Acta Medica Okayama

Volume 9, *Issue* 1 1954 *Article* 2

DECEMBER 1954

Experimental Studies on the March of Spasm During Epileptic Convulsion

Dennosuke Jinnai* Takakazu Yoshida†
Terumichi Souji‡ Futami Kosaka**

*Okayama University,
†Okayama University,
‡Okayama University,
**Okayama University,

Experimental Studies on the March of Spasm During Epileptic Convulsion*

Dennosuke Jinnai, Takakazu Yoshida, Terumichi Souji, and Futami Kosaka

Abstract

March of spasm in epileptic convulsions was first observed by Tackson in 1863, when he said that in certain epileptic convulsions there is a phenomenon, where the convulsion starts from a certain muscle group and gradually spreads to other muscle groups. He called this, "march of spasm" and reported that it spreads according to the arrangement of motor representations in Rolando's area of the cerebral cortex. Since then, many important studies concerning the cerebral motor cortex were performed and reported. Recently, when Erickson had brought out a method in measuring electroencephalographic waves, Jackson's theory has been acknowledged. In Japan, Hayashi and his school has made an extensive study on epileptic convulsion. They used nicotine, cardiazol and others as chemical stimulations and decided the conduction tract of epileptic convulsion in dogs. The characteristic part of chemical stimulation is that, the nelve cells excite themselves when it is injected directly among them in certain concentrations and do not excite themselves when performed among nerve fibers. This was proved by Ishizuka. We used this method in dogs to see what was the mechanism of this phenomenon, "march" which is seen in epileptic convulsions and what tracts they took for conduction. And as its result, we found new facts that the presence of the motor cortex was needed for the march of spasm, and the conduction tract descending from the lenticular nucleus were quite different from Hayashi and his school had previously reported.

Experimental Studies on the March of Spasm During Epileptic Convulsion

By

Dennosuke Jinnai, Takakazu Yoshida, Terumichi Souji and Futami Kosaka

(Department of 1st Surgery, Okayama University Medical School)

Received for publication on 1 February 1954.

Introduction

March of spasm in epileptic convulsions was first observed by *Jackson* in 1863, when he said that in certain epileptic convulsions there is a phenomenon, where the convulsion starts from a certain muscle group and gradually spreads to other muscle groups. He called this, "march of spasm" and reported that it spreads according to the arrangement of motor representations in *Rolando*'s area of the cerebral cortex. Since then, many important studies concerning the cerebral motor cortex were performed and reported. Recently, when *Erickson* had brought out a method in measuring electroencephalographic waves, *Jackson*'s theory has been acknowledged.

In Japan, *Hayashi* and his school has made an extensive study on epileptic convulsion. They used nicotine, cardiazol and others as chemical stimulations and decided the conduction tract of epileptic convulsion in dogs. The characteristic part of chemical stimulation is that, the nerve cells excite themselves when it is injected directly among them in certain concentrations and do not excite themselves when performed among nerve fibers. This was proved by *Ishizuka*. We used this method in dogs to see what was the mechanism of this phenomenon, "march" which is seen in epileptic convulsions and what tracts they took for conduction. And as its result, we found new facts that the presence of the motor cortex was needed for the march of spasm, and the conduction tract descending from the lenticular nucleus were quite different from *Hayashi* and his school had previously reported.

Experimental Materials and Methods

For experimental animals mainly adult dogs weighing from 10 to 15 kgm. were used. 3% morphine HCl was subcutaneously injected at the rate of 0.05 cc. per kgm. for premedication. 30 minutes after injection, when their muscle tension in general have loosened, they were fixed to a supporting rack in prone position and for stimulation or removal of the cortex, the skull was trepanated. Skin was incised from the nasion, passing the occipital protuberance to the lower part of the nape along the saggital line. The extension of this incision varied to what kind of operation was to be performed. The temporal muscle was exfoliated with a knife and a raspatory from the surface of the skull. According to experiments, the muscle groups which were attached to the interparietal process and to linea nuchalis superior were exfoliated too and the temporal, the parietal and the occipital skull bones were trepined. 10% cardiazol solution (0.04 to 0.07 cc.) were injected locally for stimulation.

1. Stimulation and removal of the motor cortex.

First, sulcus cruciatus was looked for, and with this as an aim the motor area (area 4) was decided and stimulated with a thyratron pulse generator, which was previously reported by *Mori* and *Numoto* of our staff. During removal of the cortex an electrocoagulator was used to coagulate and cut brain vessels coming from the surface of the part that was removed. For actual removal, a small spatula was used and the cortex was removed to the depth of 0.3 to 0.5 cm.

2. Stimulation and removal of the lenticular nucleus.

Sulcus sylviaticus was looked for and a needle was stuck vertically for about 8 to 11 mm. from the surface of the brain for stimulation. For its removal, it was done according to *Suda*'s method and both putamen and globulus pallidus were removed together with it. That is, a sharp edged metal spatula with a width of 5 to 7 mm. was stuck vertically for 11 mm. from the surface of sulcus ectosylvius medius. The place of insertion was used as a fulcrum and the end of the metal spatula was spun to make a ring. In this way these parts were removed.

3. Stimulation and removal of the thalamus.

A 3 to 4 cm. incision was made along gyrus entolateralis. With a small muscle retractor the edge of the incision was retracted carefully and parts of the fornix, fimbria hippocampi, nucleus caudatus were exposed. Just below this is the thalamus.

For stimulation, the fornix was exfoliated and the medial nuclei group, which is the one that causes seizures most easily, was ascertained and stimulation was done directly on the thalamus.

For its removal, a small incision was made along the fornix and with a ring forceps it was removed as if scooping it from the lateral posterior to the medial anterior direction.

4. Stimulation and removal of nucleus caudatus.

To reach nucleus caudatus, it was done absolutely the same as in the case of the thalamus and this appeared adjoining the lateral anterior part of the thalamus. For its removal an incision was made with a narrow knife along its outer fringe and was picked off with a ring forceps or a tumor clamp.

5. Stimulation and removal of nucleus niger.

When the occipital lobe was pressed anteriorly, upward and laterally with a wide brain retractor, tentorium cerebelli was seen. This tentorium was incised and when the cerebellum was pressed posterierly and downward corpora quadrigemina appeared. Nucleus niger was stimulated by sticking a needle vertically for about 0.9 to 1.1 cm. in between colliculus superior and colliculus inferior.

For the removal of nucleus niger, first, the adhesion between the ventral surface of the cerebellum and colliculus inferior was carefully removed, when this was done the mouth of aqueductus *Sylvii* to the fourth ventricle was seen. A long narrow knife was inserted into the aqueduct and the lower half of the midbrain was cut from left to right. Then the knife was returned into the aqueduct and an incision was made horizontally to the side where the removal was going to be made. At the lateral side of colliculus superior and inferior, and at the height of the surface of the horizontal section, an incision was made upward and downward till it crossed the base of the brain. In this way the ventral side of the midbrain was freed from its surrounding and this part was removed by scooping it with a spatula.

To observe especially precise, a four channel ink-writing electromyogram recorder was used. And a electromyogram from muscles of the extremities (in the anterior extremity from M. flexor digitor sublimis, in the posterior extremity from M. gastrocnemius medialis) were drawn so that the order of the march could be decided.

Acta Medica Okayama, Vol. 9 [1954], Iss. 1, Art. 2

Experimental Results

A. March of spasm during stimulation of the motor cortex.

1) Cortical stimulation.

When the motor cortex was stimulated, a spasm started in the peripherial parts corresponding to the area that was stimulated and

Fig. 1.

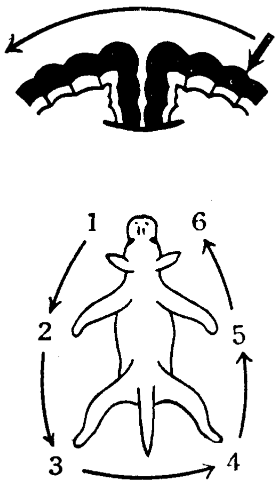


Fig. 2.

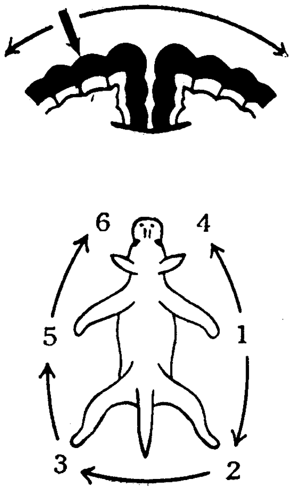
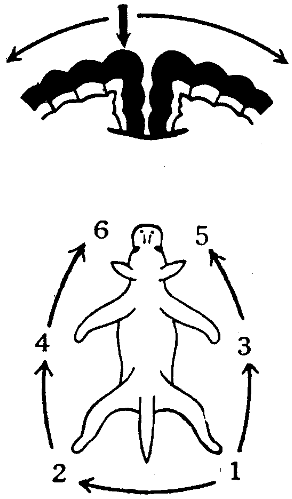


Fig. 3.



the spasm marched according to the anatomical arrangement of motor representations in the motor cortex. That is, when the areas for the anterior or posterior leg was stimulated the spasm marched to both sides. When the face area was stimulated the spasm marched to just one side and took the 'U' from (Figs. 1 to 3). When the spasm marched to the other side it always went from one posterior leg to the other posterior leg and never from one side of the face to the other side of the face.

2) Cortical stimulation after subcortical cutting.

When stimulating the area just above the place where subcortical cutting was done, spasm started from areas adjoining the area that was stimulated and marched to both directions. The part where the cutting was performed did not become the starting place of the spasm, though it took the same rhythm after the spasm had marched to every part of the body. When areas other than the area where the cutting was performed were stimulated there was no change in the march of spasm. (Figs. 4 to 6.)

Fig. 4.

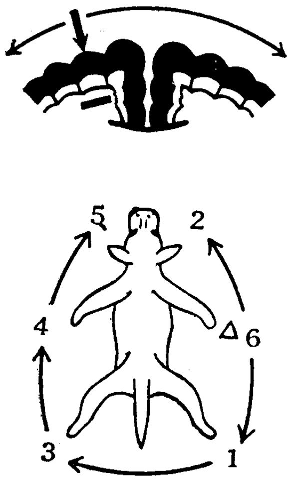


Fig. 5.

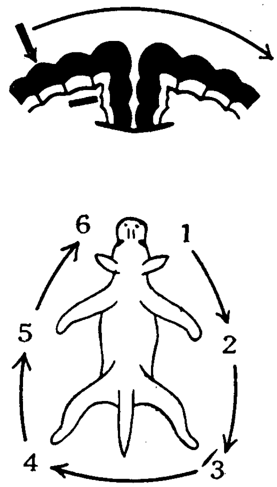
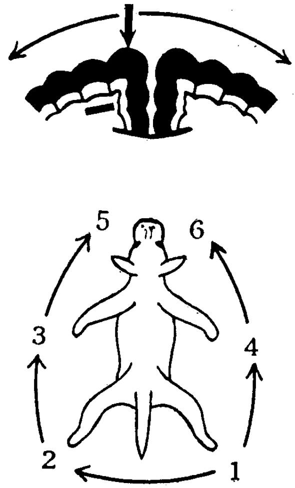


Fig. 6.



3) Cortical stimulation after cutting in between cortical areas.

In this case, spasm started from parts corresponding to stimulation and showed a similar march as stated previously, but it was obviously seen that its march was delayed where the cutting was performed in between areas comparing with places where no cutting was done. (Figs. 7 & 8.)

Fig. 7.

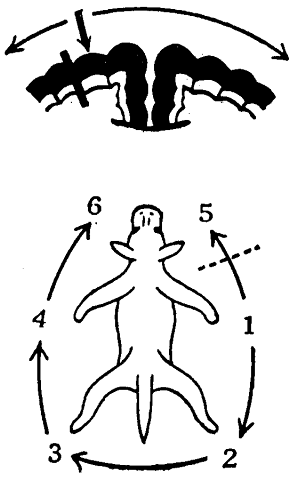


Fig. 8.

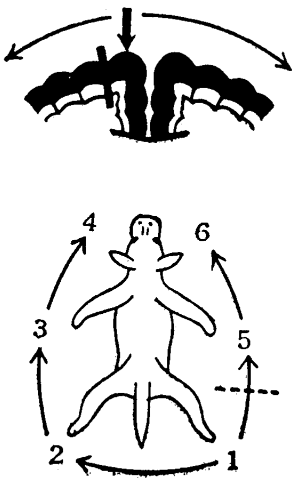
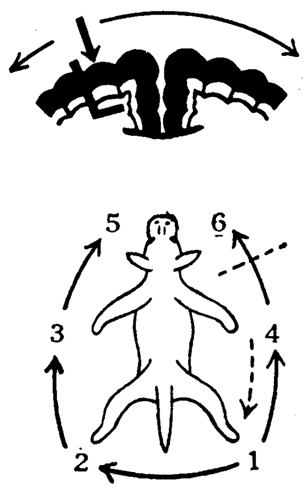


Fig. 9.



In areas where subcortical cutting and in-between interruption were performed on one side, spasm did not start from that area, when its area was stimulated but started from the area adjoining this and where in between part with this area was not interrupted. The impulse of the stimulation spread both ways but was delayed on the side where the in-between interruption was made. (Fig. 9.)

Fig. 10.

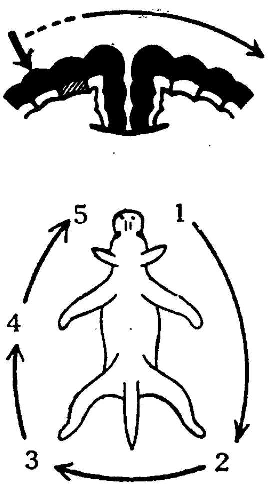


Fig. 11.

