ON THE SEGMENTAL DISTRIBUTION OF SENSORY DISORDERS.¹

BY JAMES ROSS, M.D., LL.D., F.R.C.P.,

Joint Professor of the Practice of Medicine in the Victoria University, and Senior Assistant Physician to the Manchester Royal Infirmary.

BEFORE proceeding to describe the distribution of sensory disorders in various diseases, it is necessary for us to possess a minute and accurate knowledge of the sensory nervous mechanism itself. In describing the sensory apparatus, I will presume that every one of my audience is acquainted with the knowledge imparted in the usual text-books, and I will only enter into details in dealing with that part of my subject upon which little or no information is to be obtained in ordinary anatomical works.

The sensory mechanism consists of peripheral end organs, afferent nerve-fibres and conducting-paths, and centres. The peripheral end organs vary in structure according to their situation, and according to the nature of the sensory function they subserve. Several forms are found in the skin, other forms in the muscles, and still others in the peripheral expansions of the nerves of special sense. From these end organs fibres issue which join together to form bundles that pass inwards to enter the spinal cord through the posterior roots (Fig. 1, N R), and through the homologues of these roots in the medulla oblongata, pons, and crura cerebri. On entering the spinal cord the fibres cross almost immediately to the opposite half of the cord, in which they ascend (Fig. 1, C P), and after being joined by the afferent fibres from the special senses also of the opposite side, all the strands are found lying close together in the posterior part of the internal capsule

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(Fig. 1, IC), and thence ascend in the corona radiata to terminate in the cortex of the hemisphere. Between their origin in the periphery and their termination in the hemisphere of the opposite side, these fibres are interrupted, more than once probably, by the interposition of grey matter. Such an interruption takes place probably in the root ganglia, and in the posterior grey horn, and some fibres may possibly be interrupted in the optic thalamus; but whether the conduction

FIG. 1.—DIAGRAM OF THE SENSORY MECHANISM.

BB, Brain; s, Spinal cord; NR¹, NR², Posterior roots of spinal nerves; CP, Sensory conducting paths; IC, internal capsule; L¹, Lesion of internal capsule causing hemianæsthesia of opposite side; L², Unilateral lesion of spinal cord causing anæsthesia of opposite half of body below level, and a belt of anæsthesia in same side on level of lesion.

be maintained by continuous fibres or by relays of cells and fibres, it is unquestionable that the fibres of the afferent nerves and conducting paths find their ultimate termination in the grey matter of the cortex of the brain. But into the question of the accurate localisation of these centres I shall not enter.

Such then is a rude outline of the sensory mechanism, and now let us observe it in action. When an impression is made on the surface of the body—say the prick of a pin on the skin

—a molecular disturbance of one of the peripheral end organs or of the terminal fibrils of the sensory nerves results; this disturbance is conducted inwards by the fibres of the afferent nerves and conducting-paths until ultimately a molecular disturbance is set up in that part of the cortex of the brain which is directly connected with the injured surface, and finally the cortical disturbance becomes correlated with a feeling or sensation in the irritated part of the skin. That the essential correlate of the feeling is the molecular disturbance of the cortex is proved in two ways: *firstly*, if the disturbance set up on the surface is prevented from reaching the cortex by division of the conducting-fibres in any part of their course no feeling results; in other words, that particular part of the periphery is rendered anæsthetic; and *secondly*, when, as in the aura of many cases of epilepsy, a spontaneous disturbance begins in the sensory part of the cerebral cortex, various sensations are felt in the periphery in the absence of any outward disturbance to correspond with them. A molecular disturbance of the cortex is, then, the essential condition of consciousness, but the feeling is, in accordance with the law of eccentric projection, localised in the periphery.

Speaking broadly, every form of feeling localised in one half of the body is organised in the cortex of the cerebral hemisphere of the opposite side; and, as is well known, complete severance of the sensory conducting-paths, as they lie together in the posterior part of the internal capsule (Fig. 1, 1 C), causes anæsthesia of every form of sensibility of the opposite half of the body, with the exception of sight and hearing, which are only enfeebled, these organs being bilaterally associated and consequently partially organised in both hemispheres of the brain.

A unilateral division of the dorsal region of the spinal cord, (Fig. 1, L₂) by interrupting the sensory conducting paths after the afferent fibres have crossed, causes anæsthesia of the opposite half of the body below the level of the lesion, and, by injuring nerve roots, a band of anæsthesia passing round the body on the same side and on the same level with the lesion. When, however, the lesion is situated in the cervical region of the cord on a level with the roots of the brachial plexus,

the anæsthetic area will be found on the surface of the upper, and when on a level with the roots of the lumbo-sacral plexus, on the surface of the lower extremity. This statement leads me to the central problem of sensory distribution with which I wish to deal in this paper; namely, to discover the area of skin connected with each posterior nerve root, or, in other words, to find out the segmental distribution of sensory nerves.

With regard to the purely spinal nerves no difficulty arises in the case of those derived from the dorsal region of the cord, inasmuch as their well-known anatomical course sufficiently indicates their sensory and muscular distribution; but it is wholly different in the case of the nerves derived from the plexuses. An endeavour has been made to trace, by means of dissection, the fibres of each peripheral nerve up through the plexus to the root or roots from which they are derived, and this method has recently, in the hands of Dr. Herringham,¹ been attended with a considerable degree of success. I have myself for some years been engaged in unravelling the problem by means of clinical and pathological observations, and I even applied embryological considerations in a rude way to the explanation of the phenomena; but the question has been greatly advanced and placed upon a more scientific basis than previously by Dr. Paterson's² succession of able and instructive papers on the limb-plexuses of mammals, his investigations being wholly based upon developmental observations.

In using embryological facts for the elucidation of the distribution of cutaneous nerves in man, it is necessary for us to attend: *firstly*, to the constitution of a spinal nerve; *secondly*, to the distribution of those nerves in the lowest forms of vertebrate animals, *thirdly*, to the modifications in

¹ Herringham, (W. P.) "The Minute Anatomy of the Brachial Plexus," 'Proceedings of the Royal Society,' vol. 41, 1887, p. 423.

