

A small fertile pinna is given natural size at fig. 4, and the same specimen is enlarged two times at fig. 5, where the arrangement of the microsporangia is clearly exhibited.

My thanks are due to Mr. H. W. Hughes, F.G.S., to whom I have been so often indebted in the past for assistance in my studies of the Carboniferous Flora, for the opportunity of describing these interesting specimens.

On the Efferent Relationship of the Optic Thalamus and Deiter's Nucleus to the Spinal Cord, with special reference to the Cerebellar Influx Theory (Hughlings Jackson) and the Genesis of Decerebrate Rigidity (Sherrington).

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In the following experiments it was determined to re-investigate the matter of the thalamo-spinal mechanism from the point of view of tracing the relations of the thalamus to the mesencephalon and hind-brain.

Now, the thalamic grey centres are in association with the bulb and cord by the thalamo-bulbar and spinal tracts, placed on and around which are the rubro-spinal, tecto-spinal, Deiter-spinal, and the lateral cerebello pontine tracts. As the pyramidal fibres run through the mesencephalon it became necessary to exclude them in arranging the investigation.

The general methods employed were as follows :—

A. The localisation of the genesis of decerebrate rigidity and the influence of the cerebellum were determined by making successive coronal sections through the thalamus, mesencephalon pons, and bulb.

B. Excitation of the superior and middle cerebellar peduncles in normal animals and in others in which the pyramidal tracts had been previously degenerated by suitable lesions in the middle zone of the cerebral hemispheres.

C. Excitation of the cut surface of the thalamus and mesencephalon with or without previous pyramidal degeneration.

The experiments were all performed under complete anaesthesia, the anaesthetics used being chloroform or ether. In cases where the brain was



FIG. 4. $\frac{1}{2}$.

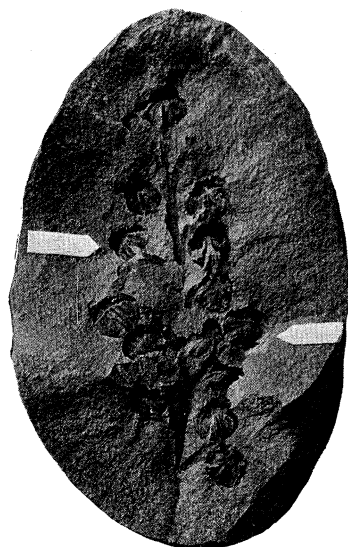


FIG. 5. $\times 2$.



FIG. 1. $\times 2$.

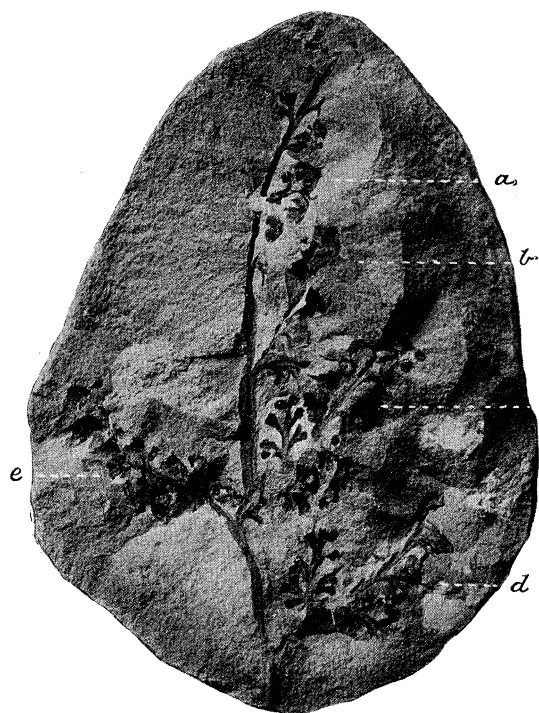


FIG. 2. $\times 2$.