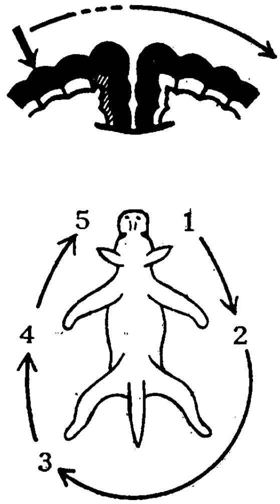
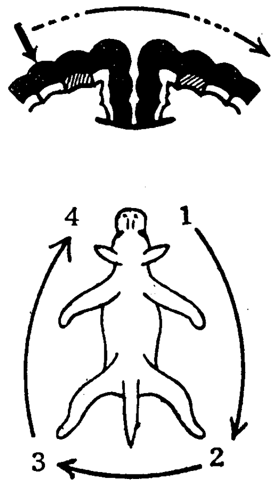


Fig. 12.



4) Cortical stimulation after removal of cortex.

After one or several areas in the motor cortex were removed and when the remaining cortical areas were stimulated, the march of spasm by passed the peripherial parts corresponding to the areas that were removed. But once the spasm has spread to every part of the body these parts join the same rhythm of convulsion. (Figs. 10 to 12.)

When the whole motor cortex of one side was removed, the march of spasm was observed on the side of the removal, and on the opposite side every part started at the same time without march. (Fig. 13.)

When all of the motor areas except one were removed, the spasm started from the corresponding part and in the other parts every one started at the same time and no march was observed. (Fig. 14.)

Fig. 13.

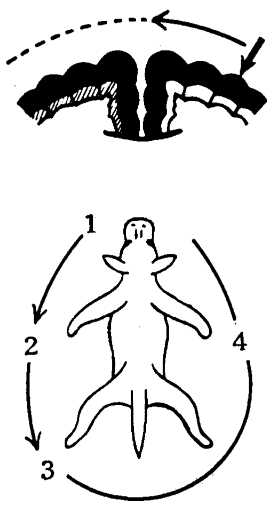


Fig. 14.

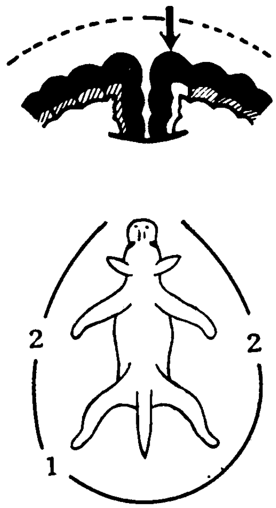


Fig. 15.

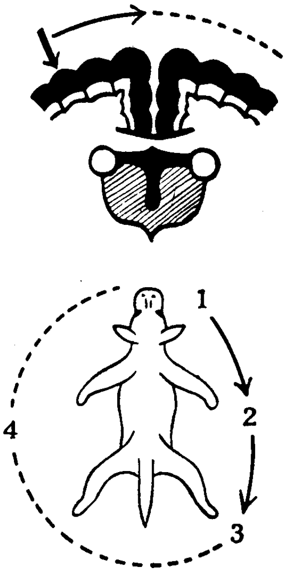


Fig. 16.

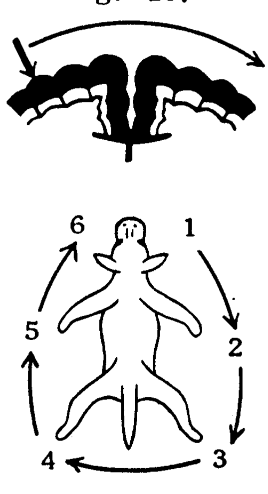


Fig. 17.

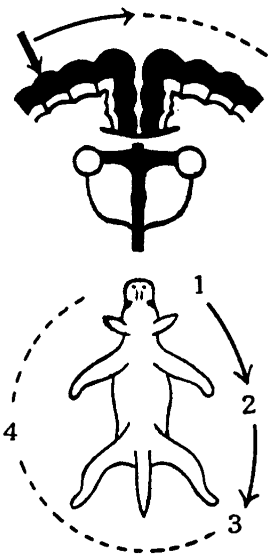
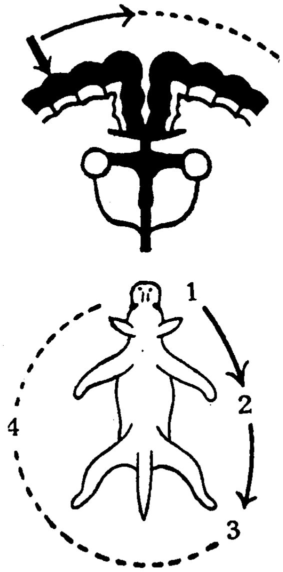


Fig. 18.



5) Cortical stimulation after the removal of the thalamus of one side.

When the motor cortex was stimulated after one or both thalamus were removed, there was no influence to the march of spasm

Fig. 19.

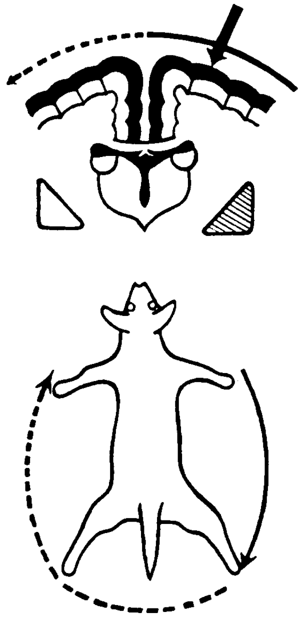


Fig. 20.

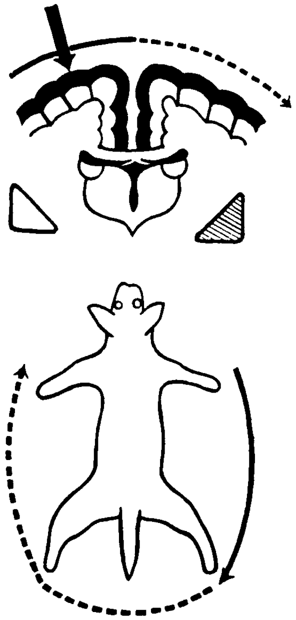
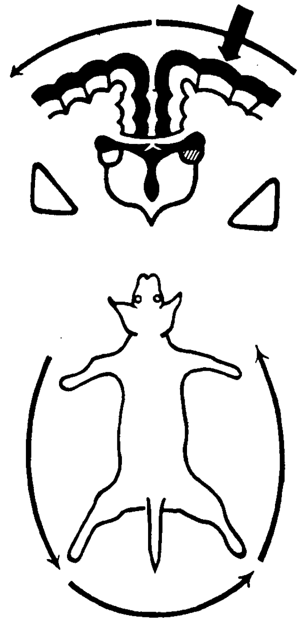


Fig. 21.



on the side corresponding to the stimulation, but the spasm in extremities of the opposite side started at the same time and no marches were observed. (Fig. 15.)

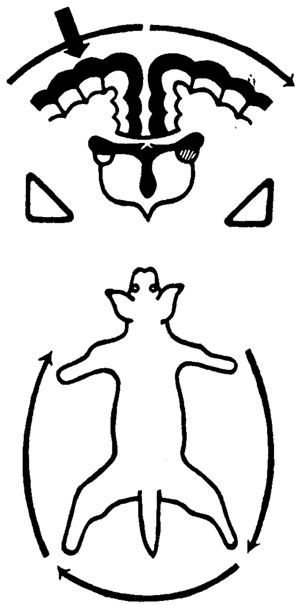
6) Cortical stimulation after cutting corpus callosum.

There was no change in the seizure by cortical stimulation when corpus callosum was cut. (Fig. 16.)

7) Cortical stimulation after cutting in between both thalamus.

When the part in between both thalamus was cut the march of spasm was only seen on the side corresponding to the stimulation, regardless the existence of corpus callosum, and no march was seen on the opposite side. (Figs. 17 & 18.)

Fig. 22.



8) After the removal of nucleus lenticularis of one side.

Fig, 23.

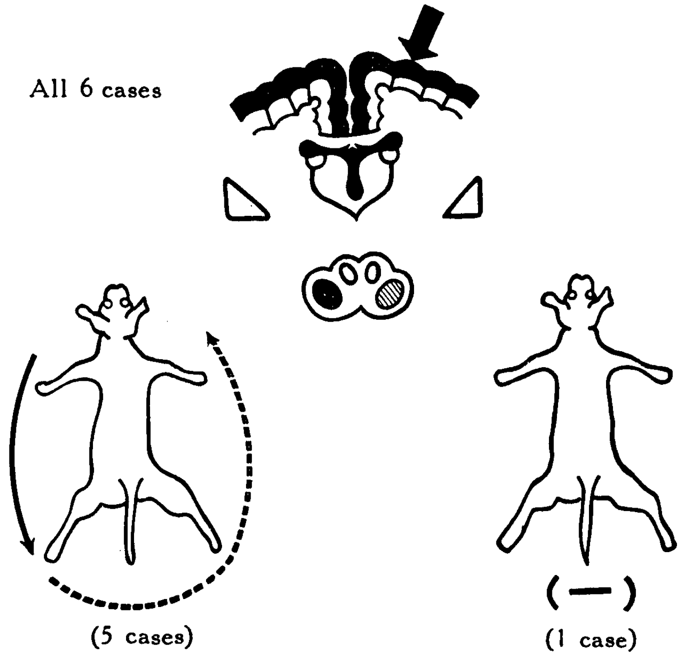
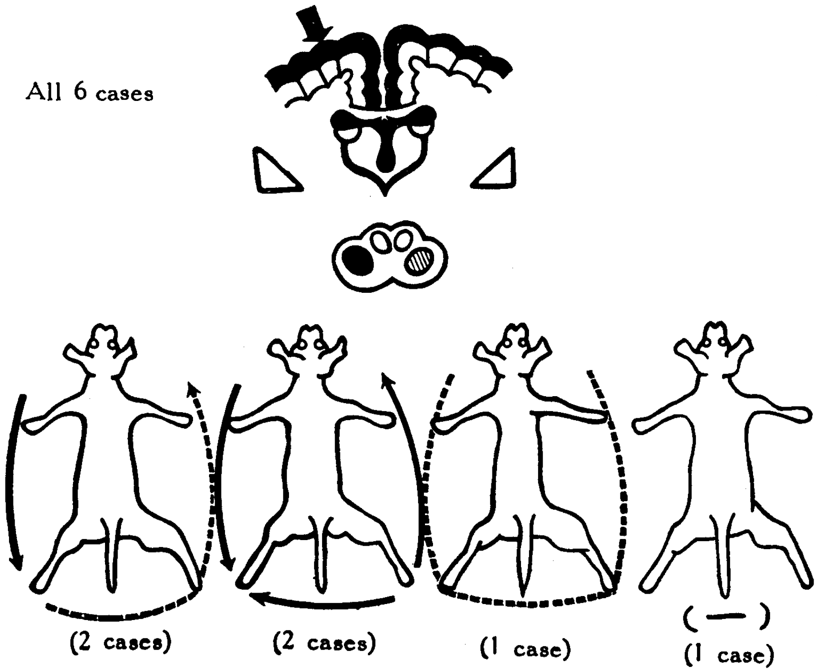

All 6 cases
(—)
(5 cases)
(1 case)

Fig. 24.


All 6 cases
(—)
(2 cases)
(2 cases)
(1 case)
(1 case)

In this case, when the cortex of the side that was removed or of the opposite side was stimulated, spasm always started from the side of the removal and marched only on that side. It was not observed on the opposite side. (Fig. 19, 20.)

9) When the cortex was stimulated after both nucleus lenticularis were removed no seizures occurred at all.

10) After removing one or both nucleus caudatus and when the cortex of the side of the removal or the opposite side was stimulated, spasm started from the corresponding part, that is, from the opposite side and showed a complete march of spasm. (Fig. 21, 22.)

11) After removal of nucleus niger of one side, when the cortex of the side of the removal or the opposite side was stimulated, a spasm started mainly from the opposite side of the stimulation in either cases and the march of spasm was seen just on that side and was missing from the opposite side. (Fig. 23, 24.)

Preliminary summary.

i) The march of spasm progresses according to the anatomical arrangement of the cortical motor representation and its propagation to the opposite side always goes from the posterior leg of one side to the other one. No other form of march was observed.

ii) In stimulated cases of the area where the subcortical cutting was done, spasm did not begin from the part corresponding to the stimulation, but began from the corresponding part adjoining this area and showed a march of spasm. When other areas were stimulated the march of spasm showed no change at all.

iii) When the cutting in between each area of the motor cortex was done there was no change in the march of spasm, except for the slowing of the time causing the march.

iv) By removing the motor cortex, the march of spasm by passed the part corresponding to the removal during its propagation but after a general seizure it was also seen in these parts.

v) Cutting of corpus callosum showed no influence in the march of spasm.

vi) When the motor cortex was stimulated after the thalamus was removed and the space between both thalamus was cut, spasm started from the opposite side of the stimulation and there was no influence in the march of spasm on that side, though it was missing from the other side. That march is called an one-sided march.

vii) When the motor cortex was stimulated after nucleus lenticularis of one side was removed, spasm started from the same side of the removal and the one-sided march of that side appeared.

viii) Removal of both nuclei lenticulares stops completely the convulsion by stimulation of the motor cortex.

ix) Removal of nucleus caudatus gives no influence to the march of spasm by stimulation of motor cortex.

x) After removing nucleus niger of one side and when the motor cortex was stimulated, spasm started from the opposite side of the removal and the march of spasm was confined only to that side.

B. March of spasm during stimulation of the thalamus.

1) Simple stimulation of the thalamus.

When the thalamus of one side was stimulated, spasm mainly began from the posterior leg of the opposite side, and showed, a march according to the arrangement of the cortical motor representation. (Fig. 25.)

At times, it started from the front leg, but rarely from the face. This is probably because it is difficult to inject where we want to when giving stimulation to the thalamus and also the area for the posterior leg is the largest in the dog's thalamus. The march occurred much faster when the thalamus was stimulated than when the cortex was.

2) Stimulation of the thalamus after removing the motor cortex of one side.

