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THE NEW SYDENHAM SOCIETY.

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PROFESSOR

SCHROEDER VAN DER KOLK

ON THE

MINUTE STRUCTURE AND FUNCTIONS

OF

THE SPINAL CORD AND MEDULLA OBLONGATA,

AND ON THE

PROXIMATE CAUSE AND RATIONAL TREATMENT

OF

EPILEPSY.

TRANSLATED FROM THE ORIGINAL

[WITH EMENDATIONS AND COPIOUS ADDITIONS FROM MANUSCRIPT NOTES OF THE AUTHOR].

BY

WILLIAM DANIEL MOORE, A.B., M.B.,

OF TRINITY COLLEGE, DUBLIN, HONORARY MEMBER OF THE SWEDISH SOCIETY OF PHYSICIANS, AND OF THE NORWEGIAN MEDICAL SOCIETY.

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MINUTE STRUCTURE AND FUNCTIONS OF THE SPINAL CORD.

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TO THE

MINUTE STRUCTURE AND FUNCTIONS OF THE MEDULLA OBLONGATA, &c.

SECOND PART.

TRANSLATOR'S PREFACE.

In completing the task confided to me by the Council of the New Sydenham Society, I think it necessary to explain that the following pages do not consist of mere translations of the Essay of Professor Schroeder van der Kolk on the Spinal Cord, originally published by the Royal Academy of Sciences at Amsterdam, in 1854, and of his Treatise upon the Medulla Oblongata and Epilepsy, published by the same learned body in 1858. The distinguished author has kindly sent me so large an amount of additional matter, together with alterations of two or three portions of the original, in reference to which his views have undergone some modification, that the present must be considered as a second edition of the above important works, enlarged and carefully revised by their author.

Under his direction, the appendix to the Dutch edition of the Essay on the Spinal Cord has been interwoven with the text. A German translation by Professor Theile, of Weimar, will shortly be published, in which the two works have been thrown yet more completely into one. The Council of the New Sydenham Society has, however, determined, that while both treatises shall be published in one volume, with a common index, they shall in other respects be kept distinct.

There is probably no part of the human body, which is more highly calculated to excite our admiration of the infinite skill displayed in its construction, than the nervous system, nor is there any portion of the Creator's work where the adequate adaptation of means to end is more wonderfully shown than in the mechanism by which the coördination of movements is provided for. To the elucidation of this mechanism the present volume contains some valuable contributions.

The author's observations on the influence of the corpora olivaria in the articulation of words, and on the variety of lesions of speech which accompany morbid affections of different parts of the brain and medulla oblongata, are, I think, worthy of especial attention.

His remarks on the intermittent character of many convulsive and neuralgic attacks, which are yet dependent on persistent causes, are calculated to afford much important aid in the establishment of the diagnosis in some difficult cases, where the most regularly recurring fits of severe suffering, though perfectly intermittent, are nevertheless the result of intense organic disease.

Not less important are the results of the measurements made by the author, of the diameters of the capillaries of the medulla oblongata in cases of epilepsy; whence he infers, that in patients who do not bite their tongues during a fit, the vessels are more liable to be dilated in the course of the vagus, and that from the consequent disturbance of the organs of respiration, the paroxysms are in such instances more dangerous to life.

Lastly, the indications laid down for the rational treatment of epilepsy, are deserving of attentive consideration. I am glad to know that the valuable essay by Kussmaul and Tenner, on epileptic convulsions as consequent on large losses of blood, which is quoted by the Professor at page 209, is in course of translation for the New Sydenham Society, and will soon be issued to its Members in a complete form.

The foregoing are some of the more important practical points dwelt upon in the following pages. In conclusion, I gladly take this opportunity of expressing my sense of obligation to the distinguished author of the original works for his kind coöperation during the progress of the task intrusted to me. I have had the privilege, while engaged in this translation, of constant correspondence with him, and of consulting him on all subjects in reference to which I might feel in any doubt. He has carefully revised each sheet while passing through the press, thus affording to the reader the best possible guarantee, that however the translation may fail in composition, it faithfully conveys the author's meaning.

I am also under obligation to Mr. Benjamin Wills Richardson, one of the Examiners in the Royal College of Surgeons in Ireland, who has taken the trouble of revising the translation, both in manuscript and in proofs. To Mr. Hutchinson, the indefatigable Secretary of the New Sydenham Society, I am indebted for numerous suggestions and much valuable assistance. The plates have been carefully copied, by Mr. Tuffen West, from those in the original work, which are after drawings from nature by the author himself.

7, South Anne Street, Dublin,
June 6th, 1859.

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June 8th, 1859.

ON THE
MINUTE STRUCTURE AND FUNCTIONS
OF THE
SPINAL CORD.

BY

J. L. C. SCHROEDER VAN DER KOLK,

PROFESSOR IN THE UNIVERSITY OF UTRECHT.

Published by the Royal Academy of Sciences at Amsterdam.

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The grouping of the different Figures has been altered somewhat from that of the original work. In transference from the 4to. to the 8vo. form this was unavoidable. It is hoped that, with the help of the subjoined list, the reader will not experience any difficulty in finding the several displaced Figures.

ON THE

MINUTE STRUCTURE AND FUNCTIONS

OF THE

SPINAL CORD.

CHAPTER I.

HISTORIC SKETCH OF INVESTIGATIONS AS TO THE MINUTE STRUCTURE OF THE SPINAL CORD.

THE examination of the intimate structure of the brain and spinal cord is, undoubtedly, one of the most difficult investigations in minute anatomy. The peculiar softness of these parts, the fact that they are destroyed by slight pressure, the extraordinary minuteness and delicacy of their tissue (their primitive filaments being quite imperceptible to the naked eye, while it is with difficulty that, under a tolerably strong magnifying power, a single thread can be followed even for a very short space)—lastly, the infinite number of the primary filaments (which in many places interlace in the most varying manner, forming a network incapable of being unravelled)—are so many reasons why the most persevering efforts of very distinguished anatomists have led to such varying results, and why great difference of opinion still exists in reference to the most important questions.

Among these questions is that of the difference between the white or medullary, and the grey substance. The latter contains in many places various ganglionic cells, from some of which issues an extremely fine network of ramified filaments, often very difficult to distinguish from the interposed web of minute blood-vessels, and the connexion of which with the medullary matter (white nerve, or cerebral filaments) is still far from being universally agreed upon and clearly demonstrated.

The constitution of the spinal cord, on the discovery of which depends the explanation of a number of important physiological questions, has of late years, in an especial manner, attracted the attention of the most eminent anatomists.

The question as to whether the nerve filaments run from their ultimate distribution directly through the spinal cord into the brain, seemed formerly scarcely to admit of doubt; since not only are sensations communicated through the spinal column to the brain, but also the orders of our will are conveyed thence with inconceivable rapidity to the different muscles.

After Ehrenberg had shown that the brain and spinal cord in their intimate structure consisted of minute tubes,* the immediate connexion of the nerves through the latter with the former, appeared to have been demonstrated by Valentin beyond all doubt.† Remak, who subsequently engaged in the microscopic examination of the grey substance, and closely investigated the ganglionic cells with their efferent filaments,‡ was one of the first who seems to have had some doubt as to the direct course of the nerves through the spinal cord into the brain. He refrains, however, from giving a decided opinion; and writes thus: De ratione, quæ inter radices nervorum spinalium et substantias medullæ spinalis intercedit, nihil ad huc constat, neque ipse quamque huic rei investigandæ plurimum operæ dederim, aliquid certe ad huc proferre possum. Id solum persuasum habeo, fibras radicum nervorum, non tam simplicem originem habere, ut in fibras longitudinales medullæ spinalis mox transeant.§

An important addition to our means of accurately investigating the minute structure of the brain and spinal cord, was made more recently by Hannover, who first suggested the use of chromic acid, with which he had become acquainted through Jacobson of Copenhagen.|| The solution he employed contained one part of acid to from sixteen to twenty of water, and the portions of cord were steeped in it from two to four months before dissection. By this means he

* C. G. Ehrenberg, *Beobachtung einer ungekannten Structur des Seelenorgans.* Berlin, 1836. See also Poggendorf's *Annalen*, 1833.

