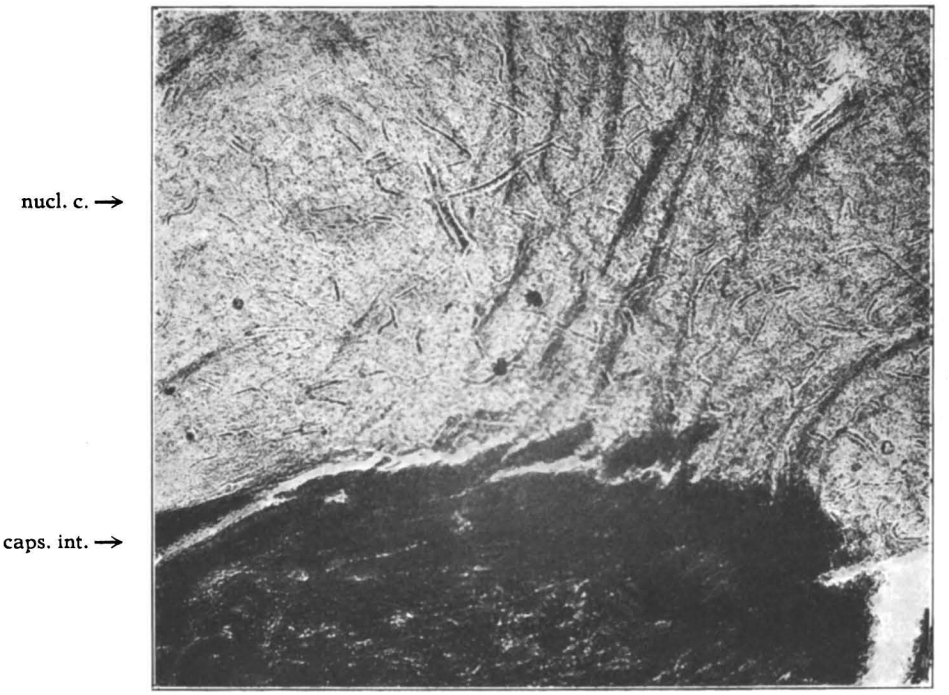

Fig. 11. Degenerated granules from the capsula interna to the corpus striatum.
Serie IX. B. 209.

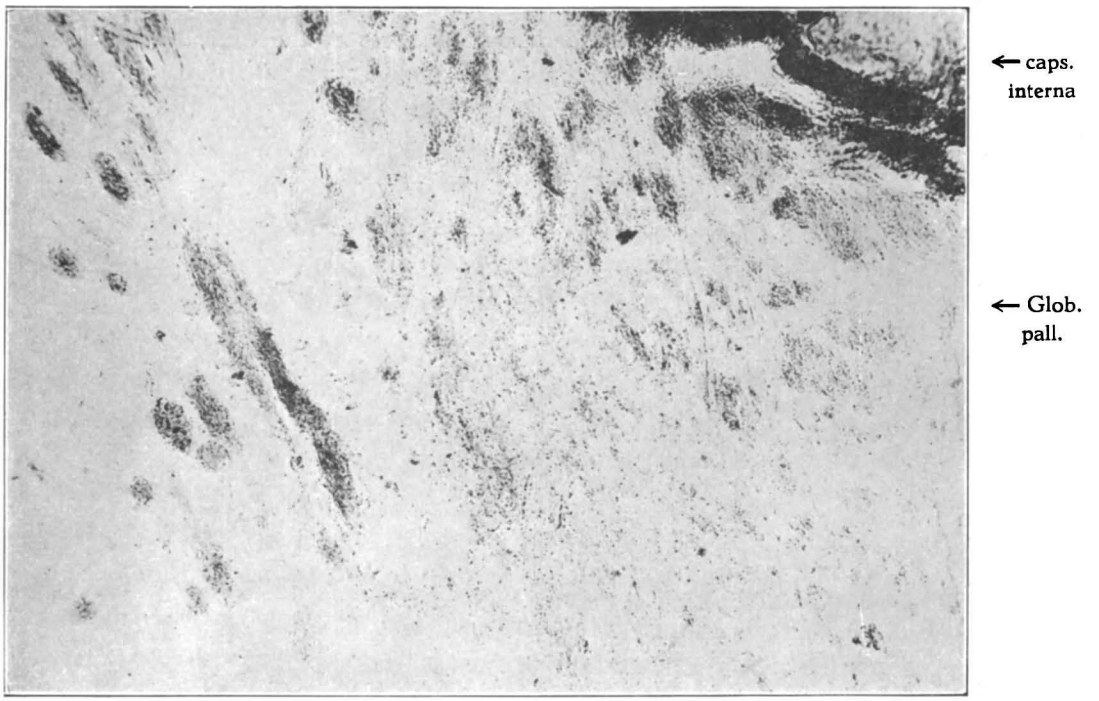

Fig. 12. Degeneration of the capsula interna to the palaeostriatum.
Serie IX. B. 209.

pallidus by fibres, which run from the area temporalis into the capsula interna and from here into the globus pallidus (palaeostriatum) (KAPPERS).

3. There is no cortical connection with the putamen.

Haarlem, October 1927.

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