NOTE ON REGENERATION OF PRÆ-GANGLIONIC FIBRES OF THE SYMPATHETIC.

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In a former Paper I[1] have given an account of some observations on the origin from the spinal cord of the nerve fibres which are present in the cervical sympathetic, and of the peripheral distribution of the fibres derived from each spinal nerve. These observations—which in part confirmed and in part extended the results of others—showed that in the cat the first seven thoracic nerves sent nerve fibres to the cervical sympathetic; that the fibres of each nerve had its characteristic distribution. Thus the 1st thoracic nerve supplied the pupil and the nictitating membrane but sent few or no fibres to the vessels of the ear, and none to the hairs of the face and neck; the 2nd thoracic differed from the 1st in sending a considerable number of fibres to the blood vessels of the ear, and as a rule in sending more fibres to the nictitating membrane and fewer to the pupil; the 3rd thoracic sent a few fibres only to the pupil; the 4th thoracic sent none to the pupil, a few only to the nictitating membrane, but as a rule sent a few to the hairs of the face and neck; the 5th also sent no fibres to the pupil, very few and sometimes none to the nictitating membrane, but some to the vessels of the ear and to the hairs of the face and neck. The 6th and 7th thoracic supplied the hairs only, the 6th sending more fibres to them than the 7th.

There is good ground for believing that all these fibres of the cervical sympathetic terminate in the superior cervical ganglion, the impulses they normally convey passing to the nerve-cells of the ganglion and so to the nerve-fibres given off by the cells.

Suppose now that the cervical sympathetic is cut, and the ends are placed together. Presumably the cut peripheral fibres will regenerate. If they do, will they grow past the superior cervical ganglion, and form

[1] *Phil. Trans.*, Vol. 183. B. 85. 1892.

nerve-endings in the peripheral structures, or will they terminate around the cells of the ganglion? And in the latter case, will the fibres of each spinal nerve become connected with only those nerve cells with which they are normally connected, or will they run indiscriminately to such cells as may be on their course, so that for example the upper thoracic spinal nerves can cause erection of hairs and the mid thoracic spinal nerves dilation of the pupil?

On June 25 of last year I cut in an etherized kitten (ten to twelve weeks old) the right vagus and sympathetic nerves in the neck four to five centimetres below the superior cervical ganglion. Both nerves were cut, since in the neck they are closely joined by connective tissue, and it seemed to me that the less this was injured the less chance there would be of a growth of connective tissue between the ends of the sympathetic. The cut ends of the nerve were placed in contact. The operation had the usual result of section of the cervical sympathetic. On the cut side the nictitating membrane covered one-third to a half of the cornea, the eyelids were closer together, the pupil was smaller, the blood vessels of the ear dilated. For a month the symptoms remained much the same, and then slowly and steadily decreased. Two months after the operation, the nictitating membrane and pupil showed a slight difference only in the two sides. At the end of three months it was difficult to be certain of a difference in the nictitating membrane on the two sides, but the pupil on the cut side was still a trifle smaller. Later all effects of the operation had apparently disappeared. The animal was still kept, in order to give time for complete regeneration. On June 25, 1895, that is a year after the operation, the animal was anæsthetized, the spinal cord cut across just below the 7th cervical vertebra, the spinal nerves from the 8th cervical to the 7th thoracic on each side tied in the vertebral canal, the corresponding portion of the spinal cord removed. The nerves were then stimulated with a weak tetanizing current and the effects on the pupil, eye, and nictitating membrane were first observed and subsequently those on the blood vessels of the ear and on the hairs of face and back of neck.

In the following Table the results are given, and it will be understood that unless otherwise mentioned the right and the left nerves had no difference in effect.

Effect of Stimulating Spinal Nerves, on right and on left side, the Cervical Sympathetic having been cut on the right side one year previously.