† *Nova acta Leopold.* 1826, Tom. xviii. p. 131.

‡ *Observationes anat. et microsc. de syst. nerv. Structura.* Berlin, 1838.

§ *l. c.* pp. 19, *et seq.*

|| A. Hannover, *Die Chromsäure, ein vorzügliches Mittel bei Mikroskopische Untersuchungen, in* Müller's *Arch.*, 1840, p. 548.

detected the transverse fibres in the spinal cord (*commissures*) in birds, frogs and fishes, and thought he had satisfied himself that the cerebral fibres took their origin from ganglionic cells.* At a later period, in his work on this subject, he says, that by mistake he had formerly, in stating that the fluid should have a light-yellow colour,† indicated a too concentrated solution. In this work he shows clearly the origin of the nerve fibres from the ganglionic cells in the cortical substance and gives good drawings of it.‡ He states that the fibres of the spinal cord descend perpendicularly, and curving at obtuse angles pass over into the roots of the nerves, the cerebral fibre and the nerve fibre having thus direct connexion with each other.§ The transverse fibres he describes anew, without, however, having been able to trace them to the periphery of the medulla. A few of these would sometimes appear to bend round into the nerve roots,‖ and portions of them do indeed pass from one to the other side of the cord, but no decussation takes place. Although he had observed them in birds, amphibious animals, and fishes, he had not been able to detect them plainly in any of the mammalia. Excepting in isolated instances in fishes, Hannover does not remember to have ever seen nerve fibres distinctly arising from the ganglionic cells in the spinal cord.¶

The conclusions of Stilling and Wallach were quite different. These observers inferred that the roots of the nerves ran transversely between the white columns of the spinal cord and the grey matter, and were merely direct prolongations of the transverse fibres of the latter, the anterior roots decussating in the middle with the posterior roots from the other side of the spinal cord.** They considered that the will acted chiefly through the grey matter. †† In this first essay they still confounded the ganglionic cells with dilated blood-vessels; but the subsequent investigations of Stilling ‡‡ are much more complete, and are, in general, justly considered to be correct. In his later work he, indeed, describes the multi-polar ganglionic cells, but the connexion between the nerve-roots and the spinal corpuscles, as

* *l. c.* p. 555.

† A. Hannover, *Recherches Microscopiques sur le Système Nerveux.* Copenhague, 1844.

‡ *l. c.* p. 11, Figs. 1, 2, 11, 17, 22, 23.

§ *l. c.* p. 12. ‖ *l. c.* p. 13. ¶ *l. c.* pp. 16 and 19.

** *Ueber die Textur des Rückenmarks*, 1842, pp. 27, *et seq.*

†† *l. c.* p. 38. ‡‡ *Ueber die Textur der Medulla Oblong.* Erl., 1843.

he calls them, or ganglionic cells, was still unknown to him,* although he suspects that they are closely connected with the motor power.† Although the origin of the nerve-roots from the grey substance, so far as it is visible under low magnifying powers, is represented with the greatest accuracy by Stilling in his two most valuable works,‡ his investigations were, on account of the low magnifying powers employed, insufficient to show the more minute connexion between the nerve-roots and the other fibres of the medulla oblongata; while his experiments, by partial transverse sections of the spinal cord showing that reflex movement is not prevented, and that even voluntary motion remains beneath the divided part,§ described in an earlier essay, have had much influence in suggesting the idea of a local cross-origin and decussation of the spinal nerves. These experiments were instituted in consequence of some previously performed by our Van Deen,|| and were for the most part in opposition to the latter; but they are scarcely capable of affording any certainty as to the course of the very minute fibres in so complicated an organ.

Volkmann adopted quite another mode of showing that the nerves could not run uninterruptedly through the spinal cord to the brain. Were this the case, he argued, all the filaments which are distributed as nerves throughout the body, must be present in the upper part of the cord, and the medulla spinalis should bear resemblance to a cone, that is, the medullary matter or white columns ought to be so much thicker in the cervical portion, as would be necessary to enable it to contain all the nerve filaments; ¶ which is by no means the case. In this inference he was especially strengthened by his investigations on the spinal cord of a serpent (*Crotalus mutus*), in which he reckoned not fewer than two hundred and twenty-one pairs of nerves, whose united thickness exceeded the circumference of the spinal marrow at the second cervical nerve more than eleven times.** The nerve-roots, therefore, according to him

* *l. c.* p. 47. † *l. c.* p. 5.

‡ *Ueber die Med. Oblong.*, and on the *Pons Varolii.* Jena, 1846.

§ *Ueber das Rückenmark*, p. 35; especially also in his essay, *Untersuchungen ueber die Functionen des Rückenmarks.* Leipz. 1842, pp. 139 and 152, Figs. 15 and 20.

|| Van Deen, *Nadere ontdekkingen over de eigenschappen van het Ruggemerg.* Leiden, 1839, pp. 27 and 61.

¶ Volkmann, *Nerven-Physiologie,* in Wagner, *Physiol. Wört.* 2 B., p. 482. ** *l. c.* p. 485.

arise in the spinal cord, and do not run directly through to the brain.

With much sagacity he further shows, that the motor filaments at their origin in the spinal cord are so adapted, that every stimulation applied to them must produce a corresponding combination of movements (coördinated movements). Since, he says, the application of a stimulus to the web of the frog is sufficient to bring into motion all the corresponding motor fibres, there is no doubt that this effect may be produced by a single cerebral fibre, penetrating to the point of insertion of the allied crural motor nerves. Still less reason is there, he adds, to doubt, that a single cerebral fibre is sufficient to bring into action all the motor fibres which work simultaneously, as for example, the nerves of one and the same muscle, and which, therefore, are in all probability so arranged as to be incapable of acting independently of one another.*

We shall hereafter see how these observations contain the foundation of the true explanation of the course and relation of the nerve-roots and the spinal cord. Had Volkmann been better acquainted with the relation of the ganglionic cells, their efferent filaments, and their connexion with the nerve-roots and other fibres of the spinal cord, he would certainly have left little for his successors to add, and it is indeed surprising that so little attention has since been given to the important expressions and experiments of this writer. But circumstanced as he then was, he could explain these and other phenomena only by the hypothesis of a decussating conduction in the spinal cord.† A little reflection will, however, suffice to show that such a theory is incapable of satisfactorily accounting for the great regularity and steadiness of either the voluntary motions, or of the natural phenomena of reflexion, swallowing, and other such like movements.

R. Wagner went a step further by more closely examining the multi-polar ganglionic cells and their efferent filaments or fibres in the electrical ray, and although the great harmony of action in this animal led him to suspect an immediate communication between the filaments of these cells and the nerves, he by no means succeeded in discovering a direct transition or connexion between them.‡ He,

* *l. c.* p. 555.

