must be obtained by induction; and that these principles, when of the most general kind, are axioms." Then he quotes passages in proof from Aristotle's writings. It is, however, pretty evident that Aristotle's reverence for facts was no more than a pious opinion, which he habitually ignored in the actual handling of questions of natural knowledge. His treatise "On the Parts of Animals" bristles with errors of observation which a very moderate amount of painstaking would have rectified. Had the ancient Greeks, and their successors in the Middle Ages, been more accurate observers of facts, and had they sought for and invented instruments for the more exact observation of facts, they would not have so conspicuously failed to establish at least the foundations of exact science. The historian of the inductive sciences, however, will have it otherwise. He sums up his argument thus: "The defect was that, although they had in their possession *Facts and Ideas*, the *Ideas* were not distinct and appropriate to the *Facts*." Is it not rather the case that the "*Ideas* were not distinct and appropriate to the *Facts*," precisely because the "*Facts*" were indistinctly seen and imperfectly apprehended? "Mr. Mulhall calculates that "our steam power in the United Kingdom is equal to the force of 169,000,000 able-bodied men, a number greater than the whole population of Europe could supply.—*National Progress during the Queen's Reign*, p. 22.

AN EXPERIMENTAL INVESTIGATION OF THE CERVICAL AND THORACIC NERVE ROOTS IN RELATION TO THE SUBJECT OF WRY-NECK.

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[ABSTRACT*]

THERE is an abundance of evidence to show that in a large proportion of cases of spasmodic wry-neck, surgical measures, such as division of muscles and stretching of the spinal accessory nerve, are useless, and that there must be few cases in which even excision of a portion of the nerve can be expected to lead to permanently good results, in that in the majority of cases which come under observation, muscles beyond its control take part in the spasm. Further, in that the sterno-mastoid has a double nerve supply, the spinal accessory and the posterior branches of certain cervical spinal nerve roots, even in those cases in which the spasm appears to be limited to this muscle, it scarcely seems reasonable to suppose that severance of only one of its paths of connection with the central nervous system is likely to do more than lessen the spasm in the muscle, while another path by which impulses can reach it from the nerve centres is still intact. Complete section of both of these paths of connection with the central nervous system can alone be expected to result in complete arrest of spasm in the muscle. If this be true with regard to the cases in which the sterno-mastoid alone appears to be involved, how much more unlikely is it that any such surgical measures directed to the spinal accessory nerve can influence the spasm in muscles, over which this nerve has no control, and which are obviously involved in so many cases of wry-neck.

The only surgical procedure which offers a reasonable prospect of permanent relief in such cases is division (with excision of portions) of the posterior branches of the upper cervical spinal nerve roots, an operation devised by Gardner in Melbourne and Keen in America, and which has been practised by Horsley in this country. This being the case, it seems of no small importance that we should accurately determine by experiment (1) The exact number of nerve roots; electrical excitation of which results in contraction of muscles which bring about movements of the head on the trunk; (2) The precise position in which the head is placed by contraction of the group of muscles supplied by each individual nerve root; (3) In how many roots a given muscle is represented; and (4) The muscles represented in each nerve root.

The necessity for such an investigation will be obvious if the results which I have obtained in the present research are compared with the statements made in the standard text books on Anatomy in this and other countries.

The experiments on which the present paper is based have

* The full text of the paper giving details of the experimental methods employed and the results obtained appears in the current number of *Brain*.

been conducted in monkeys, *macacus rhesus* chiefly, and also a few *macacus sinicus* being used. In all the experiments the first point investigated was the position assumed by the head on excitation of the motor portions of the individual cervical and thoracic roots. The investigation was further conducted so that a given root was excited in some instances, and all the muscles which responded were noted, while in other instances a given muscle was kept under observation, while each nerve root of the series investigated was in turn excited, and a note made of those, stimulation of which evoked contraction in the muscle.

On comparing the results of this research with those I obtained when the limb plexuses were under investigation, there appears to be considerably more individual variation with regard to the nerve root supply of the neck muscles than of those of the limbs.

As in the case of the limb muscles, so in those of the neck, it was abundantly evident that different segments of any given muscle responded when one or other of the nerve roots supplying the muscle was excited electrically.