When stimulating the thalamus of the side where the whole motor cortex of one side was removed, spasm began all at one time on the opposite side, then marched to the posterior leg, anterior leg and the face of the side of the stimulation. (Fig. 26.) When the thalamus of the opposite side of the removal was stimulated, spasm started from the posterior leg opposite to the side of the stimulation and marched to the anterior leg and the face, then the extremities of the stimulated side convulsed together. (Fig. 27.)

3) Stimulation of the thalamus after removing both motor cortex.

When the entire motor cortex of both sides were removed and

Fig. 25.

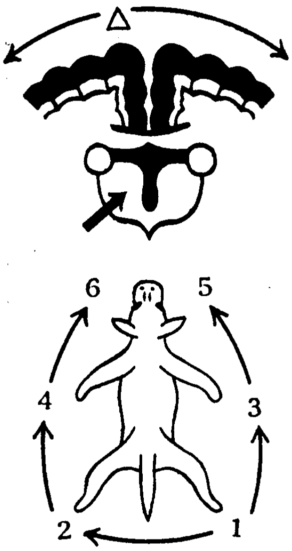


Fig. 26.

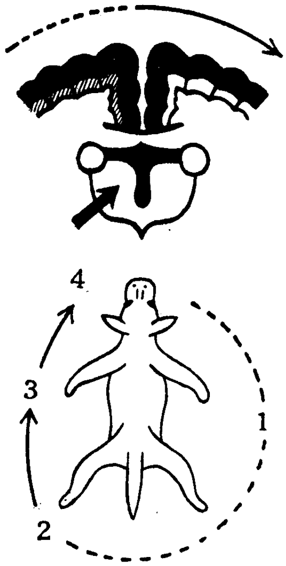


Fig. 27.

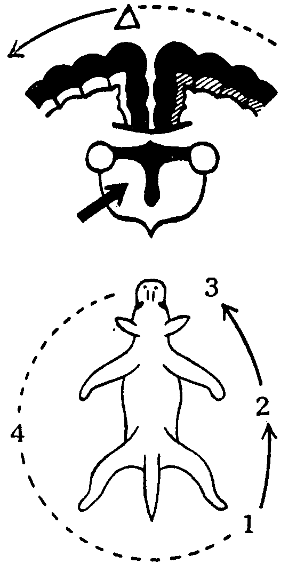


Fig. 28.

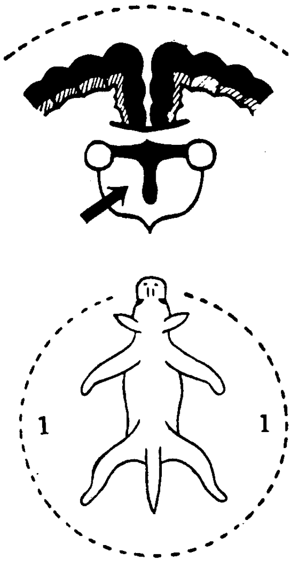


Fig. 29.

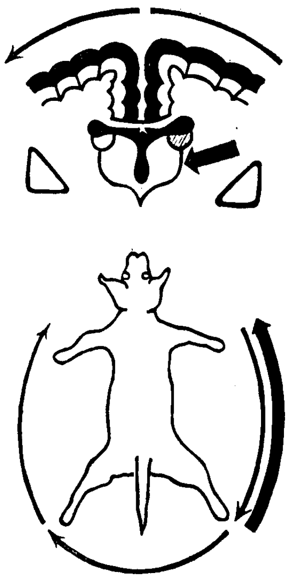
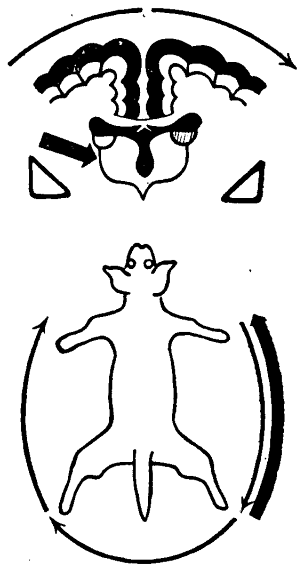
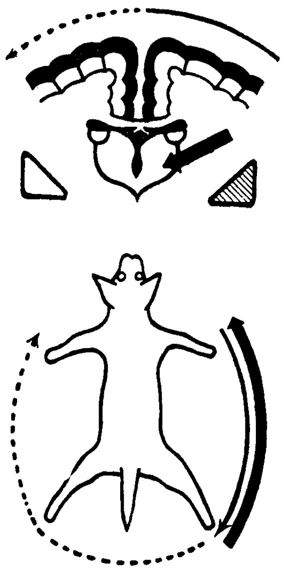


Fig. 30.



the thalamus of one side was stimulated, both the beginning place of the convulsion and the march of spasm were not seen and a general seizure started all at one time. (Fig. 28.)

Fig. 31.



4) Stimulation of the thalamus after removing nucleus caudatus of one side.

A) After removing nucleus caudatus of one side and stimulating the thalamus of the same side, there was a complete march of spasm on the side of the stimulation and it mainly started from the posterior leg. (Fig. 29.)

B) After removing nucleus caudatus of one side and stimulating the thalamus of the opposite side, there was a complete march of spasm on the opposite side of the stimulation and it mainly started from the posterior leg. (Fig. 30.)

5) Stimulation of the thalamus after removing nucleus lenticularis of one side.

A) After removing nucleus lenticularis of one side and stimulating the thalamus of the same side, spasm started mainly from the posterior leg of the side of the

Fig. 32.

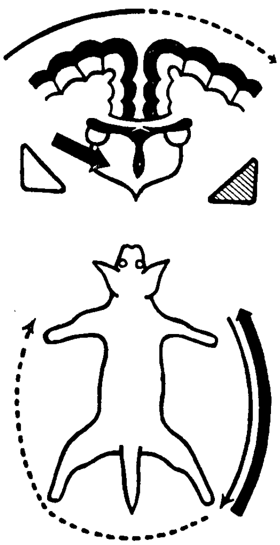
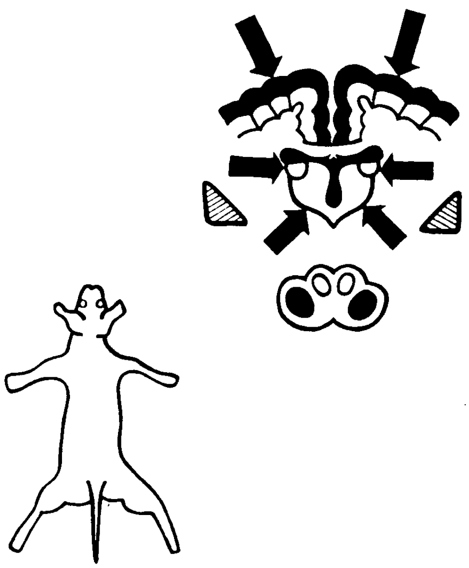


Fig. 33.



(—)

Fig. 34.

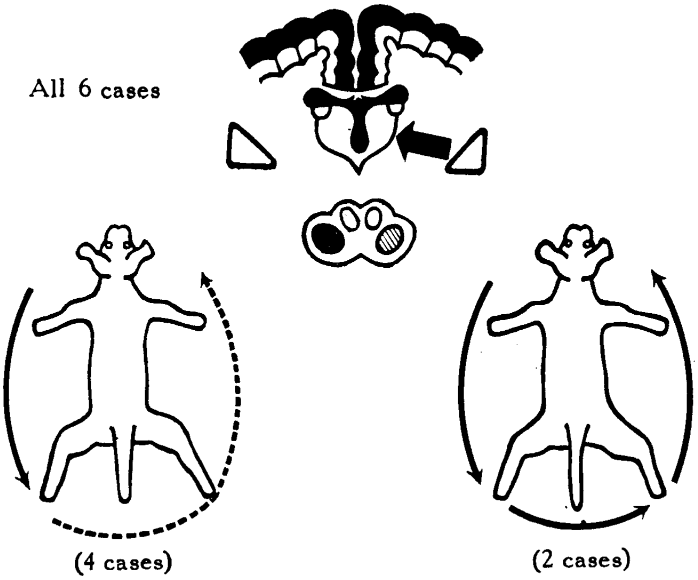
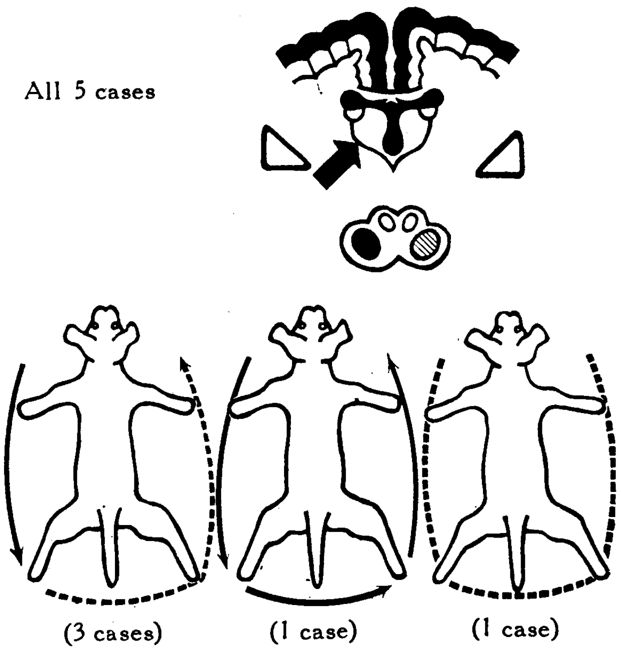


Fig. 35.



removal and the march was seen on that side. The march was missing from the opposite side of the removal. (Fig. 31.)

B) After removing nucleus lenticularis and stimulating the thalamus of the opposite side, the march started from the side of the removal, just as it did in 5). A) and the march was kept to that side. (Fig. 32.)

6) Stimulation of the thalamus after removing nucleus lenticularis of both side. In this case when either thalamus were stimulated there were no more seizures. This was the same when both the motor cortex and nucleus caudatus were stimulated. (Fig. 33.)

7) Stimulation of the thalamus after removal of nucleus niger of one side.

A) After removing nucleus niger of one side and when the thalamus of the same side was stimulated, the march always started from the opposite side of the removal and in 4 out of 6 cases the march was kept to that side but in the remaining 2 they showed a complete march. (Fig. 34.)

B) After removing nucleus niger of one side and stimulating the thalamus of the opposite side, the march of spasm started from the opposite side of the removal and was confined to that side in 3 out of 5 cases. In one case the march started from the same side of the removal and showed a complete march and in the remaining case the spasm started all at one time. (Fig. 35.)

Preliminary summary.

1) When the thalamus was stimulated, the march of spasm started from the posterior leg opposite to the side of the stimulation.

2) The march of spasm caused by stimulating the thalamus needs the existence of the motor cortex.

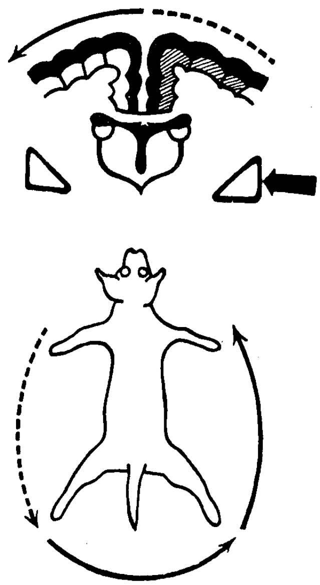
3) After removing nucleus caudatus of one side, and when the thalamus of the same side or the opposite side was stimulated, a complete march of spasm started from the side of the removal. The removal of nucleus caudatus does not show any influence at all to the march.

4) After removal of nucleus lenticularis of one side and when the thalamus of the same side or the opposite side was stimulated, an one-sided march started on the side of the removal.

5) When both nucleus lenticularis were removed there was no spasm, regardless the stimulation of the thalamus. This was the same, as stimulating nuclei of a higher position, that is, those of the motor cortex and nucleus caudatus

6) After removing nucleus niger of one side and when the thalamus of the same side or of the opposite side was stimulated, most of the march of spasm started from the opposite side of the removal and was confined to that side.

Fig. 36.



C. *March of spasm when stimulating nucleus lenticularis.*

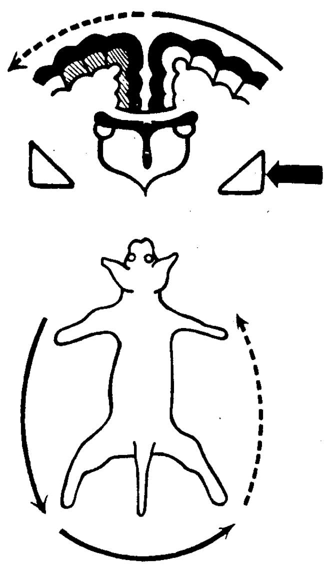
1) Simple stimulation of nucleus lenticularis.

When a simple stimulation was given to one of the nucleus lenticularis, a complete march of spasm was seen starting from the front leg of the opposite side, at times from the posterior leg and in either cases the march spread from the posterior leg to the opposite one.

2) Stimulation of nucleus lenticularis after removal of one motor cortex.

A) After removing the motor cortex of one side and when nucleus lenticularis of the same side was stimulated, the anterior and posterior legs of the side corresponding to the removal showed a seizure which started at the same time without a march, it propagated to the posterior leg of the side that the removal was performed and changed into a general seizure (Fig. 36).

Fig. 37.



B) After removing the motor cortex of one side and when nucleus lenticularis of the opposite side was stimulated, a convulsion started from the front leg of the side of the removal and marched to the posterior leg of that side. Then it propagated to the side corresponding to the removal and the spasm of both the anterior and posterior legs occurred at the same time (Fig. 37).

3) Stimulation of one nucleus lenticularis after removal of both motor cortex.

In all 8 cases there were no beginning place nor march of spasm, though there was a general seizure which started all at one time (Fig. 38).

Fig. 38.