† *l. c.* pp. 528, *et seq.*

‡ Wagner, *Physiol. Wörterb.* iii. B., 1 Abth. p. 378, Tab. iii., Figs. 42-45.

however, gave, according to his ideas, linear representations of the connexion between the sensitive or rather reflex and motor nerves, by means of the multi-polar ganglionic cells, which would afford a simple explanation of the principal phenomena.*

Other writers, however, repudiated this opinion, and endeavoured to defend the old doctrine of the cerebral origin of all nerves. The investigations of Budge in reference to the posterior or sensitive roots in the frog, are remarkable in this point of view. Thus he found that these roots divide into two columns, one of which immediately assumes an upward direction,† while the other penetrates deeply into the grey matter, and there lies among numerous globular masses of ganglia, though he did not succeed in tracing its filaments further in the direction of the brain. ‡ Nevertheless, he inferred that the latter also must necessarily repair to the brain, and therefore supposed that he must have destroyed them, although he expressly says, that in no single case was he able to trace these deeper fibres§—a remarkable proof how much an idea once conceived may obstruct the recognition of the truth. For these reasons, I consider this observation of Budge, in which, notwithstanding that his opinion conflicted therewith, he faithfully relates what he has seen, to be of great importance. Although it does not appear that Todd and Bowman have themselves made microscopical investigations, they infer from physiological grounds, that the nerves terminate in the grey substance of the spinal cord, which is, as it were, composed of united segments, and of which the anterior white columns, according to them, serve for motion and sensation, the posterior for the coördination of motion.—*Physiol. Anat.*, p. ii., pp. 321, *et seq. Cyclop. of Anat. and Phys.*, pp. 721, *et seq.*

After I had, in the year 1847, detected a close connexion between the peripheric distribution of the sensitive and motor nerves, by the discovery of the remarkable law of the course and distribution of sensitive nerves in the skin, namely, that throughout the body the sensitive branches of a mixed nerve run to the part of the skin which is moved by the muscles receiving motor filaments from the same nerve-trunk, so that, the action of the muscles being known, we can, according to this law,

* *l. c.* pp. 398, 400.

† Müller's *Archiv*, 1844, p. 177, Tab. viii., Fig. 6, *s. g*, Fig. 7, *a*.

‡ *l. c.* pp. 180, *et seq.*, Fig. 6, *t*, Fig. 7, *b*.

§ *l. c.* p. 181.

even *à priori,* define the distribution of the sensitive nerves in the skin;* several phenomena led me to suspect that a closer central

* See *Tijdschrift der Wis.- en Natuurk. Wetensch. van de Eerste Klasse van het Kon. Ned. Inst.* 1847, pp. 44, *et seq.*, on the connexion between the sensitive and motor nerves. Although this essay was also inserted in Froriep's *Notizen*, in October, 1848, it appears to have attracted but little attention; since, so far as I am aware, this law of distribution has not been mentioned in any subsequent works. And yet it appears to be a general law, applicable not only to the human subject, but also to animals, and therefore cannot be said to be devoid of importance;† on this account, I think it not out of place, on the present occasion, briefly to explain the law in question, which I have announced in the following terms: that *while the nerve gives off motor branches to the muscles, its sensitive branches run to the part (of the skin) which is moved by the same muscles,* or, in other words, *a spinal nerve gives its motor branches to the muscles as instruments of motion, and its sensitive branches to the part moved.*

A few examples may illustrate this law: the nervus perforans Casserii in the arm gives motor branches to the biceps and brachialis anticus, which bend the forearm; its sensitive branches are distributed to the forearm itself, especially to the radial side, which is most strongly raised by these muscles; the median nerve gives its first branches to the flexors of the fingers, its sensitive branches to the inside of the fingers, which are moved by these muscles; the ulnar nerve does the same on the ulnar side, and this gives, moreover, posteriorly motor branches to the ulnaris externus and interossei externi, and also sensitive branches to the part of the outside of the hand and fingers moved thereby. The musculo-spiral nerve gives branches to the triceps, and sends hence its sensitive ramifications to the back of the forearm, which is extended by the muscles situated there; the subsequent part of the nerve gives branches to the extensors of the fingers and sensitive branches to the back of the fingers which are moved by them. The superior lumbar nerves give branches to the psoas and iliacus internus, and further on, sensitive branches to the front of the thigh, which is flexed by the psoas and iliacus internus. The same is appli-

† Thus in Dr. J. Peyen's Essay on the Peripheric Terminations of the motor and sensite fibres of the nerve-roots occurring in the brachial plexus of the rabbit, in Henle and Pfeuffer's *Zeitscrift f. rat. Med.*, 1853, IV. B., 1 Th. pp. 52, *et seq.*, not one word is said of this law, and the investigations of the writer have not even led him on its track. He has attended alone to the relation of the nerve-roots to the peripheric distribution, and arrives at the result, that in general the same nerve-root provides with sensitive filaments the parts of the skin under which lie the muscles innervated by it. This differs, at first sight, from my law; but the latter concerns the several nerves where they enter the muscles, while Dr. Peyen has paid less attention to particular muscles, and has therefore arrived at less definite results.

connexion must exist between the sensitive and motor nerves of the same trunk; for these reasons, I endeavoured to ascertain whether a more accurate investigation of the structure of the spinal cord would not enable me to trace out this connexion.

Although the result of my examination of this difficult part did not entirely correspond to the expectations I had formed, it appeared to me that my investigations were capable of elucidating most questions as to the structure and functions of the spinal cord, and I felt that any contribution to the clearing up of this uncertain subject (in reference to which the numerous vivisections which have been performed have led rather to greater perplexity than to the establishment of fixed truths) could not be devoid of importance.

I communicated the results of my investigations first provisionally in the Reports of the transactions of the section for Physical and

cable to the crural and sciatic nerves, with all their branches. This law is especially exemplified in the third and fourth cervical nerves; these give branches to the sterno-cleido-mastoid, and other cervical muscles which move the head laterally, and at the same time branches, which turn, and running again upwards, pass to the side of the head which is moved by these muscles; yet they give also muscular branches to the levator anguli scapulæ, and simultaneously descending sensitive filaments running over the shoulder and the clavicle, which are drawn up by the sterno-cleido-mastoid and levator scapulæ. To animals, also, this law is strictly applicable. The reason of the law is, that we should not perceive the action of the muscles themselves, nor their degree of contraction; if we did so we should be born anatomists: the muscles themselves receive no true sensitive nerves, but we obtain knowledge of their action through the change which, in motion, they occasion in the sensitive skin; hence it follows, that in losing sensation we are also deprived of a measure of motion, and can no longer correctly direct our movements. On the other hand, it appeared to me, that a moderate irritation, such as tickling or rubbing, produces a reflex movement in the muscles which receive motor branches from the same nerve-trunk; I perceived this in paralyzed persons, and it is easily seen in very young children, in whom tickling the palm of the hand produces flexing of the fingers, and tickling the back of the hand causes extension of the same, so that this law is also applicable to the employment of friction with volatile liniments, for the purpose of exciting the action of muscles. Thus in a case of paralysis, I saw powerful contraction of the fingers overcome by friction with volatile liniment on the back of the hand, and in like manner the involuntarily flexed arm extended by similar frictions on the back of the forearm. Galvanism, however, does not accurately follow the distribution of the nerves, but excites the several muscles which are met with in the course of the current.

Medical Science of the Provincial Society of Utrecht, on the 26th of June, 1848,* and subsequently brought them more in detail, and illustrated by various preparations, in the autumn of the same year, before the Royal Netherlands Institute.

Thus by hardening the spinal cord in spirit, in the manner recommended by Stilling, I succeeded in preparing several thin sections, both transverse and longitudinal, in which, after I had got them sufficiently transparent, a multitude of multipolar ganglionic cells became visible. In addition, I observed, especially in the anterior horns of the grey substance, a network of branched filaments, connecting these cells one to another, forming a very complicated interlacement. In the posterior cornua, too, I met with ganglionic cells, though for the most part of a smaller size, which likewise appeared to be mutually connected by filaments. These collections of cells in the grey matter seemed to form several more or less coherent groups, from which I could in some sections trace the origin of the anterior nerve-roots, whence I concluded, with Volkmann and Wagner, that the anterior nerve-roots are not continned through the spinal cord to the brain, but arise from groups of multipolar ganglionic cells. The posterior roots I could also, in some cases, trace to ganglionic cells of the posterior horns, which, in my opinion, are connected with the group of ganglionic cells and the anterior cornua, while another portion of the posterior roots appeared to pass longitudinally upwards, without penetrating into the grey substance.† These last observations in reference to the posterior roots I did not, however, venture to put forward as perfectly certain, on account of the great difficulty of tracing and distinguishing the connecting filaments with sufficient accuracy. The ganglionic cells and the posterior parts were in general smaller, more oblong, and less ramified than the anterior, and generally speaking, exhibited fewer pigment granules. Sometimes I met also between the division of the filaments small, triangular, ganglionic cells, betraying themselves as such by enclosing a nucleus. The filaments of the larger ganglionic cells are often thicker than the primitive medullary filaments present in the spinal cord. This structure I found most

* See these observations also translated into Swedish by J. F. Liedholm, in the *Hygiea, Medicinsk och farmaceutisk Månads-skrift*, xi. B. 1849, Sep. pp. 553, *et seq.*

† See *Aanteekeningen in de Sectie voor Nat. en Gen.*, *l. c.* p. 8.

distinctly in the lowest part of the spinal cord, where the medulla or the whitish fibres occur in smaller number; the same structure and connexion are likewise evident throughout the entire cord.

