Researches

INTO

SENSORY DISTURBANCES FROM CEREBRAL LESIONS.¹

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INTRODUCTORY REMARKS.

WE must begin by craving the indulgence of our readers for the form in which the following paper is cast. The nature of the sensory changes produced by lesions of the cerebral cortex and other parts of the brain has been the theme of innumerable works by the acutest intellects in medicine of the last 50 years. Our research would have been impossible but for their labours, and yet we can never acknowledge what we owe to them. Many whose views have helped to make our work fruitful are known to us through their publications, and to them we can repay our debt by referring at suitable points to the similarity of our results to those of our predecessors. Others have been our teachers and the masters for whom we have gladly worked. To them our debt can never be repaid, for much of the identity in outlook comes from personal intercourse and cannot be fixed by citation. First amongst this group must always stand the name of Dr. Hughlings Jackson.

Scope of Communication.

This paper is a preliminary communication in which we put forward a general view of the mode of action on the afferent side of the nervous system. Any such generalisation must not only contain much that is common to the views of others, but also many things incompatible with the conceptions even of those with whom we are otherwise in harmony. Where possible we shall always acknowledge our concurrence with those who have preceded us, but in the small space at our disposal we cannot enter into criticism of work with which we are not in agreement. In many cases, although our theoretical conclusions may coincide with those put forward by other workers, our experimental results may differ fundamentally. In the same way similar clinical observations may lead us to other conclusions, but it will be impossible to stop our exposition in order to discuss these differences.

We shall attempt to put forward in this paper a general conception of the mechanism underlying sensation based upon a study of human beings in whom disease, accident, or surgical interference has produced some stationary lesion. Many of these patients have occupied our attention from time to time for many years, and it will be impossible in this preliminary communication to give a complete history of all our cases.

Methods of Investigation.

We lay great stress upon the methods we have used for testing sensibility in this research. As these, however, have only limited interest we shall publish them elsewhere. As far as possible we shall avoid the use of all general terms. We wish to lay peculiar stress on the confusion which arises from the use of all such expressions as "deep sensibility" when reporting the results of a clinical examination. Not infrequently "deep sensibility" is said to be affected from a lesion of the cortex when the observer means to state that the appreciation of posture, of passive movement, or of vibration, was defective. Similarly, "atopognosis" is a combined loss of the faculties of recognising posture and the situation of the spot stimulated, two functions capable of independent investigation. In every case, therefore, we shall describe our observations under headings which imply the simple test used in analysing the loss of sensation.

We shall begin by tracing sensory impulses from the point where they enter the spinal cord and follow them to those centres where they form the basis of that psychical process we call sensation. For this investigation exact knowledge of the site of the lesion is less important than a precise determination of the nature of the sensory changes in selected cases. It is only by the study of the nature and grouping of these affections of sensation that we can obtain any knowledge of the nature of cerebral activity and of the form in which impulses reach the higher centres to underlie the psychical elaboration of sensation.

Nature of Lesions.

It is our pleasant duty to express our sincere thanks to all those who have helped us in this work. To the staff of the National Hospital, Queen-square, we owe innumerable opportunities of observing many valuable cases, and Dr. Head wishes to thank them for their generous hospitality. To Sir Victor Horsley we are particularly grateful for permission to use our observations on his remarkable case of excision of a portion of the cerebral cortex.

In consequence of such help we have been able to investigate a large number of selected cases. This includes patients in whom the clinical symptoms justified us in assuming certain affections of the optic thalamus. A second group consists of patients with limited lesions of the surface of the brain, most of which resulted from successful removal of a cerebral tumour or other cortical disease. In this group the site of the lesion is known with more or less accuracy, and we have included solely stationary cases examined months or years after operation. Finally, we have employed the same methods to investigate many instances of lesions in the neighbourhood of the internal capsule and deeper parts of the brain.

I.—THE GROUPING OF AFFERENT IMPULSES IN THE SPINAL CORD AND BRAIN-STEM.

1. THE SPINAL CORD.

It is a matter of universal belief that man has been evolved from the lower animals; and yet when we deal with sensation and sensory processes we speak as if he were created with peripheral end-organs, each capable of reacting to one of the sensory qualities of human experience. The impulses starting in these end-organs are supposed to pass unaltered to the brain, there to set up that peculiar and unknown change which evolves a specific sensation. Spots were found on the skin sensitive to touch, to pain, to heat or to cold only. With the discovery of these highly developed end-organs the doctrine of specific nerve energy seemed to be proved in the strictest manner.