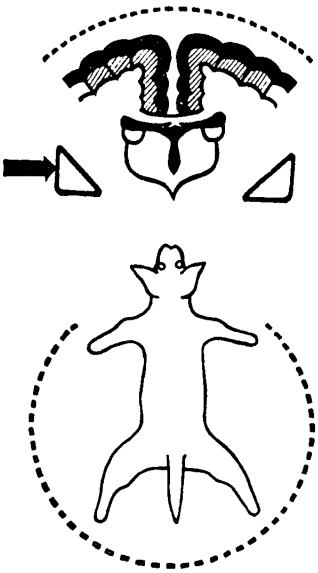
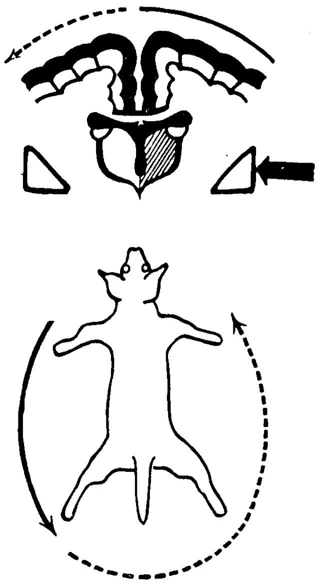


Fig. 39.



4) Stimulation of nucleus lenticularis after removal of one thalamus.

A) After removing the thalamus of one side and when nucleus lenticularis of the same side was stimulated, spasm started from the anterior or the posterior leg opposite to the side of the stimulation and there was a march on that side but the anterior and the posterior legs of the side of the stimulation convulsed together and showed no sign of march (Fig. 39).

B) After removing one thalamus and when stimulating nucleus lenticularis of the opposite side, spasm started from the front leg opposite to the side of the stimulation in 4 out of 6 cases. In one of the remaining 2 cases a clonic convulsion started from the posterior leg opposite to the side of the stimulation and on that side it showed a march but on the side of the stimulation no march of spasm was observed. In one case a general seizure started all at one time. (Fig. 40.)

5) Stimulation of nucleus lenticularis after removing one nucleus caudatus.

A) After removing nucleus caudatus of one side and when stimulating nucleus lenticularis of the same side, a complete march of spasm started from the opposite side of the stimulation. (Fig. 41.)

B) After removing nucleus caudatus of one side and when stimulating nucleus lenticularis of the opposite side, a complete march of spasm was seen starting from the opposite side of the stimulation. (Fig. 42.)

6) Stimulation of nucleus lenticularis after removing one nucleus niger.

Fig. 40.

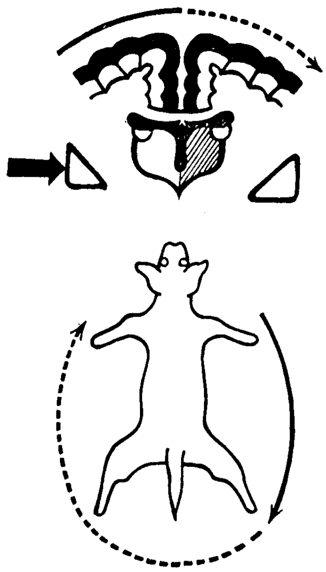


Fig. 41.

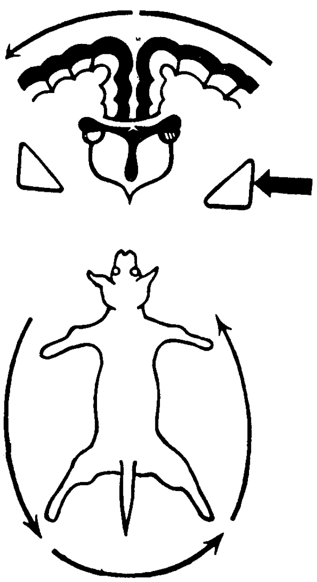
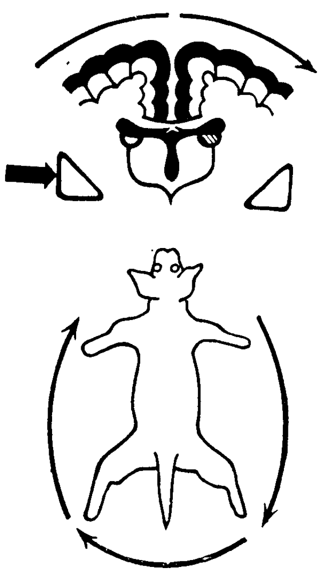


Fig. 42.



A) After removing nucleus niger of one side and when nucleus lenticularis of the same side was stimulated, in 3 out of 6 cases a march of convulsion kept to the opposite side of the stimu-

Fig. 43.

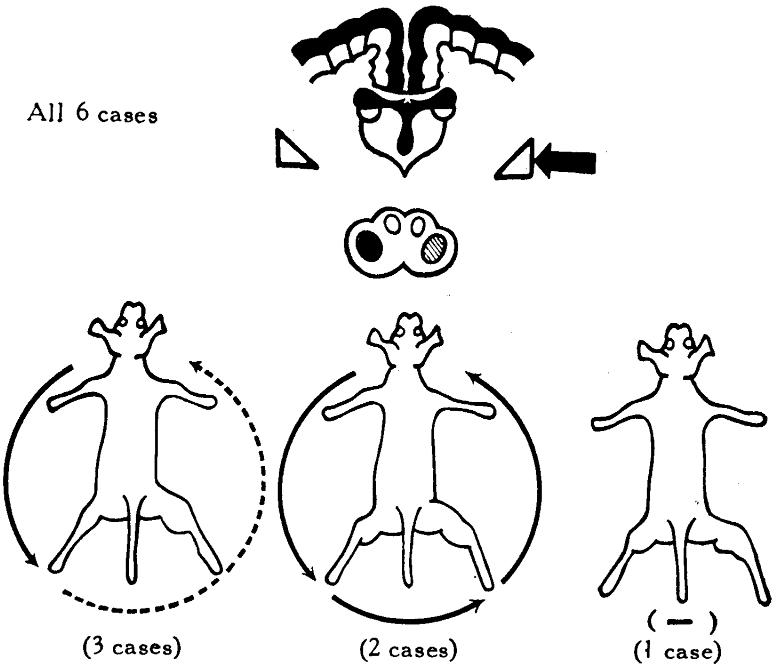
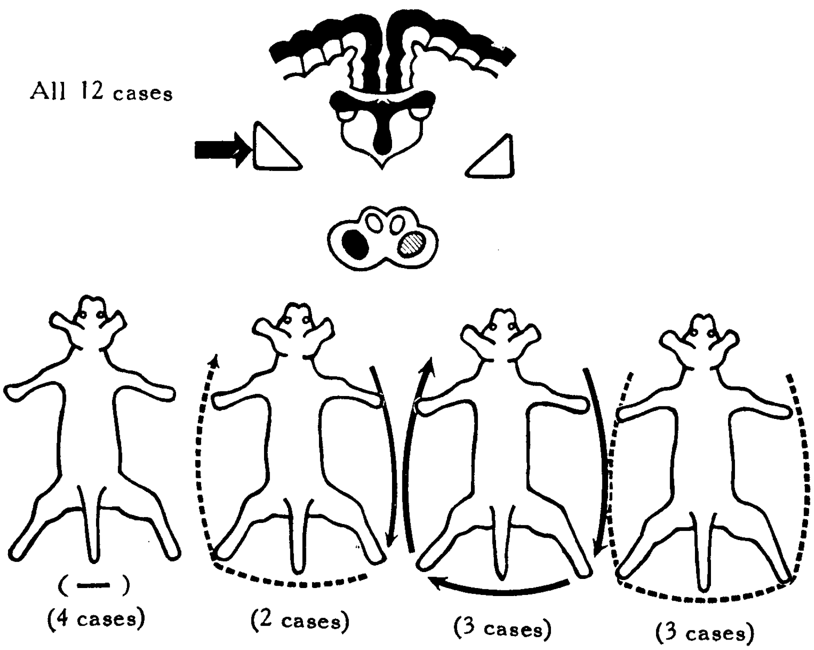

All 6 cases
(3 cases)
(2 cases)
(—)
(1 case)

Fig. 44.


All 12 cases
(—)
(4 cases)
(2 cases)
(3 cases)
(3 cases)

lation was seen. In 2 cases there was a complete march of spasm and in one there was no spasm at all. (Fig. 43.)

B) After removing nucleus niger of one side and when nucleus lenticularis of the opposite side was stimulated, 4 out of 12 cases did not show any seizures. In 2 cases a spasm started from the opposite side of the stimulation and its march was kept to that side. In 3 cases there was a complete march of spasm and in the remaining three cases there were no march of spasm. (Fig. 44.)

Preliminary summary.

1) When nucleus lenticularis is stimulated, there is a march. The motor cortex is needed for this march.

2) When the thalamus of one side is removed and nucleus lenticularis of the same side or the opposite side is stimulated, a spasm usually starts from the opposite side of the stimulation and it is an one-sided march which is missing on the side of the stimulation.

3) When nucleus caudatus of one side is removed and nucleus lenticularis of the same side or of the opposite side is stimulated, a complete march of spasm starts from the opposite side of the stimulation in either cases and the removal of nucleus caudatus does not have any effect on the march of spasm.

4) When nucleus niger of one side is removed and nucleus lenticularis of the same side or of the opposite side is stimulated, the march of spasm mainly starts from the opposite side of the stimulation and is kept to that side or show a complete march.

D. March of spasm when stimulating nucleus caudatus.

1) Simple stimulation of nucleus caudatus.

A complete march was seen starting from the opposite posterior leg of the stimulation (Fig. 45).

2) Stimulation of nucleus caudatus after removing the motor cortex of one side.

A) After removing the motor cortex of one side and when nucleus caudatus of the same side was stimulated, a spasm started at one time from the side corresponding to the removal which was followed by a march of spasm on the opposite side. It was an one-sided march. (Fig. 46.)

Fig. 45.

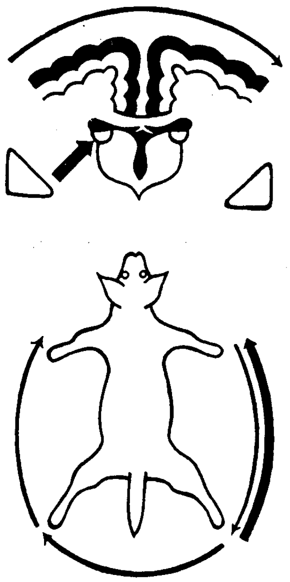
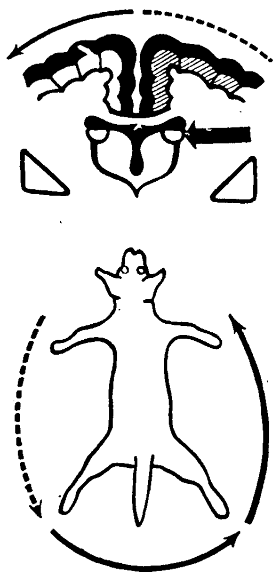


Fig. 46.



B) After removing the motor cortex of one side and when nucleus caudatus of the opposite side was stimulated, a spasm started from the opposite side of the stimulation and the march was only seen on that side. (Fig. 47.)

3) Stimulation of nucleus caudatus after removing both motor cortex.

A general seizure started all at one time without no march. (Fig. 48.)

4) Stimulation of nucleus caudatus after removing one thalamus.

A) After removing the thalamus of one side and stimulating nucleus caudatus of the same side, a march started from the opposite side of the stimulation and there was a march of spasm on that side. It was missing on the side of the removal and was an one-sided march of spasm. (Fig. 49.)

B) After removal of the thalamus on one side and stimulating nucleus caudatus of the opposite side, a spasm started from the opposite side of the stimulation and the march was kept to that side and was missing from the side of the stimulation. It was an one-side march of spasm. (Fig. 50.)

5) Stimulation of nucleus caudatus after removing of one nucleus lenticularis.

A) After removing nucleus lenticularis on one side and stimulating nucleus caudatus of the same side, a spasm started from the side of the removal and a march was seen on that side but missing from the opposite side. It was an one-sided march. (Fig. 51.)

B) After removing nucleus lenticularis on one side and stimu-

Fig. 47.

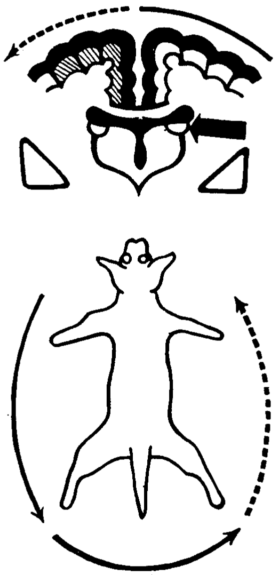


Fig. 48.

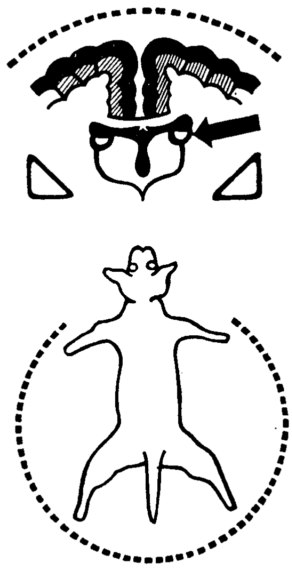


Fig. 49.

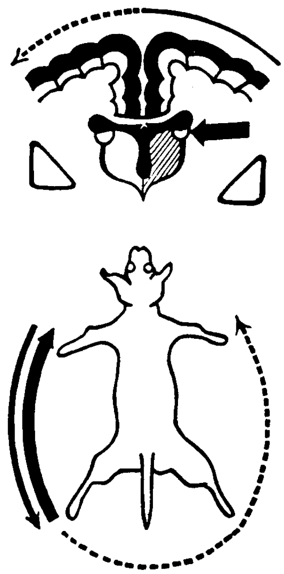


Fig. 50.