² Paterson (A. M.) 'Edin. Graduation Thesis for 1886' (gold medal); "The Morphology of the Sacral Plexus in Man," 'Journal of Anatomy and Physiology,' vol. xxi. April, 1887, p. 407; "The Limb Plexuses of Mammals," 'The Journal of Anatomy and Physiology,' vol. xxi. July, 1887, p. 611; "On the Function of the Muscle Plate and the Development of the Spinal Nerves and Limb Plexuses in Birds and Mammals," 'The Quarterly Journal of Microscopical Science,' vol. xxviii. 1887, p. 109.

the distribution of cutaneous sensory nerves which occur in the course of development, giving special attention to the *constitution of the limb plexuses*; and *fourthly*, to the distribution of the visceral sensory nerves. We shall then be in a position, *fifthly*, to apply the knowledge so gained to the explanation of sensory disorders.

1. *Constitution of a Spinal Nerve.*

Aspinal nerve is derived from the cord by a posterior(superior) gangliated (Fig. 2, Pr) and an anterior (inferior) non-gangliated root (Fig. 2, a r), and at the point of union of the two, the nerve

FIG. 2.—DIAGRAM SHOWING CONSTITUTION OF A SPINAL NERVE.

c, Spinal cord; Pr, a r, Posterior gangliated and anterior non-gangliated root of nerve respectively; SPD, Superior primary division; IPD, Inferior primary division; d, v, its dorsal and ventral branches respectively; s r, Sympathetic (gangliated) root

divides into a superior primary division (Fig. 2, SPD) supplying the skin (the muscles do not concern us at present) of the back over the neural canal, and an inferior primary division (Fig. 2, IPD) which subdivides into a dorsal trunk (Fig. 2, d), supplying the lateral, and a ventral (Fig. 2, v) trunk supplying the ventral surfaces.

In addition to these, a branch is given off to the viscera—the sympathetic root (Fig. 2, S r)—about which we shall have more to say by-and-by.

2. *Distribution of Sensory Nerves in the Lowest Vertebrata.*

Let us now glance at the distribution of the sensory nerves in the lowest vertebrata—the amphioxus (Fig. 3) for example—and for the sake of clearness of comparison, we will assume that our typical vertebrate animal is composed of nearly the same number of segments as are found in man, and arranged in the same order, namely: three cranial (Fig. 3, s_3) (adopting the most commonly received views), seven cervical, (Fig. c,) twelve dorsal (Fig. 3, d_{12}), and nine lumbo-sacral (Fig. 3, ls_9), the lowest two sacral and the coccygeal segments being so unimportant in man as to render it unnecessary to carry the comparison further. In such an animal each segment is supplied by its own pair of nerves.

FIG. 3.—REPRESENTATION OF PRIMITIVE VERTEBRATE ANIMAL—THE AMPHIOXUS—DIVIDED FOR CONVENIENCE INTO THREE SEGMENTS FOR THE HEAD, SEVEN FOR THE NECK, TWELVE FOR THE DORSAL, NINE FOR THE LUMBO-SACRAL REGION, AND AN INDEFINITE NUMBER FOR THE COCCYGEAL REGION.

SPD. The superior primary divisions of the nerves supplying the surface over the neural canal; IPDD the dorsal trunks of the inferior primary division supplying the lateral surface of the body; and IPDV, the ventral trunk of the inferior primary division supplying the ventral surface. The parts supplied by the dorsal trunks of the inferior division are alone lined.

Now, each pair of nerves (except the last coccygeal) emerges between two segments, and if we name as in man the pair between the last cranial and the first cervical vertebra, the first cervical nerve, and the pair between the last cervical and the first dorsal vertebra, the eighth cervical nerve, it is clear that we shall have two cranial and eight cervical pairs of nerves, or ten pairs to ten segments, while in the dorsal and lumbo-sacral regions we shall have twelve and nine pairs of nerves to twelve and nine segments respectively. The shaded area in the annexed diagram (Fig. 3, IPDD) represents the

cutaneous surface supplied by the branches of the dorsal trunks of the inferior primary divisions of the nerves; the lower unshaded area (Fig. 3, *IPDV*) that supplied by the ventral trunks of the same division; and the upper unshaded area (Fig. 3, *SPD*) the part supplied by the branches of the superior primary divisions.

In the vertebrate animal, selected as our type, section of the posterior roots of a pair of nerves will cause anæsthesia of the corresponding segment of the body, and nearly the same result follows section of the posterior roots of the dorsal region in man, the chief difference being that, in the amphioxus, the nerves of one segment are not connected peripherally with adjacent nerves, whereas, in the higher animals, the nerves of successive segments anastomose freely with one another at their peripheral ends and overlap in their distribution, so that section of a pair only causes partial anæsthesia of the corresponding segment.

Speaking broadly, then, section of the posterior roots of a pair of dorsal nerves produces anæsthesia of the skin of the corresponding segment of the body, and the question we have now to determine is, how does it happen that section of the nerve roots is not attended by the same results in the other regions of the body? The answer is that the same result does follow section of nerve roots in other regions; but in them the segmental distribution is obscured because the nerves have been dragged out of their course by the displacement of old parts which occur in the course of the development of new organs, and more especially by the development of limbs. Our task now consists in giving a rough sketch of the developmental displacements which have been the main cause of diverting the nerves from their primitive segmental course.

3. *Modifications of Sensory Distribution occurring in the Highest as compared with the Lowest Vertebrata.*

The superior primary branches in man—represented in diagrams (Figs. 5 and 6, *SPD*) by the unshaded area which stretches from the root of the nose over the forehead, top, and back of the head, and back of the neck and body down to the tip of the coccyx—differ little in their distribution from that

of the corresponding branches in the primitive vertebrate type. The two cranial branches have united to form the first division of the fifth nerve which supplies the skin over the anterior part of the neural cavity as far forwards as the root of the nose (Fig. 6, s.p.d.). As the neural cavity, however, has become much expanded in the higher vertebrata, and especially in man in order to make room for the greatly increased size of the brain, the skin of the back of the neck with the superior branches of the upper cervical pairs of nerves is dragged upwards in such a way that the skin over the back of the head is supplied from the cervical and not from the cranial portion of the cord, and consequently the posterior (superior) branches of the upper (anterior) cervical nerves are directed slantingly backwards and upwards (upwards and forwards) instead of backwards (vertically upwards) as in the primitive vertebrate type. From the superior branches of the upper cervical nerves we pass on to the other cervical nerves, thence to the dorsal, lumbar, sacral, and coccygeal nerves (Fig. 5, s.p.d.) in their numerical order from above downwards (before backwards), as in the primitive vertebrate type, the chief difference being caused by the development of the erect posture in man, and consisting in the fact, that in him the nerves behind the first dorsal have an increasingly downward (backward) inclination, instead of being directed backwards (vertically) as in the primitive vertebrate animal.