All other forms of sensory appreciation were supposed to be produced by the physical transformation of these primary sensory elements, in association with an ill-defined faculty called the "muscle-sense." Recognition of the locality of a stimulus and the posture of the limb under examination were attributed to judgment and association.

But alongside the systematic investigation by von Frey and others of the capabilities of these specific areas in the skin, the clinicians were discovering the importance of "muscular sensibility." Sherrington's demonstration of afferent fibres in muscles and tendons placed the existence of the "muscle-sense" beyond a doubt. The use he made of these afferent impulses from deep structures in his theory of the proprioceptive system necessitated a complete exploration of the nature of deep sensibility.

By their experiment directed to this end, Rivers and Head [31*] showed that beneath the skin, independent of all "touch" and "pain spots," lies an afferent system capable of a wide range of functions. Pressure that in ordinary life would be called a touch can be appreciated and localised with considerable accuracy. Increase of pressure, especially on bones and tendons, will cause pain. Moreover, it is from the impulses of this deep afferent system that we gain our knowledge of the posture of the limbs and the power of recognising passive movements.

Complexity of Peripheral Mechanism of Sensation.

Evidently, therefore, the peripheral mechanism of sensation is less simple than was at first supposed. For there are two sets of end-organs that can respond to tactile stimuli and

¹ The substance of this paper formed the Croonian lectures delivered before the Royal College of Physicians of London on June 13th, 15th, 20th, and 27th, 1911. The results will be published in more detail in the forthcoming number of *Brain*.

* These and other reference numbers relate to a bibliography to appear at the end.

two independent mechanisms for the initiation of pain. Further analysis showed that the peripheral apparatus in the skin, by which we become conscious of the nature of external stimuli, is highly complex. No one sensory quality is subserved by a single set of end-organs, but every specific sensation is the result of the combined action of more than one group. This is exactly the result that might have been expected when we bear in mind that the structure of man is the product of a long evolution.

Grouping of Different Impulses in Spinal Cord.

But it is equally obvious, from an evolutionary standpoint, that these diverse impulses could not pass uncombined to the highest physiological level. Within the spinal cord the opportunist grouping of the periphery gives place to an arrangement according to quality (Head and Thompson [11]). All impulses capable of generating pain become grouped together in the same path and can be disturbed simultaneously by an appropriate lesion of the spinal cord. In the same way sensibility to heat or to cold may be lost independently of one another, showing that all the impulses upon which they are based have been sorted out into two functional groups, each of which passes by a separate system in the spinal cord.

The most remarkable condition revealed by an intramedullary lesion is the complete separation of the impulses underlying the appreciation of posture, the discrimination of two points and their correlated faculties from those of other sensory groups. All tactile, painful, and thermal impulses coming from the periphery undergo regrouping after entering the spinal cord, and whether they arise in the skin or in deeper structures become arranged according to functional similarity. Then, after a longer or shorter course, they pass away to the opposite side of the spinal cord.

Impulses concerned with Postural and Spacial Recognition.

This process of filtration leaves all the impulses concerned with postural and spacial recognition to continue their course unaltered in the posterior columns; they are the survivors of peripheral groups dissociated by the passing away of certain components into secondary afferent systems. At any point in the spinal cord these columns transmit not only impulses from the periphery which are on their way, after a longer or shorter passage, to regrouping and transformation, but at the same time they form the path for impulses, arising both in the cutaneous and deep afferent systems, which undergo no regrouping until they reach the nuclei of the medulla oblongata.

Thus a lesion confined to one half of the spinal cord, even at its highest segment, may interfere with the passage of sensory impulses, some of which are travelling in secondary paths, whilst others are still within the primary level of the nervous system. All impulses concerned with painful and thermal sensations from distant parts, disturbed by such a lesion, will be travelling in secondary paths, and will have come from the opposite half of the body, for after regrouping they have passed across the spinal cord. But those impulses underlying the appreciation of posture, the compass-test, size, shape, form, weight, consistence, and vibration will be affected on the same half of the body as the lesion. They still remain in paths of the peripheral level and have undergone no regrouping.

In such a case the parts on the side opposed to the lesion may be insensitive to pain, heat, and cold; but all the postural and spacial aspects of sensation will be perfectly maintained. Yet all power of recognising position, of estimating size, shape, form, and weight, or of discriminating the two compass points will be lost in the limbs which lie on the side of the lesion, although tactile sensibility and localisation of the spot stimulated may be perfectly preserved.