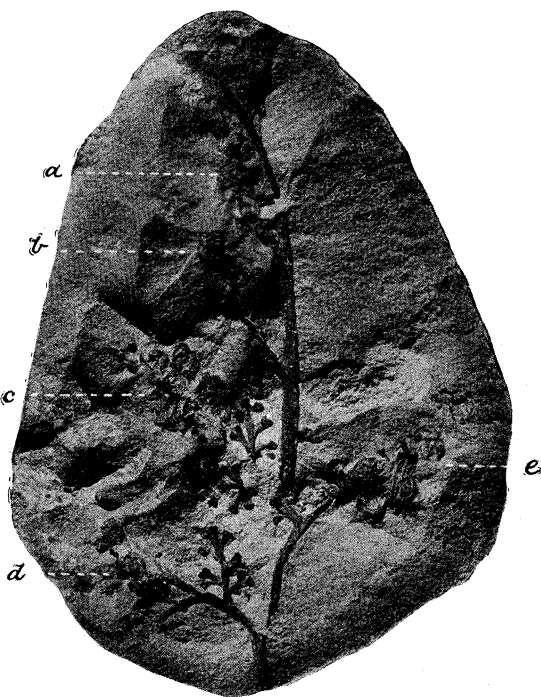


FIG. 3. $\times 2$.

Crossothea (Sphenopteris) Höninghausi, Brongt.

removed in slices the carotids were previously tied on both sides. The animals used were cats, dogs, and monkeys.

The following results were obtained :—

A. Those Relating to Decerebrate Rigidity.

It was found that rigidity did not commence till the section was made at the level of the posterior part of the optic thalamus. The rigidity thus obtained became more intense as the lesion was carried farther back in the mesencephalon. The rigidity lasted till the line of section passed through the trapezium. Directly the section passed behind the pons the rigidity disappeared, and did not return as long as the animal was kept alive. In some cases at this stage the animal assumed a general position of flexion for a short time. Gradual removal of the cerebellum was found to be without influence in decerebrate rigidity when this had been previously produced, but immediately the lesion was carried through Deiter's nucleus the rigidity was abolished. This abolition of the rigidity was homolateral.

Similarly division of the Deiter spinal tract without any injury to the rest of the cerebellum caused homolateral relaxation of decerebrate rigidity. In some cases, however, the relaxation was not complete, or it returned to a slight degree after a time. In such exceptional cases subsequent unilateral bulbar transection did not always abolish the persistent rigidity, which then must clearly be of spinal origin. An irritative lesion of Deiter's nucleus or the tract caused a temporary increase of the spasm.

When unilateral lesions were made in the mesencephalon the results varied with the position of the section. If the lesion was made immediately behind the thalamus, contralateral rigidity was by far the most marked; if farther back, the homolateral rigidity was most marked.

Section of the afferent roots belonging to a limb caused the abolition of the decerebrate rigidity in that limb and prevented its occurrence when performed previous to the mesencephalic transection. Division of the posterior columns or of the direct cerebellar tracts, or of both, in no way interfered with the occurrence of decerebrate rigidity or caused its abolition.

In all the experiments in which removal of the tentorium was required marked extensor rigidity exactly like that following mesencephalic transection occurred. The same result was invariably obtained, but the more carefully the removal was accomplished the less marked was the rigidity.

Bisection of the superior vermis without previous removal of the tentorium also produced a bilateral extensor rigidity exactly like decerebrate rigidity.

Removal of one lateral half of the posterior part of the superior vermis also caused a bilateral extensor rigidity most marked homolaterally.

Removal of the cerebellar hemispheres by successive sagittal slices without previous removal of the tentorium always caused a bilateral extensor rigidity. With the removal of only a small portion the rigidity was slight, but with the subsequent removals it became much greater.

When, however, nearly the whole of one cerebellar hemisphere had been removed the homolateral rigidity became very much less, but remained in full intensity on the contralateral side. When the lesion included Deiter's nucleus the homolateral rigidity completely disappeared, and when the mesencephalon was subsequently transected there was no recurrence of rigidity on the homolateral side.

