Neurectasy, or, Nerve-stretching for the relief or cure of pain : being the Bradshaw Lecture delivered at the Royal College of Surgeons of England, on the 6th December 1883 / by John Marshall ; with an appendix by the author, dated March 1887 and 12 illustrations by Victor A.H. Horsley.

The Bradshaw Lecture 1883 with Appendix 1887

John Marshall

NERVE-STRETCHING

NEURECTASY

OR

NERVE-STRETCHING

FOR THE RELIEF OR CURE OF PAIN

BEING

The Bradshaw Lecture

DELIVERED AT THE

Royal College of Surgeons of England

On the 6th December, 1883

BY

JOHN MARSHALL, F.R.S., LL.D., F.R.C.S.E., F.R.C.S.I. (Hon.)

THEN PRESIDENT OF THE COLLEGE
AND PROFESSOR OF SURGERY IN UNIVERSITY COLLEGE, LONDON

WITH AN APPENDIX BY THE AUTHOR

DATED MARCH 1887

AND 12 ILLUSTRATIONS BY VICTOR A. H. HORSLEY, F.R.S.

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PREFACE.

As the 'Bradshaw' Lecture for 1883, on 'Nerve-stretching for the Relief and Cure of Pain,' delivered at the Royal College of Surgeons of England, was fully reported at the time both in the 'Lancet' and in the 'British Medical Journal,' I always intended to allow a certain interval to elapse before publishing the lecture in a separate form, in order that the subject might become more matured; but certainly the delay in its publication has exceeded my intentions.

I now publish the Lecture almost as it was delivered, subject only to its subdivision into sections, and to such further revision as seemed desirable in order here and there to modify its colloquial style, and to avoid repetitions quite justifiable in a lecture. Such new materials as have offered themselves I have preferred to put into the form of an Appendix, the sections of which correspond with those adopted in the Lecture, so that they can easily be read together if it be desired to do so.

It has not been attempted to exhaust every possible source of information, nor to mention the numerous individual cases

of nerve-stretching which have been recorded since 1883. This would have involved an expenditure of time beyond what is now at my disposal, and also a detailed criticism as to the bearing of most of the recently recorded facts. I have therefore restricted myself to a general use of the newer experiences of British, Continental, and American surgeons; but I have added a list of references by means of which access may be obtained to a tolerably complete bibliography on the whole subject from the commencement.

The 'Bradshaw' Lecture

ON

NERVE-STRETCHING FOR THE RELIEF OR CURE OF PAIN.

Mr. Vice-President, Mr. Junior Vice-President, and Gentlemen,—Dr. William Woods Bradshaw, a physician who practised first at Andover and then at Reading, was M.D. of the University of Erlangen, and also possessed other titles from that University. He was M.A. of the University of Oxford, a member of the Royal College of Physicians of London, and a Fellow of this College. He was therefore a man not undistinguished in our profession, and he held a high position in the county in which he resided. He contributed a few papers to medical journals, and likewise indulged himself in writing articles on matters of general interest, under the signature of 'Beta.' He died in the month of August seventeen years ago; and fourteen years afterwards his Widow left 1,000*l.* to the Royal College of Physicians of London, and another 1,000*l.* to this College, in order to establish perpetual lectureships in Dr. Bradshaw's name.

This lectureship has been held only once previously to the present occasion, and that by Sir James Paget; and as my predecessor chose for his subject some 'new' forms of disease, so I have selected as my subject what may yet be called a 'new' operation; for it is only within the last dozen years that 'nerve-stretching' has been extensively introduced, and performed more and more frequently for the 'relief or cure

of pain.' It has also been employed in a variety of spasmodic diseases dependent on nervous disturbance. But it is in relation to its effects in relieving or curing pain that I now chiefly wish to direct your attention to this particular operation of 'nerve-stretching.'

1. *Extensibility of Nerves.*—The first point I have to mention concerning nerve-stretching is that one must understand by it not the mere drawing-out of a nerve, so that one may see it lifted from its bed in the body, but a *palpable* stretching. And this opens up the question—Can a nerve be stretched? Now nerves are extensible to a certain degree, but to a much slighter degree than we would imagine. Here is a Table showing the degree of *extensibility* of nerves, and

TABLE I.—EXTENSIBILITY OF NERVES. HUMAN NERVES AFTER DEATH (*Vogt*).

	Extending weight in pounds	Distance lengthened in inches	Ratio to whole nerve
Median nerve . . .	$6\frac{1}{2}$	$\frac{3}{4}$	$\frac{1}{24}$
" "	Extreme weight possible	$1\frac{1}{4}$	$\frac{1}{16}$
" "	Breaking strain	$2\frac{1}{4}$—$2\frac{3}{4}$	$\frac{1}{9}$—$\frac{1}{7}$
Great sciatic and its branches .	66 (supposed weight of lower limb)	4—$7\frac{3}{4}$(?)	—
Great sciatic (rabbit just killed)	—	(?)	$\frac{1}{9}$—$\frac{1}{7}$
Great sciatic (living rabbit) .	—	(?)	$\frac{1}{6}$—$\frac{1}{4}$
" " " " .	—	(?)	$\frac{1}{4}$

you will find that the results, after all, are not very remarkable. One of the observers states that a nerve may be stretched to one twenty-fourth of its length; another observer makes out a larger amount of stretching, and another a still larger amount. But after all one is surprised at the resistance of nerves to a force applied longitudinally to them, and at the small amount of stretching of which they are capable.

The following simple experiment will show you that a nerve is not so very extensible, though it is extensible. I take a piece of tendon and a piece of nerve, and I apply the same weight to the same length of each, and you will see how very inextensible the tendon is, and that the nerve has yielded a very little more than the tendon. You must remember, however, that the weights employed in the cases

mentioned in the Table were considerable, some of them as great as 20, 30, and even 80 pounds. Here, however, I have used only a 4 lb. weight. No doubt, with a greater weight, a perfectly fresh piece of nerve would be stretched still more than this; at the same time the amount of extensibility of nerve is certainly comparatively slight. It is not nearly so extensible as an artery, but it is a little more extensible than a tendon. It has been noticed with regard to this extension that the nerves nearer to the spinal cord are rather more extensible than those at a distance. This may be owing to the relative thinness of their sheaths. The distant nerves, though smaller, are probably relatively better protected. It has been observed that the nerves of the lower limb are less extensible than those of the upper limb, probably for the same reason, namely, that the nerves of the lower limb have thicker sheaths, for we must recognise that it is the sheath which bears the strain when one pulls upon a nerve. It has also been noticed that a long piece of nerve will stretch a great deal more relatively than a short one, and this is only in harmony with what takes place in ordinary extensible tissues. If you take two pieces of elastic tube, one twice the length of the other, and load them with the same weight, you will find that the longer piece will stretch relatively more than the shorter one. This piece, for example, has stretched about two inches with 1 lb. weight, and this piece measuring twice the length is stretched nearly five inches; so, also, the longer a given nerve the greater is its relative extensibility. (Appendix, p. 33.)

2. *Elasticity of Nerves.*—The next point we come to is the recoil of the nerve. After one has stretched a nerve, does it recoil? We find observation proves that it does recoil.

TABLE II.—ELASTICITY OF NERVES (*Vogt*).

Human nerve (after death) extended $\frac{1}{24}$—$\frac{1}{16}$; retracted to $\frac{1}{40}$.
Rabbit's nerve (living) extended $\frac{1}{4}$ (one experiment); wholly retracted.

According to one observer the *elasticity* of a nerve is so great that when it is stretched by one twenty-fourth of its length it recoils to within one fortieth of its original length. This shows the recovering power or resiliency of the sheath of the nerve.

Lastly, I may remark that in the living body the extensi-

bility of a nerve is greater, and so is its elasticity. A living nerve having all its tissues in a healthy condition—that is, with its sheath flexible and its elements mobile amongst each other—may be stretched a great deal farther than a dead nerve. So, on the other hand, it will recoil more effectually. Its elasticity is greater, and its power of recovery, as shown in Table II., may be absolutely perfect. This is just what we might expect. (Appendix, p. 33.)

3. *Cohesion or strength of nerves as shown by their breaking-strain in pounds' weight.*—Passing on to other considerations as to the effect of this pulling upon a nerve, the next and most practical question is—How much weight will a nerve bear? Now it is very remarkable that the nerves will bear such an extraordinary weight before they break. In Table III. you will see a list of the *breaking-weights* of some of the

TABLE III.—COHESION OF NERVES: BREAKING STRAIN IN POUNDS (*Trombetta*).

Human Nerves after Death (*Trombetta*)		Pounds
Trigeminus	1. Supraorbital	6
	2. Infraorbital	12
	3. Mental	$5\frac{1}{2}$
Cords of Brachial Plexus		50 to 64
Ulnar nerve		58
Musculo-spiral		61
Median		84
Crural		83
Internal Popliteal		114
Great Sciatic	(*Johnson Symington*)	86 to 176
	(*Tillaux*)	118 to 127
	(*Gillette*)	165
	(*Trombetta*)	82 to 288
	(*Ceccherelli*)	154 to 220
Lowest weight		82
Highest weight		288
Mean weight		185

Living nerves in animals.—Great sciatic will bear 1·8 of the body-weight. (*Stintzing.*)

Average weight of human body is 150 lbs.; 1·8 of 150 lbs. = ~~83·3~~ 270 lbs.

The normal functions of healthy sciatic nerve in animals completely restored, even after the nerve has been stretched with a force equal to a little more than half the body-weight. (*Stintzing.*)

Safe strain for healthy sciatic (man), 60 lbs. Safe strain for diseased sciatic (man), 30 lbs.

smaller nerves of the body, varying from 6 lbs. in the case of one of the branches of the trigeminus to 12 lbs. for another branch; and the weights increase gradually with the size of the nerve as one passes to the cords of the brachial plexus, and thence to the crural, and the great sciatic nerves.

However, for a moment, let us give special attention to the breaking-weight of the sciatic nerve. This has been tested by Symington, Tillaux, Gillette, Trombetta, and others; and these observers differ most extraordinarily. The weights employed vary from 82 lbs. to 280 lbs. This discrepancy, of course, must have an explanation, and it can be accounted for on various grounds. Thus there is no doubt that the nerves experimented on must have been taken from bodies of different height and conformation, and were those of persons, who, when living, had not been in identical conditions as to health. Some of the nerves, too, might have been themselves diseased. Again, the nerves examined would of course be tested at different periods after death, in different climates, and even some in hot and some in cold seasons; so that, no doubt, the effect of post-mortem changes might account largely for the striking differences in the results. As a mean outcome, however, of all these various experiments, we find that 180 lbs. is the weight that the sciatic nerve will bear. It is easy to understand, therefore, that when I just now put only a 4 lb. weight upon a nerve of small size I was far within the power which is required in order fully to stretch that nerve.

I will now pass from this Table, to which I shall have again to refer, with only one additional remark, viz., that as I just now contrasted the extensibility and the elasticity of the dead and the living nerves, so here it is shown, after Stintzing (whose name I shall frequently mention), that whereas the sciatic nerve in a dead animal broke with ·5 or half the weight of its own body, that weight being about 10 lbs., another living sciatic nerve bore 1·8 of the body-weight. This again shows a great difference in the power that exists in the living as compared with the dead nerve to resist longitudinally applied force. (Appendix, p. 34.)

4. *Effects of stretching on the structure of a nerve.*—But

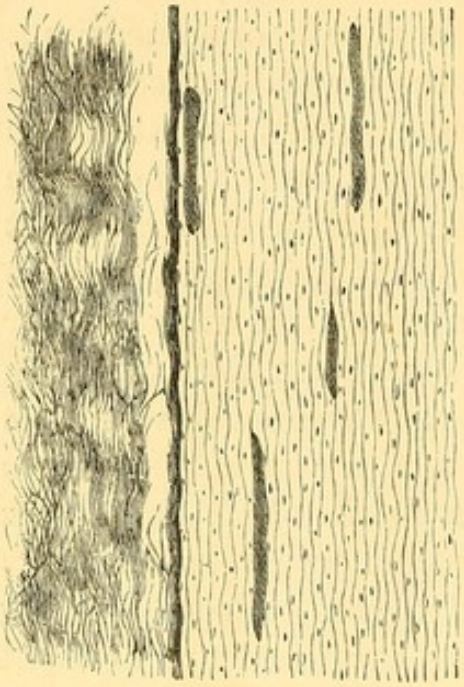
still more interesting results are displayed when we examine the immediate *effects of stretching on the intimate structure of a nerve*. And here I might express the general results in the form of a truism; for one may state that experiment has shown that every constituent of a nerve is more or less injuriously affected or changed by a mechanical force acting longitudinally upon it, just in proportion to the amount of that force. As I have said, this is a truism, but it is useful, inasmuch as it throws a mantle of reconciliation over the various observations and facts which have been accumulated on this question during the last eleven or twelve years. No one who has not perused the literature of the subject could anticipate the widely different statements which have been made concerning it. If, however, we recollect that the particular results must vary according to the force used and the condition of the nerve itself, we shall find that we may follow in a very general way the various effects which have been produced.

Long before nerve-stretching came into vogue as an operation, Haber and Harless examined the effects of stretching nerves. They pointed out a tension of the sheath, an elongation of the fasciculi and the tubular fibres, and a compression of these within the tightened sheath. Valentin went further and showed that the individual tubules of the nerve were elongated and narrowed in diameter. Vogt added somewhat to these observations, chiefly, however, by confirming them. Gen noticed remarkable constrictions formed on the nerve-tubules, constrictions to which I shall presently refer. Quinquand discovered segmentation in the so-called medullary sheath of the nerve tubules. Schleich observed that these segments at last became broken; and that, here and there, one saw the axis-cylinder, as it is called, passing between and through them. So that thus we have a series of differing statements concerning the effects of stretching upon the anatomical constituents of the nerves.