This remarkable arrangement enables us to analyse the nature of the peripheral impulses upon which depends our power of postural and spacial recognition. Obviously, even at the periphery, they must be independent of touch and pressure. The power to distinguish two points applied simultaneously and to recognise size and shape requires as a preliminary the existence of sensations of touch. But the patient may be deprived of all such powers of spacial recognition without any discoverable loss of tactile sensibility. In the same way our power to appreciate the position of a limb, or to estimate the weight of an object, is based upon impulses which, even at the periphery, exist apart from

those of touch and pressure called into simultaneous being by the same external stimulus.

This long delay of the postural and spacial elements in reaching secondary paths enables them to give off afferent impulses into the spinal and cerebellar coördinating mechanisms which lie in the same half of the spinal cord. The impulses which pass away in this direction are never destined to enter consciousness directly. They influence coördination, unconscious posture and muscular tone, and although arising from the same afferent end-organs they never become the basis of a sensation.

Finally, the last survivors of these impulses from the periphery become regrouped in the nuclei of the posterior columns and cross to the opposite half of the medulla oblongata in paths of the secondary level. So they pass to the optic thalamus and thence to the cortex to underlie those sensations upon which are based the recognition of posture and spacial discrimination.

Illustrative Case.

The following case is an example of the effects produced by a lesion situated in one-half of the spinal cord just below the point at which the postural and spacial impulses become regrouped in the nuclei of the posterior columns.

CASE 1. *Brown-Séquard paralysis.*—*On the right*—Weakness of arm and leg. Reflexes exaggerated; ankle clonus and extensor plantar reflex. Loss of painful sensibility over right cheek: touch, heat, and cold unaffected. *On the body and limbs*—Tactile, painful and thermal sensibility were perfect; but in the arm and leg posture, passive movements, and vibration of a tuning-fork could not be appreciated within normal limits, the compass test was defective, and he could not recognise size, shape, form, weight, or consistence of objects by the right hand. Localisation was not affected. *On the left*—Motion perfect. Reflexes normal. Loss of sensation to pain, heat, and cold. All other forms of sensibility, including localisation, perfectly preserved.

This case is an excellent illustration of the principles laid down in this section, and the retention of muscular power in the right hand enabled us to test the faculty of recognising size, shape, form, weight and consistence with an accuracy otherwise impossible.

Three Main Divisions of Afferent Impulses.

In conclusion we believe that at the extreme upper end of the spinal cord, just below the formation of the posterior column nuclei, afferent impulses pass upwards in three main divisions:—

1. The impulses underlying sensations of pain, of heat, and of cold are travelling in secondary paths in the opposite half of the spinal cord from that by which they entered.

2. Those impulses upon which depend postural recognition and spacial discrimination still remain uncrossed in the posterior column. They consist of one group arising in the deep afferent system, upon which depends our recognition of posture, passive movement, weight, consistence, and vibration. A second group arises in the end-organs of the skin, and these impulses underlie the discrimination of two points applied simultaneously, and the allied appreciation of size, shape, and form.

3. Contact sensibility evoked by touch and by pressure may remain entirely undisturbed. Apparently it depends upon impulses which run in a bilateral path, and it is therefore unaffected by a purely unilateral lesion (Rothmann [32], Petré [26], Head and Thompson [11]). This tactile group formed by the union of tactile impulses within the cord carries with it the impulses which underlie the power of recognising with accuracy the situation of the stimulated spot, and localisation therefore remains unaffected.

2. THE BRAIN-STEM.

The larger number of afferent impulses traverse the spinal cord, grouped, according to their sensory qualities, in paths that can be isolated by disease. This enables us to analyse the nature of the groups formed, either by specific selection at the first synaptic junction, or by gradual filtration away into secondary tracts, of impulses arising originally in the same peripheral system. But in their further passage through the brain-stem to the optic thalamus the impulses run in paths which are anatomically more closely associated. This makes any analysis of the grouping of afferent impulses in this region unusually difficult.

Pain, Heat, and Cold Impulses.

Impulses underlying sensations of pain, heat, and cold alone seem to run unaltered between the upper end of the spinal cord and the optic thalamus.² They receive the accession of the regrouped secondary impulses from the face, which cross to join the specific path for pain, for heat, or for cold. These paths are so situated that they can be interrupted without disturbance of any other form of sensation on the body, and the analgesia and thermo-anæsthesia so produced resemble in quality the loss to pain, heat, and cold caused by a lesion of the spinal cord.