Removal of the vermis and the cerebellar hemispheres by horizontal slices caused bilateral extensor rigidity, which remained till Deiter's nuclei were involved in the lesion. Removal of the cerebellum in this way had no influence on existing decerebrate rigidity, which, however, became abolished when Deiter's nucleus was destroyed.

Stimulation of the vermis and the dorsal surface of the cerebellar hemispheres caused relaxation of the spasm in decerebrate rigidity. The relaxation was most marked on the homolateral side.

The results obtained in this way were exactly the same whether the pyramidal tracts had previously been removed by degeneration or not.

Sections of the superior cerebellar peduncle had only a very slight effect as regards rigidity. In this experiment it was always necessary to remove part of the tentorium, and no matter how carefully this was performed, a certain amount of rigidity supervened. Section of the superior peduncle caused the rigidity to become slightly increased. Subsequent mesencephalic transection in front of the line of section of the peduncle caused the rigidity to become greatly increased.

The effects of section of the superior cerebellar peduncles and of piecemeal removal of the cerebellar hemispheres on the knee-jerks were also noticed.

Section of the superior peduncle on one side, directly after emerging from the cerebellum, caused the homolateral knee-jerks to become increased. Piecemeal removal of the cerebellum by sagittal slices, when about one-third of the lateral lobe had been removed, caused in cats an increase in the homolateral knee-jerk, the contralateral jerk remaining the same or being slightly increased. More extensive removal increased the knee-jerks on both sides, the homolateral being brisker than the contralateral. Complete removal, including Deiter's nucleus, produced no further change.

In dogs, piecemeal removal of one cerebellar hemisphere produced the same results as obtained by Dr. Risien Russell, namely, increased jerks on the homolateral side, diminished on the contralateral. This did not occur till

about one-half of one lobe had been removed, and further removal had no other effect. Removal of one lateral half of the posterior part of the superior vermis caused an increase in the homolateral knee-jerks.

In both cats and dogs injury to other parts of the mesencephalon, and simply scratching the superior cerebellar peduncle, caused the homolateral knee-jerks to become increased.

The results of these experiments can be summed up as follows:—

1. Decerebrate rigidity does not commence till the lesion passes through the posterior part of the thalamus and is independent of any injury to the pyramidal system.

2. The inhibitory centre lies in the thalamus, the control is a crossed one, and the decussation takes place high up.

3. The cerebellum has no influence on decerebrate rigidity; the adjuvant centre is Deiter's nucleus.

4. Decerebrate rigidity does not appear to be due to the interruption of the afferent channel of the cerebro-cerebellar circuit.

5. The tonic condition depends upon the reflex arc being intact; injury to the posterior columns or the direct cerebellar tract has no effect.

6. A condition of extensor rigidity occurs after partial or complete removal of the tentorium, bisection of the vermis, injury to the vermis, or partial cerebellar ablation.

The results as regards the knee-jerks agree with those obtained by Risien Russell in dogs, and by Ferrier and Turner in cats and monkeys. Complete removal of one hemisphere, however, is not necessary to produce the changes.

B. *The Results obtained by Stimulation of the Middle and Superior Cerebellar Peduncles.*

In order to expose the peduncles of the cerebellum the posterior part of the calvarium, the tentorium, and the greater part of the posterior fossa on one side were removed, the occipital lobe was drawn up, and the cerebellum drawn back to expose the middle peduncle. Stimulation of the middle peduncle produced bilateral, facial, and nasal movements most marked homolaterally. The trapezii and pectorals of both sides were affected, the forelimbs were protracted at the shoulder and flexed at the elbow, the hind-limbs were slightly flexed and drawn up. The back muscles were also thrown into a state of contraction, the effect in all parts being especially homolateral. Eye movements also occurred. They were, however, very various, usually movement towards the homolateral side.

Stimulation of the superior peduncle was not very often successful; in the majority of cases the results were the same as for the stimulation of the

middle peduncle. These results occurred whether the pyramidal tracts were intact or degenerated.