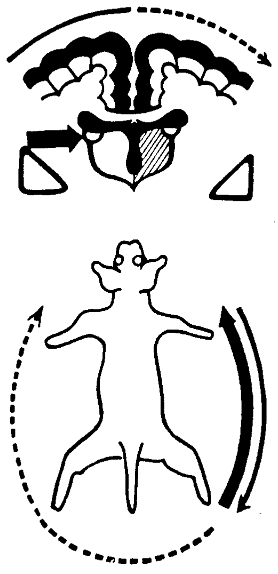


Fig. 51.

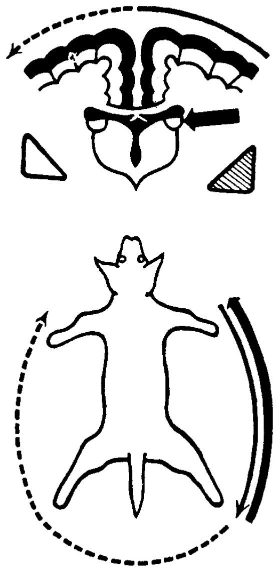
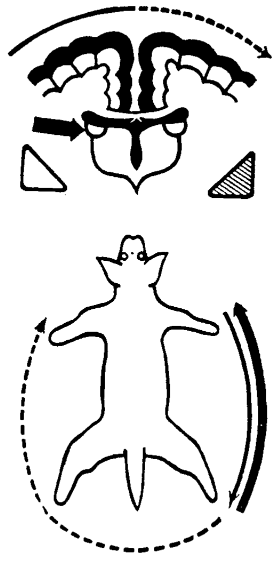


Fig. 52.



lating nucleus caudatus of the opposite side, a march was the same as in the previous case and started from the side of the removal and was missing on the opposite side. It was an one-sided march. (Fig. 52.)

Fig. 53.

All 6 cases

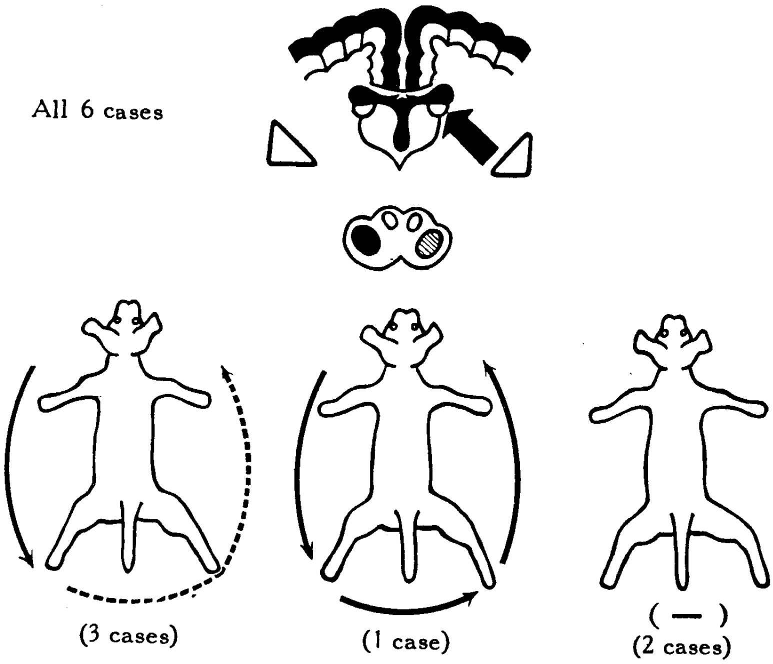
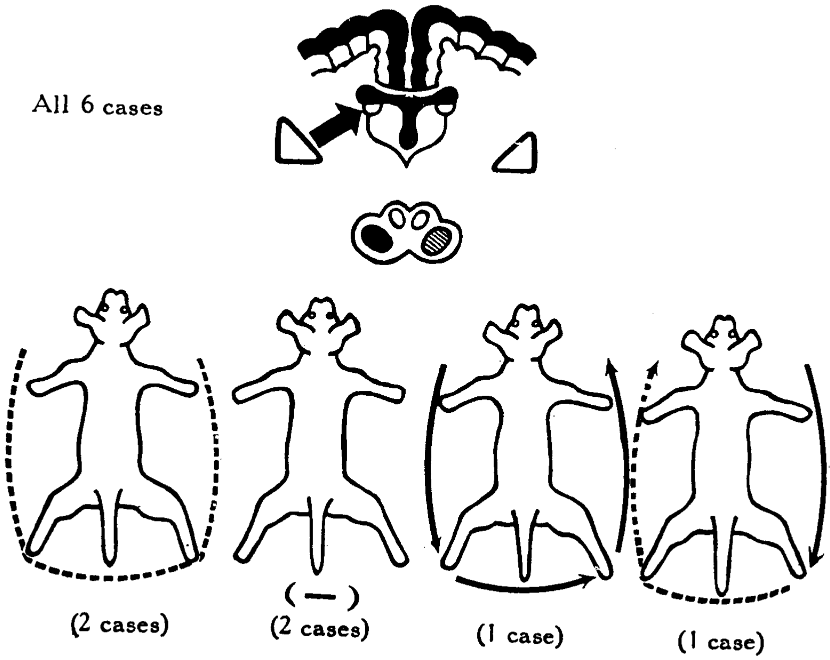


Fig. 54.

All 6 cases



6) Stimulation of nucleus caudatus after removal of one nucleus niger.

A) After removal of nucleus niger on one side and stimulating nucleus caudatus of the same side, a spasm did not appear in 2 out of 6 cases, while in the others a spasm started from the opposite side of the stimulation. I ı 3 cases out of them it was an one-sided march and in the others it was a complete one. (Fig. 53.)

B) After removal of nucleus niger on one side and stimulating nucleus caudatus of the opposite side, a general seizure starting all at one time appeared in 2 cases. In the other 2 cases there was no convulsion at all. In the fifth case a complete march of spasm started from the side of the stimulation and in the sixth case the march started from the opposite side of the stimulation and was kept to that side. (Fig. 54.)

Preliminary summary.

1) There was a march of spasm when nucleus caudatus was stimulated. In this march, also, the existence of the motor cortex is needed.

2) After the thalamus of one side was removed and when nucleus caudatus of the same or of the opposite side was stimulated, a spasm started from the opposite side of the stimulation and the march of spasm was kept to that side and was an one-sided march.

3) After nucleus lenticularis of one side was removed and when nucleus caudatus of that side or of the opposite side was stimulated, a spasm started mainly from the posterior leg of the side of the removal and the march of spasm was kept to that side and was missing in the opposite side. It was an one-sided march of spasm.

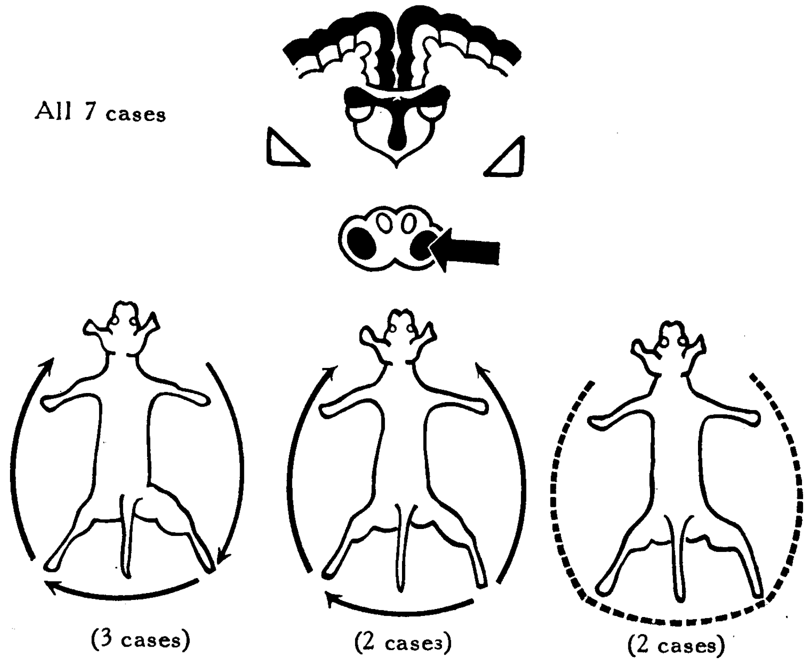
4) After nucleus niger of one side was removed and nucleus caudatus of the same side was stimulated, an one-sided or a complete march of spasm started from the opposite side of the stimulation. When the opposite nucleus caudatus was stimulated, a general seizure which started all at one time was seen in some while in others there was no general seizures at all or an one-sided march of spasm or a complete march of spasm which started from the opposite side of the stimulation were seen.

E. March of spasm when stimulating nucleus niger.

1) Simple stimulation of nucleus niger.

In 5 out of 7 cases, a complete march of spasm started from the anterior or posterior leg of the side of the stimulation and in the remaining 2 cases a general seizure which started all at one time were seen (Fig. 55).

Fig. 55.



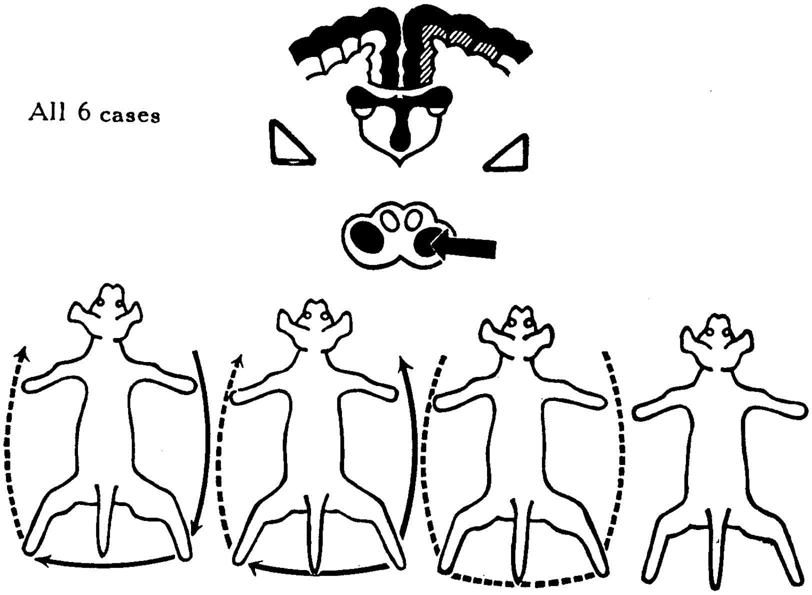
2) Stimulation of nucleus niger after removal of the motor cortex of one side.

A) When the motor cortex of one side was removed and nucleus niger of the same side was stimulated, in 4 out of 6 cases a spasm started from the anterior or the posterior leg of the same side of the stimulation and the march was kept to that side and was missing in the opposite side. In one case, a general seizure occurred all at one time and in the remaining case no convulsion appeared at all. (Fig. 56.)

B) After removal of the motor cortex of one side and when nucleus niger of the opposite side was stimulated, in 3 out of 6 cases a spasm of the anterior and posterior legs occurred together

Fig. 56.

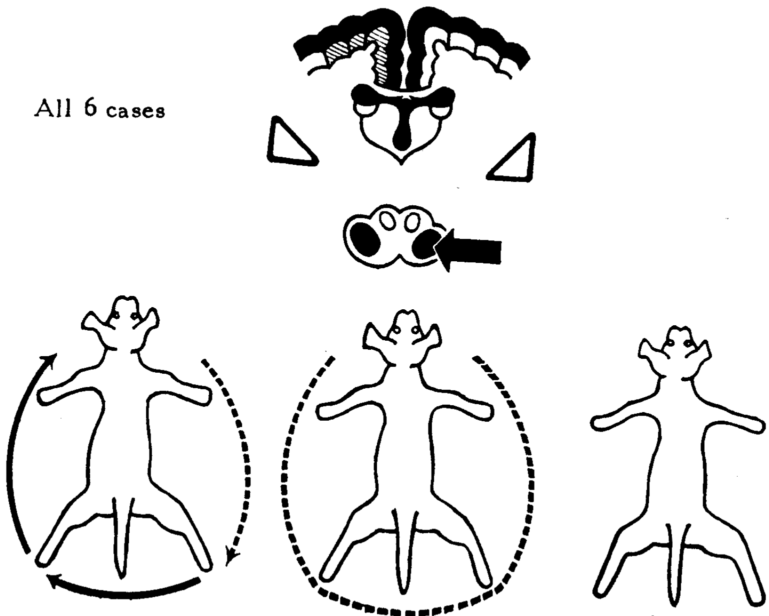
All 6 cases



(2 cases) (2 cases) (1 case) (—) (1 case)

Fig. 57.

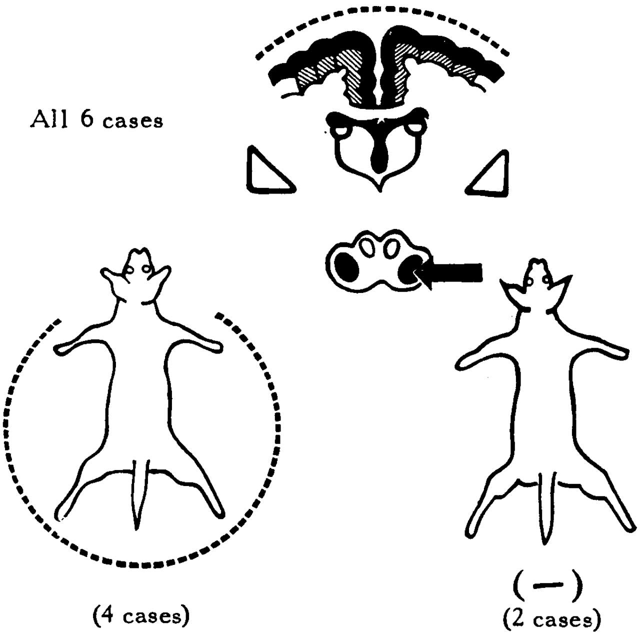
All 6 cases



(3 cases) (1 case) (—) (2 cases)

to the corresponding side of the removal and there was no march of spasm on that side. But there was one on the side of the removal. In 2 cases there was no convulsion at all and in the remaining case a general seizure which occurred all at one time. (Fig. 57.)

Fig. 58.