Thus when a lesion of the bulb interferes with sensations of pain, not only may the skin be insensitive to prick but the readings of the pressure algometer may be raised on the analgesic side. In the same way the affected area on the body may be insensitive to all degrees of heat and to all stimuli capable of evoking normally a sensation of cold. It is, however, important to remember that although the uncomfortable sensation produced by excessive pressure is greatly diminished, a lesion in this situation does not usually abolish completely all painful pressure (Cases 2 and 3). Thus it would seem that the grosser forms of pain and discomfort may possibly find their way by another path if the usual one is closed; whereas an equivalent lesion in the spinal cord blocks all painful impulses whatever their origin.

Not only can these three forms of sensibility be affected together, but any one of them may escape or be affected alone. The following case shows that, with a one-sided lesion of the bulb, the opposite half of the body may become analgesic, and yet the threshold values of sensibility to heat and cold may be equal on the two sides.

CASE 2.—October, 1906. sudden onset of pain in the right lower jaw. Since June, 1907, he has noticed loss of sensation on the left half of the body and right half of the face. First seen by us June, 1909, and since then his condition has not changed materially. Motor power and reflexes unaffected. Diplopia in all directions. Pupils unaffected. Optic neuritis in both eyes. Hearing diminished in right ear.

Sensation on the face.—Loss to prick with no loss to pressure-pain on the right side of the face, head, and neck. No other change in sensation to measured stimuli, but touch seemed "less vivid," heat "hotter," and cold "less cold," over the right than the left half of the face.

Sensation on the body.—The left half, except the perineum and scrotum, was insensible to prick. Pressure-pain was also diminished. Otherwise sensation was unaffected.

This case showed (1) a local lesion affecting the sensation of the right half of the face and neck; (2) a remote disturbance of sensibility to pain over the left half of the body with considerable raising of the algometer readings over the analgesic area; (3) heat and cold showed the same threshold on the two halves of the body.

All recent work has shown that the paths for the transmission of the impulses for pain, heat, and cold run up in the neighbourhood of the nucleus of the trigeminal nerve. This close local association is particularly well shown by cases of occlusion of the posterior inferior cerebellar artery (Wallenberg [38], Bruer and Maiburg [2], Spiller [37]).

Separation of Spacial Discrimination and Postural Recognition Impulses.

In addition to these well-known facts the following instance of this condition also shows that impulses underlying the appreciation of posture and passive movement have become separated from those concerned with spacial discrimination. The compass-test gave identical results on the two halves of the body, and size, shape, and form could be appreciated on both hands. And yet the amount of passive movement necessary to evoke a sensation was three to four times greater in the affected fingers. Evidently a change in grouping has taken place at the posterior column nuclei and the impulses for spacial discrimination now tend to run apart from those of postural recognition.

CASE 3.—An instance of "occlusion of the posterior inferior cerebellar artery." Sudden onset Dec. 25th, 1908.

² This does not necessarily mean that the impulses are carried by uninterrupted fibres. It has been suggested by Long [18], Cajal [4], Kohnstamm [15] that the nuclei of the formatio reticularis are intercalated in the course of the afferent conduction tracts. Such anatomical relay would not interfere with the above physiological conclusions, as it does not necessarily imply any regrouping of sensory impulses.

Seen by us first in July, 1909. Horizontal and rotatory nystagmus, but diplopia had passed off. Left pupil did not dilate fully to shade. Left palpebral fissure smaller than right. Movement of left half of the palate defective, but vocal cords and tongue moved well. Gait unsteady; he tended to deviate to the left but fell to the right when his eyes were closed. No paralysis. Reflexes normal.

Sensations on the face.—Left half insensitive to prick, but sensitive to pressure-pain. Tactile and thermal thresholds were equal and normal on the two halves of the face, but all temperatures seemed "duller" on the left half.

Sensation on the body.—Loss to prick, to heat, and to cold over the right half of the body, right arm, and right leg. Sensibility to pressure-pain diminished over this area but not lost.

Diminished power of recognising posture and pressure movement in right arm and right leg. All other forms of sensation normal.

This typical case of "occlusion of the posterior inferior cerebellar artery" showed:—

1. A sensory disturbance over the left half of the face representing the local lesion.

2. Analgesia, with raising of the algometer readings, and complete loss of sensation to heat and to cold over the right half of the body.

3. Diminished recognition of posture and passive movement in the right arm and leg, but all spacial discrimination was perfect (compass-test, appreciation of size, shape, form).

4. Slight cerebellar incoördination in the left arm and leg, which was not increased by closing the eyes.

Gathering Together of Sensory Paths.