Hence I thought it might be inferred, that the motor nerves take their origin from groups of reciprocally-connected multipolar ganglionic cells, the filaments of which are again connected with anterior longitudinal nerve fibres. These longitudinal anterior columns I regarded as conductors of the orders of our will, the influence of which is diffused over a definite group of ganglionic cells, so as to excite with equal force all the nerve filaments springing therefrom.

Posteriorly, it seemed to me that the sensitive roots consisted of nerve filaments of sensation alone, which did not penetrate into the grey substance, but repaired directly upwards towards the brain; and of reflex nerve fibres, which, penetrating into the posterior cornua by means of the ganglionic cells and of their filaments, united with the groups of ganglionic cells constituting the source of motor nerves in the anterior horns of the grey substance. I inferred that these reflex filaments passed into several groups of ganglionic cells and united them more or less with one another, so that by reflexion several ganglionic groups, and therefore also, several nerves and muscles are at the same time brought into play; an arrangement which affords a simple explanation of the coördination of muscular action in reflex movement. Every ganglionic group therefore, in my opinion, possesses two poles, namely, one anterior and superior derived from the brain, conducting the orders of our will, and one posterior and inferior for the reflex nerves; both voluntary and reflex action being attended with discharges from the ganglionic groups, while the coördination of the muscles is in either case preserved.

This was, in short, the general result of my observations, which I had also extended to different animals, and in support of which it appeared to me that many arguments might be adduced.

In the interval which has since elapsed, the minute structure and composition of the spinal cord have been more closely investigated by several distinguished writers, with, however, very different results, and the development of a great variety of opinions, leaving the subject still in much uncertainty. It is, however, gratifying to me to see, that by the latest investigations all the propositions which I put forward in 1848, and which were published in that year, have been confirmed.* For these reasons I consider that it would not be unprofitable, having some time ago resumed my former investigations, and having discovered an entirely new and improved mode of making the preparations, again to bring forward my observations, enriched and extended by later experiments.

I shall first endeavour to show what other writers have brought to light on this important subject, so as to lay before the reader a synoptical view of the present state of our knowledge in reference to it.

The labours of Stilling, Volkmann and Wagner, having thrown doubt upon the correctness of the old theory of a direct connexion of the nerves through the spinal cord with the brain, the views of those observers who placed the origin of the nerves in the spinal cord, found a violent opponent in Kölliker, who endeavoured, by fresh investigations and calculations, to refute the arguments of Volkmann,† and to reëstablish the old opinion that all nerves arise directly from the brain.

That all the nerve filaments proceeding from the spinal cord may be comprised in its upper part, which, as we have above seen, Volkmann had denied on very plausible grounds,‡ Kölliker endeavoured to prove by fresh measurements of the thickness of the nerve-roots, compared with the constant increment of medullary matter as we proceed upwards in the cord.§ The probability of this was, he thought, much increased, by the greater tenuity of the nerve filaments in the spinal marrow than in the nerves, which Volkmann had indeed mentioned, but had not stated with any precision.‖ The powerful argument adduced by Volkmann, of the great disparity between the tenuity of the spinal cord and the thickness of the large number of nerves in the *Crotalus mutus*, Kölliker endeavoured, without any further proof, to weaken and to refute by the purely hypothetical position, that in this serpent the medullary filaments are so much slighter that his calculation is still applicable to it.¶

Any one, however, who is practically acquainted with the fineness of the medullary filaments in the spinal cord, their great number,

* See *Aanteekeningen van de Sectie-vergadering van het Prov. Utr. Gen.* June, 1848.

† *Mikrosk. Anat.* 2 B. 1 St. pp. 425, *et seq.*

‡ Wagner, *Phys. Wört.* 2 B. pp. 482, *et seq.*

§ *Mikrosk. Anat.* 2 B. 1 Abth., pp. 431, *et seq.*

‖ *Mikrosk. Anat. l. c.* p. 434.

¶ *l. c.* p. 346, *et seq.*

and the difficulty of estimating the quantity in a square line; and who recollects the multitude of ganglionic cells which exist, with their efferent filaments extending into the medulla, and bears in mind the various directions, both longitudinal and transverse, taken by the nerve filaments and grey fibres in the cord, must be at once convinced that such measurements and comparisons as those of Kölliker rest on a very uncertain basis, and really prove but little. We shall, in fact, see that the inaccuracy of these measurements has been subsequently established by Schilling.*

With this main question, whether all the spinal nerves arise from the brain? is most intimately connected that of the use of the multipolar ganglionic cells. Thus Kölliker assumes that these ganglionic cells are nowhere connected with the nerves; he found that the filaments derived from them constantly subdivide into progressively finer branches, so that if a connexion with the nerves must take place, this can be the case only with the most minute ramifications.† He considers it to be impossible, that a prolongation of a central ganglionic cell should pass as cylinder axis into the doubly outlined nerve fibre, although in a late essay Wagner positively states that he has undoubtedly seen such to be the case.‡ Of this, I not only do not see the difficulty (as all the filaments of the ganglionic cells do not run out into such fine networks), but I have more than once decidedly confirmed Wagner's observation.

Kölliker seems, however, himself to feel the difficulties of his views, as he subsequently says that he not only does not deny the origin of the nerves in the medulla, but considers it very probable; but he thinks there are no direct facts to prove it.§ This sounds strange indeed, as the subsequent positive observation of Wagner and Leuckart was known to him,|| though he denies its correctness; so that he can by no means prove himself wholly free from partiality, as he is unwilling to admit facts observed by others, when they are opposed to an opinion he has once embraced.

But Kölliker is not satisfied with denying the direct connexion of these ganglionic cells with the nerve-roots, for neither will he admit their connexion with one another, by means of their ramified filaments;¶ or he leaves us to suppose that if such connexions be

* E. G. Schilling, *De Med. Spin. texturâ*. Dorpat, 1852.

† *l. c.* p. 425.