In endeavouring to unravel the distribution of sensory nerves, our main difficulty arises when we come to deal with the limb plexuses. As we have just seen, the superior primary divisions do not enter into the formation of plexuses, which are consequently constituted by the complex union of branches of the inferior primary divisions of the nerves. Two suppositions are possible with regard to the plexuses; either the dorsal branches of the inferior division alone, or both the dorsal and ventral branches are arrested in the limbs.

The first alternative was maintained by Goodsir,¹ but the most cursory inspection of the distribution of the nerves, even in

¹ Goodsir, 'Edin. New Phil. Journal,' new series, vol. v. January, 1887; 'Anat. Memoirs,' vol. ii. p. 539; quoted from Paterson, 'Journal of Anat. and Physiol.' vol. xxi. p. 620.

adult man, shows that it cannot be true, at least with regard to the sensory branches. Were it true, the sensory nerves of the ventral branches would be as regular in their distribution as we have already found the sensory branches of the superior divisions of the nerves to be. Beginning with the cranial branches which have amalgamated to form the third branch of the fifth nerve, we should pass on to the cervical and then to the dorsal nerves in their numerical order. That, however, is not the order met with. The skin over the clavicle and first intercostal space is supplied by the descending branches of the cervical plexus, derived from the third and fourth cervical nerves; but, instead of the skin immediately adjoining this being supplied, as it ought to be according to Goodsir's supposition, by the ventral branches of the remaining cervical branches in their numerical order, it is supplied by the cutaneous filaments of the intercostal branch of the intercosto-humeral nerve derived from the second dorsal nerve. Clearly, then, the ventral as well as the dorsal branches of the inferior primary divisions of the fifth cervical to the first dorsal nerve inclusive are arrested in the upper limbs. From the second dorsal to the first lumbar nerve the anterior sensory branches follow in their numerical order; but we find that the skin of the inguinal and hypogastric regions, as well as the sides of the scrotum, are supplied by cutaneous branches of the first lumbar nerve, whilst the adjoining skin of the penis, the centre of the scrotum and the perinæum are supplied by the pudic, which is derived from the third and fourth sacral roots. It is manifest, therefore, that the ventral as well as the dorsal branches of the inferior primary divisions of the second lumbar to the second sacral inclusive are arrested in the lower extremity. That both branches of the inferior primary divisions of the spinal nerves enter into the formation of the limb plexuses has been still more convincingly proved by Dr. Paterson from embryological observations, but I naturally prefer to approach the subject from the clinical standpoint. It is now apparent that we cannot make a further step in unravelling the distribution of the cutaneous nerves until we study the constitution of the limb-plexuses, at any rate so far as their sensory branches are concerned.

CONSTITUTION OF THE LIMB-PLEXUSES.

It has been known to myself¹ for some considerable time, that if the upper extremity be placed in the embryological

FIG. 4. The lined portion on post-axial border of right arm of figure represents the area of anæsthesia caused by destructive lesion of the eighth cervical and first and second dorsal nerves, and the shaded portion in pre-axial border of left arm of figure represents the area of anæsthesia caused by destructive lesion of the fifth cervical root, as in Erb's paralysis. A back view would show a similar distribution to the front one.

position, that is, with the thumb directed outwards or upwards and the palm forwards or towards the front of the body, the

¹ Ross (J.), "Distribution of Anæsthesia in cases of Disease of the Branches and of the Roots of the Brachial Plexus," *BRAIN*, April, 1884, pt. xxv. p. 51; "A Case of Multiple Tumours, &c." *Ibid.* January, 1885, pt. xxviii. p. 501. See also Thorburn (William), "Cases of Injury to the Cervical Region of the Spinal Cord," *Ibid.* January, 1887, pt. xxxvi. p. 510.

pre-axial border from the tip of the shoulder down to the metacarpo-phalangeal articulations of the index finger and thumb is supplied by the fifth cervical root (Fig. 4, 5, 5), and that the post-axial border, from the axilla to the finger tips inclusive, is supplied by the humeral branch of the second, the first dorsal, and the eighth cervical nerves (Fig. 6, 8, 1, 2).

Observations made in cases of disease of the cauda-equina, and especially in the case of a man suffering from latent spina-bifida, which I had an opportunity of showing to the society at a previous meeting, and a report of whose case will be found in the present number of 'BRAIN,' in what will prove a very able and important paper by Dr. William Thorburn, has convinced me that, if the lower extremities be also placed in the embryological or tailor position, the pre-axial border is supplied by the cutaneous nerves of the upper four lumbar nerves, and the post-axial by the coccygeal and sacral sensory nerves. From the same case I was able to conclude, that the most distal parts of the pre-axial border were supplied from the lower of the four lumbar nerves and of the post-axial border by the higher of the sacral nerves. Dr. Herringham comes to conclusions with regard to the distribution of the cutaneous nerves of the brachial plexus which fully bear out my inferences from pathological observations. He states that (1) of two spots on the skin that which is nearer the pre-axial border tends to be supplied by the higher nerve, and (2) of two spots in the pre-axial area the lower tends to be supplied by the lower nerve, and of two spots in the post-axial area the lower tends to be supplied by the higher nerve. Dr. Paterson, who approaches the subject from a different standpoint to either Dr. Herringham or myself, formulates other important laws with regard to the distribution of the nerves in the plexuses. He finds that (1) the inferior primary divisions of the nerves entering the plexuses divide into dorsal and ventral trunks; (2) that both of these trunks are arrested in the limb; (3) that in the formation of the plexuses the dorsal unite with dorsal and the ventral with ventral branches only, and (4) that the parts derived from the dorsal parts of the embryonic limb—the extensor surfaces—are supplied by nerves derived from a union of dorsal trunk, and the parts derived from the primi-

tive ventral surfaces—the flexor surfaces—by nerves derived from a union of ventral trunks. In a recent conversation with Dr. Paterson, I find that he does not at present insist upon the truth of the third of these laws so strongly as he did when he wrote his paper on the limb-plexuses. He now admits that the small sciatic nerve, for example, is formed probably by a

FIGS. 5 and 6.—DIAGRAM SHOWING CUTANEOUS DISTRIBUTION ON THE ANTERIOR AND POSTERIOR ASPECT OF THE BODY RESPECTIVELY.