When all afferent impulses from the face have undergone re-grouping and passed, in secondary tracts, to the opposite half of the nervous system, the various sensory paths are gathered closely together in preparation for their ending in the optic thalamus. Every sensory path now lies within the opposite half to that by which its impulses entered the central nervous system. The complete integrity of sensations on the same side as the lesion shows that no bilateral paths are open to any form of sensory impulse.

From the analytical aspect these brain-stem lesions can give little information as to the grouping of the elements underlying sensation. But occasionally by watching the gradual disappearance of one form after another a hint may be gained with regard to the independence or association of any two groups of impulses.

Moreover, the tendency we have already noticed for the grosser forms of pain or discomfort to find a way to consciousness, although the more specific forms of pain, heat, or cold are blocked, becomes more evident the closer the lesion lies to the optic thalamus. And yet it is probable that this discomfort is not conducted by a bilateral path.

The following case, which we owe to the kindness of the late Dr. Beevor, illustrates the concentration of paths just before their entry into the optic thalamus. Incidentally it seems to show that the power of localising the spot touched may be greatly affected at this level with but little loss of tactile sensibility.

CASE 4.—Tumour of the right side of the mid-brain and optic thalamus verified by post-mortem examination. Five months before death the following signs were present. Loss of power in the left arm and leg, with profound ataxy. Extensor response from left sole with normal response from right. Athetoid movements of left hand, together with a fine tremor when the left arm was extended. Eye movements greatly restricted; nystagmus in all directions; fixed pupils.

The loss of sensation was confined to the left of the middle line. Sensations of prick diminished over left arm and leg, but lost on the left palm only. Tactile sensibility very little, if at all, affected during the time he was under observation by us. Localisation lost over left upper extremity. Compass-test gravely affected over left arm and leg. Appreciation of size and weight abolished in left hand.

This is a case where a malignant growth affected the corpora quadrigemina and that portion of the mid-brain at a point where the paths for sensory impulses are converging to an end in the thalamus. The clinical signs indicate that this lesion started in the mid-brain, although at the time of death the right optic thalamus was also destroyed.

During the course of the disease this case showed that:—In this situation the impulses underlying postural

recognition, spacial discrimination, and localisation (spot-finding) may be dissociated from those concerned with touch and pain. At one stage of his illness the patient was therefore able to appreciate contact with von Frey's hairs and cotton-wool, but could not localise the spot touched. Nor could he tell the head from the point of a pin, or the relative size and weight of objects placed in his hand.

Brain-stem: Summary.

To sum up the conclusions of this section, we can say that the brain-stem between the nuclei of the posterior columns and the final termination of all sensory paths in the optic thalamus is the seat of the following changes:—

1. The impulses for pain, heat, and cold continue to run up in separate secondary paths on the opposite side of the nervous system to that by which they entered. They receive accessions from the regrouped afferent nerves of the head and upper part of the neck. Although these paths are frequently affected together they are independent of one another, and any one of the three qualities of sensation may be dissociated by disease.

2. Lesions of the spinal cord tend to diminish simultaneously all forms of painful sensibility, but with disease of the brain-stem the gross forms of pain and discomfort may pass to consciousness, although the skin is analgesic. This applies not only to painful pressure but to the discomfort produced by excessive heat.

3. The impulses concerned with postural recognition part company with those for spacial discrimination at the posterior column nuclei. Up to this point they have travelled together in the same column of the spinal cord, but as soon as they reach their first synaptic junction they separate. Above the point where they enter secondary paths the power of recognising position and passive movement can be affected independently of the discrimination of two points and the appreciation of size, shape, and form.

4. It would seem as if those elements which underlie the power of localising the spot touched or pricked become separated off from their associated tactile impulses before they have actually come to an end in the optic thalamus. The long connexion of localisation with the integrity of tactile sensibility is here broken for the first time.

All these changes are preparatory to the great re-grouping which takes place in the optic thalamus, and will form the subject of the following section.

(To be continued.)

An Address

ON

INDICATIONS FOR SURGICAL INTERFERENCE IN THE TREATMENT OF TUBERCULOUS JOINT DISEASE IN CHILDREN,

WITH REMARKS AS TO THE AFTER-RESULTS.

*Delivered in Opening a Discussion in the Section for Diseases
of Children, Royal Society of Medicine, on Dec. 15th, 1911,*

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MR. PRESIDENT AND GENTLEMEN,—The terms of the reference are sufficiently vague to allow me to speak of the surgical treatment of tuberculous joint disease in children somewhat widely, but the time allotted compels me to be brief.