	Opening of Eyelids and Retraction of Nictitating Membrane.	Dilation of Pupil.	Contraction of Arteries of Ear.	Erection of Hairs on back of Neck[1].	Secretion. Fore-foot.
VIII C.	0	0	0	0	0
I Th.	Good	Very good	0	0	0
II Th.	Good	Moderate, rather less on right than on left	Moderate on left Slight on right	0	0
III Th.	Moderate	Slight on left Trace on right	Good	0	0
IV Th.	Slight on left No effect on right	0	Good on left Moderate on right	Moderate on left Trace on right	Slight
V Th.	0	0	? 0[2]	Good on left Slight on right	Moderate
VI Th.	0	0	0	Good on left Slight on right	Good
VII Th.	0	0	0	Good on left Slight on right	Good

[1] Cf. This *Journal*, xv. 213, 1893. The hairs of the face showed at best but a trifling movement and are therefore left out of account.

[2] One observation only was made; possibly with more careful attention some vaso-motor action might have been found.

After stimulating the spinal nerve the vagus and sympathetic in the neck were exposed on each side. The vagus on the right side was tied and cut a little below its superior laryngeal branch, *i.e.* centrally of the point of original section. Stimulation of the central end gave certain reflex effects; stimulation of the peripheral end did not cause contraction of the œsophagus in the neck or any appreciable slowing of the rate of heart-beat. The vagus on the opposite side caused of course both effects.

The cervical sympathetic was stimulated, and the usual results noted, two drops of warm 1 p. c. nicotin were then brushed over the superior cervical ganglion. After this, stimulation of the cervical sympathetic had a barely appreciable effect and that only on the nictitating membrane. Hence, the regenerated fibres had not grown out to the periphery, but ended in the ganglion.

On examining the nerves where they were cut originally, the usual spindle-shaped swelling was found, the connective tissue sheath of this surrounded both the vagus and the sympathetic. The nerves of both sides were treated with osmic acid and sections made. The right sympathetic centrally of the junctional swelling, *i.e.* low in the neck, was normal in appearance; peripherally of the swelling, up to the superior cervical ganglion, the medullated fibres were less densely packed; fewer medullated fibres, and more non-medullated fibres being present. A rough count of the medullated fibres gave about two thousand centrally, and about eleven hundred and fifty peripherally of the cut. The branches given off by the superior cervical ganglion were normal, the anterior branches contained, as is usual in the cut, many small medullated fibres.

Notwithstanding that a return of function was not found in the vagus, there were many medullated fibres in the peripheral part of the nerve low in the neck. They were however much fewer than on the opposite side, and they were more separated from one another by non-medullated fibres. Centrally of the junctional swelling, *i.e.* in the upper part of the neck, there were more medullated fibres than peripherally, but distinctly fewer than on the opposite side. Some observations of Gad and Joseph bear on the latter point, and I may return to it at a later time.

The experiment appears then to give a decisive answer to the various questions I have raised earlier. The sympathetic regenerates, though the regeneration is not quite complete. The regenerated fibres

[1] Gad and Joseph. *Arch. f.* (*Anat. u.*) *Physiol.* 1889, p. 204.

do not grow out past the superior cervical ganglion, but end in the ganglion itself. Further, the fibres from each spinal nerve end in connection with their proper nerve cells. Thus the fibres of the 1st thoracic nerve again become connected with nerve cells supplying the nictitating membrane and pupil, and leave entirely on one side the nerve cells supplying the blood vessels and the muscles of the hairs. The fibres of the 4th thoracic nerve pick out the nerve cells supplying the blood vessels and the hairs, and pass by the nerve cells supplying the pupil. And a similar selective power is shown by each spinal nerve. The only feasible explanation appears to me to be that the sympathetic fibres grow out along the peripheral piece of nerve,—as nerve fibres usually are supposed to grow out—spreading amongst the cells of ganglion, and that there is some special chemical relation between each class of nerve fibre and each class of nerve cell, which induces each fibre to grow towards a cell of its own class and there to form its terminal branches. At bottom then the phenomena would be a chemiotactic one.

It is with considerable hesitation that I give an account of a single experiment. I do so, however, because I am doubtful whether I shall be able to undertake further inquiry for some little time to come, and the questions involved may perhaps seem sufficiently interesting to lead others to investigate them.