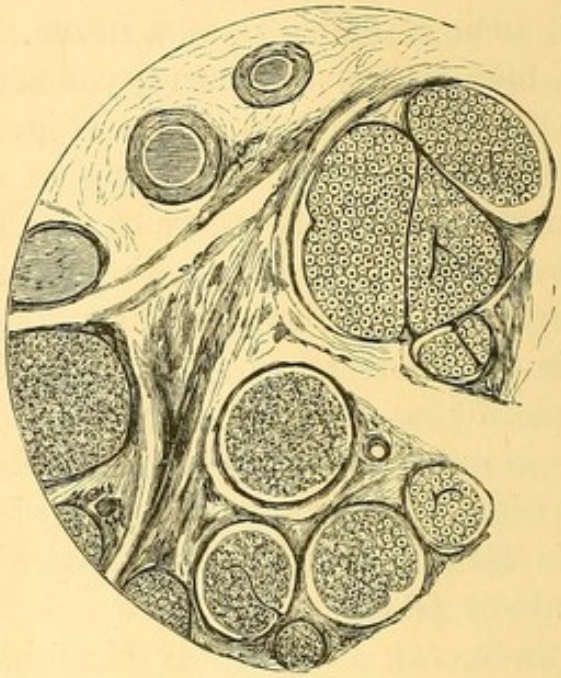
But Mr. Horsley, at my instigation, has recently made some interesting observations which throw additional light upon this subject, and for which I think he deserves special mention. He has made sections for me of an unstretched nerve and of a stretched nerve, both properly hardened; and

in the Illustrations here exhibited, taken from his drawings of specimens under the microscope, we can trace much more effectually than by mere description all the changes which have been noted by different observers as wrought by stretching the constituents of a nerve. In the sheath, or epineurium, which covers the nerve, you see on the *longitudinal section* of the *unstretched* specimen (Fig. 1, page 8), that the fibres are beautifully wavy like those of ordinary fibrous tissue. The nerve tubules lie more or less loosely in their sheath, whilst even the perineurium, the fine membrane lying between the epineurium and the tubules, likewise presents a wavy contour in the unstretched state. Bloodvessels, shown dark, are seen plainly at intervals on the section. Contrasted with this specimen is one from a *longitudinal section* of the same nerve (Fig. 3), the popliteal, *stretched* by a weight of 28 lbs., which is far within its breaking-strain, which would be probably about 60 lbs. Here the epineurial fibres, instead of being wavy, run in perfectly straight lines, stretched out as tight as they can be, the perineurium is perfectly straight, and the tubules, somewhat narrowed, are also stretched to an extraordinary degree. In a *transverse section* of the *unstretched* nerve (Fig. 2), you recognise the spaces in which the fasciculi of the nerve-fibres lie, smaller bundles being shown as combining into a larger one, and the cut ends of the individual nerve tubules contained in each fasciculus. In this condition, the perineurium is loose, the channels in which the nerve fasciculi lie are more or less open, and there is a space between each fasciculus and the perineurium, that space being most likely a lymphatic space, occupied during lifetime with lymph-fluid. Several open bloodvessels are also shown. But on a *transverse* section of a *stretched* nerve (Fig. 4) we see, irrespective of the changes which have taken place in the bloodvessels, a complete alteration. Thus the epineurium or sheath is tightened out and marked with rigid lines, as if the whole texture were rendered tense, and it cuts like a sort of hard, solid block. The fasciculi are compressed, and the lymphatic spaces within the membrane covering these bundles are obliterated, indicating, as it would appear, the compression of the bundles themselves and their constituent tubules. This is the

condition which no doubt Haber and Harless observed many years ago, but they did not exhibit it in the very decided manner demonstrated in Mr. Horsley's preparations.

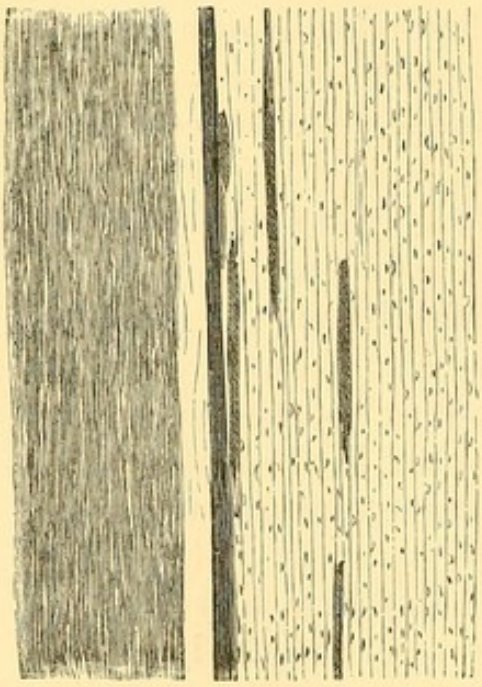


Sheath. Nerve-fibres.
1. Longitudinal section.

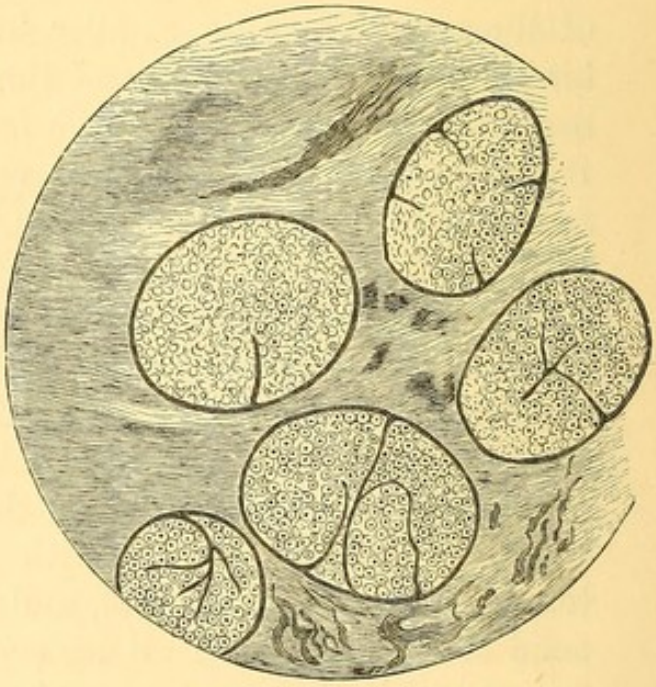


2. Transverse section, showing fasciculi and sheath.

FIGS. 1 and 2.—Sections from *unstretched* internal popliteal nerve (human), magnified 60 diameters.—*Horsley.*



Sheath. Nerve-fibres.
3. Longitudinal section.



4. Transverse section, showing fasciculi and sheath.

FIGS. 3 and 4.—Sections from stretched internal popliteal nerve (human), magnified 60 diameters.—*Horsley.*

Let us next consider the minute changes which take place in the nerve-tubules. Here (Fig. 5, A) is the diagram of a nerve-tubule with one of its annular constrictions, or so-called nodes of Ranvier, in its natural form, showing also the nucleus of the outer hyaline sheath of Schwann. The black part, stained by osmic acid, represents the soft medullary sheath; the lighter part is the axis-cylinder or axis fibre. It

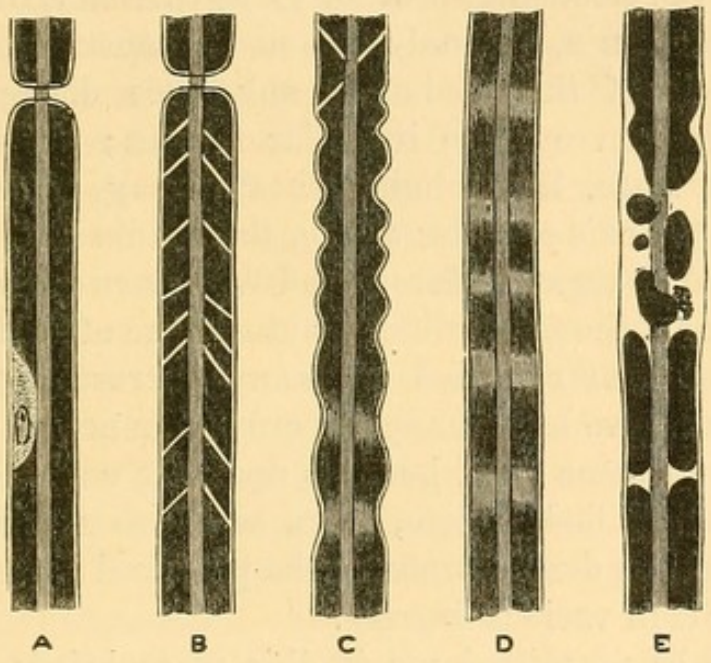


FIG. 5.—Nerve-fibres, normal and stretched; stained with osmic acid. Magnified about 350 diameters.—*Horsley.* A, Uninjured nerve-fibre, showing a node of *Ranvier*, the medullary sheath stained black, and the internodal nucleus and protoplasm. B, Uninjured nerve-fibre, showing the peculiar cleavage of the medullary sheath, probably due to the action of reagents, or to contraction of the white substance. C, D, E, nerve-fibres after various amounts of stretching, then relaxed, hardened, and stained. C shows puckering of the outer or tubular sheath, and commencing fissuring or cleavage of the medullary sheath; D shows well-marked cleavage or segmentation of the medullary sheath; E shows complete destruction of the medullary sheath, the axis-cylinder remaining intact. This last preparation, E, was made from a small nerve stretched to actual rupture. C, D exhibit the amount of change which is probably produced by the ordinary operation of nerve-stretching.

had been observed by Leuterman that the medullary sheath, after a certain time, often broke up into these curious segments between and independent of the annular constrictions of the tubule, each consisting of small portions of medullary substance, B. This is evidently not a purely accidental occurrence. It might be a crystallisation, it might be a solidification, it might be a coagulation. At all events, it results in the somewhat regular segmented appearance described by Leuterman. I wish, however, to mention especially that this cleavage

was noticed quite independently by Mr. Horsley, and for that reason I show this diagram, B, which has been drawn under his instructions.

We further find, that in a stretched nerve, as shown in C and D, there is a puckering of the tubular sheath, the regular nodal constrictions are obliterated, and an appearance of a commencing cleavage or segmentation becomes recognisable. Supposing the stretching process to be carried a little further as represented in E, not only the nodal constriction, but the segmentation of the medullary substance disappears, this becoming broken up into irregular masses; whilst, as most authorities state, the tubular sheath may remain unruptured, and the axis-cylinder entire, though no doubt they may both be broken across. Marcus and Wiet have actually noticed the breaking of the axis-cylinder, but rupture of the fine hyaline sheath has been recorded by many microscopists. These observations have been made not only upon nerves which have been dead for some time, but also upon the nerves of animals quite recently killed. Here, then, we have a series of noteworthy changes demonstrated to be produced upon a nerve by stretching it in various degrees.

It may be permitted me in this place briefly to mention an experiment which bears on the question of the kind of compression which the fasciculi and the tubuli of a stretched nerve must undergo. Evidently the channels formed in the perineurium and epineurium for the protection of the fasciculi of tubules are narrowed, the lymph spaces around these fasciculi disappear, and the fasciculi themselves are compressed as well as subjected to longitudinal tension. Now, these same channels of course resemble tubes; and so likewise the fine hyaline sheaths of the separate nerve-fibres are elastic hollow tubes enclosing the medullary sheath and axis-cylinder. Hence it occurred to me to ask, what happens when a more or less elastic tube is elongated? Is its original total capacity increased or diminished? You will probably think neither the one nor the other, and that is what I supposed. But a very simple experiment will show you that when I extend an elastic tube its total capacity is increased. Here is a glass tube to the lower end of which a piece of elastic

tubing is strongly attached, and is tightly closed below; both contain a coloured fluid which reaches a certain level in the glass tube. When I stretch the elastic tube, thus, you perceive that the fluid descends; so that given an elastic tube of a certain length and diameter, when it is elongated and narrowed by being stretched, its total capacity becomes greater than it was in the unstretched condition. Applying this to what may happen within a nerve, it would seem that the perineurial channels, although diminished in their transverse diameter, might be so much elongated when stretched, that their total capacity would be increased, not diminished. So, also, with regard to the tubules; for I assume that what is physically true on a large scale must be true on a small one. These microscopic tubules being elongated would really have a greater internal capacity than when in their natural condition; and if this be so, we can understand that this stretching may take place without any absolute compression. But, on the whole, one may conceive that here there is a sort of struggle between two conditions, a lateral narrowing producing a transverse compression, and an elongation producing a longitudinal expansion. There would occur a narrowing of the tubule itself, and a stretching out of its soft contents to fill it, whilst in itself it becomes more capacious, and the result, as we can readily understand, would be such as to shatter—if I may use the phrase—the delicate medullary substance into fragments, and so to produce the temporary destruction of its continuity represented in the diagram, E. (Appendix, p. 34.)

5. *Effects of stretching on the nutrition of living nerves.*—If we next proceed to inquire as to what further happens to a living nerve which has been stretched, we find that the structural changes just described are followed by *nutritive disturbances*, ending in *degenerations*, of which I may now take account before I speak of the effects of stretching on the physiological properties or functions of the nerve concerned. First, the sheath becomes hyperæmic, and charged with little ecchymoses and even larger hæmorrhages; it is then infiltrated, suffers from proliferation of its elements, and is swollen; its

blood-vessels become tortuous and pressed upon; and its lymphatics and lymphatic spaces must also suffer compression. Then, with regard to the tubules themselves, the nuclei of the hyaline sheath soften and disappear, and rapid degenerative changes set in, during which the fine tubular sheath melts away, the medullary matter liquefies and runs into the form of oil-globules, and so escapes from the tubules, and, lastly, the axis-cylinder, which, however, offers much resistance to 'degenerative' change, is broken up and is absorbed. In this fashion the whole mass of nerve-tissue becomes disintegrated under the effect of soft atrophic changes. After a longer or shorter time, varying according to the severity of the stretching, and usually measured by weeks or even months, these degenerative changes are followed by reparation of all the elements of the nerve-tissue. The precise nature of the reproductive processes is not yet clearly made out, but they are certainly most surprising and have great significance. (Appendix, p. 34.)

6. *Effects of stretching on the functions and properties of a nerve.*—With regard to the physiological results of nerve-stretching, there is also, as might be anticipated, a considerable variety of statement and opinion. Speaking generally, it may be said that all the properties and functions of a mixed nerve are affected in a greater or less degree, according to the amount of force with which it is drawn out or stretched. This is so, certainly, as regards its sensory and motor functions, for if the stretching be only of a moderate kind, there is but very little and only a temporary loss of either; but as the stretching becomes stronger and stronger, both functions are diminished and ultimately are completely lost. The sensory fibres seem to be sooner and more markedly influenced than the voluntary motor fibres. All the modifications of common sensibility in the parts to which the nerve is distributed are affected, not only the sense of touch, but those of pressure, heat and cold, each being depressed or annihilated provided that the stretching is powerful enough. The consequent motor paralysis is also similarly graduated until it becomes complete. These results are easily under-

stood. But it is somewhat remarkable, if it be true, that the reflex phenomena dependent on the action of the stretched nerve, though of necessity these are also gradually interfered with and ultimately suspended, are not so immediately affected as the sensory and the voluntary motor phenomena performed through its agency. It has been shown, moreover, that the inherent irritability of a nerve, that is, its general property of conducting impressions, is increased not only by a moderate degree of lateral pressure upon it, and even by a tolerably strong pressure, but also when it is subjected to a slight amount of stretching. Of course, under a heavier pressure and a more powerful extension the proper conducting power of a nerve is finally lost. In these two facts, viz. that the reflex function of a stretched nerve is not extinguished so early as its sensory and voluntary motor functions, and that a certain increase of its inherent irritability follows upon moderate stretching, we may possibly find two important conditions which may assist in explaining the effects of a moderate nerve-stretching as a palliative or curative operation; for both conditions are probably intimately associated with the vasimotor (which I prefer to vasomotor) and the trophic functions of a mixed nerve, concerning which, however, sufficient is not yet known.

It is scarcely necessary for me to add that when, after having undergone the degenerations just described as the effects of stretching, the several constituents of a previously healthy nerve are, after a time, reproduced, so all the properties and uses of such a nerve would be gradually and more or less perfectly restored.