SPD, Distribution of superior primary divisions of nerves; IPDd, IPDv, Distribution of the dorsal and ventral trunks of the inferior primary divisions respectively. The area of distribution of the dorsal trunks of the inferior primary divisions is alone lined.

union of dorsal and ventral fibres, and the external or short saphenous nerve is undoubtedly so constituted.

The enunciation of these laws has now placed us in a position to map out the distribution of the lateral and anterior

branches of the cutaneous nerves. And first, with regard to the anterior or ventral branches (Figs. 6 and 7, IPDV), we have already seen that the cranial branches, distributed to the lower lip and chin, and the cervical branches, distributed to the anterior part of the neck and over the clavicle, may be taken in their numerical order. The only point worthy of notice is, that, while the branches of the superior division of the upper cervical nerves are dragged upwards (forwards) over the back of the head, the branches of the ventral trunks of the inferior division are dragged so that they slant downwards (backwards), this being rendered necessary in order to supply the skin of the upper and anterior part of the thorax, which would otherwise have been left destitute of nerves by the arrest of the lower four cervical and first dorsal nerves in the limb.

Passing on from the third and fourth cervical nerves, we come to the fifth cervical nerve, which supplies the pre-axial border of the upper extremity. Now, in the course of development, the arm rotates outward at the shoulder-joint, so that the outer and anterior surface of the shoulder slips, as it were, under the skin of the dorsal surface, and thus the dorsal branch of the inferior division supplies the skin over the ventral surface of the shoulder; while at the distal extremity of the limb there is a reverse process, insomuch as the skin of the ventral surface, with its nerves, is drawn dorsally over the last phalanx of the thumb, and the two last phalanges of the fingers. The circumflex nerve is the dorsal branch of the inferior division of the fifth nerve, while the ventral portion of the same root runs in the musculo-cutaneous nerve, the cutaneous branches of which supply the pre-axial border of the lower third of the arm and of the whole of the forearm and hand down as far as the metacarpo-phalangeal articulations of the thumb and index finger. The musculo-cutaneous nerve is also connected with the sixth root, while the median is derived from the sixth and seventh cervical, and the first dorsal roots; but it is probable that the cutaneous branches of these two nerves are derived from the fifth, sixth, and seventh cervical roots, the fibres of the first dorsal root which run in the median nerve supplying most probably the small muscles of the ball of the thumb. The anterior surface of the post-axial border of

the upper extremity is supplied by the nerve of Wrisberg, the internal cutaneous, and the terminal branches of the ulnar; these nerves are derived from the inferior cord of the brachial plexus, which, in its turn, is made up of the eighth cervical and first dorsal roots, the eighth cervical supplying, according to Herringham's law, the distal parts; that is, the ulnar half of the palm and two and a half fingers, and possibly the greater portion of the inner surface of the forearm. In tracing the anterior nerves in their numerical order, then, we pass in a descending order from the fourth cervical root supplying the skin on the anterior and inner surface of the shoulder, to the fifth root supplying the anterior surface of the pre-axial border of the lower part of the arm and of the forearm and hand, to the sixth and seventh supplying the middle of the forearm, the radial surface of the palm, and the palmar surface of the thumb and one and a half fingers; and then in an ascending order from the eighth cervical root supplying the ulnar half of the palm and two and a half fingers, and a part of the anterior and inner surface of the forearm, to the first dorsal root supplying chiefly the anterior and inner surface of the arm, to the cutaneous branches of the second root (intercosto-humeral) distributed over the second intercostal interspace; and then passing down the front of the thorax and abdomen to the symphysis pubis, we meet with the remaining dorsal nerves in their numerical order.

In endeavouring to unravel the cutaneous nerves of the lumbo-sacral plexus, it must be remembered that the limb has been rotated inwards, in the course of development, in such a way that in the adult the ventral surface is represented by the inner side and back of the thigh, the back of the leg, the heel, and the sole of the foot; while the dorsal surface is represented by the surface of the buttock, the front of the thigh over the extensor muscles, the front of the leg, and the dorsum of the foot. Following the course of the ventral branches of the inferior divisions, we pass from the anterior branch of the twelfth dorsal nerve to the hypogastric and inguinal branches of the ileo-hypogastric and ileo-inguinal nerves, both derived from the first lumbar root, the genito-crural derived from the second lumbar, the cutaneous branches

of the obturator nerve derived from the third and fourth lumbar roots, the plantar cutaneous and the internal and external plantar nerves, which are branches of the internal popliteal derived from the fifth lumbar and first and second sacral roots; and then, ascending along the outer border of the sole supplied by the external or short saphenous—a mixed dorsal and ventral nerve derived from the second and third sacral roots—we pass up the middle of the back of the leg and thigh supplied by the small sciatic nerve and its branches derived from the third and fourth sacral roots, and finally to the skin about the anus and coccyx supplied by the fifth and sixth sacral and the coccygeal nerves.

The nerves derived from the dorsal trunks (Figs. 6 and 7, I P D d) of the inferior primary divisions are distributed (the area of their distribution is alone shaded in Figs. 6 and 7) in a similar manner to the nerves of the ventral trunks, only in tracing them we must pass down the dorsal instead of the ventral aspects of the limbs. The two cranial dorsal trunks unite to form the second branch of the trigeminus which is distributed to the upper lips, nose, and side of the cheeks, and from these we pass down the side of the neck, taking the lateral branches of the four upper cervical nerves in their numerical order. From the tip of the shoulder supplied by the fourth root we pass to the dorsal branch—the circumflex nerve—of the fifth root, thence to the external and internal cutaneous and the radial nerves, which are branches of the musculo-spiral, derived chiefly from the sixth and seventh roots; now ascending along the posterior aspect of the post-axial border, we encounter the posterior cutaneous branches of the ulnar, the internal cutaneous, the nerve of Wrisberg, and the humeral branch of the intercosto-humeral, derived respectively from the eighth cervical and first and second dorsal roots, and then we descend along the lateral aspect of the trunk, taking the remaining dorsal nerve-roots in their numerical order.