‡ *Gött. Gelehrt. Anzeig.*, 1850, Feb. No. 4, pp. 53, *et seq.*

§ *l. c.* p. 426. || *l. c.* p. 425. ¶ *l. c.* p. 425.

present, they must occur very rarely, as he had never seen them.* In this he falls into a singular contradiction of his own physiological explanations of the functions of the spinal cord. Thus he says, in mentioning the experiments of van Deen, Stilling and Eigenbrodt, showing that after unilateral division of the spinal cord, voluntary motion is still present below the section (an observation which he had himself confirmed),† that a communication of sensation and voluntary motion through contiguity alone cannot be admitted, as in that case the conduction through the medulla would not be limited to the course of definite fibres‡—a point in which I quite agree with him. Subsequently, however, he again states, that the reflex phenomena, which takes place in the grey substance, are not necessarily bound to the continuity of fibres, as they occur in very remote parts;§ he thinks, that under particular circumstances, that is, in case of particular irritations or of an unusual disposition of the brain or spinal cord, there is a deviation from the regular course of conducting through fibres, and that in the grey substance a so-called cross-conduction (that is, a transference to the grey substance of the condition of the sensitive and motor fibres) takes place, which is then further communicated to other nerve filaments.‖ But as the reflex phenomena take place not only during vivisections and under extraordinary circumstances, but also swallowing, coughing, sneezing, and a multitude of other physiological acts, we cannot explain them by assuming the existence of an unusual state of things. The accurately adjusted movements, which, for example, in swallowing, are necessary in the complex connexion of the muscles, show that the transference of the stimulus from the sensitive to the motor nerves, is not performed loosely by means of an indefinite cross-conduction of the nervous influence, but along definite and prescribed paths, since these actions manifest themselves at all times and in all individuals in the same manner. But if Kölliker considers a cross-conduction in the medullary fibres in the experiments of van Deen and Stilling to be impossible, I do not see why he assumes this cross-conduction in reflex action, which he supposes to take place in the grey matter, and through the ganglionic cells, unless it be to maintain his theory,

* *Skizze einer Wissenschaftl. Reise nach Holland u. z. w.* in *Zeitschrift f. Wissensch. Zoog.* iii. B., 1 St. 1850, p. 85.

† *l. c.* pp. 438, *et seq.*

‡ *l. c.* p. 439.

§ *l. c.* p. 442.

‖ *l. c.* p. 443.

that the filaments of the ganglionic cells are not connected with one another nor with the nerves.

In order to account for the strange phenomenon, that after the section of one half of the spinal marrow, neither voluntary motion nor reflex phenomena are impeded on the cut side, Kölliker, following Arnold, brings forward the ingenious hypothesis, that the medullary filaments of the spinal cord decussate only by one half, and that therefore a motor nerve, for example, of the right side, contains filaments both from the right and left side, and that consequently, if the right side be cut through, the parts beneath the section may still be voluntarily moved by the filaments of the left side. This he illustrates in a linear figure.* But although it is true that many phenomena can be thus accounted for, numerous difficulties may be brought forward against this explanation.

In the first place, this view of the half decussating course of the nerve filaments in the spinal cord affords no explannation of the phenomenon, that if the cord be half cut through a little above the nerves of the fore- or hind-feet, these feet are completely paralyzed. Experiments proving this were performed some years ago, in my presence, by van Deen, for the hind-foot,† and by Stilling above the fore-foot, with the same result,‡ and have been confirmed by Eigenbrodt.§ There is no reason why, in this instance, the opposite fibres which do not decussate, and are not divided, should be at the same time paralyzed, which, according to Kölliker's theory, ought not to be the case, and yet constantly takes place.

Further, if his explanation is correct, we must admit that the filaments which do not decussate would appear to be unconnected with the side of the spinal cord through which they run, which is incredible. It is, indeed, well known, that after cerebral apoplexy, hemiplegia or paralysis of the one side exists; while on the opposite side —which in the spinal cord must also, according to the above theory, contain paralyzed filaments (those which do not decussate)—no trace of any lesion is discoverable. Hence it would follow that in paralysis of the right side, the left half of the cord should contain undecus-

* *l. c.* p. 440, Fig. 131.

† Van Deen, *Nadere ontdekkingen over de eigenschappen van het Ruggemerg.* Leiden, 1839, p. 61, experiment 47.

‡ Stilling, *Untersuchungen ueber die Funct. d. Rück.* Leips. 1842, p. 243, experiment 47.

§ *Ueber die Sectionsgesetze im Rückenmark.* Giessen, 1849, p. 50.

sated but paralyzed medullary filaments, exercising no kind of influence on this left half of the cord, as nothing morbid can be found on that side of the body.

We shall hereafter see how all these phenomena may be much more easily explained, and I shall for the present return to the historical account of what has been done in reference to this difficult subject.

Without being acquainted with the investigations of Kölliker, L. Clarke, of London, followed a totally different mode of making thin laminæ of the spinal cord transparent, of which I shall hereafter give a comparative statement, and which seems to have been extremely successful. He examines in several transverse sections the varying form of the anterior and posterior horns of the grey substance at different heights of the cord, the distinct course of the nerve-roots through the grey substance, and the ganglionic cells with their ramified filaments, which he illustrates with very good, and some even very beautiful drawings.*

He treats at particular length of the transverse fibres, a portion of which run, according to him, as nerve-roots in their course from behind forwards, divide into fasciculi, and in the grey substance form a network, in which the ganglionic cells are situated. Some of these posterior filaments even pass, according to Clarke, into the anterior nerve-roots, at least the anterior and posterior nerve-roots are interwoven in the centre as in a network. The transverse lateral fibres pursue another course, and form the commissures in the centre of the spinal cord; many fibres from these, too, are, he states, connected with the anterior and posterior nerve-roots.† The posterior roots are distinguished by interlacing with larger, broader, and more numerous fasciculi, and form a sort of plexus,‡ whence individual bundles penetrate into the posterior horns, and spread throughout the gelatinous substance. Some of these penetrate into the commissures, while others, in the spongy portion of the posterior cornua, divide to form a network, and pass into the anterior horns; some filaments pass over into the posterior and lateral longititudinal white columns.

The anterior nerve-roots penetrate, without previously interlacing, into the anterior cornua, where they divide into very slender fasciculi

* *Phil. Transactions*, 1851, part ii. p. 607, Plates xx.—xxv.

† *l. c.* p. 609, Tab. xx., Figs. 1, 2, 3, and particularly Tab. xxiii., Fig. 14.

‡ *l. c.* p. 606, Plate xxi., Fig. 6 and Fig. 14.

and distinct filaments, which follow different directions. Some of these pass into the outer border of the anterior cornua and penetrate into the anterior lateral columns; while others, after having made their way round through the groups of ganglionic cells, run inwards and unite with the anterior commissures, and decussate in the latter with those of the other side. The remainder pass into the centre of the anterior horns, and are lost in the network of the ganglionic cells.*

The ganglionic cells are, according to Clarke, united to one another by their efferent filaments, which subdivide into very minute branches; the space between the latter being occupied by an extremely fine network of very delicate fibres, the result of their further subdivision. Many of these filaments, especially those of the ganglionic cells, which are situated on the borders of the grey horns, run out between the white longitudinal columns, between which blood-vessels also are found. Clarke was, however, unable to decide whether these filaments pass into the blood-vessels.‡

That these ganglionic cells are very closely related to the nerves, follows, in this observer's opinion, from the remarkable fact, *that not only are they always found in the neighbourhood of the nerve-roots, but that they increase in number in a direct ratio to the greater thickness of the nerves, with which they are connected.*‡

Nevertheless, he states, that he has never been able to perceive any direct connexion between their efferent filaments and the nerves. The nerve filaments, according to him, surround the ganglionic cells, and are apparently in contact with them, but this contact does not present the character of true connexion. What he adds is, however, extremely remarkable, that it is very usual to see one or two of the cell filaments running outwards into a bundle of the anterior or posterior nerve-roots; and of this he gives a very satisfactory drawing, exactly as I also have found it.§ Still he does not look upon these filaments running into the nerve-roots as constituting the origin of a nerve, because he has seen similar efferent filaments of the ganglionic cells running among the white longitudinal columns (with blood-vessels), where no nerves or nerve-roots were to be found. If he had traced the deeper connexion of longitudinal and transverse fibres, and considered their functions, he would not have allowed

* Page 617, Tab. xxiii., Fig. 14, Tab. xxv., Fig. 15.

† *l. c.* p. 614. ‡ *l. c.*

§ *l. c* p. 615, Tab. xxv., Fig. 15.

himself to be carried by this last observation from the true track, but would have recognized the origin of nerves from the ganglionic cells, of which he gives a very good representation in the case of two ganglionic cells, and three filaments.