The preceding observations by no means exhaust all which may here be stated concerning the effects of stretching upon the functions of nerves. For, in a recent and valuable memoir by Stintzing, which it is scarcely possible to commend too highly, we have an account of a most elaborate inquiry into the whole subject, illustrated by experiments on living animals, and conducted on scientific methods. He confirms to a great extent what was previously known; but the important feature of his investigation is this, that he aims at obtaining exact measurements of his results. Touch he measures

by an æsthesiometer, cutaneous sensibility by aid of the faradaic current, and muscular contractility by the constant current. He records his numerous results by means of curves, so that they can be readily and truly appreciated. He thus compares the effects produced by various stretching weights, having different ratios to the weight of the animal's body experimented upon; so that he gives the physiological disturbances produced in the great sciatic nerve by a weight of $\frac{3}{10}$ths, $\frac{4}{10}$ths, and one half of the body-weight, and so on up to the breaking weight of that nerve, which, as I have already mentioned, is equal to 1·8 of the body-weight. His researches, therefore, supersede the less definite observations of earlier experimenters, who give us no accurate statement of the forces applied, but merely describe the act of stretching of the nerve, whilst they simply noted without measuring the actual results. Stintzing has also tested other nerves besides the sciatic, and he has compared the effects of stretching nerves upwards and downwards, that is, from the branches upwards and from the trunks downwards. He has also studied what may be called the cross-effects of nerve-stretching, and has shown distinctly that by stretching nerves on one side of the body, various degrees of disturbance of nerve-function occur on the opposite side, a highly important factor in all probability in regard to the explanations which may be attempted of the effect of nerve-stretching as a palliative or curative proceeding in cases of disease of the central nervous apparatus. At all events, I repeat, Stintzing's essay, recording his measurements and tabulating his positive results, is certainly the most trustworthy monograph we at present possess upon this subject, and no doubt it will largely influence scientific opinion and guide future research and practice. (Appendix, p. 39.)

7. *Effects of nerve-stretching on the nervous centres.*—Among the interesting questions which have arisen as to the effects of nerve-stretching is this: Are the actual mechanical effects of pulling upon a cerebral or spinal nerve transmitted onwards to the brain or spinal cord, or are they not? On this point Vogt, one of the earlier German observers, said, no; whilst

Gillette, a French experimentalist, said, yes! asserting that if the sciatic nerve was stretched, the spinal cord was moved in the spinal canal.

Later observers have arrived at various conclusions. Thus Gussenbauer and Braun, working together, state that they have seen, in one case, a movement through the whole length of the cord up to the occipital foramen; in a second case the movement was perceptible but not measurable; and in a third case they saw no movement at all. In the case in which the movement was measured, the amount, when recorded in millimetres, looks large, but it was only one-fiftieth of an inch, although the greatest amount of movement, that in the lumbar region, amounted to one-tenth of an inch, which, of course, is a palpable movement. Dana, an American observer, confirms the fact of there being some movement. Symington doubts it. Langenbuch, one of the greatest authorities on nerve-stretching, who has stretched more nerves than any man, found exactly what was met with in one of Gussenbauer and Braun's cases, namely, that although the movement was propagated to the spinal ganglia and to the sheaths which cover the roots of the spinal nerves as they pass out of the intervertebral foramina, it was not communicated to the intraspinal roots of the nerves, and necessarily not communicated to the cord. Mr. Horsley has made four experiments upon the great sciatic nerve in the dead body, and he found no movement of the spinal cord; and, yesterday, having the opportunity of again testing the point in this College, I repeated this experiment together with him, and we found no appreciable resulting movement. We did find what may be an explanation of a movement in certain cases, namely, that, when you apply traction to the large nerves, the spinal column has its curves slightly altered, so that it becomes straighter in certain parts, and this, of course, produces some movement in the cord. When that alteration was prevented, we saw no proper movement. We recognised a slight movement in the dura-mater, and if you remember the attachments of the ligamentum denticulatum on either side between the dura-mater and the cord, you will understand that if the duramater be moved you may gently disturb the cord. I believe,

in these two ways, such casual movements as have been observed by Braun, Gussenbauer, and Dana may be fully accounted for; and, at all events, that practically there is no stretching effect propagated through the roots of the nerves to the cord itself. We found that the stretching effect passed on to the sciatic plexus, and also on to the main roots of the nerves and their fibrous sheaths prolonged from the dura-mater, and hence it must act slightly upon the spinal ganglia of the posterior roots. It might also sometimes move the cord a very little through the ligamentum denticulatum; but we found no tension or dragging of the intraspinal or intrameningeal rootlets of the nerves, and no constant movement, and certainly no direct stretching effect in or upon the cord. But in this disturbance of the spinal ganglia we may possibly have another important factor of a trophic character, in the *modus operandi* of nerve-stretching in the palliation of *cases of central* nervous disease. (Appendix, p. 40.)

8. *Effects of nerve-stretching as an operation for the relief or cure of pain.*—Having thus directed your attention to the special effects of 'nerve-stretching,' as shown by actual experiment on dead and on living healthy nerves, let us next consider its therapeutical effects. Conscious that you all have access to medical periodicals, and that some among this audience have tested for themselves the success or failure of this operation, I content myself with pointing out to you a Table founded on one published by Artaud and Gilson, but added to from Ceccherelli, who has written a most interesting review of this subject in the Italian journal *Lo Sperimentale*, which travels very much along the same lines, but in a therapeutical sense, as Stintzing's practical observations. Ceccherelli's figures, added to Artaud's and Gilson's, give us a long catalogue of 252 cases of nerve-stretching in various diseases. Now if you look down the second and third columns, you will find no doubt that the results are most variable. Take, for example, tetanus and epilepsy, the successes are very rare. But the two upper components of the table, namely, the affections classified under the term 'neuralgia' and the special tabetic spinal disease which produces 'locomotor ataxy,' sclerosis of the posterior columns

TABLE IV.—RESULTS OF 252 CASES OF NERVE-STRETCHING IN DISEASE (*Artaud, Gilson,* AND *Ceccherelli*).

——	Number of cases	Success	Partial Success	Doubtful	Failures	Deaths
Neuralgia of all kinds . .	99	74	12	7	6	—
Central disease with pain (tabes)	36	5	16	—	7	8
Central disease with contractions	14	12	1	—	1	—
Facial tic	7	6	—	—	1	—
Traumatic spasms . . .	12	10	1	—	1	—
Tetanus	45	14	—	2	—	29
Epilepsy	4	1	3	—	—	—
Peripheral paralysis (motor and sensory)	34	34	—	—	—	—
Lepra (included in the above) .	—	—	—	—	—	—
Optic nerve (hallucinations) .	1	—	—	1	—	—
Totals . . .	252	156	33	10	16	37

of the cord and the posterior nerve roots, include the morbid conditions which are chiefly responsible for the 'pain' which is the subject of consideration in this lecture, that is to say, neuralgia with all its prolonged torture, and tabes or locomotor ataxy with its lightning flashes of acute suffering. Now, what effect has nerve-stretching on these two sets of cases? With regard to neuralgia, you see the proportion of successes noted in the first column is very great. With regard to tabes the successes are exceedingly few; but the instances of partial improvement, in which an amelioration or even a temporary cessation of pain is mentioned, are not to be ignored; for at least the pains were improved, and that is a part of the general question which I wish to bring before you to-day. I could add to this Table a list of many successes and many failures from other sources, but I will caution you against accepting all such details. We know that statistics must be received with distrust; that cases of failure frequently remain unrecorded; that it is extremely difficult to analyse and describe the subjective condition of pain; that patients often speak of their symptoms too hopefully; that in another direction the surgeon is only too glad to accept such accounts; and, lastly, that recurrences constantly pass utterly unnoticed, cases being put down as successes, which, if watched sufficiently long, would not justify that term. Making full allowance for all this, still you will find such a preponderance of facts in

favour of nerve-stretching curing or relieving neuralgia, that you cannot resist the conclusion that it is really beneficial in that disease.

The two additional Tables (V. and VI.), the one taken from Nocht and the other giving the experience of my own hospital,

TABLE V.—RESULTS OF NERVE-STRETCHING (*Nocht*).

	Total cases	Cured			Failed	Died
		Quickly	Slowly	Total		
Sciatica	24	16	5	21	2	1
Facial neuralgia	17	10	5	15	2	—
Traumatic neuralgia	19	10	2	12	6	1
Locomotor ataxy (true)	10	Pain: Removed 4, Relieved 3, No effect 1 } 8 + 2 deaths				
Total cases	70					

TABLE VI.—U. C. H. AND SELF.

	Cases	Improvement		Failure
		4 decided	4 partial	
Sciatica	9	4	4	1
Locomotor ataxy	2	—	2	—

both having been compiled from cases treated long after those recorded in Table IV., which, I may state, includes most of the British cases, certainly offer some encouragement to the belief that nerve-stretching is not only available for the successful treatment of neuralgia, but also for the amelioration of the distressing pains of tabes. Time does not permit me to enter further on the clinical aspect of the question, on which we must still wait for the amount of experience which will, in the future, yield its *indisputable* verdict. (Appendix, p. 40.)

9. *Rationale of the effects of nerve-stretching for the relief or cure of pain.*—I proceed now to consider the possible modes in which nerve-stretching relieves or cures the pains of neuralgia and tabes, to which two diseases I must henceforth exclusively confine my attention.

With regard to the pain of neuralgia, it has such peculiar characters that we can readily distinguish it from the pains produced by tabes. First of all it is often, in fact commonly,

unilateral; those of tabes are liable to fly from side to side. The pain of neuralgia runs along the course of a nerve; it is concentrated, as it were, along the path or territory of a particular nerve. The pains of locomotor ataxy, on the other hand, are diffused over the areas of many nerves; they may occur on both sides of the body; they may be in the limbs or in the trunk—in fact, we do not know where they may not be. Again, the pain of neuralgia is nearly always increased by movement or pressure, and this owing, of course, to its localised character. The pain of neuralgia often starts from, or is more severely felt at or near certain apertures where the nerves pass out from the osseous or fibrous framework of the body, or turn around given points of bone. Thus one most painful point in sciatica is where the nerve passes out close to the sacro-sciatic ligament, for every movement or twitching of the adjacent muscles is liable to press upon the tender nerve, and to influence its circulation by acting on the branches of the sciatic artery and vein which supply the nerve. Another painful point is just below the head of the fibula, where the external popliteal turns round the bone, is there bound down by the fascia, and so is liable to tension or pressure. The fact, indeed, is that most neuralgic pains are not only increased by external pressure, but they manifest themselves at particular points of the nerve, which, owing to the construction of the body, are liable to internal pressure, including compression of their bloodvessels, and such hindrance to the local circulation as would intensify a condition of hyperæmia to which they might be subject.

The symptoms just detailed are those which accompany the simplest or purest form of neuralgia, namely, *peripheral* neuralgia; which, whatever may have been its original cause, whether peripheral or central, is apparently dependent on a neuritis or inflamed condition of the nerve considered as a whole. But I venture to think that the neuralgic pain in such cases is not a pain in the proper fibres running along the nerve (otherwise it surely would be transferred by the consciousness to the extremities of those fibres), but that it is a pain in the nerve itself; and must be due to *nervi nervorum*, which I here venture to predict will be found to exist in *all*

nerves. Sappey has described sympathetic nervi nervorum running upon the optic nerve, in that case, of course, supplied

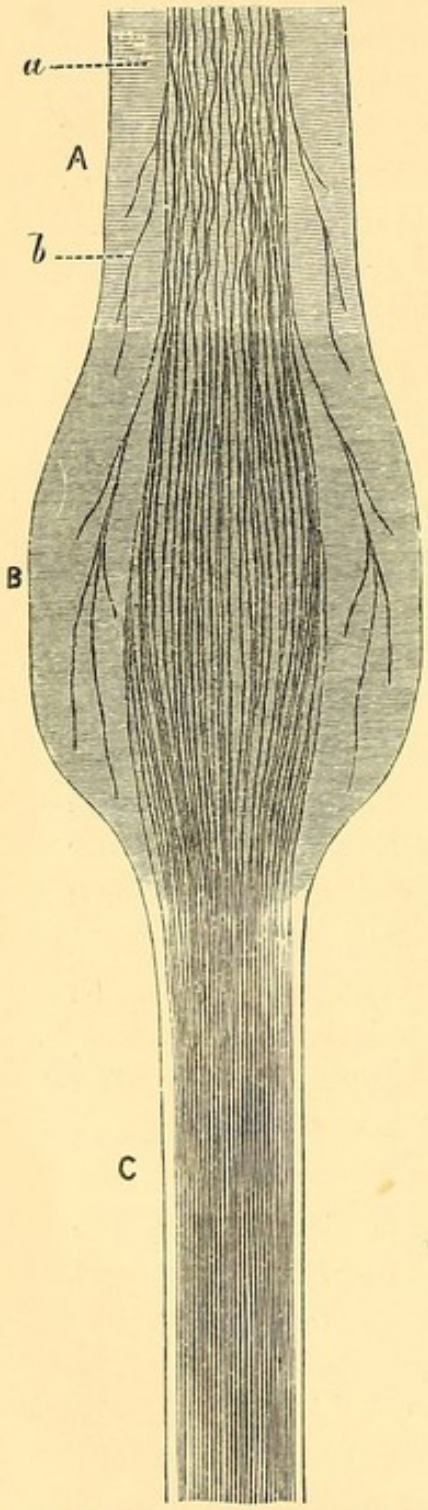


FIG 6.—Diagram of small nerve, magnified about 5 diameters.—(*Horsley*).

It shows *nervi nervorum* as imagined to exist. A, healthy unstretched part; B, inflamed and unstretched part: C, stretched part, to indicate inevitable injury to any nervi nervorum; *a*, sheath of nerve; *b*, nervus nervi.