From these experiments it appears that the cerebellum by way of its peduncles exercises a control over the skeletal muscles, the control being chiefly over the muscles of the trunk and girdles.

During the course of these experiments stimulation in the neighbouring regions of the lateral fillet, posterior corpus quadrigeminum, and IVth nerve produced the following results:—

Stimulation of the IVth nerve produced movement of the homolateral eyes upwards and outwards.

Stimulation of the lateral fillet produced pricking of and rotation of the opposite ear outwards and backwards, conjugate deviation of the eyes to the contralateral side.

Stimulation of the lateral aspect of the posterior corpus quadrigeminum produced no result. Vocalisation was not noted, since the animal was anaesthetised through a tracheotomy tube.

C. Results obtained by Stimulation of the Cut Surface of the Optic Thalamus and Mesencephalon.

It was only when the posterior part of the optic thalamus was stimulated that any results were obtained.

Stimulation in this region of what appeared to be the median nucleus produced very definite motor phenomena. The animal presented a certain degree of decerebrate rigidity, stimulation produced retraction and flexion of the homolateral fore-limb, protraction and extension of the contralateral fore-limb. The homolateral hind-limb was in some cases extended, the contralateral flexed. In other cases the result was to produce a flexion of both hind-limbs.

There was also usually contraction of the trunk muscles, most marked on the homolateral side, causing in some cases rotation, so that the homolateral shoulder became the lower.

This result was obtained in cats and monkeys, and was quite independent of the pyramidal tracts, since it was always obtained in those cases where the pyramidal tracts had been eliminated by degeneration previously. Similar results were obtained when the cut surface of the mesencephalon was stimulated at different levels. The area from which these movements were obtained was smaller than that in the thalamus. The tract appeared to be the rubro-spinal tract or one coming down with it. The tract was traced as far as the medulla.

The strength of faradic current required to produce these movements was

weaker than that necessary to elicit pyramidal movements. Continued stimulation produced coarse clonus.

Stimulation of the cut end of the posterior longitudinal bundle at the various levels of the sections produced no result in any case.

It will be seen from these results that the movements elicited by stimulation of the posterior end of the optic thalamus are co-ordinated movements affecting the whole body, and are the same as those of walking.

It would thus appear that there exists in the posterior part of the optic thalamus a centre which controls the ordinary act of walking, and the path along which impulses are carried is the rubro-spinal tract.

These results are in accordance with those of Goltz, who removed the cerebral hemispheres in dogs, and those of Brown - Sequard, Starlinger, Probst, and Rothmann, who showed that there was another motor tract beside the pyramidal as the result of cortical stimulation after the pyramidal fibres had been made to degenerate.

It seems justifiable to draw the following conclusions as the results of these experiments:—

1. The anterior cornual cells are under the control of the optic thalamus and Deiter's nucleus, the former exerting an inhibitory action, the latter an adjuvant action. The influence of Deiter's nucleus is also controlled to some extent by the cerebellar cortical cells. The thalamic control is crossed; the cerebellar influence is homolateral.

2. Both the thalamus and cerebellum exert a motor control over the muscles of the body. The cerebellar influence is chiefly on the trunk and girdle muscles, and is preponderatingly homolateral.

3. In the thalamus is a centre which controls the co-ordinated movements of locomotion. The path along which the control is exerted is probably the rubro-spinal tract.

4. The afferent and efferent cerebro-cerebellar channels appear to function as channels of communication between the cerebrum and cerebellum to produce co-ordination.

In the maintenance of the muscular tonus, the reflex arc is necessary. Section of the afferent channels in the cord has no result on the muscular tonus.

In conclusion, I must state that this work owes its inception to Sir Victor Horsley, to whom I owe very much for his great kindness and constant advice during the progress of this investigation.



FIG. 4. $\frac{1}{1}$.