He terminates his demonstration with some inferences, of which, in order to avoid repetition, I shall only observe, that according to him, two considerable columns of multipolar ganglionic cells, which he calls the posterior vesicular columns, are intimately connected with the posterior nerve-roots through the entire length of the spinal cord, commencing slender below, increasing very much in circumference in the lumbar and cervical tracts, and terminating in the medulla oblongata. That also a column of cells, whence in the neck the accessory nerve takes its origin, extends downwards to the lumbar bulb; but that the accessory is the only nerve which derives its origin from this lateral vesicular column, and it extends its roots also to the anterior column of ganglionic cells.* He further observes, that everywhere, especially in the anterior cornua, the number of ganglionic cells is directly proportionate to the thickness of the nerves.†

Finally, Clarke has also stated as deductions from his observations on the spinal cord‡:—1. That the posterior nerve-roots are of three kinds, of which two, the posterior, enter the grey cornua at right angles, while the third, under different degrees of obliquity, run upwards towards the brain, in the posterior columns; the roots of the first kind are said to bend downwards in the posterior horns (my "fibres of communication"), and in part to penetrate into the anterior white columns, where they bend upwards and downwards, occasionally forming loops; those of the second kind are described as partly passing into commissures. 2. Clarke never saw the fibres of the anterior roots ascend into the anterior white columns. 3. In addition to the transverse bundles, forming the anterior roots, we have a system of extraordinary fine fibres from the anterior grey substance, which are lost in proportion as they approach the surface of the medulla spinalis (my "lateral rays"). 4. Nearly all, if not all the fibres composing the roots of the spinal nerves, go at once to the grey substance of the medulla, and if some of them ascend directly to the brain, they must be only those of the posterior roots, which run longitudinally with the posterior columns. Moreover, Clarke, as

* *l. c.* Tab. xxv. Fig. 13. † *l. c.* p. 618.

‡ *Phil. Trans.* 1853. Part 3, pp. 347 *et seq.*

before, does not deny, that a portion of the nerve-roots is connected with the ganglionic cells, but he considers this conexion to be not yet satisfactorily established. He is also further inclined to believe, that the grey matter conveys no impressions from or to the brain. With respect to reflex action and the connexion with the muscular nerves, he does not offer any decided opinion, and he thinks that the simultaneous and sympathetic movements in remote and apparently unconnected systems of muscles, must be explained by the singular admixture of nerve-roots, which are said to diverge upwards and downwards in the medulla spinalis, and are there intimately commingled. Lastly, he also assumes, in opposition to Kölliker, a central canal in the spinal cord of man.

But it is particularly from the later investigations of Rudolph Wagner, although Kölliker has thrown doubt upon them also, that the opinion which refers the origin of the nerves to the ganglionic globules, derives its main support.

So early as 1850, Volkmann stated that Leuckart, working under him, observed in several places the transition of filaments of the multipolar ganglionic cells into genuine primitive nerve filaments, and also traced their connexion with one another; both these physiologists subsequently succeeded in clearly seeing a filament from a multipolar cell pass into a dark edged doubly-outlined brain and nerve filament. We may, therefore, says Wagner, infer, that from such a cell a prolongation is given off as cylinder axis, runs as a primitive fibre through the body, and finally, for the most part, ramifies in the periphery, and terminates in the tissues.*

These investigations were subsequently confirmed by the researches of the same writer, in reference to the electrical lobes in the brain of the torpedo. He says, that these lobes are entirely composed of aggregates of very large multipolar ganglionic cells. From these, proceed to the periphery prolongations, which are of a twofold nature; some are not ramified, and pass immediately into ordinary doubly-outlined nerve filaments, whose cylinder axes they form. Indeed the doubly-outlined external edge is often wanting, as it is very loosely connected with the cylinder axis, and the majority of these, prolongations constantly lose this outer margin; but, he says, we have undoubtedly seen fragments of this outer edge of various sizes, in particular prolongations, at one time close to their origin, at another in their further course.† In general, according to him, one

* *Gött. Gelehrt. Anzeig.* 1850, Tab. No. 4, pp. 53 *et seq.*

† *Gött. Gelehrt. Anzeig.* 1851, Oct., p. 190.

or more rarely, two, genuine nerve filaments appear to arise from each ganglionic body. The remaining prolongations, at one time branched, at another not ramified, serve to connect, at varying distances, the several ganglionic cells with one another.* Finally, Ecker has given very beautiful and conclusive representations of these preparations in his *Icones Physiologicæ*,† in which not only the transition of the filaments of the multipolar ganglionic cells into primitive nerve filaments is visible, but also the reciprocal connexion of these cells is distinctly shown, especially in figures VI. and VIII. Quite analogous to these electrical lobes, adds Wagner, are the nerve nuclei of the *vagus, accessorius, hypoglossus,* and *trigeminus,* that is, they consist of insular accumulations of multipolar ganglionic cells in the grey substance, which send out and take up fibres, and are connected with one another in a bridge form, by minute nerve filaments.‡

I may add, that Engel also infers from his observations, on the larvæ of frogs, that the nerves end in the spinal cord.§

Blattman observed the same in full-grown frogs, and states that he has convinced himself that in smaller birds, fishes, and even in mice, the nerves terminate in the spinal marrow.|| I doubt however, whether the nerve-roots cease in the cord so suddenly as he represents them in his drawings, without giving off some efferent branches.¶ He acknowledges, nevertheless, that connexions occur between nerve filaments and ganglionic cells, although he says, he has directed but little attention to this point, and that true ganglionic globules are rather rare in frogs.** Subsequently, he again speaks of numerous free nuclei of the ganglionic cells in the grey substance. I suspect that his mode of examining these parts must have greatly influenced his results.

The investigations of G. Schilling †† are of more importance. This writer speaks first in detail of Kölliker's measurements, and disputes

* *l. c.*

† Ecker, *Icones Physiol.*, 2 Heft., Taf. xv. Figs. iii., vi., vii., viii., and x.

‡ *l. c.* p. 191.

§ *Zeitschrift der kais. kon. Gesellschaft der Aerzte zu Wien*, Nov. 1847, p. 113, &c. Of this I am aware only from quotations, and have had no opportunity of consulting the original.

|| Blattman, *Mikrosk. Anatom. Darstellung der Centralorgan des Nervensystems*, 1850, p. 46.

¶ *l. c.* pp. 46 *et seq.*, and p. 53, Figs. 1 and 2.

** *l. c.* p. 18.

†† *De Medullæ Spinal. textura ratione imprimis habita originis cerebralis nervorum spinalium*, Dorpat, 1852.

their correctness and that of the results derived from them. He indeed acknowledges, that in the cervical portion of the spinal cord the thickness of the medullary substance is greater than in the dorsal, and that here it is greater than in the lumbar portion, but this does not proceed regularly; there are two places above the cervical and above the lumbar portion, where the medullary substance is invariably more slender than in the parts beneath.* The drawings of the transverse sections of the spinal cord by Kölliker† he designates, and in my opinion with justice, as incorrect.‡

Besides, there is an increase in the anterior and posterior, but not so much in the lateral columns, which, however, contain most medullary matter.§ Moreover, the limits of the grey and medullary matter are not very well defined, even under the microscope, as the grey substance sends efferent branches on all sides into the latter, and through this numerous transverse nerve fibres run, increasing its thickness.|| Lastly, all the longitudinal filaments of the medullary substance are not equally slight, as Kölliker had calculated; Schilling met some thicker than the nerve fibres themselves, and the proportion between these thick and slight filaments cannot be ascertained; whence this author infers, that what Kölliker brings forward on these grounds against Volkmann, is of no weight.¶

With respect to the nerve-roots, he says, in opposition to Clarke's observation, that he never saw the fibres of the anterior nerve-roots, after they have entered into the cornua of the grey substance, pass into the commissures, or penetrate into the fibres of the posterior horns, or as Kölliker asserts, run in an arched form into the white columns. In some cases, he distinctly saw the nerve filament from the anterior root enter into a ganglionic cell, the lines of the nerve filament passing into the lines of the filament from the cell; in one case this transition was so evident, that no doubt could exist as to the direct connexion, a circumstance which he observed with the more care, as it was of the greatest importance in reference to the origin of the nerves.** In longitudinal sections, too, he never saw the roots of the nerve filaments pass the boundaries of the ganglionic cells, but sometimes he observed a nerve-root arise from a ganglionic cell.††

Among the longitudinal white columns he found fibres, which,

* *l. c.* pp. 9 *et seq.*

† *Mikrosk. Anat.* p. 431.