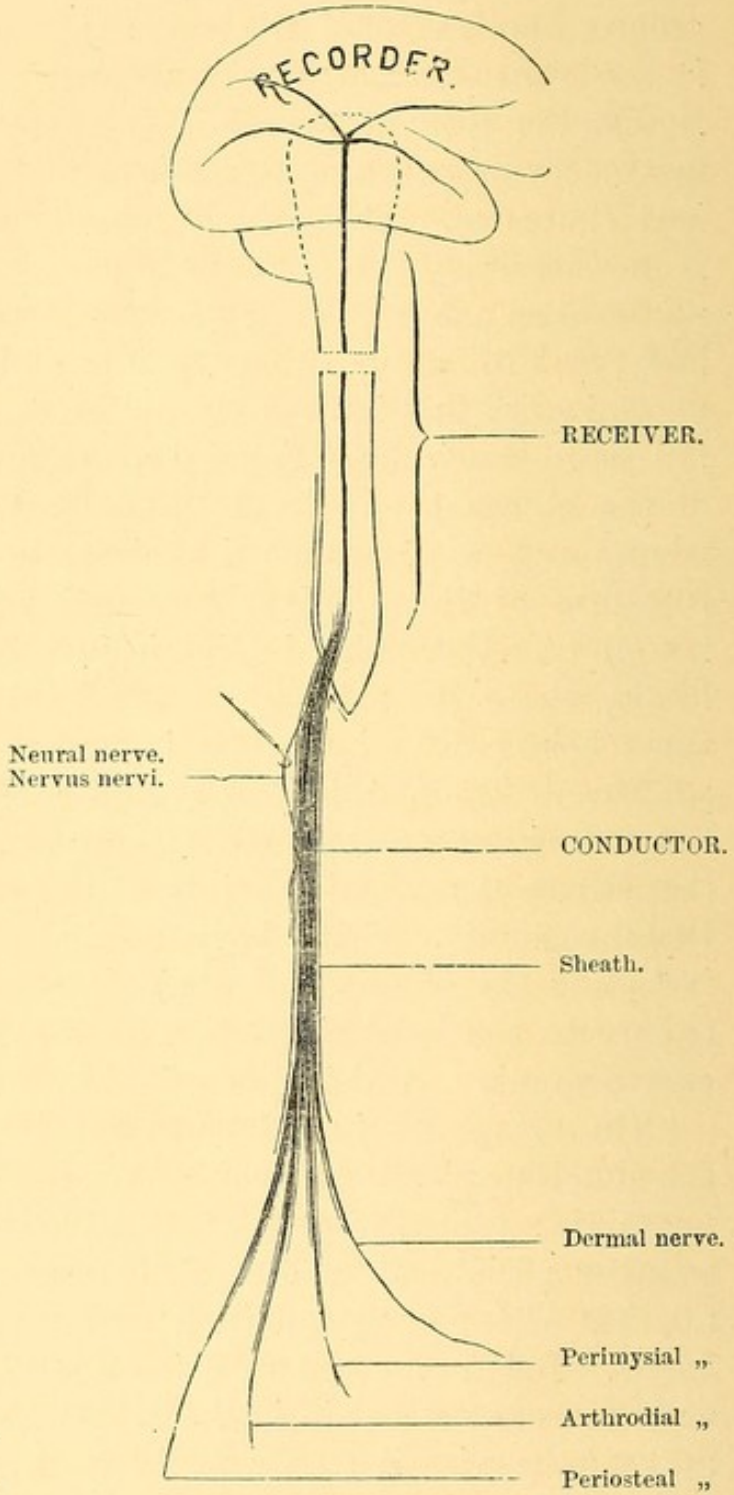


FIG. 7.—Diagram of various sensory tracts.

from the ciliary nerves. I think, on the other hand, we may anticipate that in ordinary sensory or mixed sensory and motor nerves, true sensory fibres will be found in the epineurium and perineurium, probably proceeding from the nerve higher up. This has not yet been demonstrated, but I hope and believe that some one will take up the subject and will succeed in finding them. In the meantime, I imagine them to exist; and in the upper part of this diagram (Fig. 6, A) of a healthy nerve, you will see a *nervus nervi*, *b*, supposed to be coming out from the trunk of the nerve and ramifying in its sheath, *a*, just as nerve-fibres ramify in tendons, ligaments, and other fibrous tissues, in which it is the nerves alone which suffer pain. We speak of neuralgic pain as if there was something peculiar in it, and so there is, seeing that it is pain *in* a nerve. But all pain is due to impressions on nerves. The periosteum does not feel pain, except through its nerves. So with the skin, muscles, and tendons, no tissue feels pain except through its own nerves. Hence, I contend, the argument is strong in favour of the idea that nervi nervorum are present in the sheath of a nerve. If you prick the endings of a dermal nerve, the effect of that touch is carried up (as may be traced in the diagram, Fig. 7) to the recorder, that is, it is received on the spinal cord, is conveyed to the brain, and produces a sensation of pain at a corresponding cerebral skin-point. So with a periosteal sensory nerve, so with a nerve belonging to a joint, so with the nerve of a muscle or tendon, and so, likewise, with a *neural* nerve (if I may so call it) a *nervus nervi*, coming from the sheath of a nerve, and inducing a sensation which is referred to its own extremity. Now, supposing this to be the case, what happens with these nervi nervorum? In an inflamed condition of a nerve (represented diagrammatically by the swollen portion in fig. 6, B) the hyperæmic condition, plastic effusion, exudation or irritating fluids, gouty or rheumatic, must excite these neural nerves and occasion pain. Again, the lower part of the diagram (c) represents a stretched and narrowed portion of the nerve: and what must there become of the proper nervi nervorum? They must be stretched, or even broken; their tubules must be sacrificed very much more completely than the tubules running

along the interior of the nerve. These latter, soft, elastic, and free to move, would become very elongated, but not necessarily ruptured, except in rare instances. But what must happen to nerve tubules, the free extremities of which are fastened into the fibrous sheath. They must be so stretched or broken as to be completely paralysed; and, in this way, I believe, we can account for the relief of the most common form of neuralgic pains.

Of course, I do not ignore the possibility that, besides these neurilemmal or perineurial inflammations, there may be other conditions in the internal tubules themselves which will cause pain; these would also be probably arrested or interrupted by the shattering of the medullary tissue and the stretching or breaking of the axis-cylinder, which I have already mentioned as taking place. I would not for a moment assert that all neuralgias are due to excitation of nervi nervorum, but I do think that a large proportion are; and that these may be considered to be the true peripheral neuralgias. In such cases, nerve-stretching probably acts in the manner just described, but in other cases by partially benumbing or paralysing the internal tubules, and by so arresting their functions for a shorter or longer time. In either sets of cases, the nerve-centres, which have been subjected to continuous over-excitement, also have an opportunity of resting and of recovering their normal condition; for it is possible, though it is not proved, that in certain instances these centres are themselves the seats of changes capable of producing special neuralgic pains.

As regards *tabetic* pains, these are produced in association, not so much with morbid changes in the nerve-trunks outside the dura-mater or in their peripheral branches, but rather, as far as we know, with changes in the intramenin-geal posterior rootlets of the nerves, and in the posterior columns of the spinal cord. Still, observe, the changes are chiefly in the conductors; they are not found specially in the grey substance alone, but they occur rather disproportionately in the conducting white substance; and although we speak of this tabetic affection as a central disease, we should take care to eliminate from our minds the idea that it is solely a grey

matter disease; or rather, we should not overlook the fact that it is more a disease of the conductors than of the receivers of nervous impressions. Certainly the conductors suffer obviously more than the receivers, although these latter, no doubt, likewise undergo change. The grey matter degenerates, but the white matter is more conspicuously affected, especially by sclerosis of its neuroglia and degeneration of its compressed tubules.

But how can nerve-stretching affect these intrameningeal conditions? We must here have recourse to some explanation different from that of the mere mechanical effects of stretching, because we have shown that these do not pass beyond that part of the roots of the nerves which is enclosed in the sheaths of the dura-mater. But stretching must act upon the spinal ganglia, and may thus produce an excitation of vasimotor or trophic activity. To reactions of that kind, and to the changes induced in the nerve elements in consequence, we may perhaps attribute the benefit obtained in the way of relief or cure (?) of the lightning pains, in those cases of tabes dorsalis which give rise to the phenomena of locomotor ataxy. Whilst, therefore, the explanation of the cure of peripheral neuralgias is comparatively easy, the mode of action of nerve-stretching for central neuralgias may be much more complicated. But I must ask to be excused from following any further these more or less hypothetical explanations, the scope of my lecture being rather to illustrate the practical side of the subject; whilst I will leave to others engaged in pathological investigations to pursue those lines of observation at which I have briefly hinted. (Appendix, p. 44.)

10. *Indications for the performance of the operation of nerve-stretching.*—I next proceed to ask in what special cases, besides neuralgias and tabetic disease, the operation of nerve-stretching may be usefully employed for the relief or cure of pain; and the preparations before me, mostly obtained from the Museum of the College, will serve to illustrate this part of my lecture. Amongst those specimens are some from cases which might have been so treated, and others from cases which could not. Here are two examples of neuromata from stumps, which

possibly would have been amenable to this mode of treatment. This is a painful ulcer of the skin, for which in former days a limb was sacrificed; it might probably have been cured by stretching the posterior tibial nerve, and any other nerve involved. This, again, is a nerve which has received some injury, but only appears to have upon it a small mass of coagulated blood; still it caused acute suffering, which would probably have been curable by nerve-stretching. Here is another case of a painful ulcer which, I also think, might have been well treated by the same method. In this jar we have a beautiful example of thickening of the median and ulnar nerves opposite the annular ligament of the wrist, causing such excruciating pain that the forearm was amputated,—a case which I firmly believe would have been completely cured by nerve-stretching, an operation so well suited to combat peripheral neuralgias. This, again, is a case which suggests another course; it is the fractured limb of a donkey with a nerve entangled in the cicatrix or in the soft callus. Here, probably, the treatment would be not nerve-stretching but dissecting up the nerve, and restoring it its freedom if possible; or, if not, paring off the ends of the nerve and suturing them together, as has been done with success by Mr. Holmes and others. Then, there are tumours of nerves for which one could not recommend this operation; for example, for neuromas situated in the very substance of a nerve, in which case stretching would certainly be useless; but one would carefully dissect out the tumour, or if not, one must sacrifice the nerve. Then we have still more formidable examples of tumours of nerves, existing in one or in many nerves in various parts of the body. Here is a sciatic nerve in which there are at least a dozen or fifteen little nodules; and this again is a specimen in which every nerve in the arm has one or two nodules upon it. These multiple neuromas are sometimes cancerous, sometimes sarcomatous, and occasionally they are fibromas; but all cases of this kind would be utterly unsuitable for nerve-stretching. Here is a remarkable specimen of a tumour, attached to and pressing on the intraspinal sensory rootlets of certain lumbar nerves, from which the most excruciating agony was suffered. In that case I, some years ago, divided as many of the branches

of the crural nerve which corresponded with the lines of pain as I could reach outside the pelvis, but without relief. After death, this tumour was found inside the spinal canal, sufficiently explaining the pain and the reason of the failure of the operation. Could we hope to get any benefit in another such case from nerve-stretching? The probability, I am afraid, is not; because we have seen that the stretching does not pass beyond the dura-mater, so as to affect these posterior rootlets. Moreover, no induced change in the nutrition of the tumour, through vasimotor influence, could be expected of a nature to give relief, such as seems possible to occur in the central disease associated with tabes dorsalis. The only operation here would be trephining the spinal canal at a predetermined place of selection. (Appendix, p. 44.)

11. *Mode of performing the operation of nerve-stretching.*—In reference to this practical and almost concluding portion of my subject, I would wish to make this general remark—that one would set very little value on the various physical experiments, anatomical investigations, and physiological observations, at which I have glanced, if they did not furnish us some guides as to the best mode of conducting this comparatively 'new' operation.

In the first place I need scarcely point out that in every case of neuralgia the operation must be directed to the nerve which is obviously concerned. The operation itself consists in exposing the nerve, lifting it from its bed, either upon a hook or upon the finger, and then stretching it to a certain point so as to produce that *palpable* stretching of which I spoke at the beginning of my lecture, without which the operation will fail.

But suppose, for example, that we have to deal with the great sciatic nerve—with what force and to what extent may we stretch it? In answer to this question the Tables I. and III., already given, yield valuable information, but not if we translate them too literally, for if we merely take the mean of the numbers therein recorded, that would be an unsafe guide. Thus the mean breaking-weight of the sciatic nerve is 185 lbs., but this nerve has been broken by a weight of

82 lbs. Therefore the arithmetical mean is not to be adopted: every practical surgeon would either smile or shudder at it. Nor could we take the lowest weight, 82 lbs., because some sciatic nerves might break with a still lower weight. Stintzing's observation, that a living sciatic nerve may be safely stretched with a weight equal to half that of the animal to which it belongs, affords a somewhat safer guide, according to which one might limit the strain applied to the living human sciatic nerve to about 75 lbs., which is half the average weight of an adult man. Stintzing has further observed, which is a great comfort, that the sciatic nerve may be stretched in a living animal by half the weight of its body, so as to produce complete anæsthesia and complete motor paralysis in the parts supplied by it—in other words, complete loss of all nerve-function—and yet all these states are temporary, and are followed in time by a perfect recovery. The inference would be, then, that in man every function would be ultimately restored if the limit of force supplied to the sciatic nerve were that of half the body-weight. In short, if one applied a weight of 75 lbs. to the human sciatic, and the nerve did not break, we might feel assured that whatever sensory, motor, or even reflex and vasimotor paralysis or trophic disturbance ensued, it would all be eventually recovered from in an ordinary state of the health.

But, as I have said, we must translate the results of these experiments in a special sense, that is in their application to diseased and not healthy conditions. The nerves we are supposed to operate upon are not quite healthy nerves, nor are the patients quite healthy persons. We must therefore descend far below the limit of 75 lbs. I would myself counsel that no inflamed or diseased sciatic nerve should ever be stretched by a greater weight than 30 or 40 lbs. I should say that even 30 lbs. is a reasonable weight. By means of a dynamometer, such as I have here, it may be shown how difficult it is to apply, under the most favourable mechanical conditions even, a force equal to 30 lbs. to a portion of a nerve. If I first pull as hard as I imagine I should do upon a living sciatic nerve during an operation, I find that the force employed is about equal to 20 lbs.; but if I pull very hard it is increased

to 30 lbs., and that, I believe, is as hard as a surgeon could well pull when holding a soft nerve between his finger and thumb. It takes both hands for a strong man to exert a force equal to from 80 to 100 lbs. ; but if, after the lecture, you will try pulling upon this nerve when held by the finger and thumb, as you would do in an operation, you will find that 30 lbs. is about the limit of your pull. This piece of nerve is somewhat changed by decomposition, but it will quite well bear the strain of 30 lbs., which I take, finally, to be a perfectly safe force to employ. Assuming such a limit for the sciatic nerve, of course this would require to be graduated for smaller and smaller nerves downwards to 3 or 4 lbs.

A special form of dynamometer was devised by Gillette to be employed in operations of this kind, but I believe he soon abandoned its use, and I should agree with him in that resolve. Surgeons should educate their power of appreciating the resistance of a nerve so as to be able safely and adequately to stretch it—adequately in order to relieve or cure, safely so as not to injure a patient. We do, indeed, educate ourselves in a great number of instances without the use of measuring instruments. We can tie an artery without tearing through the outer coat, and either with or even without tearing the middle coat ; we can test the state of tension of the eyeball and determine whether it is greater or less than it should be ; we can displace or extrude a cataractous lens safely ; we can use a certain amount of force in reducing a hernia, so as not to burst the intestine and yet succeed in our purpose. Now, if the surgeon can do these things without dynamometers, why should he not be able to undergo a similar dynamical self-discipline, and cultivate his sense of resistance and the results of his employment of force so as to acquire tact in the stretching of a nerve? To do this is far preferable to the employment of any measuring instrument, which being set might deceive him at any moment. A given nerve might be so strong that his instrument would be safe, but the next nerve, apparently similar, would be in danger of suffering too great injury or even of complete rupture. But if the nerve be held by the hand, and so stretched, you may feel the resistance which is opposed by it, and you may judge, especially after a few trials

upon dead nerves, how much force is needed to produce that adequate stretching of which I have spoken. The living nerve perceptibly yields to traction; you may not hear a tearing, but you feel an internal creeping movement in the constituents of the nerve—mostly, no doubt, in the sheath and its prolongations. You can detect a certain attrition and vibration in the structural elements of the nerve, and being educated to distinguish these you will operate safely.