Passing now to the lumbar roots we come to the iliac branches of the ileo-hypogastric, ileo-inguinal nerves, derived from the first lumbar, the external cutaneous from the second, the middle and internal cutaneous and the long or internal

saphenous branches of the anterior crural derived from the second, third, and fourth lumbar roots; and now crossing over the dorsum of the foot and ascending along its external border to the outer surface of the leg we come in succession to the cutaneous branch of the musculo-cutaneous, the external or short saphenous, and the cutaneous branch of the external popliteal, all derived from the fifth lumbar and the first, second, and third sacral roots; and then we pass along the external aspect of the back of the leg and thigh, which is supplied by the small sciatic nerve, derived from the third and fourth sacral roots, and finally we come to the skin of the anus and perinæum, middle of the scrotum, and penis, supplied by the inferior hæmorrhoidal, inferior pudendal, and pudic nerves, derived from the third and fourth sacral nerves, and to the skin about the anus and coccyx, supplied by the coccygeal nerves. I have, however, been unable to discover how the dorsal, as apart from the ventral branches of the lower sacral and coccygeal nerves, are distributed.

4. *Distribution of the Visceral Sensory Nerves.*

Having now mapped out the cutaneous surface of the body into its segmental nerve-territories, it remains for us to deal, as briefly as possible, in the same way with the innervation of the viscera. In describing the constitution of a spinal nerve allusion was made to the sympathetic branch, which parts from the nerve at or near the union of the posterior (superior) and anterior (inferior) roots. These branches form the *rami communicantes*, which, emerging from the spinal cord along with the other roots, enter the lateral and collateral ganglia of the sympathetic, ranged along the sides and front of the spinal column. Now the researches of Gaskell¹ have shown that there are two varieties of these branches; in the one the fibres are destitute of medulla, while in the other they are medullated, the two forming respectively a grey and white trunk. Gaskell has also shown that the grey trunk is made

¹ Gaskell (W. H.), "On the Structure, Distribution of, and Functions of the Nerves which innervate the Viscera and Vascular Systems," 'The Journal of Physiology,' vol. vii. 1886, p. 1.

up of nerve fibres which have a centripetal course; they have already passed through the ganglia of the sympathetic, where they have been deprived of their medulla, and now pass inwards to supply the blood-vessels of the vertebral column, and the cord with its membranes. According to this view, the white *rami* alone contain fibres for the innervation of the viscera, or *splanchnic* fibres. The splanchnic nerves issue, according to Gaskell, from the spinal cord in definite thoracic, cervico-cranial, and sacral regions. The thoracic group emerge with the roots of the spinal nerves from the second dorsal to the second lumbar inclusive. The cervico-cranial group are contained in the internal branch of the spinal accessory nerve, which is derived from the first, second, and probably the third cervical nerves, and its fibres pass out to join the ganglia on the main stems of the vagus and glosso-pharyngeal nerves. The sacral group, which constitute the main portion of the *nervi erigentes*, emerge along with the roots of the second and third sacral nerves, and pass directly to the hypogastric plexus; whence they send branches upwards to the inferior mesenteric plexus and downwards to the bladder, rectum, and generative organs.

The question now is, from what cells in the spinal cord do these fibres take their origin? Some years ago, I had myself suggested that the sympathetic fibres were derived from the cells of Clarke's column. My reasons for coming to this conclusion were that the ganglion cells in Clarke's column are bipolar and in other morphological respects similar to the cells of the sympathetic ganglia;¹ that this column is present in the thoracic portion of the cord, which supplies nerves to the viscera; that it is absent on a level with the lower cervical and lumbo-sacral portions which supply nerves to the limbs; and that one of the nuclei of origin of the spinal accessory nerve and of the vagus—the great visceral nerve—consists of a group of bipolar cells like those of Clarke's column. This idea has, quite independently of anything that I have said, been worked out in detail by Dr. Gaskell, and placed by him

¹ This idea was, I believe, first suggested to me by a passage in Poincaré's work on the Nervous System, which I have not had time or opportunity to identify, otherwise I should have given the distinct reference.

upon a scientific foundation. He has also shown that some splanchnic fibres are derived from the cells of the lateral part of the anterior grey horn—the respiratory tract of Bell ; while others are connected with the spinal ganglia and enter the cord in the posterior roots, these being doubtless endowed with sensory functions. It has not, however, been found possible to separate the sensory from the motor fibres in their peripheral distribution, but it is highly probably that the two kinds of fibres run together in the same nerves to reach the respective viscera. I shall therefore presume upon the knowledge of my audience of the further distribution and connections of the splanchnic nerves, including the *vagi*, and shall now proceed to apply the distribution of sensory nerves just sketched out to the explanation of the sensory disorders met with in various diseases.

5. *Application of the Distribution of Sensory Nerves to the explanation of Sensory Disorders.*

In dealing with this part of my subject, I shall pass over the more familiar applications of sensory distribution in the diagnosis of disease ; such as the indication which the presence of anæsthetic and hyperæsthetic belts of skin surrounding the body and passing down the limbs gives for localising disease in the spinal cord and spinal roots, and shall direct my attention to the explanation of the pains observed in disease of the internal organs. Now, disease of an internal organ—say the *stomach*—is accompanied by pain over the seat of the organ—the epigastrium in the case of the stomach—a pain that may be regarded as of splanchnic origin and named accordingly the *splanchnic* pain. In addition to this pain, the patient complains of pain between the shoulders and in front of the chest. On being asked to point to the seats of these pains, he places the palm of the hand broadly across the chest just below mid-sternum for the front pain, and indicates the shoulder pain by passing one hand over the shoulder of the same side and pointing with the tips of the fingers to a situation somewhat low down between the shoulders, moving the finger tips from side to side to show that the pain is

bilateral and somewhat diffused. Short, stout patients fail to reach as low down between the shoulders as they desire by passing the hand from above, and then attempt to reach it by passing the forearm behind the back and directing the tips of the fingers upwards; most of them find themselves still further now from the desired point than before, and immediately return to the first means of indicating the seat of the pain by passing the hand over the shoulder. Some patients indicate the seat of the pain by passing the forearm behind the back, flexing and supinating the forearm so that its radial border rests on the shoulder blade, and then moving the nail of the thumb transversely across the spine from side to side opposite the spinous process of the fourth or fifth dorsal vertebra. These associated pains of dyspepsia are, therefore, situated in the region of distribution of the posterior and anterior branches of the fourth and fifth dorsal nerves. Sometimes the patient may experience a feeling of oppression or constriction in the left side, which may be caused either by irritation of the lateral branches of the same nerve, or by a partial spasm of the intercostal muscles supplied by them. The explanation of these associated pains in dyspepsia is to be found in the fact, that the stomach has been developed as an upper thoracic organ, and that in its downward displacement it has carried its nerves with it. The splanchnic nerves of the stomach are derived from the fourth and fifth, and probably the sixth dorsal nerves, and when the splanchnic peripheral terminations of these nerves are irritated the irritation is conducted to the posterior roots of the nerves, and on reaching the grey matter of the posterior horns it diffuses to the roots of the corresponding somatic nerves and thus causes an associated pain in the territory of distribution of these nerves, which may appropriately be named the *somatic* pain. Another very important associated pain of gastric disorder is brow-ache. The patient indicates the seat of this pain by placing the palm of the hand broadly across the forehead, and while raising the hand he generally bends the head a little forward and to the side to meet the palm. The severity of this pain is indicated by the mournful and lugubrious expression of the patient while the hand is being placed on the forehead. It is most likely that this pain is caused by irrita-