‡ *De Med. Spin. text.* p. 10.

§ *l. c.* p. 11.

|| *l. c.* p. 12.

¶ *l. c.* p. 54.

** *l. c.* p. 29.

†† *l. c.* Tab. ii., Fig. 5, *b*, *c*.

arising from the grey matter, or even from the ganglionic cells and curving upwards, ran as white medullary filaments to the brain;* the posterior nerve-roots he observed, however, passing in part into the longitudinal white columns.†

Lastly, and this is of importance, he says, that the longitudinal fibres, at least the anterior and middle or lateral columns, arise from the grey matter, and in fact from the ganglionic cells, while from the same ganglionic cells the roots of the nerves also take their origin, and thus both are connected by means of these cells.‡ Thus also, according to him, the volume of the grey substance corresponds to that of the nerve-roots, and the thickness of the latter again accords with the increase of the longitudinal fibres, which convey the cerebral power into the nerves, and the nervous power to the brain; all which quite agrees with what I brought before the sectional meetings in 1848, but which was unknown to this writer. In conclusion, he says:—

1. That the longitudinal medullary fibres of the spinal cord steadily increase in number from below upwards.

2. That these longitudinal fibres take their origin from the grey substance, and at least in part, from the ganglionic cells.

3. That the number of the long fibres, as well as the number of the fibres passing into a nerve filament, increases from the inferior portion of the spinal cord in the same ratio as the grey substance increases in circumference.

4. The fibres of the anterior nerve-roots arise from the anterior horns of the grey substance, and in fact from the ganglionic cells.

5. The greater part of the posterior roots passes probably into the longitudinal fibres which are present in the posterior horns.

6. The grey matter contains no proper fibres but those which arise from the commissures.

7. The anterior commissure also consists of grey matter.

This last was described by Kölliker, and most writers, as a white commissure. I formerly believed with Schilling that these commissures consisted of grey matter, but my later investigations have convinced me of the correctness of Kölliker's opinion.

Lastly, these results are still further confirmed by the investigations of Gratiolet.§ This writer differs from Schilling, in considering

* *l. c.* p. 33, Tab. ii., Fig. 5, *d.* † *l. c.* p. 40.

‡ *l. c.* p. 55.

§ *Structure de la Matière epinière* in *l'Institut.* 1851, Août, pp. 272 *et seq.*

the anterior commissure as consisting of white medullary fibres. Gratiolet describes the multipolar ganglionic cells as not uniformly disseminated through the anterior horns of the grey substance, but as being accumulated in different groups, especially in the neighbourhood of the white fasciculi. In the expanded portions of the spinal cord these groups are larger than in the narrower parts, they are also of greater size in large than in smaller animals. According to this writer, they are connected with one another, and are not isolated; their radiations or filaments divide and subdivide, forming a great plexus with irregular meshes, observable, with especial distinctness, in the Ruminantia. These meshes are elongated in the neighbourhood of the white bundles; they are more rounded off in the middle of the grey substance; they are largest and most numerous in the lumbar bulb.

Besides these very distinct connexions, uniting the multipolar ganglionic cells into a system, we can, on accurate examination, trace a great number of nerve filaments into them, and demonstrate the continuity of some fibres of the anterior nerve-roots with definite prolongations of the cells. The latter are, therefore, in connexion on the one side with the anterior and middle columns of the spinal cord, and on the other with the roots of the anterior or motor nerves. Gratiolet adds, that these facts have been observed by him with the greatest accuracy, and have been fully established.

He was less fortunate in his attempts to discover a connexion between the posterior roots and the grey substance. In longitudinal sections, the fibres of the posterior roots are seen to bend into the posterior longitudinal columns, which appear to be in great part composed of these roots. From the anterior fasciculi of the roots some fibres proceed to the posterior grey commissure, others pass into the spongy substance, where they form little bundles, giving a striated appearance to the gelatinous substance. Notwithstanding all his endeavours, Gratiolet did not succeed in tracing a connexion between these fibres and the ganglionic cells, although he suspects the existence of such a connexion.

The radii of the ganglionic cells, the filaments of the anterior nerve-roots, and the fasciculi of the posterior roots, form, in the anterior cornua, a tissue which cannot be unravelled, and which is still further increased by the accession of a great number of fibres of the anterior nerve-roots, and of the middle fasciculi, which pass from the one side of the spinal cord to the other in the anterior horns (*commissura anterior*). The fibres, however, of the anterior nerve-roots appear, according to this writer, not to pass directly into this commissure.

The same author further considers it to be established, that the grey centres on either side are connected with one another, but that the nerve-roots which repair to them do not decussate with those of the opposite side; the fibres decussating here, he thinks, belong to the longitudinal fibres going to the brain.

Since 1848, I carried my investigations on the minute structure of the spinal cord still further, and laid their results before the Dutch Academy of Sciences. This took place on the 24th of December, 1853. The communication was, however, not read until the subsequent meeting on the 27th of January, 1854. The essay was first printed in the second volume of the "Transactions of the Academy," and is at present being translated into German by Professor Theile, of Weimar, with some additional observations by myself. But this historic sketch requires that I should briefly mention what has been done on this subject since I brought forward the essay in question.

To begin,—two essays by Rudolph Wagner demand attention; the first of which was published in the number of the *Göttinger Gelehrt. Anzeigen* for the 30th of January, 1854, the second in the following number, of the 6th of March. These essays present in many parts a striking agreement with my statements, not only in reference to the facts observed by me, but even with respect to many of my physiological theories. Of course, I have not the most remote suspicion that Wagner was acquainted with my former announcements in the "Transactions of the Utrecht Society," for 1848; but I think that, in this striking agreement with my statements, we have a convincing proof of their truth.

In his first essay of the 30th of January, 1854, *On the Elementary Organization of the Brain*, Wagner correctly regards primitive fibres and ganglionic cells as the essential parts of the brain and spinal cord, and arrives at the following conclusion:—"The brain and spinal cord are nothing else than massive accumulations of primitive fibres, and multipolar ganglionic cells. Combinations of primitive fibres do not occur except through the interposition of ganglionic cells. Consequently, all transferences from one primitive fibre to another take place by anatomically demonstrable paths. Grey substance and its actions on the nerve-fibres are the indistinct expression of what is quite distinct: multipolar ganglionic cells connected with primitive fibres. All phenomena of innervation depend on combinations with one another, and with central and peripheric nerve paths, of individual ganglionic cells and larger aggregates of the same, as special seats of innervation of various physiological importance. It is not necessary to assume the existence of a transference from fibre to fibre in the sense, perhaps, of the so-called paradoxical spasm; such a transference is, for many reasons, on which it is not requisite at present to enter, highly improbable; it could have only a disturbing action in the course of physiological phenomena."*

With respect to the structure of the spinal cord, Wagner states his ideas only briefly. In considering the posterior roots this writer assumes, just as I have stated:—

1. Purely sensitive fibres, which, without being connected with ganglionic cells, pass upwards towards the brain and there excite sensation.

2. He assumes a second class of purely sensitive fibres, which are said to unite with the ganglionic cells in the posterior cornua, and are connected with the little multipolar ganglionic cells also described by me as existing in these horns, whence again fibres are said to ascend longitudinally towards the brain, while others as commissural fibres pass behind the canal into the ganglionic cells of the opposite posterior horn. This canal, too, according to Wagner, is open, and is not a solid column of ganglionic cells, as is very incorrectly stated by Kölliker.