There yet remain several other details in connection with the operation, which, I think, do not usually receive sufficient attention, but which here deserve consideration, namely, the *situation* at which the stretching should be made, its *mode* or *character*, whether by jerks or by a steady pull, its *direction*, and its *duration*. In most of these respects Stintzing's observations come incidentally to our aid, for we may use his facts in many ways. Thus he found that the best way to obtain results with given weights corresponding with one quarter, one third, or a half of the body-weight, and so forth, and to ensure commensurate and commensurable events, was to keep up a steady traction with given weights for a definite uniform time. Now the times that he adopted in some of his experiments varied from three to six minutes; but in certain special experiments, when he wished to secure exactly parallel conditions, he maintained the stretching force uniformly for *five minutes*. I believe that if stretching with a moderate power prolonged over a certain period had been the customary *modus operandi*, safer and better results would have been on record. A short sudden pull is not sufficient, however hard it may be; a series of jerks are inadequate, for each jerk only repeats the mischief produced by a previous one; but you must pull firmly and *steadily*, and if you thus put a strain upon the nerve and stretch it continuously, say for from three to five minutes, by means of a moderated force, you will gradually and perceptibly produce those internal changes in the nerve which I have described as being essential to a genuine nerve-stretching. As regards the *direction* of the pulling, whether it should be downwards from the nerve centres, or upwards from the branches of distribution, it does not seem in the physiological experiments to have made much difference in the results.

Stintzing is, however, of opinion that for therapeutical purposes it would be preferable in neuralgic cases to stretch upwards from the branches, but downwards from the spinal cord in tabes. For myself, I should advise stretching both ways for neuralgia, which is commonly a *peripheral* affection, and yet is one which extends usually higher than the portion of the nerve which can be reached by the surgeon. It is in connection with this fact that the only remaining point in regard to the operation has now to be considered, namely the *situation* at which the nerve should be exposed and stretched; for it should be a rule to do this near to the seat of severest pain, which is usually at the upper part of the nerve where it issues from the body or escapes from the bones of the face or skull, or where it comes off from an accessible plexus.

In the treatment of tabes by stretching the sciatic or the crural nerves, or both, it would seem, as the diseased conditions are essentially *central*, to be of less consequence to stretch the nerve upwards from its branches; but it would be well to do so. At all events, it is here essential to stretch downwards from the body. (Appendix, p. 44.)

12. *Dangers of the operation of nerve-stretching.*— With regard to the risks which attend this operation, there are two kinds, immediate and remote. The only immediate risk specially associated with it, is that of completely rupturing the nerve, which, however, has happened in the case of very small nerves in the face without serious inconvenience. The remote dangers, both in neuralgias and in tabes, are either failure to relieve pain, or the aggravation of it, or a fatal issue, as shown in Tables IV. and V. Each of these results is relatively more frequent in tabes than in neuralgia, as, indeed, might be expected. But the deaths are comparatively few. Of the eight fatal cases recorded in Table IV., one was due to the effects of chloroform, another to thrombosis in the large veins, another to inattention as regards the antiseptic dressings, and a fourth to the same cause. Four cases, however, have occurred in which the death may undoubtedly be attributed to an acceleration of the morbid changes in the spinal cord occasioned by nerve-stretching; but in one of these cases

there was much active spasm as well as pain. There remain one fatal case of severe traumatic neuralgia, and one only of pure sciatica. We may here leave quite unnoticed the large number of deaths in the cases of nerve-stretching for tetanus.

I would here observe that fatal results have followed other apparently less severe operations than this. For example, a boy, both of whose hip-joints and knee-joints were badly contracted, had these extended in both limbs by force. He collapsed, and died within three days. At the post-mortem examination hæmorrhages were found along the spinal cord. Shampooing even has been known to result in a fatal issue, no doubt from too violent a mode of performing it. With a proper selection of cases, due care in the conduct of the operation, and the employment of a strict antiseptic method, which is indispensable, the exposure and stretching of nerves, I may venture to say, cannot be condemned as a dangerous operation. (Appendix, p. 48.)

13. *Non-cutting or bloodless operations for nerve-stretching.* In completing this lecture, I must remind you that the cutting operation, to which I have hitherto confined your attention, is not the only method by which certain nerves may be stretched. For it has been shown, as regards the great sciatic nerve, that if you flex the thigh upon the body, so that the knee comes close to the chin, then extend the leg upon the thigh, and lastly, flex the foot forwards upon the leg, so as to tighten the ankle-joint behind, you can produce an extraordinary strain and tension upon that nerve as it passes out of the pelvis. Trombetta, the great advocate of this method—Billroth usually has the credit for introducing it, but I believe Trombetta first performed it—found that in the dead human body the sciatic nerve could be elongated to the extent of one inch by this method. The proceeding must be accomplished resolutely and firmly, and in order to be successful I would say that it should be continued for five minutes, according to the rule which I have indicated in regard to the cutting operation. Mr. Horsley, having stretched the sciatic nerve on the dead body by Trombetta's plan, found that the diameter of the nerve was diminished as in

the ordinary mode of stretching. In a living person, upon whom I was about to stretch the sciatic nerve for an ordinary obstinate sciatica, I found when that nerve was simply exposed, that it could be very tightly stretched by the forced flexion of the straightened-out lower limb upon the body. There thus exists an undoubted means of stretching the sciatic nerve without a cutting operation, but one would doubt its complete efficacy, and the method is hardly applicable to any other nerve. Nevertheless, the results of this non-cutting or *bloodless* (*unblutige*) operation, as contrasted with the cutting (*blutige*) one, appear to be satisfactory, as recorded by Trombetta, Lange, and Stintzing, who adds some clinical cases to his experimental observations. Thus, in tabes dorsalis, in which disease this bloodless operation, so far, less formidable as it inflicts no wound, has been alone employed at present, it has turned out successful in one instance, decidedly beneficial in a second, partially so in a third, and still less so in a fourth; so that it has realised some good results.

Lastly, quite recently, I have alighted upon some observations made by Motschutkowski, based on what he has proved to happen in the use of Sayre's suspension apparatus employed in spinal curvature. It is found that thus suspended the living human frame becomes lengthened by an inch to two inches and a quarter, and that the trunk alone is elongated by about seven-eighths of an inch. Having opened the spinal canal, and then suspended the dead body by a Sayre's apparatus, Motschutkowski observed that the spine itself became elongated also by seven-eighths of an inch; but he mentions, in accordance with what I had noticed when the curves of the vertebral column were straightened out, that, although the membranes were moved, he was not quite sure that there was a very slight amount of tension on the posterior rootlets of the nerves. But considering the powerful mode of stretching which he employed, acting throughout the entire movable portion of the vertebral column, it is probable that the consequent straightening of the spinal curves would produce a certain amount of tension on those posterior rootlets and thus act feebly on the cord. It might certainly act on the spinal ganglia. Motschutkowski's patients were all suffering

from tabes; they were suspended for ten minutes at a time, three times a week. He reports fifteen cases; in thirteen of these there was a positive diminution of the lightning pains, as well as of some of the other abnormal symptoms which characterise that agonising disease; there was also slight but decided improvement in the ataxic condition, and some recovery of muscular power; in two cases there was no observable change for the better. This method will have to be further tested. (Appendix, p. 49.)

14. *Conclusions.*—On surveying the whole subject, I may now, gentlemen, conclude my lecture by stating that the operation of nerve-stretching well deserves and demands further consideration; that the facts at present known concerning it throw some light on its probable modes of action; and that its application for the relief or cure of pain in neuralgia and in tabes will probably come to be conducted on different plans. If this lecture should be published, I trust to be enabled to add to it an Appendix, in which some of the gaps now purposely left open by me will be more or less completely filled up. In the meantime, I believe that this comparatively 'new' operation will find a more prominent place in British Surgery.

I desire to thank Mr. Horsley for his able assistance, Mr. Thring for collecting the results of the University College Hospital cases, and Mr. John Castaneda for verifying the tabulated records. And now, assuming my official position as President of this College, I beg leave to offer all present my sincere thanks for their attendance here to-day, to express my obligations to the Members, Fellows, and Council of the College for the honour they have done me, and to add, with regard to our visitors, that they have contributed by their presence to the success of this attempt to pay a just tribute to the generosity of the lady who has founded the lectureship, and to keep alive the remembrance of her husband, the physician in whose name it has been founded. (Appendix, p. 49.)

NEURECTASY, OR NERVE-STRETCHING;

BEING AN

APPENDIX TO THE 'BRADSHAW' LECTURE FOR 1883.

Note.—The term 'neurectasy' (from *νεῦρον* and *ἔκτασις*) may sometimes serve as a useful change from that of 'nerve-stretching,' and so I venture to introduce it here.

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1 and 2. *Extensibility of Nerves* and *Elasticity of Nerves.*—In reference to these two divisions of the subject, it may be remarked that a certain degree of extensibility and elasticity is obviously necessary, particularly in the nerves of the limbs, in order that they may not be injured during extreme movements of those parts. Especially is this the case in instances in which, as in the hind limbs of many animals (such as crouching and leaping mammals and the frog), the several segments can be doubled up very closely and extended very freely. So also it may be observed that, in the secondary operation of suturing divided nerves, where the ends have parted company, and are also required to have a certain portion removed from each before they are brought together, the nerves must evidently be more or less stretched with impunity.

The safety of the nerves in the former case, and their harmless elongation in the latter, are probably in part provided for by a certain excess of length, and consequent longitudinal looseness or freedom of the nerves and their branches; but it has recently been observed (Cantlie) that in the sciatic nerve of the frog, and in many nerves in the human body, a coiled or spiral appearance in their structure appears and disappears as they are relaxed or stretched out. I have constantly noticed a delicate, transversely-striated appearance in a loose nerve, and also a delicately wavy outline, both of which disappear when the nerve is slightly stretched, but I have not recognised any proper coiled or spiral disposition of the constituent structures of the nerve. In any case, the

appearances described indicate a provision for a natural and harmless extension and relaxation of the nerves in their natural beds. In the more powerful and temporarily destructive 'neurectasy,' or 'nerve-stretching,' for the relief or cure of pain, such provisional arrangements must be completely overpassed.

3. *Cohesion* or *Strength of Nerves.*—There is nothing to be added in regard to this part of the subject.

4. *Effects of stretching on the structure of nerves.*—It has only to be noted under this head, that it has now been abundantly proved that the axis-cylinders of adequately stretched nerves are frequently broken across; and there is reason to believe that unless these essential elements of the nerve have suffered injury sufficient to suspend or even destroy their functional activity, the operation will be useless, or at best only temporarily successful. In the much more decided proceedings of neurotomy and neurectomy, in which these axis-cylinders are, of course, divided or excised, their continuity, and of necessity their functions, are completely interrupted, so that those operations have more decided effects than simple nerve-stretching.

5. *Effects of nerve-stretching on the nutrition of living nerves.*—As regards the changes of degeneration which the nerve-tissues undergo after they have been strongly stretched or submitted to other forms of injury, and again, as to the mode in which they are subsequently regenerated, recent researches of numerous observers tend to make matters very clear.

It has been shown that, after effectual nerve-stretching, the process of degeneration spreads both ways along the nerve, that is both centrally and peripherally, that it corresponds to the severity of the stretching, and that it does not always affect all the component fibres of the nerve. It is more decided when the nerve has been stretched over the surgeon's hook than from between the fingers, and is then most marked near the place of application of the hook, as might be anticipated. It has been further shown that after division of a nerve, or after resection of a portion of a nerve, both of its ends or parts show signs of degeneration, but the changes occur more rapidly in the peripheral part. If the separation of the cut ends be permanent, all the pre-existing nerve-fibres will ultimately degenerate except such as may belong to anastomotic branches proceeding from other nerves. The axis-cylinders are

certainly the last parts to disappear. Schiff, indeed, declares that this part of the nerve fibres is one of the 'most resistant tissues of our organism'; and Wolberg affirms that they do not undergo degeneration, for he has found them in the sciatic nerve of a cat fifty days, and in another case ninety days, after removal of a portion of that nerve. But there is reason to admit that they generally do undergo degeneration, if permanently cut off from their proper nerve centre.

The union of divided and resected nerves, the regeneration of their constituents, and the subsequent restoration of their functions, constitute examples of living processes so striking, and not many years since so unforeseen, that the records of successful cases of *nerve-suture* read almost like a physiological and surgical romance. It is true that Dupuytren is credited with having performed this operation, that it was practised by Arnemann in 1826 and by Flourens in 1828, and that, in 1852, Augustus Waller published an account of his then exhaustive researches on the degeneration and regeneration of the nerve-tissues. But it is only within the last twenty years that nerve surgery has been extensively practised, and that cases of successful operations have multiplied on all hands. In 1884 Weissenstein had already collected seventy-six cases, and at least twenty-four must now be added to these. In this country, Holmes, Wheelhouse, Birkett, Harrison, Banks, and quite lately Sutton, appear in the list of recent and more or less successful operators. Reverting to Weissenstein's seventy-six cases, forty-three of them are examples of so-called *primary* nerve-suture performed immediately after an injury, while the remaining thirty-three are cases of *secondary* suture, in which the nerve operated upon had been injured and its continuity interrupted for a shorter or longer period ranging from a few weeks to fourteen years. In the meantime, the numerous experiments and the improved observations of Schwann, Schiff, Schultze, Ranvier, Wolberg, Cattani, Nicaise, Rawa, Tillmann, and Vanlair have revealed the remarkable reparative power of the nerve-tissue, and have elucidated the details of its mode of regeneration, on which the success of the operation of nerve-suture depends. Aseptic treatment has contributed largely to these favourable results. A brief summary of them is not without interest in this Appendix.

In the first place, if the facts have been carefully observed and properly interpreted, it would seem, in accordance with the views of Schiff, Tillmann, and Wolberg, that the cut ends of a divided

nerve, if immediately adjusted together by means of catgut sutures, may unite directly; for, in one case after a few hours, and in another case within four days, the functions of a nerve thus circumstanced are stated to have become completely restored. Usually, however, the process of reunion is somewhat slower, and the restoration of function, implying a regeneration of nerve-tissue, occurs gradually and is still further delayed. A common sensory nerve regains its powers sooner than a motor nerve, and almost without exception the sensory function of a mixed nerve is restored earlier than the motor function. According to Rawa, who performed on animals nearly a hundred experiments of various kinds, complete physiological restoration may require from six to twenty months. In the human subject, after the operation of primary suture for simple division or rupture of a mixed nerve without separation of the cut ends, both functions have been completely restored within a fortnight, signs of sensibility in the parts supplied by the nerve beginning even at the end of a week. After a secondary nerve-suture, where a mixed nerve has been entangled in a cicatrix, or its long-separated ends have become atrophied or indurated, so that portions of it have to be removed in order to have fresh surfaces to apply to each other, traces of the return of the sensory function have been recognised after an interval of from two to four weeks, and of the motor function in from twenty to sixty days, or this latter event has been delayed for more than a year. Complete restoration of motility has, however, been observed at the end of twenty-six days, though it has been postponed for two years. In a remarkable case in which the long-separated ends of the median and ulnar nerves could not be approximated, small flaps have been turned downwards from the proximal ends, and upwards from the distal ends of those two nerves, and have so successfully united, both anatomically and physiologically, that a considerable restoration of their functions ensued. In the experiments of Rawa on animals, it was found that nerves applied and held together side by side united completely; and hence it has been suggested that, if two adjacent nerves happened to be severed at unequal heights, and their ends could not be duly approximated, the long proximal end of one could be sutured to the long distal end of the other, whilst the short ends of each might be attached to the side of each adjacent trunk; in other words, the two nerves would be united above and below the lines of severance, whilst the intermediate part would be single, though composed above of one nerve and below of the other. Indeed, a case is actually recorded by Gunn, in which the lower part

of a divided ulnar nerve having been revived by an oblique section, was sutured to the denuded side of the median nerve, with the result of obtaining some restoration of both sensibility and movement four months afterwards; and a similar result appears to have followed an operation by Deprès, in which separated filaments of the distal end of a divided median nerve were interwoven amongst opened-out filaments of the trunk of the ulnar nerve. As is well known, through Philippeaux's and Vulpian's remarkable experiments on the lingual and hypoglossal nerves, sensory and motor nerve-trunks may be made to unite interchangeably, with ultimate retention of some proper function.