tion of the pneumogastric nerve, but as what we may call the somatic associated district of this nerve extends over most of the head and face it is difficult to know why the forehead should be particularly selected. It has occurred to me that the pain might be due to some changes in the cerebral vessels caused by irritation of the vaso-motor nerves of the carotid cerebral circulation, which are derived from the upper thoracic region, but this view does not afford a very satisfactory explanation.

Let us now consider the associated pains of disease of the *lungs*. Disease in the substance of the lung, which does not press upon neighbouring parts, is not accompanied by very definite pains of any kind, unless the pleura be implicated. In uncomplicated cases of pneumonia the patient complains of a dull pain in the region of the inflamed organ, which is most probably of splanchnic origin ; while the most prominent associated disorders appear to be caused by irritation of the pneumogastric nerves. These consist of palpitation, gastric disorders, and rumbling of the bowels with an uneasy feeling of flatulence. An attack of acute crupous pneumonia, especially in young people, is often ushered in by severe vomiting, accompanied occasionally by diarrhœa, so that at first the general symptoms are more like those of acute gastric catarrh than of an inflammation of the lungs. In the course of a pneumonia, also, patients often complain of a pain at mid-sternum and between the shoulders, such as we have found to accompany primary disease of the stomach, and they sometimes appeal to the medical attendant to prescribe something to remove the wind on the stomach, the presence of which is also indicated by belchings.

The pain of *pleurisy* is often felt over the anterior part of the abdomen, this being clearly caused by direct irritation of the intercostal nerves in their passage over the pleura in the first part of their course. The accompanying stitch of pleurisy is mainly caused by spasm of the intercostal muscles and of the diaphragm from reflex irritation. All these pains are, therefore, the result of direct or reflex irritation of the somatic nerves, which pass in or near the inflamed membrane. There is, however, an associated pain

often present in pleurisy for which it is somewhat difficult to find an explanation. We allude to pain, often severe and urgent, over the outer third of the clavicle, and reaching to the shoulder tip—the territory of the anterior branch of the fourth nerve. Sometimes the pain feels as if a nail were being driven into the joint, and in these cases it may be inferred that the sensory nerves of the joint (a branch of the supra-scapular nerves derived from the fourth and of the circumflex nerve derived from the fifth cervical root) are in a state of irritation. Now the fourth and fifth cervical pairs of nerves have no splanchnic connections, and consequently this pain cannot be the associated somatic pain of splanchnic irritation. In observing a case of pleurisy a few days ago, and casting about for an explanation, one of the students suggested that, considering the connections of the phrenic, the pain might be caused by irritation of that nerve. It then occurred to me that Peter¹ had described a phrenic neuralgia, and on referring to his description I found that he regards pain over the shoulder tip as a constant symptom. It is only right to add, that the phrenic nerve is regarded by some physiologists as a purely motor nerve; but, considering how exquisitely sensitive the diaphragm becomes in pleurisy and in peritonitis, it can hardly be destitute of sensory nerves. In favour of the view, that the shoulder tip pain is caused by irritation of the phrenic, is the fact that essentially the same pain is met with in pericarditis, peritonitis, abscess of the liver, and during the passage of gall stones; while we shall immediately see, that it is probably met with in a more or less disguised form during attacks of angina pectoris.

A patient, suffering from pleuro-pneumonia, attended by me at present, along with my friend Dr. Judson Bury, and who has also been seen several times by Sir W. Roberts, manifests the pains of the two diseases in a very obvious manner. He is a highly nervous man, of gouty constitution, and as in previous illnesses he has proved intolerant of opium in any form, it is found most difficult to allay his sufferings, so that a very undesired opportunity is afforded for studying

¹ Peter (M.), "Neuralgie diaphragmatique et faits morbides connexes." *Archives Générales de Médecine*, vi^e série, tome xvii., 1871, p. 303.

the character of his pains. A physical examination reveals crepitation and dulness of the bases of both lungs; but the disease predominates on the right side, and the pleuritic stitch is entirely limited to it. When the patient is quiet and freest from pain, he suffers only from a dull aching on the right side over the posterior and lateral aspects of the lower part of the chest, which is most likely the splanchnic pulmonary pain. In addition, he complains of pain at mid-sternum, and of a feeling of flatulent distension of the stomach and bowels, which is likewise indicated by occasional belching, and by borborygmi and the passage of wind *per anum*. These periods of comparative calm are of short duration, being interrupted by paroxysms of cutting and radiating pains, neuralgic in character, and of great severity. "When the attack comes on," says the patient, "I feel a cutting pain in the right side which stops my breathing; my heart then begins to jump; and," placing his hand over mid-sternum, he continued, "I have a severe pain here which I think would be relieved if I could only get up some wind." The description of the remaining pains was only elicited by cross-examination. On my asking him if he had a trilling pain along the outer third of the clavicles passing to the shoulder-tips, his countenance immediately lighted up with intelligence, and he said, "I have *that*," and evidently referring to my description, he continued, "that is just it exactly." He then indicated by his finger-tips that the shoulder-pains passed down for about two inches along the outer aspects of the arms. Curiously the pain is more persistent in the left than in the right shoulder, although the pleurisy is situated on the right side, and there are no signs of pericarditis and no suspicion of aneurism. Wishing to know whether or not he had the pain between the shoulder-blades which so frequently accompanies the mid-sternal pain in gastric disorder, I passed my hand to that situation, and asked him if he had a pain there, "No," he said, "it is at the back of my neck." To my surprise I found that the situation of this pain was the nape of the neck, and so urgent had it been a few hours before my examination that he got the nurse to apply a hot linseed-meal poultice to the nape, which he said afforded him great

relief. As this pain did not extend up the occiput, it was situated in the surface area supplied by the posterior branches of the fourth and fifth cervical nerves, and it is the lateral and anterior branches of these same nerves which supply the skin over the outer part of the clavicles and shoulders, and consequently both pains are likely to have been caused by irritation of the phrenic nerve. At the beginning of a paroxysm of pain the action of the heart becomes tumultuous and irregular, and, although the patient is a stout man, the abdominal aorta is seen and felt to pulsate strongly. The bowels also rumble a good deal, and he seems to find some relief in belching, and still greater when wind passes *per anum*; these last symptoms being probably due to associated irritation of the pneumogastric nerves.

