II. "An Experimental Investigation of the Nerve Roots which enter into the Formation of the Lumbo-sacral Plexus of *Macacus rhesus*." By J. S. RISIEN RUSSELL, M.B., M.R.C.P., Assistant Physician to the Metropolitan Hospital. Communicated by Professor VICTOR HORSLEY, F.R.S. Received March 22, 1893.

(From the Pathological Laboratory of University College, London.)

(Abstract.)

As the history of this subject was fully detailed in a former paper* by the author on the brachial plexus of the Dog, only such experimental work as has been done in connexion with the lumbo-sacral plexus is reviewed in the present communication.

In dealing with the anatomy of the Monkey it is shown that the class of plexus most commonly met with has many features in common with that described by Sherrington as the "prefixed" class of plexus; while of the variations met with that which occurred most frequently has many points in common with the class of plexus designated "postfixed" by that observer; but that there is one very notable difference between the last two, as in no instance was the 2nd sacral nerve root found to contribute a branch to the sciatic nerve, a contribution which Sherrington describes in this class of plexus.

Certain indirect effects brought about by muscles in connexion with joints on which they have no direct action, and the necessity for the exclusion of such indirect effects in the study of the movements at these joints, are discussed. The methods employed in operating are detailed, and the plan on which the results are arranged for description given.

Excitation experiments form the first part of the experimental portion of the paper; and, for convenience, the compound movements obtained by excitation of the whole nerve root are described in conjunction with the minute differentiation obtained by excitation of the individual natural bundles of the nerve roots. Following this is a description of the results of the direct observation (after dissection) of muscles thrown into action by excitation of the separate nerve roots. And as a corollary to this part of the subject, the question as to whether a single bundle of nerve fibres representing a single simple movement ever remains distinct in a nerve root during its course to the muscles which it supplies without inosculating with other motor nerve fibres is considered. The obvious necessity for control experi-

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ments led to the observation of the alteration in the action of the posterior extremity in progression, in climbing or in standing, evoked by section of one or more nerve roots. A second method of control consisted in the observation of the influence of section of a root or roots in excluding part of an epileptic spasm induced in the limb by intravenous injection of absinthe. As a corollary to this, the question as to whether the results differed in any way when the section of the root or roots was made some time previously, or at the time when the general convulsions were evoked, was tested. Special attention is called to the advantages of this method of experimentation, made use of by the author in a former research, but otherwise not yet adopted by other investigators.

Excitation Experiments.

In discussing the results obtained by this method of experimentation the discrepancies which exist between the results obtained by Ferrier and Yeo, by Sherrington, and by the author respectively, are pointed out. With regard to the upper limit at which nerve fibres leave the spinal cord for the supply of the lower limb, the first of these observers are held to have placed the limit too low, while Sherrington has placed it too high, the author finding that the 3rd lumbar root is the highest which supplies nerve fibres to muscles acting directly on the limb. The author agrees with Ferrier and Yeo in considering the 1st sacral nerve root the lowest of the series which contributes nerve fibres to the limb, and he has never found the 2nd sacral nerve root supplying the limb even in that class of plexus designated "postfixed" by Sherrington, in which, according to this observer, the 2nd sacral sends a branch to the sciatic nerve.

Great difficulty is experienced in attempting to reconcile Sherrington's results with those obtained by the author, as regards the number of nerve roots in which a given muscle is represented, and, conversely, the number of muscles and, in consequence, movements represented in certain roots; unless it be that Sherrington has included every variation, while the author has only included those roots in which a given muscle is most commonly represented and those movements or muscles most commonly found represented in any given nerve root.

The author does not think that the developmental processes which bring about the arrangement of nerve fibres do so on a purely anatomical basis, without regard for physiological combination; and arguments in support of this view are adduced.

Contrary to the observations of Sherrington, who found that each bundle of nerve fibres which contributes to the formation of a nerve root represents, as it were, a miniature root, containing nerve fibres

for the regulation of all the movements represented in the compound root, the author finds that each separate bundle of nerve fibres in a nerve root represents a single simple movement, and not all the movements of the compound root in lessened degree. The explanation offered for this difference in the results is that possibly Sherrington did not separate the bundles of nerve fibres from each other for a sufficient distance in their course, and thus did not effectually exclude the possibility of diffusion of the current to other bundles of nerve fibres contained in the same nerve root.

The single simple movements thus eliminated are found to bear an almost constant relation to the nerve roots, the same movements being as a rule found in any given root, and such movements always bear the same relation to the spinal level. Further, each bundle of nerve fibres representing a single simple movement in a nerve root remains distinct in its course to the muscle or muscles producing such a movement, without inosculating with other motor nerve fibres.

The group of muscles supplied by any given nerve root occupy both the anterior and posterior surfaces of the limb; in other words, muscles whose unimpeded action would produce one movement are represented in the same nerve root as others whose action would produce a movement diametrically opposite.

When a certain group of muscles are found to predominate in their action in one root, they as a rule predominate in that root. If those producing flexion at a certain joint predominate in their action in one nerve root, those producing extension predominate in another.

In those instances in which two opposed movements are represented in three consecutive nerve roots, the middle root of the series is that in which both movements are represented, while the root above contains the one movement, and that below contains the other.

As regards the order of representation of the movements of flexion and extension from above down, they are found to alternate, flexion being at a higher level than extension in the highest segment of the limb, while extension is above flexion in the next segment, and so on. And these results are found to agree with those obtained in connexion with the anterior extremity of the Dog, except in the case of the elbow joint in its relation to the knee.

It is found possible by stimulation of a single bundle of fibres in a nerve root to produce contraction of a single muscle, and of it alone; but this effect is not nearly so easy to obtain as in the case of the cervico-dorsal roots, owing to the distance between the points of exit of the roots from the neural canal and those where they unite to form the plexus being too short to allow of sufficient separation of

the nerve fibres so as to exclude the possibility of diffusion of the current.

The same muscle is represented in more than one nerve root, usually two, and to an unequal extent in these. And when variation is met with it is a rule that one of the nerve roots in which the muscle is represented is different, rather than that it is represented in more nerve roots.

When the same muscle is represented in two nerve roots, the muscle fibres innervated by one root are not innervated by the other, so that only part of the muscle contracts when a single root is excited.

Ablation Experiments.

Division of any given nerve root produces paresis of the group of muscles supplied by it, which paresis is temporary, nearly all of it being recovered from. The amount of paresis or paralysis produced is proportional to the number of nerve roots divided; and this again varies according to whether the roots divided are consecutive or alternate ones, the effect being much greater in the former than in the latter case. Such division of one or more nerve roots does not result in incoordination of the remaining muscular combinations represented in other nerve roots; the remaining movements are merely more feeble.

Exclusion of a certain Root or Roots during an Epileptic Convulsion in the Limb.

Division of one or more nerve roots produces alteration of the position of a limb during an epileptic convulsion, which altered position depends on the muscular combinations that have been thus thrown out of action. And the effect is identical when the root or roots are divided at the time when the convulsions are evoked and when they have been divided some weeks previously. No incoordination is produced in the remaining muscular combinations; and there is no evidence of overflow of the impulses which ought to travel down the divided root, into other channels through the spinal centres, so as to reach the muscles by new paths.