In the majority of the above-quoted operations or experiments, the occurrence of anatomical and physiological union is evidenced by the earlier or later restoration of function; but in certain other cases, usually of an experimental kind, the anatomical condition of the nerve has been ascertained by dissection and microscopic examination. It is conceivable, though it has not been demonstrated, and indeed would not be easily demonstrable, that in instances of rapid recovery of function a direct union of axis-cylinders with axis-cylinders, and of the sheaths of Schwann, takes place through a thin layer of uniting plasm; and in other somewhat slower cases of functional restoration, it is possible that, before any marked degeneration of the peripheral part of the nerve occurs, short new nerve fibres pass through the bond of union from the proximal to the distal part, and so re-establish its structural and functional continuity. Most frequently the process is more elaborate, consisting first of a cicatricial union, and secondly, of a regenerative act. In the former stage, the epineurium and its prolongations across the approximated ends of the nerve are joined by means of the usual cell proliferation and formation of a corresponding connective tissue; and the process may end there, in which event there is no restoration of function. In the latter stage there occurs, sooner or later, but often after much delay, a reproduction of new nerve-fibres, the axis-cylinders of which are said to grow down from nerve-cells in the grey substance of the corresponding nerve-centre, and to descend amidst the degenerated fibres and through the cicatricial bond of union, from the proximal into the distal part of the nerve and its peripheral branches; whilst they receive their hyaline and medullary protective and insulating sheaths, with their characteristic nodal divisions and nuclei, by a local reproductive process originating, according to Holberg, in some action of the nuclei and cells of the perineurium, which undoubtedly has peculiar

morphological properties, like the deep layers of the perimysium and periosteum.

To omit none of the marvels of nerve repair and reproduction, it may here be mentioned that, in a dog operated upon by Vanlair, nearly two inches of the sciatic nerve having been resected, the proximal end was fastened by catgut to the depth of $\frac{3}{8}$ of an inch into one end of a tube of decalcified bone, whilst the other end of the cylinder, which was about $2\frac{1}{4}$ inches long, was turned out of the course of the nerve and fixed into a neighbouring muscle; at the expiration of six months and a half, the conducting cylinder was found to have been partly absorbed, whilst the nerve itself had grown down in the form of numerous small branches, which passed for upwards of two inches into the muscle, some even entering the Haversian canals of the softened bone cylinder. In connection with this endeavour to train new nerve-fibres 'which way they should go,' it has been suggested that even catgut threads between the cut ends of nerves which cannot be closely approximated might serve to lead or train new nerve-fibres to pass from one cut end to the other. It has also been proposed in operations of nerve-suture to make use of any intermediate band of connective tissue which may be found connecting the severed ends of a nerve; but this idea is inconsistent with the fact that such bands do not of themselves serve to train or lead nerve-fibres along them. Vanlair has, moreover, shown by further experiments that new nerve-fibres rather readily follow congenial anatomical and physiological paths, namely along the course of other living nerves, which may thus perform the office of trunks to other branches than their own.

Lastly, it may be stated that both in experiments on animals, and also in operative proceedings on man, transplantation of portions of nerve has now been occasionally, and so far as apparent union is concerned, successfully performed; but in no case has any restoration of function been observed. Gluck has transferred pieces of nerve from rabbits to fowls and they have apparently united in place. Albert, in 1876, inserted a portion of the peroneal nerve, taken from a freshly amputated human limb, between the widely separated ends of the median nerve of another patient; and Vogt supplied a similar gap in the human subject by a piece of sciatic nerve from a dog; in both cases living union, as evidenced by healing in of the wound, seemed to occur, but without functional recovery.

Returning now from this long digression on the remarkable regenerative endowment of the nervous tissues, to its bearing on the

question of the ultimate consequences of nerve-stretching,—after which operation the continuity of the nerve remains uninterrupted and the epineurial and perineurial channels are preserved as fit paths along which new nerve-fibres may be trained and developed,—it is evident that one need not fear the non-occurrence of ultimate repair and restoration of function, even after the most complete degeneration of the proper nerve elements, the medullated fibres with their axis-cylinders. Partly from microscopic examinations, but also from inference, it is believed that here also new axis-cylinders, reproduced from the nerve-cells of the corresponding centre above, grow down amidst the older degenerated fibres, and acquire, as they descend, new tubular and medullary sheaths derived from the local action of the surrounding perineurial elements. Cattani's observations on the sciatic nerves of rabbits stretched by the bloodless method, confirm these conclusions. So powerful is the tendency to reparation in a nerve simply stretched and not either torn or divided, that the practical point to bear in mind is that nerve-stretching, in order to be capable of suspending the sensory function even of the nervi nervorum for a sufficiently long period to bring about a permanent cure, must be thoroughly and adequately accomplished, and that it may be so without risk, if the nerve-centres are in a healthy or sufficiently healthy state.

6. *Effects of nerve-stretching on the functions and properties of a nerve.*—Upon this part of the subject, there is but little to append to what is stated in the lecture. It had, however, escaped my notice that Weir Mitchell had observed that when a nerve is stretched by about one-fifth of its normal length, it loses its susceptibility to mechanical stimulus; and if elongated to the extent of one-fourth, surrenders its power of reacting to electrical excitation; in both cases, provided that the stretching be gradual, not sudden. Zederbaum found, with regard to the effects of *pressure* on the motor function of nerves, that when the sciatic nerve of a rabbit was loaded with a pinching weight of 75 grammes ($2\frac{1}{2}$ oz.), no effect was produced; a weight of 400 grammes ($13\frac{1}{2}$ oz.) arrested the reflex excitability; 500 grammes (17 oz.) increased the voluntary motor excitability, but 900 grammes destroyed it. Smaller weights acting longer had the same relative effects. Curiously enough, after weighting one nerve, the reflex excitability of the nerve of the opposite side appears to be increased, owing doubtless to some centric irritation. Jendrassic noted that even severe stretching of the crural nerve in a rabbit did not affect the patellar tendon reflex;

which may, however, evidently mean that through anastomosis, certain of the nerve filaments concerned may belong to other nerve-trunks. Billroth has made the pertinent remark, that pressure and stretching seem to act differently on nerves (at least in some circumstances, it may be noted); for whilst the effect of the latter is first to diminish and then to destroy sensation, that of continued pressure, as in crutch paralysis of the arm, first shows itself in loss of muscular power.

7. *Effects of nerve-stretching on the nerve-centres.*—In regard to this point, it has been shown by Godlee that by pulling on the facial nerve outside the base of the skull in the dead subject, no mechanical disturbance is produced in the intracranial portion situated beyond the petrous bone. In the same way, Horsley has noted that the Gasserian ganglion remains practically undisturbed by traction on the divisions of the fifth nerve, and is not obviously or injuriously affected even by tearing out the superior maxillary division. On the contrary, it is shown by Pauline Tarnowski that by violent stretching of the sciatic nerve in the rabbit, the spinal cord may be seriously injured: for not only does this give rise to extravasation of blood beneath the pia mater, but it occasions capillary hæmorrhages, and consequent traumatic irritation followed by atrophy of both the posterior and anterior horns of the grey matter. It must not be overlooked, that in comparison with the much longer and stronger defensive structures supplied by the meningeal sheaths of the spinal nerves in man, which are found to prevent all but a slightly appreciable disturbance of the spinal cord, the parts are much more slender and delicate in the rabbit. Nevertheless the observations of Pauline Tarnowski have an obvious clinical significance in reference to the employment of neurectasy in cases of central spinal disease.

8. *Effects of nerve-stretching as an operation for the relief or cure of pain.*—Since the delivery of my lecture (Nov. 1883), many separate communications on this subject of nerve-stretching have appeared in journals, or in the reports of the proceedings of societies, in this and other countries, each contributing its share to a more correct appreciation of the value of this operation in regard to its palliative or curative influence in disease. Amongst them may be mentioned the records of cases by Walsham, Morris, Pye, Brailey, and Stokes in this country, whilst other examples too numerous to be particularised have been published on the Continent and in

America. It is not within my purpose to analyse the details of these cases; nor, indeed, to give a complete list of them, inasmuch as they cover a wider clinical area than that which comprises a discussion of the use of this operation as a remedy against pain. But as in my lecture, so here, I prefer to quote the tabulated results of many operations.

It is right to mention that the earliest important Table was that of Fengor and Lee (1881), which included 95 cases; next in succession came that of Chauvel (1881), containing 116 cases; after that appeared Artaud's and Gibson's (1882), with 132 cases, which with 91 others added by Ceccherelli (1882), and 29 additional examples, constitutes the basis of Table IV. presented in my lecture. Next to this must be mentioned Chandler's Tables (1882), including 264 cases; then, the compilations of Harte, in Agnew's Surgery (1884); and, lastly, thanks to the remarkable diligence and painstaking care of Vincenzo Omboni (March 1883), the fullest Table yet compiled, comprehending the results of no fewer than 512 separate operations. It is scarcely necessary to state that the later Tables for the most part contain the cases tabulated in the earlier ones; and this is certainly true of Omboni's records, which are, moreover, most carefully constructed so as to give the date of each operation, the name of the operator, the disease, the duration of this, the particular nerve or nerves stretched in each case, the results described under four heads, namely, as cures, ameliorations, temporary improvements, and failures,—and, lastly, special remarks when these seem to be required. Besides this, the cases are arranged in the following groups:—I. Neuralgias, *a*, of the cranial nerves; *b*, of the spinal nerves, including 1, those of the trunk, 2, those of the upper limb, and 3, those of the lower limb. II. Spasmodic affections, including 1, clonic spasms, 2, tonic spasms, and 3, simple contractions. III. Epilepsy. IV. Tetanus. V. Peripheral paralysis, 1, of motion, and 2, of sensation. VI. Central diseases, including 1, Myelitis, 2, Paralysis agitans, 3, Athetosis, and 4, Ataxy. Lastly, two unclassed cases.

The Table of results given by Omboni is too generalised, and is also somewhat confused as to certain of its totals; so that I append here a more analytical Table, prepared from his very specialised records.

TABLE SHOWING THE RESULTS OF NERVE-STRETCHING IN 512 CASES, FOUNDED ON *Omboni's* DATA.

Diseases	Cases	Cures	Improvements		Failures	Deaths	
			permanent	temporary		from the disease	from the operation
Neuralgias	222	143	37	25	17	—	—
Cranial nerves	62	31	11	13	7	—	—
Trunk nerves	6	4	—	1	1	—	—
Upper limb	37	23	9	4	1	—	—
Lower limb	117	85	17	7	8	—	1
Spasmodic affections	41	21	5	11	4	—	—
Clonic spasms	25	11	4	9	1	—	—
Tonic spasms	13	8	1	2	2	—	—
Contractions (permanent)	3	2	—	—	1	—	—
Epilepsy	7	2	2	2	1	—	—
Tetanus	51	10	—	11	30	41	1
Paralyses (peripheral)	40	2	36	—	2	—	—
Motor	6	2	2	—	2	—	—
Sensory	34	—	34	—	—	—	—
Central diseases	149	5	49	51	44	7	10
Myelitis	44	1	11	9	23	2	3
Paralysis agitans	4	1	1	—	2	—	—
Athetosis	2	1	1	—	—	—	—
Ataxy	99	2	36	42	19	5	7
Unclassed skin diseases	2	2	—	—	—	—	—
Totals (addition of thicker figures)	512	185	129	100	98	48	12

On comparing this with previously published Tables, and making every allowance for errors of statement and premature claims as to the cure or permanent relief of pain, it is certain, first, that nerve-stretching has established itself as an operation capable of both a curative and a palliative action in a large majority of cases of neuralgia; and it must be admitted that a return of the disease after an interval of a certain duration, say of one year, ought sometimes to be regarded as an entirely fresh attack. It is equally certain that this operation has afforded relief in a large proportion of spasmodic diseases, such as facial tic especially, though here the proportion of undoubted relapse of the malady is greater than in the neuralgias. As to epilepsy, the operation is probably useless. In regard to tetanus, it would seem that with an increased number of cases fewer actual cures are recorded, after nerve-stretching, than in the older Tables, a discrepancy not easily explained but casting doubt on those records; indeed, it is difficult in the present state of pathological science to understand a beneficial modus operandi

of nerve-stretching in cases of confirmed tetanus. Passing over the peripheral paralyses, which here consist simply of cases of lepra anæsthetica, we arrive at the results of nerve-stretching in cases of diseases affecting the nerve-centres. Here the results are palpably unhappy or, it may be said, disastrous; the few tabulated cures (about two per cent. in myelitis and ataxy taken together) may be regarded as apocryphal; the instances of amelioration, it is to be feared, are more imposing numerically than actually, most of them being admitted to be only temporary; the failures are pronounced, and the deaths attributable to the operation are numerous.

In a prize Thesis, presented to the Medico-Chirurgical Faculty at Rome in 1884, and published under its authority 1885, the author, Vincenzo Morini, in making use of Omboni's materials, deducts twelve cases, in which resection of a part of a nerve was had recourse to after stretching; and he then incorporates 26 new cases, 16 of which were operated on by Italian surgeons, 3 occurred in Germany, and 7 in France. To these there might here be added a few others from Germany, several from America, and those which have been performed in this Country since Omboni's Table was completed. Of Morini's additional cases 17 were neuralgic, and of them 9 were cured, 6 were relieved, and 2 died of consecutive phlegmonous inflammation; but the other cases of tetanus, myelitis, and ataxy were mostly failures.

As regards facial spasm (tic douloureux) Professor Zezas of Vienna, 1885, has collected, tabulated, and commented on 19 cases operated on by various surgeons, including himself; and these same cases have since been arranged together with others in a new Table by Professor William Keen, of Philadelphia (1886), who again has added 2 cases, one being his own patient. Certain of these 21 cases also appear in a Table published by Godlee (1883), and even in Omboni's catalogue. Professor Keen, in a note, criticises the list, and remarks that the case imputed to 'Germon' has no existence; that Chandler's Tables are inaccurate; that, in four cases in Harte's Tables mistakes have been made between the facial and the inferior dental nerves; and lastly, that in 4 of the 21 cases in his own Tables neurotomy, or even neurectomy, had been performed previously to neurectasy. He concludes that absolute relief for long periods (cure) was obtained in five cases; absolute relief for short periods (palliation) in 14 cases, followed by improvement in 8 cases and no improvement in 6; the remaining 2 cases, including his own, he declines to classify. His summary is somewhat more favourable than that of Professor Zezas. But it is indisputable that nerve-

stretching is much less useful in painful spasmodic disease than in pure peripheral neuralgias.