This differentiation of one part of a muscle from another by means of its nerve root supply served as a means of differentiating different parts of a complex muscle, such as the erector spinae in a most interesting manner, and not less interesting was the way in which segmentation of the diaphragm was thus shown. On comparing the combined movement which results on excitation of a given nerve root with the individual muscles actually represented in the same root it becomes obvious that the resulting combined movement must depend on the preponderance of certain muscles over others which if acting alone would bring about a very different movement.

The muscles deriving their nerve supply from any given nerve root occupy both the dorsal and ventral aspects of the neck and trunk.

Despite the variations met with as regards the precise muscles represented in a given root, or the roots supplying a given muscle, the movement resulting on excitation of each root remains wonderfully constant, such variations as are met with being so slight as not to alter materially the predominating movement characteristic of each root.

In the case of such small short muscles as the posterior recti and obliques, the nerve supply appeared to be derived from a single nerve root in most cases, but this is quite exceptional, as all the other muscles of the neck and back investigated derived their nerve supply from two, three, or more nerve roots.

PRACTICAL BEARING OF THE RESULTS ON THE TREATMENT OF WRY-NECK.

A knowledge of the precise muscles innervated by any given nerve root cannot fail to be of great advantage in any consideration as to the nerve roots, division of which is most likely to be attended with the relief of spasm in wry-neck. This is, of course, of special value with regard to those muscles sufficiently superficial in position to allow of their being seen or felt to be in a state of spasm. But the knowledge is also of use to us with regard to muscles too deeply seated to be seen or felt with certainty, for a knowledge of the movement brought about by the action of this or that muscle enables us to ascertain fairly satisfactorily which muscles are probably in a state of spasm.

Important as is this knowledge of the precise innervation of the various muscles responsible for the movements of the head on the trunk, no less important is the information which we derive from those experimental results in which the position assumed by the head in relation to the trunk was noted. The results obtained in this connection point clearly to the fact that in the most common forms of torticollis surgical treatment must be directed, chiefly at all events, to one or all of the four upper cervical nerve roots. It is further evident that where the lateral inclination of the head, by which the shoulder and side of the head and face are approximated, exists, the first and second cervical nerve roots are those to which attention should be directed, while in those instances in which the chief movement of the head is one in which the occiput is drawn backwards, so that the face looks more or less upwards, the third and fourth cervical nerve roots should engage our attention.

The results further point to the fifth and sixth cervical nerve roots being the least likely, of the cervical series, to conduct impulses from the central nervous system, the cutting off of which is likely to be followed by any material relief in any muscular spasm which may be present causing wry-neck.

It is also important, with a view to prognosis after such operations, that even muscles supplied by the seventh and eighth cervical nerve roots may by their spasm bring about movements of the head on the trunk indirectly, in which connection the trivial indirect movement of the head resulting on excitation of the upper thoracic nerve roots may not be altogether without a certain amount of importance.

One class of cases of wry-neck, happily not common, is placed beyond the possibility of surgical relief, as far as division of nerve roots is concerned, by a consideration of the results obtained in this investigation. I allude to those cases in which the spasm is limited to, or chiefly involves the scaleni muscles, which are innervated from the sixth or seventh cervical to the third or fourth thoracic nerve roots. Apart from the obstacle to interference with the lower cervical and first thoracic nerve roots owing to the innervation of the upper limb being derived from these roots, that accelerator and augmentor fibres of the heart are contained in the upper thoracic roots¹ may be a point not to be altogether neglected in any operation directed to these roots.

A not unimportant consideration in prognosis after such operations for wry-neck is the question whether, in those cases, for instance, in which a muscle is represented mainly in two nerve roots, but also to a lesser degree in a third, the full force of nervous discharge may reach the muscle by this comparatively insignificant path now that it can no longer reach it by the main paths. That this is not probable, is suggested by the fact that any given nerve root only supplies a portion of a muscle and not the whole of it, as I have shown in this and in previous papers, and that in a case such as that supposed above the portion of muscle would be very small, and therefore, even if receiving the full force of the discharges from the central nervous system, the muscular fibres capable of responding are too few to give anything like an adequate exhibition of the full force of the central disturbance. As further supporting this view may be instanced the fact that in investigations in which the spinal nerve roots which contribute to the formation of the limb plexuses were the subjects of experimentation,² I showed that division of one or more nerve roots altered the position assumed by the limb during general convulsions subsequently induced, by the intravenous injection of absinth, in a manner directly proportional to the amount of this or that muscle excluded from taking part in the convulsions, in consequence of the division of one or more of the nerve roots from which it is innervated.