INTRODUCTORY REMARKS.

The discussion to-day has special reference to the indications for surgical interference, and the nature of the operation done. I have been asked to include in my remarks some notes on the treatment of abscesses; and, finally, the after-results will be touched upon. It has been agreed that the various forms of tuberculous spinal disease and its complications render the ground too wide to be traversed, and therefore they are excluded.

You will observe that, as befits this section of the Royal Society of Medicine, we are dealing with the disease in children. It appears to me, however, expedient to extend

that age in this case to the end of the fifteenth year, as it may be said to mark the end of the very active period of growth in bone; and, certainly up to this time that structure retains the characteristics of early life and its reaction to tuberculous infection. It is to be hoped that speakers will not limit themselves to hospital and the poorer class of patients, but that they will also deal with well-to-do patients, although it is generally recognised that for the latter class operative interference is less frequently required. Time will not permit me to allude to the treatment of deformities arising from tuberculous arthritis, except in so far as they may necessitate operation.

In order to make the views quite clear which I entertain with regard to tuberculosis in childhood, I may state that in a general sense I am in entire agreement with the opinion of Augustus Wilson,¹ who has stated "that tuberculosis of joints can be considered as such only in its incipency, and that all conditions following this are to be looked upon as avoidable sequelæ." This axiom involves the postulates that early recognition of the affection and proper treatment, followed by careful and long-continued observation, are essential to the thorough and radical cure of the disease without deformity and with the minimum loss of function.

Looking back upon my opportunities for clinical experience from 1882 onwards—experience which has been gained in the wards of two general hospitals, at the Evelina Hospital for Children, at the Royal National Orthopædic Hospital, and at the Hospital for Hip Disease, Sevenoaks—I am conscious that the conception of tuberculous arthritis has been undergoing during the last decade a radical change. Briefly put, we may say that, whereas formerly the affection was regarded simply as a joint-disease to be treated as such, we now look upon it as a loss of resistance to the invasion of tuberculosis into a patient, manifesting itself as an inflammation and degeneration of one or more joints; or, to put it more baldly, the earlier idea was—the joint first and the general condition afterwards, whilst the present conception is that of the general condition of the patient first and the joint secondly.

In adults this is true to a certain extent, but in children this remark is more apposite. If we contrast the reactions of adults and children to tuberculous bone affections we observe that the natural processes do not wall off the disease with such frequency as in adults. Painter² remarks: "This is apparently antagonistic to the fact that tubercle tends to become arrested more often spontaneously in children than in adults." In children, when an operation is performed, the highly vascular and cellular spaces are opened up with knife and chisel, and dissemination of infection into new and unguarded localities takes place. In fact, whilst in adults the healing of tubercle is accompanied by the formation of a barrier of dense fibrous tissue, in children the young and rapidly-growing tissues do not assume this sclerotic action. We may take it then that in children the general resistance to this disease is greater than the local warding-off power, and in adults the reverse is the case.

In addition to these pathological observations, the truth of which it is difficult to deny, there are certain factors which are responsible for the change in surgical opinion during the last decade. These factors are four in number—namely: 1. The climatic treatment of bone and joint tuberculosis. 2. The employment of Roentgen rays. 3. The improved use of the new tuberculins, and the evolution of methods designed to check and control their action. 4. The recognition of the value of supporting appliances, their wider use, and the ingenuity which has been displayed in inventing new apparatus or modifying old ones to meet various conditions of deformity or limitations of movement.

CLIMATIC TREATMENT.

1. Tuberculosis of joints should be treated by open-air methods exactly as pulmonary tubercle is, and results are obtained which are very gratifying. In the year 1902, at the suggestion of Dr. Dawson Williams, I collected statistics from some of the children's hospitals in London and embodied the results of the observations in my articles.³ I

¹ Pennsylvania Medical Journal, January, 1906.

² American Journal of Orthopedic Surgery, January, 1905, p. 26.

³ The Urban Treatment of External or Surgical Tuberculosis, Brit. Med. Jour., Feb. 21st, 1903. Is the Urban Hospital Treatment of External or Surgical Tuberculosis Justified? Practitioner, September, 1903. Also Tuberculous Cripples, in Kelynack's Tuberculosis in Infancy and Childhood, p. 183, London, 1907, Baillière and Co.; and Tuberculous Bone and Joint Disease in Childhood, its Effects on the Duration and Usefulness of Life, British Journal of Tuberculosis, July, 1907.