My own experiences since 1883, unfortunately for myself limited in number owing to my resignation of active hospital work, enable me to confirm the benefits, not only temporary but persistent, of nerve-stretching in cases of pure sciatica or other neuralgias due to obstinate chronic local neuritis. Such cases are invariably relieved or cured more or less permanently in proportion to the thoroughness of the stretching process employed. There frequently occurs a painful stage, subsequently to the immediate paresis, but this subsides and disappears. Moreover, I find the direct cutting operation, with its attendant abstraction of blood, more serviceable than the bloodless one. When the operation has failed in any degree, this has been owing to the nerve having been too briefly or insufficiently stretched. I have had but one experience of the bloodless operation, and that not a very satisfactory one. As to the suspending method of treating the lightning pains of tabes, I have had but one case, which, though somewhat promising at first, ultimately ended in disappointment.

9. *Rationale of the effects of nerve-stretching for the relief or cure of pain.*—It is gratifying to me to be able here to record that within a few weeks of the delivery of my lecture, Mr., now Professor Horsley demonstrated the presence, in the trunks of the mixed nerves of the body, of those nervi nervorum, the existence of which therein I had ventured to predict. Early in 1884 he showed at a meeting of the Royal Medical and Chirurgical Society, some microscopic preparations exhibiting not only the fine non-medullated, doubtless vasimotor fibres previously described by Sappey and mentioned after him by Krause, but also certain medullated, doubtless sensory fibres running in the epineurium, and terminating in the tactile corpuscles or end-bulbs of Krause, or in small but perfect Pacinian bodies.

In the discussion on Professor Horsley's communication, some doubts were expressed as to the interpretation put upon the appearances in the specimens shown. But I am now indebted to him for five drawings from preparations recently made expressly for this Appendix. These drawings I have had engraved, as seen in Figs. 8 to 12, which are accompanied by Professor Horsley's own descriptions. It will be seen from them that he has proved beyond doubt the existence of sensory nervi nervorum; so that the conjecture I offered in my lecture as to the existence of such nerves, and their

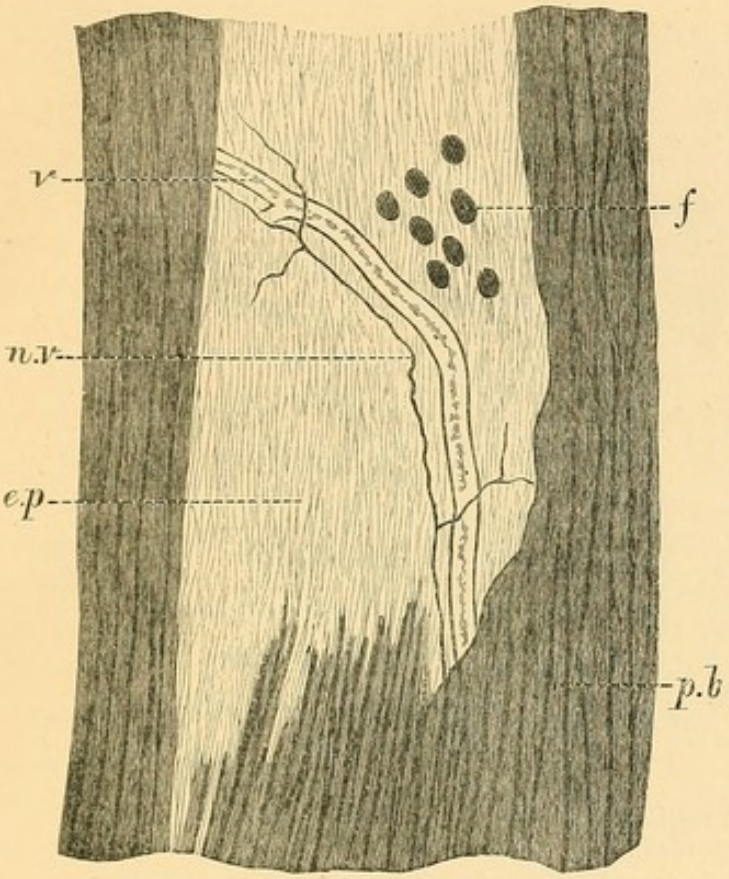

FIG. 8.—Longitudinal section of human nerve stained with osmic acid, mounted in Canada balsam, and magnified about 40 diameters. (*Horsley.*)

It shows a branching *nervus vasis*, or vasimotor nerve, improperly described by Sappey and Krause as a *nervus nervi*, accompanying a small bloodvessel; *ep*, epineurium, or sheath of connective tissue; *pb*, primitive bundle of nerve-fibres; *f*, lobule of fat, the corpuscles stained black by the osmic acid; *v*, bloodvessel containing blood corpuscles; *nv*, the *nervus vasis*.

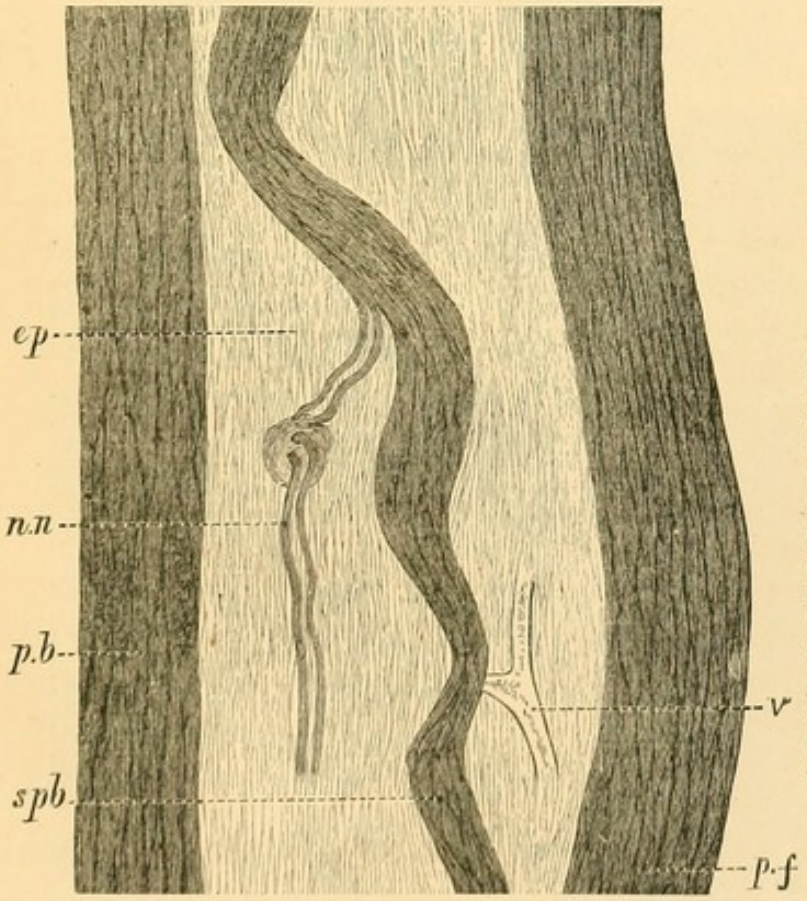

FIG. 9.—Longitudinal section of human nerve stained with osmic acid and magnified about 40 diameters. (*Horsley.*)

It shows two true *nervi nervorum* arising from a branch of a primitive bundle and running onward in the epineurium, to terminate doubtless as in Figs. 10 and 11. After leaving the bundle they exhibit a twist in their course. Compare the size of these true *nervi nervorum* with that of the *nervus vasis* in fig. 8. *ep*, epineurium; *pf* and *pb*, primitive bundle; *spb*, small branch of primitive bundle; *nn*, *nervi nervorum*; *v*, a bloodvessel.

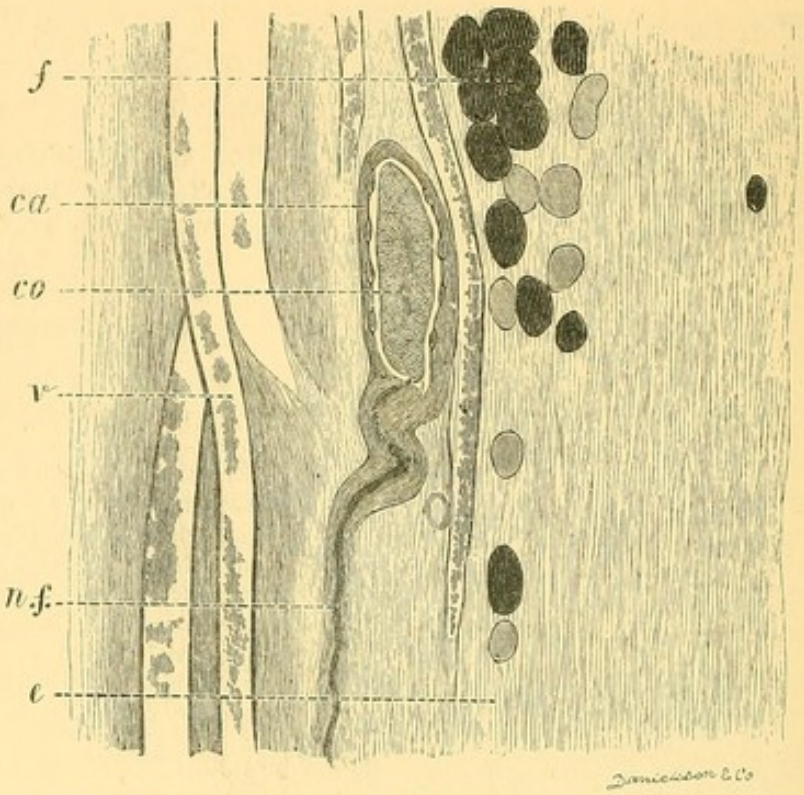

FIG. 10.—Longitudinal section of human median nerve stained in osmic acid, and magnified about 60 diameters. (*Horsley.*)

It shows a tactile corpuscle, or sensory nerve-ending, imbedded in the epineurium covering a primitive bundle and lying between bloodvessels. A *nervus nervi* is seen coursing onwards in the customary spiral manner, and entering the core of the corpuscle, within which the axis cylinder can just be distinguished. The capsule of the corpuscle is nucleated. *e*, epineurium ; *f*, fat lobule stained with osmic acid ; *v*, bloodvessel containing altered blood ; *nf*, *nervus nervi* ; *ca*, capsule of the sensory nerve-ending or tactile corpuscle ; *co*, core of the same.

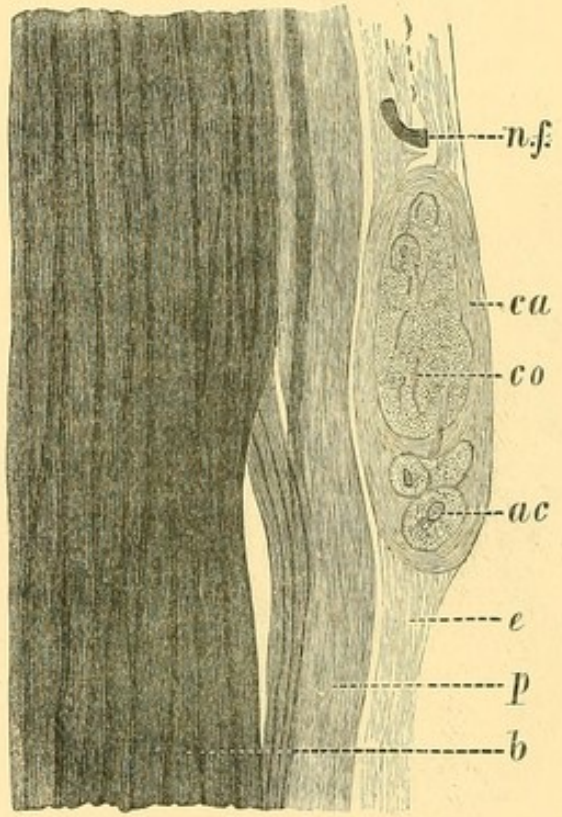

FIG. 11. — Longitudinal section of human nerve, stained in osmic acid and magnified about 250 diameters. (*Horsley.*)

It shows a sensory nerve-ending or tactile corpuscle, lying in the epineurium and upon the perineurium. The entering axis cylinder can be easily traced onwards to the end of the core ; but at the tip of the core its bendings are a little too distinctly marked in the woodcut. *e*, epineurium ; *p*, perineurium ; *b*, primitive bundle, stained very dark ; *nf*, *nervus nervi* ; *ca*, capsule of the tactile corpuscle ; *co*, core of the same ; *ac*, axis cylinder of the nerve-fibre entering the corpuscle.

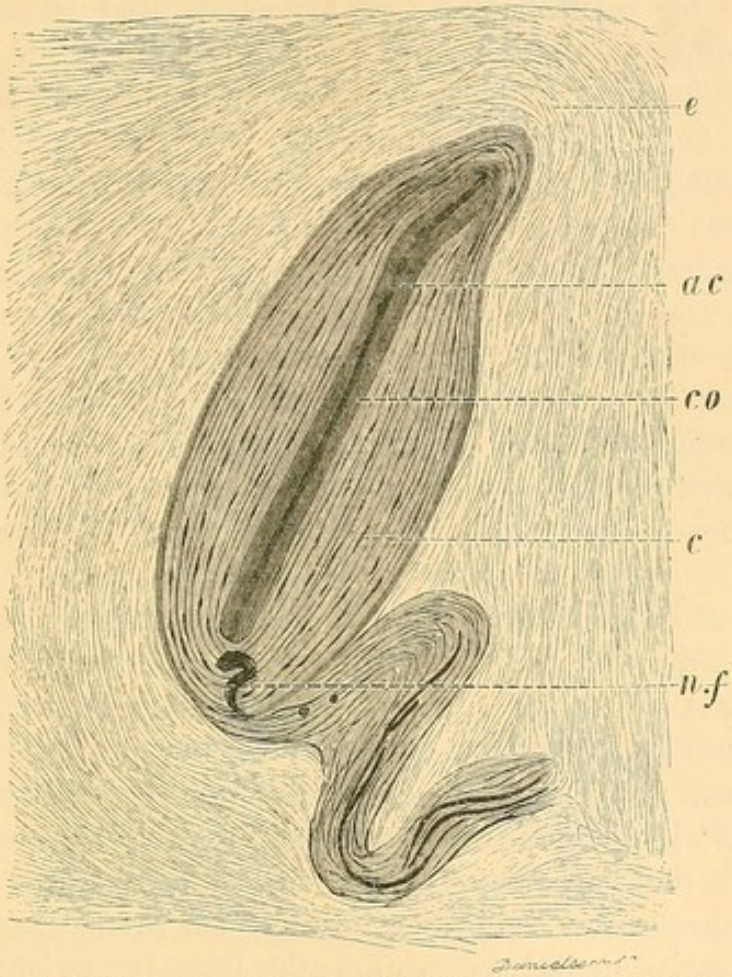

FIG. 12.—Pacinian corpuscle from the epineurium of the human ulnar nerve, just above the elbow. Osmic acid preparation. Magnified about 35 diameters. (*Horsley.*)

Two *nervi nervorum* are seen entering it. *e*, epineurium laminated; *c*, capsule of the corpuscle; *co*, central core of the same; *ac*, axis-cylinder prolongation of one nerve-fibre, *nf*.