But as opposed to these considerations must be borne in mind the fact that in the investigations dealing with the limb plexuses, I further showed that the power of recovery after division of a nerve root was wonderful, and that this occurred when all possibility of reunion of the divided ends of the roots taking place was placed beyond question. The immediate effect of the division showed itself in the altered position of the limb in standing or of its movements in progression, weakness of one or more movements of the limb being evident; but in a wonderfully short time all traces of these defects passed off, and it became difficult to detect any abnormality in the position of the limb in standing, or of its movements in progression. That the provisions for compensation were great was evident, but it was not so easy to explain how this compensation was brought about. Of the theories that might be advanced in explanation of the fact, two appeared to me to be worthy of consideration. The first of these supposed it possible that certain cells of the cerebral cortex were responsible for impulses which could reach the same muscle by different nerve roots, and that the division of one of these nerve roots by which such impulses pass might produce a reflex inhibitory effect³ on the cortical cells from which the impulses it conducts are derived, so that the amount of actual loss of motor power in the first instance is more than that resulting from the exclusion of the parts of the muscles innervated by the divided root, and that as the cerebral cells recover from the inhibitory action so power

is restored to the parts of the muscles still in connection with the central nervous system. The second hypothesis supposed no such inhibitory effect on the cells of the cerebral cortex: these cells were regarded as being capable of discharging the same amount of energy as before, but the impulses meet with a block owing to the division of the fibres along which they formerly passed. Gradually, however, the impulses are diverted, it may be through the anterior horn cells of the spinal cord along other channels, and thus in time the fibres of the muscle which are supplied by an intact root receive almost the same amount of stimulation as did the whole muscle formerly.

Between these two hypotheses there seemed little to choose when dealing with the limb muscles, most of which received their innervation from two roots, and the difference of the amount supplied by the two roots was not too great to make either of these theories untenable.

A third possibility suggests itself to me as worthy of passing consideration. Is it possible that the normal stimulus reaching the fibres of the part of a muscle still in connection with the central nervous system is capable of inducing secondarily a contraction of other fibres of the same muscle, no longer indirectly connected with the central nervous apparatus? In this connection it is worth remembering that even after complete section of all the nerve fibres to a muscle, the muscle fibres do not become fattily disintegrated, but undergo a very slow process of atrophy. It is not unreasonable, therefore, to suppose that when only part of the nerve fibres of the muscle are divided the muscle fibres connected with them may be prevented from undergoing any great amount of this simple atrophy even, owing to their being brought into physiological action indirectly through the agency of some influence derived from the muscle fibres which are still in connection with the central nervous system.

REFERENCES.

- ¹ Cf. Bradford and Dean, *Journal of Physiology*, vol. xvi, 1894, p. 34.
² *Phil. Trans.*, vol. clxiv, 1893, p. 41 and *Proc. Royal Soc.*, vol. liv, 1893, p. 243. ³ Cf. Bubnoff and Heidenhain, *Pflüger's Archiv*.

THE PTERYGO-SPINOUS FORAMEN FROM A SURGICAL STANDPOINT.

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ALMOST immediately after its exit from the skull by the foramen ovale the inferior maxillary nerve divides into two parts, the larger division forming the auriculo-temporal, inferior dental, and lingual nerves; the smaller one, the masseteric, external pterygoid, and buccal branches. In the angle formed by these two primary divisions lies the pterygo-spinous ligament, which is a fibrous band extending from the root of the external pterygoid plate to a spot on the great wing of the sphenoid a little in front of the foramen spinosum. Thus at the point of division of the inferior maxillary nerve the smaller branch is encircled by the pterygoid plate of the sphenoid above and the pterygo-spinous ligament below, and in the event of the pterygo-spinous ligament being ossified a complete foramen is formed, the pterygo-spinous foramen, from which this branch makes its exit. With regard to the comparative frequency of the existence of the pterygo-spinous ligament, and of its ossification, the following table

	Number of specimens.	Percentage (approximate).
Ligament absent	30	14
Ligament imperfectly formed and described as membranous	13	6
Ligament present and unossified	141	67
Ligament partly ossified	21	10
Ligament completely ossified	6	3
Total	211	100