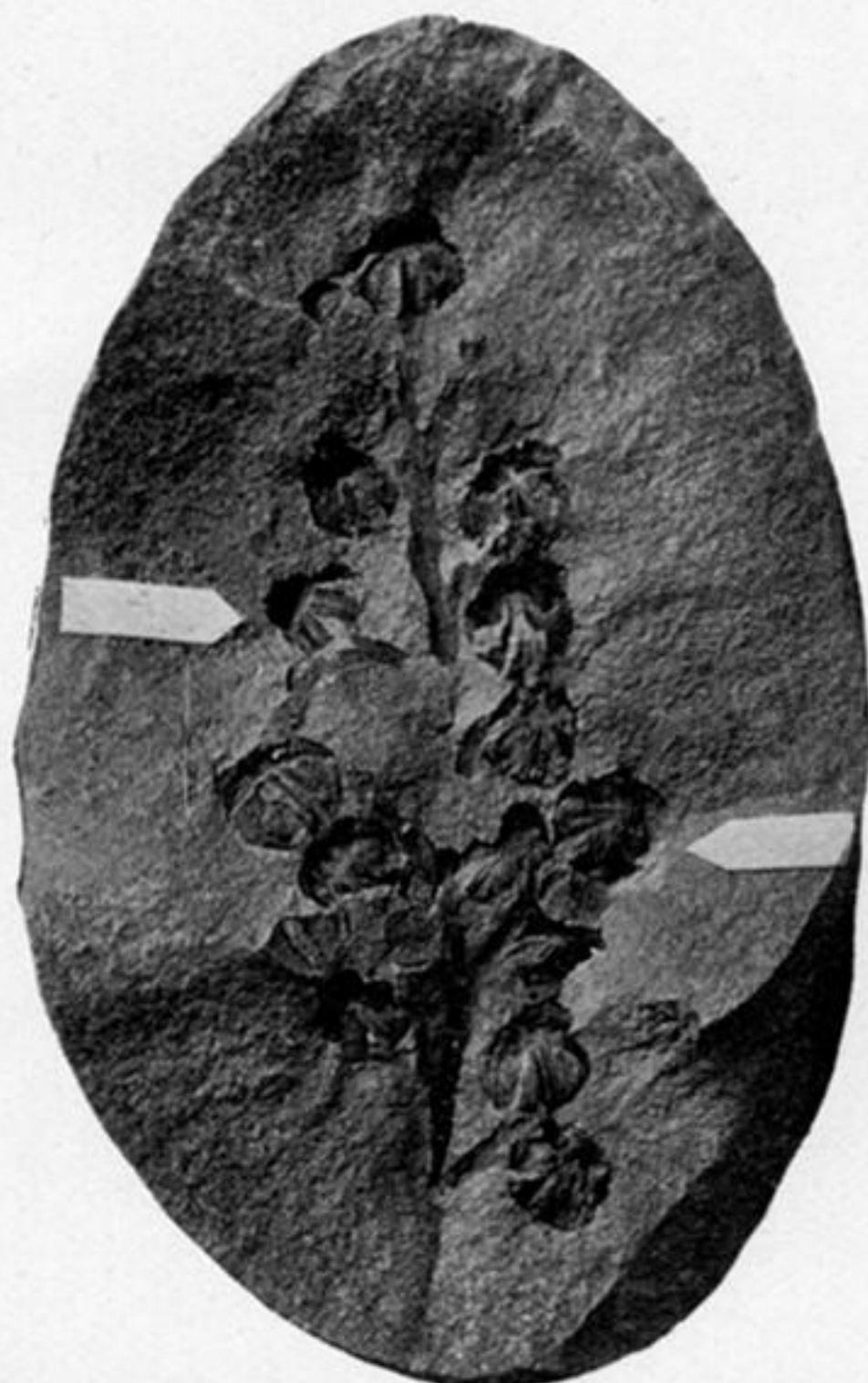


FIG. 5. $\times 2$.



FIG. 1. $\times 2$.