3) When nucleus niger was stimulated when both motor cortex were removed, 4 out of 6 cases showed general seizures which occurred all at one time and in the remaining 2 cases there were no convulsions at all. (Fig. 58.)

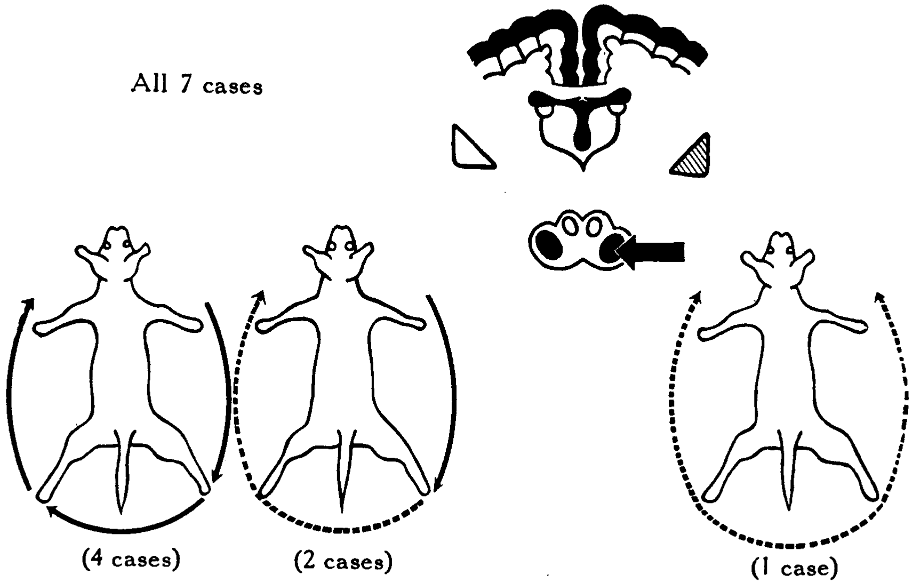
4) Stimulation of nucleus niger after removal of one nucleus lenticularis.

A) After removal of nucleus lenticularis of one side and when nucleus niger of the same side was stimulated, in 4 out of 7 cases a complete march of spasm started from the side of the stimulation, in 2 cases an one-sided march of spasm started on the same side of the stimulation and in the remaining case a general seizure which started all at once was seen. (Fig. 59.)

B) After removing nucleus lenticularis of one side and when nucleus niger of the opposite side was stimulated, the results varied and was not the same in the 26 cases of experiments here.

That is, in 8 cases a general seizure which occurred all at one time were seen, in 7 cases an one-sided march of spasm which started from the same side of the stimulation were seen. In 5 cases an one-sided march of spasm which started from the opposite side of

Fig. 59.



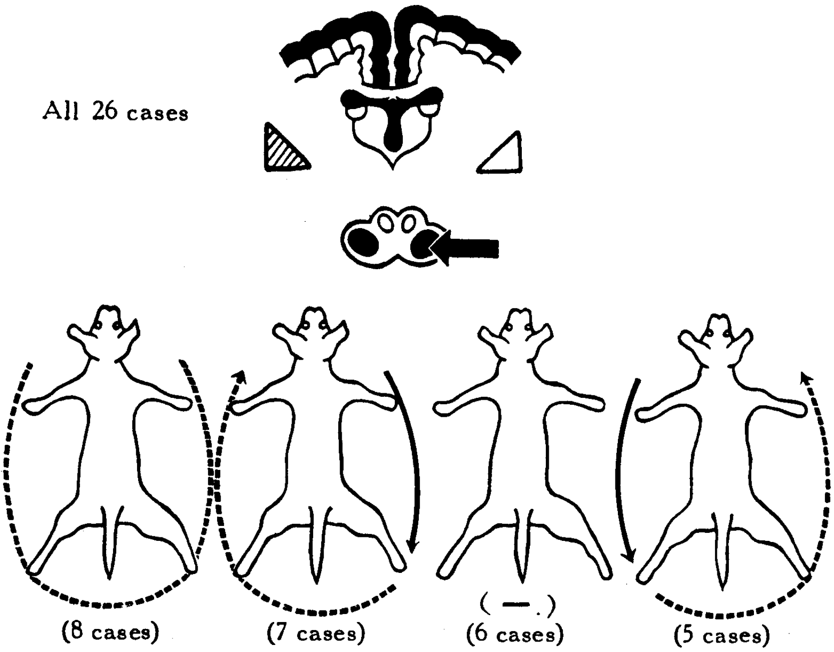
the stimulation were seen and in 6 cases no convulsion occurred at all.

In this way, after the motor cortex, the thalamus or the nucleus caudatus was removed and when nucleus niger was stimulated, or after nucleus lenticularis was removed and when nucleus niger of the same side was stimulated, there was no spasm that began from the opposite side of the stimulation of nucleus niger, but after nucleus lenticularis was removed and when the opposite nucleus niger was stimulated there were many in which the march started from the opposite side or where the convulsion was completely missing. And it seems as if the result was varying, but as it will be stated later this will be an important key for the explanation of bilateral control of lower part than nucleus niger. (Fig. 60.)

5) Stimulation of nucleus niger after removal of one nucleus caudatus.

A) After removal of nucleus caudatus of one side and stimulating nucleus niger of the same side, in 2 out of 6 cases an one-sided march of spasm started from the same side of the stimulation, in 2 cases no convulsion appeared at all, in one case a complete march started from the side of the stimulation and in the remaining

Fig. 60.



case a general seizure which started all at one time was seen. (Fig. 61.)

B) After removing nucleus caudatus of one side and stimulating nucleus niger of the opposite side, in 3 out of 6 cases a complete march of spasm started from the side of the stimulation, in 2 cases a similar one-sided march were seen and in the remaining case there was no convulsion at all. (Fig. 62.)

6) Stimulation of nucleus niger after removal of one thalamus.

A) After removing the thalamus of one side and stimulating nucleus niger of the same side, in 4 out of 6 cases an one-sided march of spasm started from the side of the stimulation and in the remaining 2 a general seizure started all at one time. (Fig. 63.)

B) After removing the thalamus of one side and stimulating nucleus niger of the opposite side, in 3 out of 6 cases a general

Fig. 61.

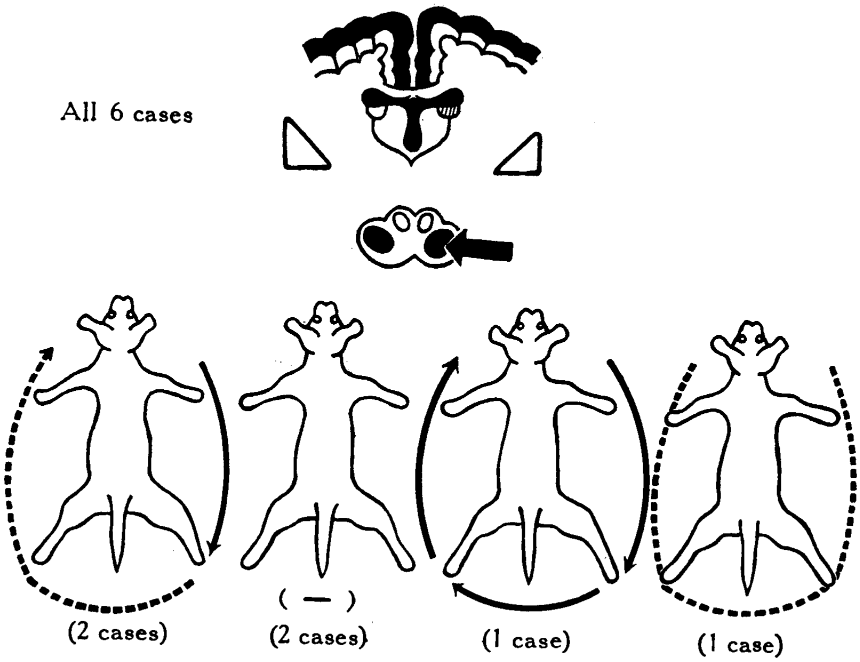

All 6 cases
(—)
(2 cases)
(2 cases)
(1 case)
(1 case)

Fig. 62.

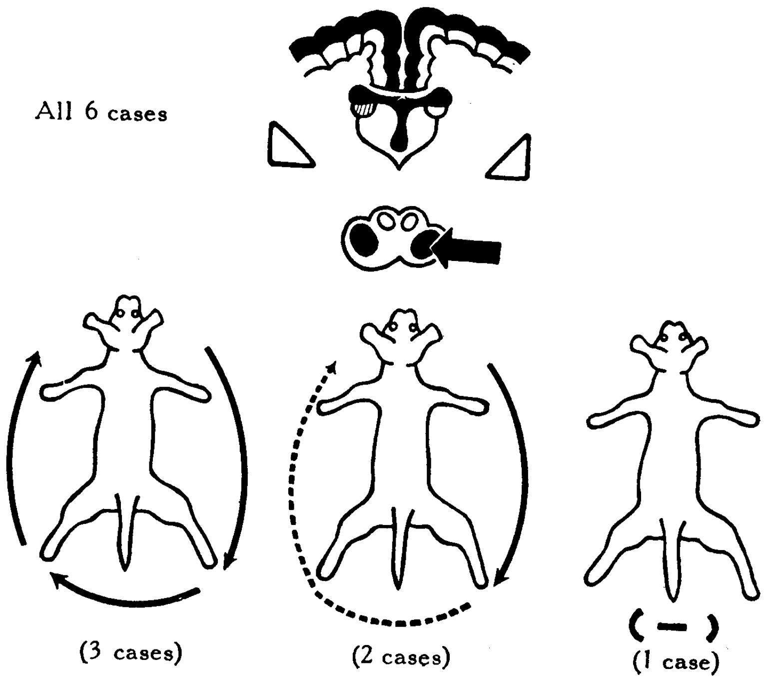

All 6 cases
(3 cases)
(2 cases)
(—)
(1 case)

Fig. 63.

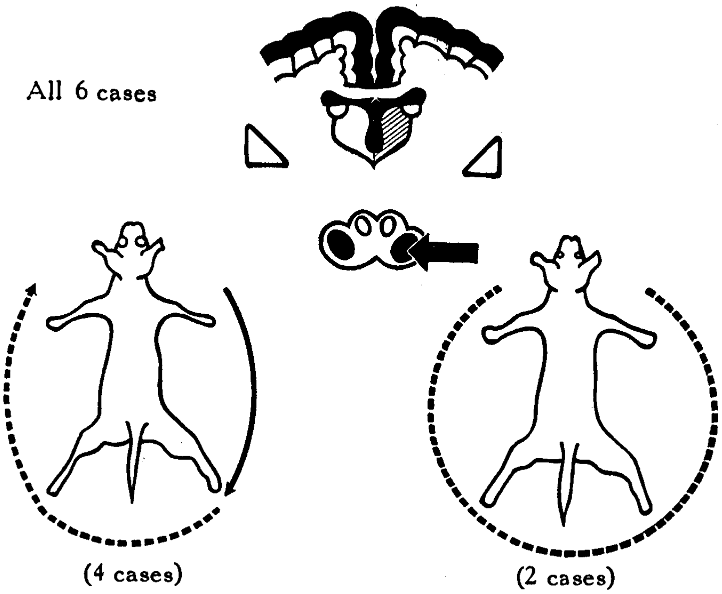
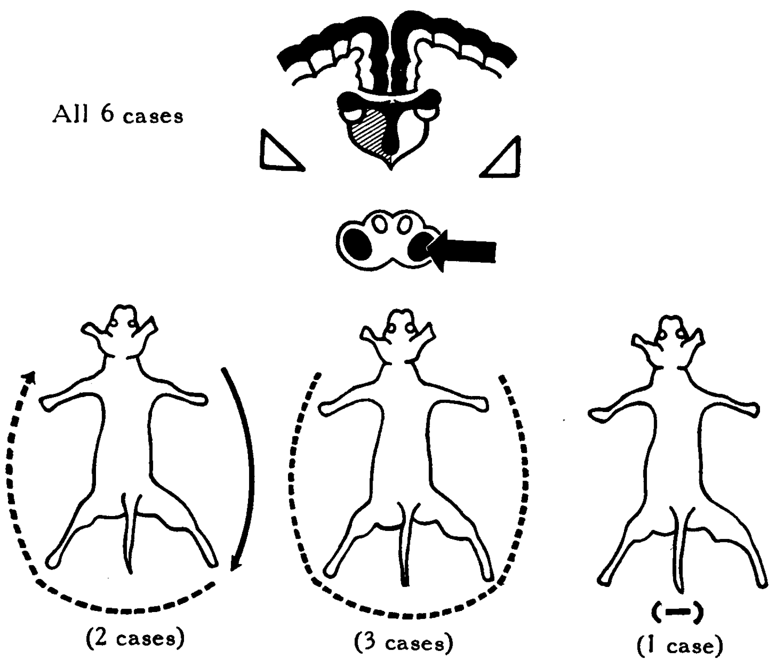


Fig. 64.



seizure started all at one time, in two cases an one-sided march started from the side of the stimulation and in the remaining case no convulsion occurred at all. (Fig. 64.)

Preliminary summary.

As seen in these experiments, the results varied only in the case where nucleus niger was stimulated. This is because the arrangement of nerve cells in nucleus niger is rough and it is thought that there is a difference according to the place where the stimulation is performed. On the other hand, it could be thought that its functional structure is much more complicated.

1) When nucleus niger was given a simple stimulation, a complete march of spasm mainly appeared from the side of the stimulation and in this march, also, the existence of the motor cortex was needed.

2) After removal of nucleus lenticularis of one side, and when nucleus niger of the same side was stimulated, a complete march of spasm started mainly from the side of the stimulation. When the opposite nucleus niger was stimulated it showed a very complicated result and there were some which showed an one-sided march starting from the side of the stimulation, while the other one-sided march started from the opposite side of the stimulation. Some show general seizures which started at the same time, while on the other hand there was no convulsion at all. The number of occurrence of these cases were about the same. And in all of the other experiments concerning stimulation of nucleus niger, a march starting from the opposite side of the stimulation was seen only in this case.