The associated pains of *cardiac* disease are best studied during attacks of angina pectoris, although they may be present in diseases of the heart and large blood vessels unaccompanied by anginal paroxysms. Some years ago Dr. Allen Sturge,¹ in a very able paper which does not appear to have attracted so much attention as it ought to have done, and the importance of which had escaped my own notice until my views on this subject had already been formed, endeavoured to show that the sensory phenomena of angina pectoris were caused by a primary irritation of the peripheral ends of the cardiac sympathetic nerves, which on reaching the spinal cord became diffused in the grey matter of the posterior horns, thus causing the pains which shoot between the shoulders and down the arm. After discussing several other hypotheses, Dr. Sturge asks, "Does the spinal cord offer a more probable solution to the problem?" In reply to this question he says, "The cardiac nerves of the sympathetic come from the three cervical ganglia on both sides. Of these, the largest nerves are the two nerves which come from the middle cervical ganglia. The strands passing from the ganglia to the spinal cord pass in the trunk of the fifth and sixth cervical nerves; those passing from the inferior cervical ganglia, in the trunk of the seventh and eighth cervical nerves. It is these four nerves

¹ Sturge (W. Allen), "The Phenomena of Angina Pectoris and their bearing upon the Theory of Counter-irritation," 'BRAIN,' Vol. V. January, 1883, p. 492.

which, in conjunction with the first dorsal, form the brachial plexus. We thus see that the region of the spinal cord which gives origin to the brachial plexus gives origin also to the greater part of the fibres which eventually find their way to the heart. Wherever, then, the original commotion may have taken place in an attack of angina pectoris, whether in the cardiac ganglia of the sympathetic, or in the spinal cord, and whether the commotion be due to some peripheral irritation from disease of the heart's substance, or be a spontaneous outburst on the part of the nerve cells implicated, it is evident that it is only when the commotion has begun in the cord, or has passed up to the grey matter of the spinal cord from the sympathetic, that any great extension in its area can take place, such as that of which I am speaking." In this remarkable passage Dr. Sturge has clearly anticipated, in principle at least, the view advanced in these pages; although our knowledge of the distribution of sensory nerves at the time at which he wrote, was much too vague to enable him to map out accurately the area affected. A similar idea also has been well expressed by Dr. Allbutt,¹ who says, "As in angina pectoris and the pseudo-angina, so in gastralgia, the spinal nerves may be included in the paroxysms, or may take even a chief part in them, the visceral and overlying spinal nerves being grouped in function and in suffering together." According to Gaskell's observations the heart derives its splanchnic nerves from the second dorsal pair of nerves, and we must therefore expect that the central area of the associated pains of cardiac disease will be found in the region of distribution of these nerves. In some attacks, however, the pains will be likely to become diffused in the areas of distribution of the first dorsal and eighth cervical above, and in those of the third and fourth dorsal below, and may very possibly extend on the one hand to higher, and on the other to lower nerves than these, in aggravated cases. Some weeks ago I obtained a very graphic description of the cardiac pains from a patient in the Infirmary under the care of my colleague, Dr. Simpson, who was suffering from free aortic regurgitation

¹ Allbutt (T. Clifford), "On Visceral Neuroses, being the Gulstonian Lectures for 1884;" London, 1884, p. 31.

and dilatation of the left ventricle, accompanied by severe attacks of angina. On being asked to describe his sensations during these attacks, he said, without any prompting, "My pain starts here"—pointing with the tip of the middle finger of the left hand to a point a little below mid-sternum; "it then shoots back between my shoulders"—moving the tips of the fingers of the right hand across the spine on a line with the second dorsal vertebra—"and darts down the inside of my arm to the elbows"—at the same time drawing the backs of the fingers of the right hand from the left axilla down the inner side of the arm to the elbow, and repeating a similar movement with the left hand down the inner side of the right arm. He then raised both hands and placed the tips of the fingers of each hand—the hands being held nearly at right angles to the body—over the second ribs, below the middle of the clavicles, and said, "I have a feeling of great tightness here." The sensory distribution of the second dorsal nerves could hardly have been better mapped out by an instructed anatomist than it was by this patient, the tightness over the second rib being most probably caused by spasm of the second, and probably also of the first intercostal muscles. A second case of angina came under my observation a short time ago, in which the patient said that the pain shot across his back and down the back of the left arm, and, on being asked to indicate the seat of the arm pain, he passed the right hand over the left arm below the shoulder, and moved the tips of the fingers along the post-axial border of the arm from the axilla to the elbow—the area of distribution of the dorsal branches of the second and first dorsal roots. But the associated pains of angina pectoris are not always so strictly limited as they were in these cases. Sometimes the pains pass down the inner side of the forearm to the tips of the ring and little fingers, and in these cases we must assume, that the irritation has extended from the roots of the second to those of the first dorsal and eighth cervical nerves. In other cases, I believe that the pain passes down the outside of the arm, in the area of distribution of the fourth and fifth cervical nerves, and as these nerves have no splanchnic connections, we must assume that the pain in this situation is caused by irritation of

the phrenics, which, in its turn, is produced by an associated spasm of the diaphragm. The shoulder-tip pain forms a marked feature in many cases of acute pericarditis, and Dr. Judson Bury informs me that this disease in young people is, like pneumonia, frequently ushered in by severe vomiting. In a case of aneurism of the aorta now in the Infirmary, under the care of my colleague, Dr. Leech, the patient complains of a pain shooting across the spine and shoulder-blades on a level with the third or fourth dorsal vertebra. There is no reason to believe that the posterior branches of the third or fourth dorsal nerves are subjected to direct pressure or irritation, and therefore the pain must be an associated one, caused by irritation of the sympathetic roots of these nerves, which are known to supply splanchnic fibres to the large blood-vessels. Anginal attacks, and, indeed, all diseases attended by great anæmia of the brain, are accompanied by a feeling of weight and oppression of the top of the head, but of the causation of this pain I cannot give a satisfactory account.