Note.—Owing to the very considerable spiral turn of the fibres at the base of the corpuscle there appears to be a separation of the nerve-fibre from the central core. This, of course, is merely optical.

relation to certain neuralgic pains, may now be regarded as having been completely verified.

10. *Indications for the performance of the operation of nerve-stretching.*—I have nothing to add to this section of the lecture, which was illustrated by actual specimens of disease.

11. *Mode of performing the operation of nerve-stretching.*—In Hildebrandt's monograph, already referred to, instructions for the exposure of the several nerves likely to require to be thus operated on are given at length, with illustrations; but to a surgeon who is also an anatomist, such lessons are superfluous.

Professor Keen approves of the use of the hooks with which to make traction, and in operations on small nerves (it was the

facial nerve for painful spasm in his case), this is good advice. Even in dealing with so large a nerve as the sciatic, a sufficiently large hook may offer advantages in preventing slipping of the nerve. As to the amount of force to be used, it is generally held that the stretching should be severe, though short of rupturing; and it has been observed that the body may be lifted up by the sciatic, and the head by the facial nerve; so that probably the directions given in my lecture may be on the side of leniency. Even rupture of a nerve, as we shall presently see, is not always to be regretted. One operator insists that the traction should be continued or repeated once or oftener until the stretched nerve lies loose and tortuous in its bed when it is let go. I now believe that I have myself failed to cure at once a case of sciatica owing to not having used sufficient force.

Every one now agrees that in all cases the pulling should take place in both directions, that is, from the central part, and from the peripheral part of the nerve. It is alleged as an argument for this that the former numbs sensibility, and the latter suspends both that and motility as well; and hence the latter is most important in stretching a motor nerve like the facial for painful tic. But a better reason is probably this, that it ensures a greater and more extended local effect on the nerve implicated, and thus increases the prospects of a lasting benefit; for experimental observation and clinical experience combine to show that slight and imperfect stretching is useless for the permanent cure or even the durable relief of pain, and particularly of painful spasm. Thus, it is found experimentally that motility is the last property to be lost by stretching, although it is also usually very slow to return; and, as regards clinical experience, it is certain that both in neuralgia and in tic douloureux, the more perfect and the more lasting the paresis or the paralysis, the better the chances of permanent improvement or absolute cure. It would almost seem as if in a given case a facial spasm should disappear after neurectasy without intervening paralysis, then the operation could not of itself have been instrumental in the cure. Even should a permanent paralysis ensue, unless in the case of an entire limb, or of an important portion of one, it would be preferable to continued suffering; and this is especially true as regards the face, in which a partial paralysis and paresis are quite endurable conditions.

12. *Dangers of the operation of nerve-stretching.*—Three instances of rupture of a nerve are mentioned amongst Omboni's 512 cases, namely, of the spinal accessory, the ulnar, and the great sciatic.

In view of the remarkable successes of nerve-suture in modern surgery, already mentioned in this Appendix, an accident of this kind would be promptly met, and need not excite apprehension; it would doubtless act as a retarding influence towards recovery of sensation and motion, and thus probably, after what has just now been stated, it might prove beneficial in certain cases, as a means of suspending nerve action for a longer time, and so favouring a permanent relief or cure. It may be remarked that rupture of the sciatic nerve has recently occurred during the operation of resection of the hip joint; but primary nerve-suture was instantly resorted to with complete ultimate success. In regard to smaller nerves, for example, the superior maxillary, these have been purposely torn out by what is termed *avulsion*, a process recommended in very aggravated cases with the view of making the operation (for facial neuralgia) more effectual, a purpose I understand from Professor Horsley which has been fully attained by him in two recent cases of resection of the superior maxillary nerve.

The additional number of deaths recorded in Omboni's Tables, which include all those in the older Tables, leave the proportion of deaths from the operation and their significance practically the same as at the date of my lecture.

13. *Non-cutting or bloodless operations for nerve-stretching.*—The effects of nerve-stretching by the bloodless method of Trombetta have been studied by Cattani on the sciatic nerves of rabbits. He found that these effects, which have already been referred to (p. 39), were more widely extended along the nerve than in stretching it by a force locally applied, especially reaching far into the peripheral branches; he also found that there was less damage to the bloodvessels of the nerve, less inflammatory action, and less subsequent development of connective-tissue elements. In his opinion, it is therefore a milder operation, and better adapted to use in peripheral disease.

With regard to Motschutkowski's plan of endeavouring to act on the spinal cord and its nerves by suspending tabetic patients, described in my lecture, I am constrained to say that it has entirely disappointed my expectations founded on his statements.

14. *Conclusions.*—The practice of neurectasy or nerve-stretching has developed so rapidly since 1880 that, instead of hesitating opinions and tentative conclusions, one may now express a matured judgment as to its value, its worthlessness, or its interdiction in particular forms of nervous disease. Properly to estimate these,

however, it is now essential to compare it with two other nerve operations, which have also attracted much attention recently, viz. *neurotomy*, or simple division of a nerve, and *neurectomy*, or resection, or exsection of a portion of a nerve.

As regards its severity, and its therapeutical results, nerve-stretching may, speaking generally, be said to occupy an intermediate position between neurotomy and neurectomy, being more complicated in its effects on a nerve, and more efficacious as a means of treatment than the former, but less decided and less radical than the latter. This general statement justifies the opinion that, as a rule, nerve-stretching should be tried in a given case, if possible, before neurectomy; it nevertheless demands some further qualifications.

Simple division of a small nerve, say a cranial nerve, owing to its absolutely local effect, and to the rapidity with which the divided nerve will reunite, has but a slight effect on the disordered condition of the nerve, and but a transitory effect in abolishing its proper function; hence restoration takes place so quickly that such disordered condition is naturally very soon re-established. Simple division of a large nerve, say a nerve of the upper or lower limb, has too serious an effect in consequence of the extensive paresis and paralysis thereby induced. On the other hand, nerve-stretching is specially available for larger nerves, like those of the limbs, because sufficient force can be safely applied to them, and the effect can be made to extend over a considerable distance; whereas, though frequently successful as applied to small nerves, inasmuch as they are easily stretched, it has often failed in aggravated disease affecting the smaller nerves of the head and face, probably because the stretching did not extend sufficiently far in a central direction. In the third place, resection of a portion of the trunk of a nerve is a much more certain remedial operation in the case of small-sized nerves of limited distribution, like those of the head and face. Moreover, this may sometimes be a simpler substitute for several simultaneous or successive operations on separate branches, which in the face would be highly objectionable; whereas the permanent loss of sensibility over a certain facial area which it entails is not of serious moment, nor indeed is a permanent motor paralysis, in comparison with the gain of freedom from the tortures of tic douloureux. But such a resection is wholly inadmissible as regards the larger nerves of the limbs, whose area of distribution is so wide and important, considered in relation to the prehensile and locomotive functions.

All this is abundantly illustrated by the clinical results of neur-

ectomy operations, a list of which for facial neuralgia, consisting of 83 cases, has recently been published (1886) by G. R. Fowler of Brooklyn. To this paper I must refer for a careful critical examination of the history, progress, and results of the operation of neurectomy, which is, of course, strictly speaking, beyond the limits of my own subject. One can only observe here that, whilst the statistics of Otto Weber, comprising 100 cases, reproduced by Hildebrandt, and those of Wagner, comprising 135 cases, seem to show a very small proportion of lasting cures, the painstaking analysis presented by Fowler of his own Table establishes the fact that out of 26 cases of operation on the superior maxillary nerve, in which Meckel's ganglion was either removed or destroyed, and out of 26 other cases in which merely a portion of the nerve was resected, the following were the periods of relief obtained in each set.

Number of cases of		Duration of period of relief in years,				
		— to ½	½ to 1	1 to 2	2 to 3	3 years
Ganglion removed . . .	26	5	3	9	6	3
,, not removed . . .	26	4	7	7	3	5
Totals	52	9	10	16	9	8

If the results as above stated do not justify the assertion of Carnochan that the removal of the ganglion is the 'key of the position,' they certainly show that the more of the nerve is removed, and the nearer to the foramen rotundum, the better. It may also be suggested that after a neurectomy in which any length of the proximal part of the nerve operated on is left behind, this ought also to be effectually stretched so as to accelerate or complete its degeneration. Sometimes, indeed, nerve-stretching has succeeded, after neurotomy and even neurectomy has failed.

In conclusion, the sum of opinion as to the special applications of neurectasy or nerve-stretching may be thus stated.

It is not only useless but it is dangerous, and should be prohibited, in all cases of serious *central disease*, such as confirmed ataxy, myelitis, fully established tetanus, pure epilepsy, and paralysis agitans.

In reflex forms of epilepsy, in an ascending neuritis bringing about epileptiform seizures, in the early stages of a distinctly traumatic tetanus, provided that in any of these cases the peripheral cause of irritation can be clearly localised and the affected nerve or nerves be accurately defined, nerve-stretching may be serviceable, if employed soon enough. So, if in ataxy it would appear that

some special peripheral disturbance of sensation or motion has arisen consecutively to the central disease, it might possibly ameliorate such local suffering; but for the genuine locomotor ataxy due to tabetic sclerosis, nerve-stretching, as just stated, stands condemned, although it is unnecessary to express this in the unrestrained language of certain continental Society discussions, now no longer noticeable; nor would one exempt from this adverse opinion the milder operation of bloodless stretching of the sciatic nerve or nerves in cases of confirmed ataxy.

As to the hope or suggestion that the excitation of a nerve, which, through vasimotor action and nutritive or trophic changes, follows a slight amount of stretching, might bring about improvement as regards pain, hyperæsthesia, anæsthesia, or paresis on the one hand, or clonic spasms, feebleness, or paralysis on the other, it seems to rest on but little favourable clinical experience. Such states, being recoverable, are cured more readily by lapse of time, by the use of soothing or stimulating remedies, and by the aid of electricity or massage.

If, then, neurectasy is to be abandoned in confirmed central diseases, is possibly beneficial in reflex affections, and is certainly so in peripheral disturbances of sensibility and motility, it must be admitted that it appears to be less successful in spasmodic than in sensory or purely neuralgic peripheral disorders.

In applying this surgical remedy to either of the two last-named classes of nerve disease, whether rheumatic, gouty, or traumatic, it is of course only admissible in aggravated and obstinate cases after other remedies have failed, and after any discoverable or reasonably conjectured local cause has been removed. This last rule is well illustrated by the recoveries which have followed the puncture of cystic growths (Fayrer), the excision of neuromas, cicatricial indurations, submucous nodules, periosteal or sub-periosteal fibromas, and bony intra-alveolar growths, the exsection of portions of the jaws, and the removal of a piece of the cranium by trephining (Durham). As to the previous employment of remedies, it must always be remembered that these, whether internal or external, are constantly being added to by modern therapeutical industry, and that more may be expected in the future in this particular field for the display of ingenuity. Quite recently, for example, osmic acid local injections, the internal administration of salol, freezing the nerve, prolonged and repeated percussion (Neale), and some special form or mode of applying galvanism or electricity (Steavenson), have been suggested or highly extolled.

These and all other remedies failing, an adequately carried-out nerve-stretching will certainly give temporary relief, and in proportion to its thoroughness prolonged relief or cure. In the case of the sciatic nerve, it may be preceded by a bloodless stretching. In that of any other nerve, the cutting operation should be at once employed as close to the nerve-centre as possible; and should it fail, the only further measure is to perform neurectomy, and then stretch efficiently or even avulse the proximal nerve-stump, which will probably effectually relieve the patient from suffering, though at the cost of some local paresis or paralysis.

LIST OF REFERENCES.

Those who wish to pursue this subject will find special references to nearly all of the authorities mentioned in the Lecture in Ceccherelli's article, contained in the 'Rivista Sintetica' of the journal 'Lo Sperimentale,' Anno XXXVI., T. 1, Settembre 1882 (Firenze). The writers otherwise quoted from are: Stintzing, 'Ueber Nervendehnung,' 1883 (Leipzig), which contains a useful bibliography; Nocht, 'Ueber die Erfolge der Nervendehnung,' 1882 (Berlin), which is likewise full of references; Vincenzo Omboni, 'Uno Sguardo allo Stiramento dei Nervi etc.,' 'Ann. Univer. di Med. e Chirurg.,' Parte Originale, Marzo, 1883 (Milano), which contains a copious list of authorities down to date; Hildebrandt, 'Nervendehnung,' &c., 1884 (Berlin), who gives many references on the subject of Nerve-Suture, quoting Wolberg, Falkenheim, and others; Vincenzo Morini, 'Sullo Stiramento dei Nervi a Scopo Terapeutico: Tesi di Laurea' (1884), 'Gazzetta Medica di Roma'—also published separately, Roma, 1885—in which many Italian cases are particularised; Browning, 'Recent Contributions to the Surgery of the Nerves,' 'Annals of Surgery,' February 1885 (St. Louis and London), which comprehends a notice of the operations of primary and secondary nerve-suture, with references to Weissenstein, Rawa, Wolberg, Tillaux, and other observers, mentioned in my Appendix; Fowler, 'The Operative Treatment of Facial Neuralgia,' *see* 'Annals of Surgery,' April 1886, in which article references are made to eighty-three cases, treated either by nerve-stretching or by neurectomy, or by both methods; and, lastly, Kean, 'Stretching of the Facial Nerve, &c.,' 'Annals of Surgery,' July 1886, where exact references to all the cases collected by Professor Zezas are given, including the cases treated by Godlee, Southam, and others. See also the long and important discussions on this subject in the 'Berlin. klin. Wochenschr.,' 1882–3.

Amongst important papers are, Horsley, 'Proceedings Roy. Med. and Chir. Society,' January, 1884; Cantlie, 'Bristol Med. Chir. Journal,' 1884; Cattani, 'Notice in London Med. Record,' 1885, p. 99; Vanlair, 'Archives de Physiol.,' 1885 and 1886; Zederbaum, 'Centralblatt für klin. Med.' 1883; Pauline Tarnowski, 'Archives de Névrologie,' 1885; Lesser, 'Deutsche med. Wochenschrift,' 1814; Lorenzo, 'Notice in Lond. Med. Record,' 1885, p. 172; Fayrer, 'Practitioner,' 1886; Durham, a case of Trephining, 'Lancet,' 1884; Steavenson, 'On Galvanism for Sciatica,' 'Lancet,' 1886; Southam, 'Lancet,' 1886; Brailey, 'Brit. Med. Journal,' 1885; Walsham's cases, 'Proceedings Roy. Med. Chir. Society,' 1884. Consult also excerpts in 'Lond. Med. Record,' Neale's valuable 'Digest,' and, of course, the usual French, Italian, and German periodicals.

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