3) After removal of nucleus caudatus and stimulating nucleus niger of the same or the opposite side an one-sided or a complete march of spasm started mainly from the side of the stimulation.

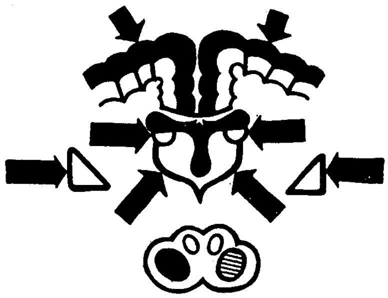
4) After removal of one thalamus and when nucleus niger of the same side was stimulated, it was mainly of one-sided marches starting from the side of the stimulation. And when the opposite nucleus niger was stimulated, there were some which showed general seizures starting all at one time. Some showed one-sided march starting from the side of the stimulation.

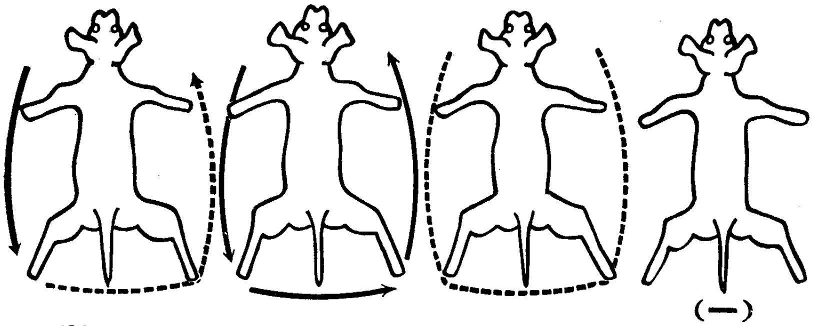
* * * * *

Putting these results together when the motor cortex, nucleus lenticularis, the thalamus or the nucleus caudatus were stimulated after the removal of one nucleus niger, they are as shown in Fig. 65 and in 23 out of 53 cases one-sided march started from the opposite side of the removal, in 12 cases they were similar complete marches, in 7 cases they were general seizures starting all at one

Fig. 65.

Motor cortex	12 cases
Thalamus	11 cases
Nucl. caudatus	12 cases
Nucl. lenticularis	18 cases
Sum	53 cases





time and in the remaining 11 cases there were no spasm at all. There was no case in which the spasm started from the same side of the removal.

F. March of spasm when stimulating various upper nuclei after sectioning the midbrain and the pons longitudinally on the saggital line.

1) After sectioning the midbrain longitudinally on the saggital line and when nucleus lenticularis was stimulated, in 4 out of 7 cases a weak march of spasm started from the opposite side of the stimulation and in one case it showed a complete one while in the other 3 they were one-sided marches. (Fig. 66.)

2) After sectioning both the midbrain and the pons longitudinally on the saggital line and when nucleus lenticularis of one side

was stimulated in all 6 cases no convulsion were observed. Also in this case, instead of stimulating nucleus lenticularis directly 5 cc. of 10% cardiazol was injected into V. digitorum communis dorsalis to provocate convulsion, but in all 6 cases no convulsion were observed. (Fig. 67.)

3) Stimulation of one nucleus lenticularis after making a separate longitudinal cutting of the midbrain and the pons at the midline.

In dogs which showed an obvious march of spasm by intravenously injected cardiazol a longitudinal cutting was made downward from the midbrain, while another upward from the pons. The end of these two cuttings did not meet and there was a distance of 3 to 4 mm. between them. In such 6 cases no convulsion appeared even after repeated stimulation. (Fig. 68.)

Fig. 66.

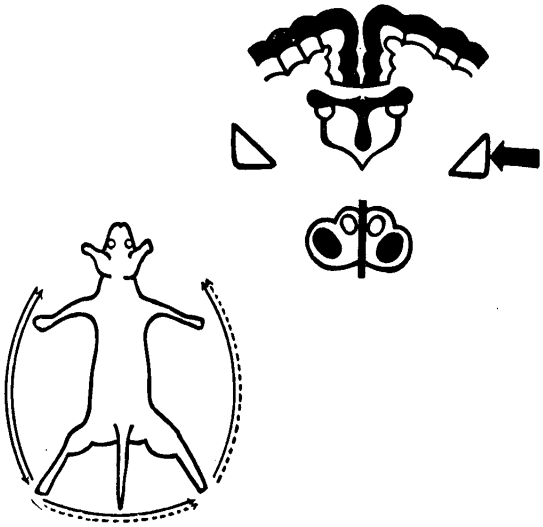
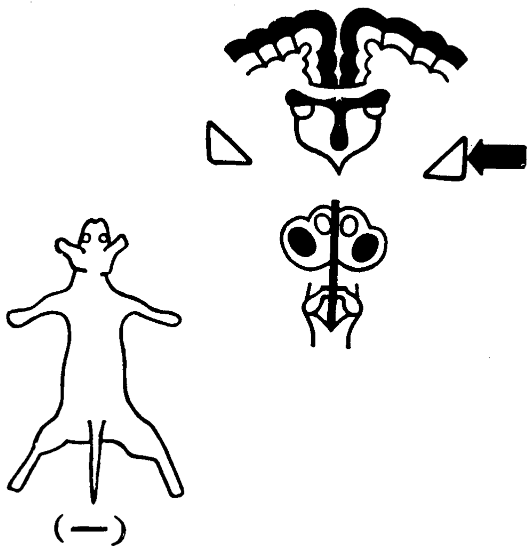


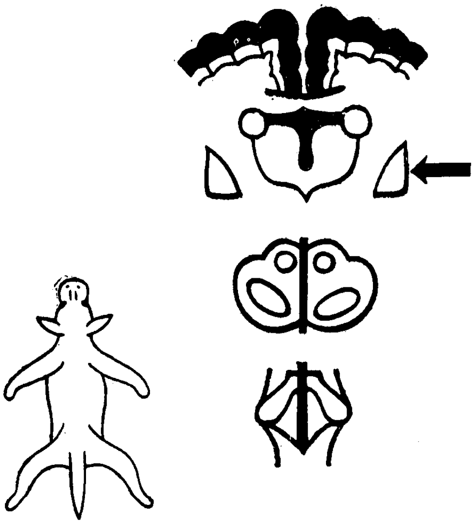
Fig. 67.



Preliminary summary.

1) Convulsions by stimulating nucleus lenticularis are seen though they may be weak when a longitudinal midline cutting is made in the midbrain. But when this cutting is extended to the

Fig. 68.



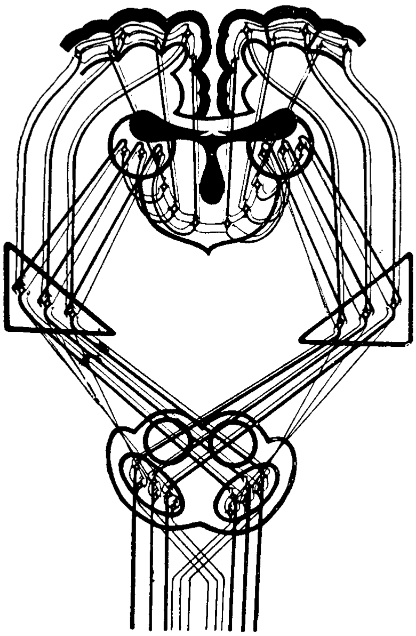
(—)

pons convulsions disappear.

2) When the longitudinal cutting is extended downwards from the midbrain and upwards from the pons convulsion cases to occur even before both cutting meet.

Summary and Discussion

Fig. 69.



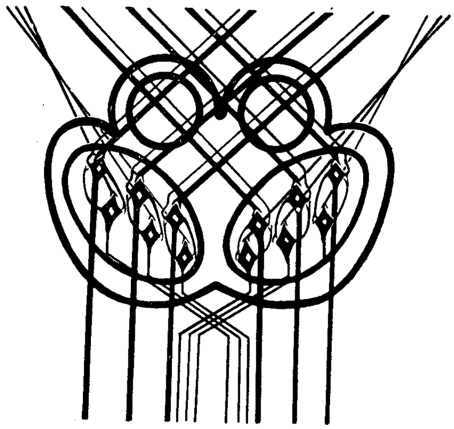
From these experiments the mechanism of this march is thought to be as designed in Fig. 69 and 70.

I would like to think about the results from the experiments I have just stated.

From the point that convulsion is induced by chemical stimulation in the motor cortex, nucleus lenticularis, nucleus caudatus, the thalamus and nucleus niger, it means that the fibers distributed to these nuclei are not what is so-called "fibers of passage", but are obviously that of a "realy station" where neurons end within the nucleus. That is why cardiazol works only on the nerves cell and not on the nerve fibers.

When one area of the motor cortex was stimulated it was obvious that a convulsion started from the part corresponding to the area that was stimulated, then the march of spasm spread both ways according to the arrangement of the motor representations from this place. From this it can be thought again, that

Fig. 70.



impulses are propagated through the cortex. When subcortical cutting is perfoımed and the area directly above this is stimulated, a convulsion starts from parts corresponding to its adjoining areas. From this, too, it can be thought that impulses are propagated side ways in the cortex. Next, when the in-betweens space of the cortical areas are cut there is a march of spasm, but the speed of this march is delayed here. From this, it can be thought that the cortex have some relations to the propagation of impulses.

But from the point that the march of spasm still exists after cutting the connection in between cortical areas, it can be thought that these impulses not only passes through the cortex, but also reaches the lower centers (thalamus and nucleus lenticularis) and then takes a returning route to the cortex, that is, it has a reverberating circuit. Concerning this, *Fulton* said that there is a fiber from the thalamus, especially from its nucleus ventralis to cortical areas 4 and 6. If this reverberating circuit did not exist, when stimulating the thalamus after the removal of nucleus caudatus impulses would only be transmitted to the opposite thalamus. Therefore, march of spasm should appear only on the side where nucleus caudatus was removed. But in this experiment, as there was no effect on the march of spasm, it can be interpreted that stimulation of the thalamus goes to the opposite thalamus but will also go to the cortex through the reverberating circuit, passing nucleus lenticularis of that side and will appear as a march of spasm on the opposite side of the removal.

Next, when the thalamus is stimulated, spasm mainly starts from the posterior leg and it propagates to both sides with this as the center. This means, at the thalamus it is difficult to stimulate the place that is needed or desired and in dogs as the cortical area for the posterior legs is highly developed and the area taken for the posterior leg in the thalamus is probably the widest. Furthermore, when stimulating the thalamus the beginning place of the spasm differs according to where it was stimulated and it can be thought that even in the thalamus areas for the movement of each legs is localized. It is also presumed there are different fibers connecting each areas of the thalamus to its corresponding areas in the cortex.

Various opinions concerning the propagation of the march of spasm to the opposite cerebral hemisphere has not been agreed yet. In my experiment, even when corpus callosum was cut there was no change in the march of spasm. But when the connection between both thalamus was cut the march of spasm localized to the side corresponding to the stimulation as in the case when the thalamus was removed and there was no march on the opposite side. This fact shows that the impulse of one hemisphere does not pass through corpus callosum but through the connection between both thalamus to the opposite side.

From the fact that when stimulating not only the motor cortex and the thalamus but also nucleus lenticularis and nucleus caudatus march of spasm could be seen starting from the opposite side, and when stimulating nucleus niger it starts from the same side, shows that there is also a station in these nuclei that governs the march of spasm. And it can be thought that the spread of impulses within one hemisphere is done within them.

But in the convulsion by stimulating any nucleus the march would be missing from the corresponding peripherial part to the area that was removed in the motor cortex and would be seen only in parts corresponding to remaining areas in the cortex. When the whole motor cortex of one side was removed, the march would be missing only on its opposite side. When both motor cortex are removed there would be no march of spasm and convulsion would happen all at one time. From these facts it can be seen that the presence of the motor cortex are always needed in the march of spasm. What is the mechanism of this? I think the conduction of impulse of the convulsion itself passes through the fibers (extra-pyramidal) which comes out from each nucleus, but the activity of the march of spasm is regulated and directed by the fibers (pyramidal) of the same area in the cortex and forms into a march of spasm. That is, it should be thought that the impulse of convulsion is conducted through the extra-pyramidal tract, while the activity of the march of spasm passes through the pyramidal tract.

First, let us think about the mechanism of the march of spasm in relation between motor cortex and the thalamus. If the face area is stimulated, a co-operative action is made between the cortical pyramidal and extra-pyramidal tracts, which induces a spasm in the face of the opposite side. At the same time the impulse is propagated within the cortex to the neighboring areas, while on the hand it is also conducted to the area in the thalamus or in nucleus lenticularis which corresponds to the face. From here it is marched to the part corresponding to the front leg in the thalamus, then it returns to the area of the front leg in the cortex. This starts the action in the area of the front leg in the cortex, which causes spasm in the front leg. When the spasm marches to the posterior leg it is thought that the impulse passes through the connection between both thalamus to the opposite thalamus. Then it starts action in every pyramidal and extra-pyramidal tracts in the motor cortex according to its order, and also causes march of spasm in the opposite side, which changes into a general seizure. When the thalamus is stimulated, the impulse is at once transmitted from the stimulated cell to other parts in the thalamus and is conducted through the descending extra-pyramidal fibers from the thalamus, while the impulse of the march of spasm passes through the reverberating circuit to the cortex. From here the cortical pyramidal tracts are excited one by one and it is thought that the march appears as its a co-operative action. When the thalamus is stimulated, it is thought that the reason why the march of spasm appears much quicker than when stimulating the cortex is for this reason. When a subcortical cutting is performed, fibers of the pyramidal and the extra-pyramidal tracts are cut in that area and for this reason the transmission of impulses just goes side ways in the cortex and even though that area is stimulated the march starts from the areas neighboring that area. It should be thought that when the cortex is removed the transmission of impulses that goes side ways is interrupted and as there is no beginning cells of the pyramidal tract to react to the impulse from the thalamus, which is coming through the reverberating circuit, the spasm passes by the part that is corresponding to this area and once these spasms have become into a general seizure, spasm is seen in this part by the activity of the lower nuclei.