Let us now turn to the great organ which lies in the cavity of the skull—the *cerebrum*. The associated pains of cerebral disease are variable, and we are not able to give a satisfactory explanation of them. In organic diseases of the brain, such as inflammation and tumours, the pains are very variable in their intensity, and may be frontal, temporal, occipital, vertical, or diffused in their localisation. In exhausted conditions of the brain, however, a disagreeable sensation is felt over the back of the head. It is sometimes described as a numbness; at other times the skin is said to be over-sensitive, and patients find the combing and brushing of the hair a very disagreeable and often a painful process. One patient said that “the pain seems as if some one were pulling my hair from the roots,” and I have known several young girls to have their hair cut short in order to avoid the necessity of combing long hair. This pain is aggravated by a slight touch, and often soothed by deep and steady pressure, and consequently it must surely be caused by irritation of the posterior branches of the upper occipital nerves; but what is the source of the irritation, and by what channels it is conducted to the spinal cord, I am

unable to say. Why irritation of the branches of the pneumogastric fibres to the stomach should give rise to brow-ache, anæmia of the brain to a feeling of pressure on the vertex, and exhaustion of the nervous system to this occipital tenderness, I cannot tell, but I have abundant clinical evidence of the fact. In reference to the last pain, it must be remembered that the cervico-cranial splanchnic region is situated as low as the three upper cervical nerves.

Passing now to the *liver*, the splanchnic pain consists of a feeling of fulness in the right hypo-chondriac region over the seat of the organ; while the somatic pain is referred to the inferior angle of the scapula and sometimes across the spine to the same point on the left side, these being the regions of distribution of the posterior branches of the seventh and eighth nerves from which the splanchnic nerves of the organ are most probably derived. In abscess of the liver, perihepatitis, and all diseases which are situated in or near the upper surface of the organ, the shoulder-blade pain is often accompanied by the shoulder-tip pain of phrenic irritation. During attacks of gall stones, the splanchnic pain is felt over the distended organ, and the associated pains as a rule shoot to the back and upwards. In exceptional cases, of which a probable example came under my observation a few days ago, the associated pain is felt towards the epigastric region, and in these cases it is probable that a calculus has been arrested at the point of entrance of the common duct in the duodenum.

In diseases of the *bowels* the splanchnic pain may be variously situated, but the associated somatic pains are felt in the back in the area of distribution of the posterior branches of the tenth and eleventh dorsal nerves, and in the front about the umbilicus. Sir James Sawyer¹ has recently pointed out that certain patients, with digestive disorders, complain of pain in the back, the situation of which they indicate by passing the extended thumb across the back at a point midway the scapular pains of liver disease and the loin pain of kidney disease. He believes that it is caused by a loaded colon. I know the cases well, and attribute the pain to irritation

¹ Sawyer (James), "Note on the Cause and Cure of a Form of Backache;" 'Lancet,' January 1st, 1887, p. 17.

of the branches of the inferior mesenteric plexus, derived chiefly from the eleventh and twelfth dorsal roots.

Diseases of the *spleen* are probably not accompanied by marked associated somatic pains.

The lumbar organs consist of the kidneys, with the ureters, the testicles, and the ovaries. The *kidneys* have not undergone much displacement during development and consequently the splanchnic and somatic pains coincide, the pains consisting of a dull aching in the loins. When, however, the pelvis and ureter become implicated, the associated pains shoot down the inside of the thigh, in the region of the ileo-inguinal and genito-crural nerves, derived from the first and second lumbar, and along the lateral aspect of the thigh, in the territory of the external cutaneous nerves derived from the second lumbar root. These pains are also often accompanied by spasm of the cremaster muscle.

Disease of the *testicle*, in addition to the splanchnic pain in the organ itself, is accompanied by dragging pains in the loins and by pains shooting down along the inguinal branch of the ileo-inguinal nerve.

In disease of the *ovaries* a woman indicates the situation of the pain in the back by placing the tips of both hands over the lower part of the lumbar region, just above the iliac crest on each side, the region of distribution of the posterior branches of the second lumbar nerves, and in front by placing the ulnar border of the hands a little above the groins, the region of distribution of the inguinal branches of the ileo-inguinal nerves, but in front it is difficult to separate the splanchnic and somatic pains. The associated pains are sometimes referred to the iliac region and hip-joints, parts which receive their sensory innervation from the three upper lumbar nerves, and then the patient indicates the seat of the pain by placing the palm of her hand in a slanting direction over the iliac region above the hip.

The pelvic organs consist of the bladder, rectum, and uterus. These organs are supplied by the sacral splanchnics, derived from the second and third sacral roots.

The splanchnic pain of *bladder* disease is a gnawing pain in the hypogastric region over the organ, while the associated

somatic pain passes along the urethra to the tip of the penis parts supplied by the pudic nerve, derived from the third sacral nerve.

The pains of *rectal* disease consist of straining and tenesmus, which are partly caused by muscular spasm and partly by irritation of the inferior hæmorrhoidal nerves ; the associated disorders consist of pains in the urethra, in the course of the pudic nerve. In some cases pains shoot down the back of the thigh in the course of the small sciatic nerve, derived from the third sacral root.

Disease of the *uterus*, apart from the ovarian irritation with which it is so generally accompanied, is declared by a splanchnic pain in the hypogastric region, and by a somatic associated pain over the lower part of the sacrum, the seat of which the patient indicates by placing the back of the hand broadly across the sacrum, in the region of distribution of the posterior branches of the second, third, and fourth sacral nerves. Ulcerations of the *os uteri* are frequently accompanied by coccygeal neuralgia, the irritation probably extending from the splanchnic connection with the third sacral nerve. In uterine displacements and enlargements, many of the accompanying pains are caused by direct irritation of the sacral and coccygeal nerves as the result of pressure.

Did time permit, I should like to have pointed out the light the theory I have advanced sheds upon the motor, vaso-motor, and secretory disturbances which usually accompany visceral pains, and upon the associations and successions of these sensory disorders, which, like the auræ of epileptic seizures, owe their origin to spontaneous discharges of energy from the cortex of the cerebrum. I must, however, come to a conclusion ; but, before sitting down, I desire to tender my thanks to Professor Young for much assistance in tracing out the course of the nerves, and for the diagrams which illustrate the text. I am also indebted to Dr. Paterson for much useful anatomical and embryological information.