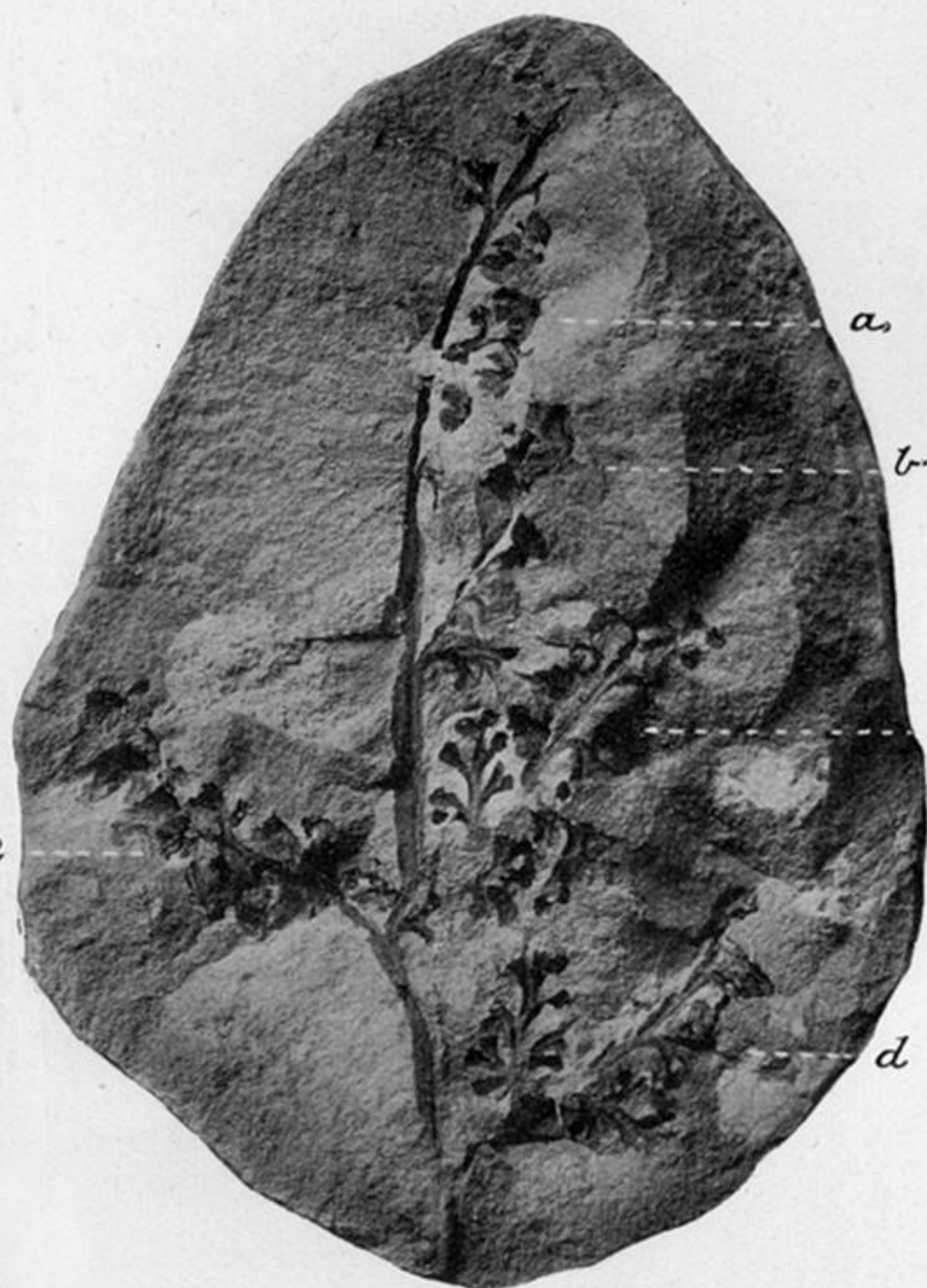


FIG. 2. $\times 2$.