From the experiment where one thalamus was removed and the motor cortex of same side was stimulated and from the other experiment where one nucleus lenticularis was removed and the motor cortex of the same and the opposite side were stimulated, it is certain that they took the two tracts which *Suda* had proposed. These two tracts are, a direct connection between the cortex and nucleus lenticularis of the same side, and the other which first goes to the thalamus of the same side then to nucleus lenticularis of that side and of the opposite side.

It is thought from the results of experiments where nucleus lenticularis was given a simple stimulation, where one thalamus was removed and nucleus lenticularis of the same side was stimulated, where one nucleus caudatus was removed and nucleus lenticularis of the same side was stimulated, that the stimulation to nucleus lenticularis, as those to the thalamus, first reverberates to the motor cortex and is then eventually directed by the beginning cells of the pyramidal tract to cause the march of spasm.

But how is the connection between the motor cortex and nucleus caudatus made?

In all experiments where nucleus caudatus were removed, it showed a complete march of spasm as seen in normal ones and from this, it can be thought that a connecting fiber does not always have to exist between the cortex and nucleus caudatus. Next, from the results of various experiments concerning stimulation of nucleus caudatus an one-sided march of spasm was seen on the side of the removal when nucleus lenticularis was removed and when the thalamus was removed it was seen on the opposite side of the stimulation. From these facts, it can be thought that the fibers concerning spasm passes the thalamus and nucleus caudatus of the same side and connects to nucleus lenticularis of that side. On the other hand, it can also be thought that there is a tract which starts from the thalamus of the same side and crosses to the opposite thalamus and passes through nucleus caudatus of the opposite side and reaches nucleus lenticularis of the opposite side. But, when one nucleus lenticularis is removed and nucleus caudatus of the same side is stimulated the march starts from the side of the removal and is not seen on the opposite side (this is called an one-sided march of spasm). From this fact, it can be thought again that there is a fiber that starts from nucleus caudatus and passes through the thalamus of the same side and reaches the thalamus of the opposite side, while it can also be thought that it starts from nucleus caudatus and reverberates to the cortex (*Kodama*, *Meynert*) and passes on from the cortex to the thalamus of the same side and reaches the thalamus of the other side. This conclusion is not decided yet. But this can be explained without thinking of a special fiber between nucleus caudatus and the cortex.

It has been explained anatomically that there is a fiber that directly connects between the cortex and nucleus niger, but as in my experiments the occurrance of spasm caused by stimulation of the motor cortex caused. When both nucleus lenticularis were removed, so it can be thought that there is no fiber directly connecting between the cortex and nucleus niger without reaching nucleus lenticularis.

From my experiment it can be thought that the pathway from nucleus lenticularis to nucleus niger is as follows. One nucleus lenticularis controls both nucleus niger and its homolateral fiber is weak and its crossing fiber which crosses at the midbrain is strong, moreover, the strong crossing fiber changes neuron at nucleus niger, then descends homolaterally on that side. On the other hand, the weak homolateral fibers connect with a different cell from those crossing fibers in nucleus niger and after changing neurons here, it is believed that they cross at the pons to the other side and descend. Because, when only the midbrain is cut longitudinally at midline, spasm is not completely stopped when nucleus lenticularis is stimulated and a weak spasm begins from the opposite side. It can also be proved and you will agree from the following fact that from nucleus niger there is a strong fiber that descends homolaterally and a weak fiber that crosses and descends. And only when nucleus lenticularis was removed and the opposite nucleus niger was stimulated did 5 cases out of 26 cases start their march from the opposite side of the stimulation. Out the same cases, 6 cases did not show any kind of spasm. When nucleus niger was stimulated after the removal of other nuclei, excluding the cortex, a march alway started from the same side of the stimulation and nerver from the opposite side. This is because after the removal of nucleus lenticularis, cells with strong homolaterally descending fibers in nucleus niger of the opposite side is in a state of shock, which is also called *Monakow*'s diaschisis phenomenon and will not react to any stimulation. So for this eason, probably the march starts from the opposite side by the weak crossing and descending fibres, otherwise, it does not occur at all. And it can well be understood, from the fact that when the midbrain and the pons are cut longitudinally at midline the spasm is completely blocked, these two pathways are independent from each other and on the whole makes a complete crossing.

Next, it can be thought that the connection between both hemispheres, concerning the march, is done only at the thalamus and not at nucleus lenticularis, nucleus caudatus nor nucleus niger. This is presumed, as said previously, from the results that when the thalamus is removed or when the connection between both thalamus is cut the march is missing on the opposite side and becomes an one-sided march. But from the fact that when one nucleus lenticularis was removed and nucleus niger of the same side was stimulated there was 4 cases which had a complete march of spasm out of 7 cases, it will have to be thought that a connection between both nucleus niger must exist, otherwise it would be difficult to explain this. But if a connection between both nucleus niger should exist, there should be cases which would show complete march of spasm when nucleus niger is stimulated after the thalamus is removed. But from the fact that there was no such cases, it would be proper to think that the pathway that would transmit the volley of impulses for the march between both hemisphere is only through the thalamus. If I should try to explain the unusual case that showed a complete march of spasm it could be thought as follows. When one nucleus niger was stimulated the beginning cells of two kinds of fibres, that is the crossing one and the homolateral one, were both stimulated together and first the beginning cell of the strong homolateral fiber received the stimulation, then followed by the beginning cell of the weak crossing fiber and both took the reverberating circuit to the motor cortex and which appeared as a complete march of spasm. This reverberating circuit took the following pathway, 1) nucleus niger → nucleus lenticularis of the opposite side → the motor cortex of the opposite side. 2) Nucleus niger → nucleus lenticularis of the opposite side → motor cortex of the opposite side ↘ → thalamus
↘ nucleus caudatus of the opposite side ↗
of the opposite side → thalamus of the same side → motor cortex of the same side

On the other hand, the reverberating circuit to the motor cortex of the side of the stimulation is blocked when the thalamus is removed, so probably for this reason it becomes into an one-sided march. If it is thought this way there is no need for a connection between both nucleus niger.

This study is still in progress and the march of spasm during stimulation of the cerebellum is being studied now. It was found that there exists a connection between both cerebellar hemispheres. Furthermore, there seems to be a connection from the cerebellar cortex to the opposite thalamus, but its detail will be reported in later papers.

Conclusion

1) A march of spasm was found it the convulsion when the motor cortex the thalamus, nucleus lenticularis, nucleus caudatus and nucleus niger were stimulated.

2) The existence of the motor cortex is always needed for a convulsion with march of spasm to occur.

3) Spread of spasm within one hemisphere is done even within the motor cortex, the thalamus, nucleus lenticularis, nucleus caudatus and nucleus niger. But for it to spread to the opposite side is done between both thalamus. (Studies concerning the cerebellum is now in progress).

4) When both nucleus lenticularis are removed there is no spasm even when nuclei in position higher than this are stimulated.

5) The connection between nucleus lenticularis and nucleus niger is mainly crossing but there are a few weak homolateral fibers.

6) These weak homolateral fibers connects with different cells than those of the strong crossing fibers in the nucleus niger. After changing neurons, the crossing fibers descend homolaterally and the homolateral fibres cross at the pons.

7) These two pathways are independent to each other and in all makes a complete crossing, but they cross at different heights.

8) From these facts I have made a scheme which shows the mechanism on the march of spasm.

9) The march of spasm arises from a close co-operative function of the pyramidal and the extra-pyramidal tracts. That is, for

the volley of impulses for the convulsion in the extra-pyramidal tract, and for the activation of the march of spasm in the pyramidal tract becomes the prime mover.

Literature

Jackson, Selected Wrightings of John Hughling Jackson, London, 1, 410 (1931). — *Fritsch* u. *Hitzig,* Arch. Anat. Physiol., 37, 370 (1870). — *Bunoff* u. *Heidenhain,* Pf. Arch. f. d. ges. physiol., 26, 137 (1881). — *Munk,* Über die Funktionen der Grosshirnrinde, Berlin, 1890. — *Brown* u. *Sherrington,* J. Physiol., 43, 367 (1911). — *Dandy,* J. A. M. A., 88, 90 (1927). — *Foerster,* Handbuch d. Neur., VI, 1 (1935). — *Erickson,* Arch. Neur. Psychiat., 43, 429 (1940). — *Hayashi,* JOKENHANSHA, 7, 68 (1943). — *Wada,* Folia Psychiatrica et Neurologica Japonica, 4, 320 (1951). — *Bechterew,* Die Funktion d. Nervenzentr., Jena, 2, 1224 (1909). — *Wilson,* Brain, 36, 427 (1914). — *Suda,* JOKENHANSHA, 4, 472 (1914). — *Ozaki,* JOKENHANSHA, 5, 49 (1942). — *Nissl, Koelliker, Müuzer, Wisener,* Zitiert nach Ando, Okajima Fol. anat. Japon, 15, 164 (1937). — *Ando,* Okajima Fol. anat. Japon, 15, 164 (1937). — *Dusser de Barrenne* u. *Mc. Culloch,* J. Neurophysiol., 1, 176 (1938). — *Yoshida,* OKAYAMA-IGAKKAI-ZASSHI, 64, 1536 (1952). — *Ogawa,* OKAYAMA-IGAKKAI-ZASSHI, 64, 1672 (1952). — *Takahashi,* NIPPON-SEIKEIGEKA-GAKUKAI-ZASSHI, 9, 222 (1934). — *Miyoshi,* NIPPON-GEKAHOKAN, 15, 53 (1938). — *Kuroki,* JOKENHANSHA, 9, 10 ; 3 (1943). — *Tominaga,* SEISIN-SINKEI-GAKUKAI-ZASSHI, 50, 1 (1949). — *Nakao,* JOKENHANSHA, 6, 11 (1943). — *Mori, Numoto,* IGAKU-TO-SEIBUTSU, 18, 98 (1951). — *Flechsig,* Anatomie des menschlichen Gehirns u. Rückenmarcks auf myelogenetischer Grundlage, Liepz., 1920. — *Grüntein,* Neur. Zentralbl., 30, 659 (1911). — *Minkowski,* Zeits. f. d. ges. Neurol. u. Psych., 102, 650 (1926). — *Monakow,* Arch. f. Psych., 16, 864 (1925). — *Riese,* Anat. Anz., 57, 487 (1923) ; Zeits. f. d. ges. Neurol. u. Psych., 90, 591 (1924) ; J. f. Psychol. u. Neurol., 31, 275 (1924). — *Wilson,* Brain, 34, 295 (1911) ; Ebenda, 43, 220 (1920). — *C.* u. *O. Vogt,* J. Psychol. u. Neurol., 12, 285 (1909). — *Jakob,* Die extra-pyramidalen Erkrankungen, Berlin, 1936. — *Pollak,* Dtsch. Zeits. f. Nervenhilk., 74, 131 (1922). — *Kodama,* Arch. f. Neurol. u. Psychiatr., 20, 318 (1927). — *Hirasawa, Kariya,* Okajima Fol. anat. Japon, 14, 603 (1936). — *Sawa,* NOKENKU, 7, 59 (1950). — *C.* u. *O. Vogt,* J. F. Psychol. u. Neurol., 25 ; Ergänz-Heft, 105 (1920). — *Magazzini,* Zeitschr. f. d. ges. Neurol. u. Psych., 8, 85 (1912). — *Meynert,* Zitiert nach Hirasawa, IGAKU-SHOHO, 1948. — *Gudden,* Arch. f. Psych. u. Neurol., 2, 693 (1870). — *Bianchi* u. *d'Abundo,* Neurol. Zentralbl., 17, 384 (1886). — *Economo,* Zeits. f. d. ges. Neurol. Zentralbl., 43, 173 (1918). — *Rothmann,* Zitiert nach Hirasawa, IGAKU-SHOHO, 1948. — *Rossolimo,* Ebenda, 1948. — *Hirasawa,* DAINO-NO-SAIKOCHUSU, 1950 ; IGAKU-SHOHO, 1948. — *Kosaka,* Mitteil. a. d. med. Fak. d. Univers. Tokyo, 5, 77 (1901). — *Jurmann*, Zitiert nach Hirasawa, IGAKU-SHOHO, 1948. — *Datsura*, Brain and Nerve, 4, 28 (1952). — *Fulton*, Physiology of the Nervous system, 1938. — *Pavlov*, JOKENHANSHAGAKU, Hayashi Yaku, 1937. — *van Wagenen* u. *Herren*, Arch. Neurol. psychiat., 44, 740 (1940). — *Mott* u. *Shäffer, E. A.*, Brain, 13, 174 (1890). — *Curits, H. J.*, J. Neurophysiol., 3, 5 (1940). — *Unverricht*, Arch. psychiat., 14, 175 (1883). — *Spiegel, E.*, W. Klin. Wochschr., 40, 2 (1924). — *Spiegel, E.*, Am. J. psychiat., 10, 595 (1931). — *Sawa, Horikawa*, SEISHIN-SHINKEIGAKUKAI-ZASSHI, 50, 3, 7 (1948). — *Kawamada*, NIPPON-GEKAGAKUKAI-ZASSHI, 52, 4 (1951). — *Foerster, O.*, Handbuch d. Neur., VI, 1935. — *Saito, Suda*, JOKENHANSHA, 3, 22, 986 (1942). — *Fracois-Frank*, Les fonctions matorce de cervean, Paris, 1887. — *Dusser de Barenne*, J. Neurophysiol., 1 (1938). — *Hirasawa, Kariya*, Okajima's Fol. anat. Japon, 14, 603 (1936). — *Kopeloff, N.*, Arch. Neurol. psychiat., 63, 718 (1950). — *Jasper, H.*, EEG. Clin. Neurophysiol., 1, 405 (1949). — *Klempin* J. f. psychol. u. Neurol., 26, 229 (1921). — *Kakegawa, Sawa*, SEISHIN-SHINKEIGAKUKAI-ZASSHI, 51, 7 (1949).