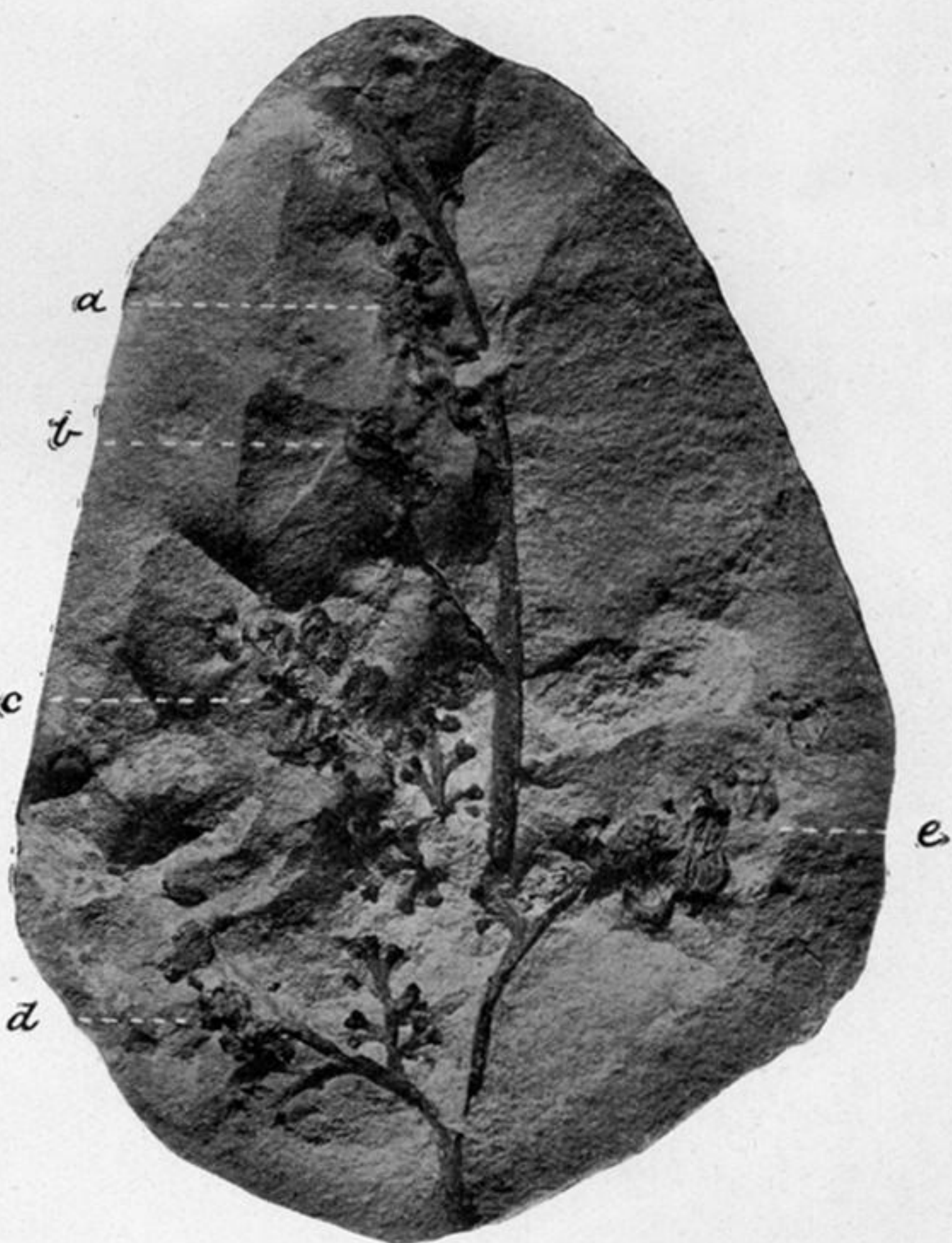


FIG. 3. $\times 2$.

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