Finally, a third, and indeed a very considerable portion of the posterior radical fibres serve not for sensation, but proceed towards the great multipolar ganglionic cells, whence the anterior motor fibres take their origin.

In Wagner's second essay, published in March, 1854,† *On the Structure of the Spinal Cord, and the foundation thence deducible for a theory of reflex movements, of coördinated movements, and of coördinated sensations,* the writer enters rather upon a defence of proper reflex nerves, into which I shall not follow him, as I elsewhere consider the principal proofs of their existence. But the author returns once more to the connexion between the reflex nerves in the posterior cornua, and the motor ganglionic cells in the anterior horns,

* *Gött. Gelehrt. Anzeig.*, 30th Jan. 1854, pp. 35 *et seq.*

† *Gött. Gelehrt. Anzeigen*, 1854. March, No. 6.

and says that he has again examined this connexion, the spinal marrow having been previously hardened in chromic acid, but that he has not arrived at any certain conclusion. He himself declares: "But I am still doubtful whether the fibres which distinctly pass from the posterior cornua of the grey substance to the large ganglionic cells of the anterior horns, are previously connected in the posterior horns with ganglionic cells, whence grey commissural fibres first repair to the motor ganglionic cells of the anterior cornua." * He also describes the ganglia in the middle towards the posterior spinal sulcus, as smaller, and with few rays, just as I too have found them. It appears to me, however, extremely improbable that, as Wagner stated in his first essay, proper sensitive nerves should also pass into these ganglia ; some filaments going to the brain for sensation, and others from the same ganglia, or reflex filaments, to the anterior cornua. I doubt very much that a purely sensitive nerve can at the same time be a reflex nerve for motion; it would from this very circumstance lose its character as a sensitive nerve, and the reception of proper reflex nerves would become superfluous. Nor are any fresh principles brought forward by the author for the explanation of coördinated movements, to which the actions of the oculo-motor nerve are referred, and of coördinated sensation. These appear to me, as elsewhere observed, to take place higher in the brain, or in the medulla oblongata.

Remak likewise, at the same time, added a contribution to our knowledge of the structure of the spinal cord,† in which he describes some preparations of transverse and longitudinal sections in man, and in the cow, made by Stilling, and sent to him two years before. Remak says that in these he can perceive the passage of the motor-roots into the anterior ganglionic cells: moreover, he finds in transverse sections, slender fasciculi of the dark-edged nerve filaments, which appear to establish a connexion between the anterior and posterior roots. He describes also, as it appears to me, the circular marginal fibres, which I have represented, and the ganglionic cells in the gelatinous substance, whence, according to Remak, an elongated

* *l. c.* p. 97. Although the extraordinary minuteness of the course of the fibres in the posterior cornua, and the difficulty of tracing it, renders it hard to arrive at perfect certainty on this subject, I believe that in my description, which I have put forward and illustrated, I have, as nearly as is possible in so fine a tissue, decided this question in favour of the latter view.

† See *Monatsberichte der K. Acad. der Wissenschaften zu Berlin.* Jan. 1854.

filament accompanies the sensitive roots; while the greater mass of these sensitive roots (my reflex fibres) radiate in broad dense bundles through the gelatinous substance into the posterior grey columns and into the sphere of the large multipolar ganglionic cells (consequently into the anterior cornua). It would, therefore, appear, that neither has Remak clearly seen this direct connexion; while in other respects his description agrees tolerably well with mine. Still, however, he observes, that the circular marginal fibres appear to indicate the paths by which in decapitated animals stimulation of sensitive nerves occasions reflex movements; we have seen, that in the anterior cornua these marginal fibres serve to take up the longitudinal columns through the lateral rays, and to convey them to the great multipolar motor cells.

It is of importance that Remak has discovered multipolar cells also in the sympathetic, which I have recently seen very beautifully in the lumbar ganglia of that nerve, and which appear to me to be present in all its ganglia, so that I can confirm this discovery.

Schiff has also instituted investigations of the spinal cord, consisting chiefly of vivisections, whence he thinks it may be inferred that the grey substance is insensible, even in the posterior cornua, but that it possesses fibres, which conduct the received impression to the brain and excite sensation, without being themselves sensitive. These he proposes to distinguish by the strange name of æsthesodic fibres, from motor fibres, which he denominates kinesodic fibres.* It clearly appears, however, from the entire essay, that Schiff has invariably confounded reflex phenomena with sensation or perception, and has fallen into the error of so many writers, who regard shrieking as an invariable proof of sensation, whereas I have shown that it may also take place without perception. But the fact established by his experiments, that if we cut transversely through the spinal cord, and then prick the grey substance with a needle, no pain is excited, as has been already observed by other writers, appears to me to be important, and confirmatory of what I have advanced in reference to this point.†

Still more important, in my opinion, are the investigations in which he endeavoured, by numerous vivisections, to prove that the anterior columns of the spinal cord possess motor fibres for the

* *Comptes rendus*, 22nd May, 1854, pp. 924 *et seq.*

† *l. c.* p. 929.

extremities, and the lateral columns fibres for the movement of the trunk, that is, of the thorax and abdomen. The organic filaments for the stomach and intestines are referred by him to the anterior columns, and on cutting through the latter, red spots, merging even into dark brown, with separation of the mucous membrane, appeared in the stomach. But the experiments in which the lateral columns in dogs were cut through on the one side, are extremely remarkable. These animals Schiff was able to keep alive from six to ten weeks, the paralysis which first occurred rapidly disappearing, so that the dogs completely recovered, and ran upon four feet; while, however, all motion of the ribs and of the abdomen, as well as respiration, had ceased on the injured side.*

If with this we connect the opinion of Clarke, who, as I have above stated,† believes he has ascertained, that through the entire spinal marrow a column of ganglionic cells is present at the sides, from the upper part of which the accessory nerve springs, the view advanced by Schiff acquires great probability, and deserves closer examination.

Further, since the first appearance of my essay, three special works on the Spinal Cord have been published, in which the propositions and statements put forward by me, have been in general confirmed; viz.:—J. van Lenhossek's *Neue Untersuchungen ueber den feineren Bau des centralen Nervensystems des Menschen.* Wien, 1855. F. Bidder und C. Kupffer, *Untersuchungen ueber die Textur des Rückenmarks.* Leipzig, 1857; and the great work of B. Stilling, *Neue Untersuchungen ueber den Bau des Rückenmarks,* 3 Lieferungen, 1856, with Atlas. In general, by far the greater number of my results have been confirmed by these writers. The work of Lenhossek is purely anatomical; he has shown that the course of the nerve-roots is not horizontal, but that it is directed obliquely upwards in the spinal cord; I have seen this established in his own preparations. Other fibres which he represents in his work as descending obliquely, although the drawings of them are more linear (Plate III., Fig. 1, letters *e e e*), appeared to me to be connective tissue, accompanied with blood-vessels; possibly they may also be the roots of the sympathetic nerve. The mode in which Lenhossek makes his

* Vierordt, *Archiv für Physiolog. Heilkunde,* 13 Jahrg. 1 Heft. 1854, pp. 30 *et seq.*

† See p. 17.

preparations renders them clear indeed, but not adapted for the easy distinguishing of the primitive fibres; he follows Clarke's method with turpentine, which, according to my experience, cannot lead to correct results, as the spinal marrow is too much altered by that agent.

The work of Bidder and Kupffer differs still more in many principal points; chiefly in consequence of the peculiar ideas of the writers, that the greater part of the grey substance, a portion of the white medullary matter, the entire posterior commissure, and a part of the anterior commissure, consists of connective tissue, and not of nerve filaments. I cannot at all coincide in this view; besides the unphysiological nature of the idea, it may suffice to observe that connective tissue always contracts strongly when it is laid in a saturated solution of chloride of calcium, in consequence of which the pia mater curls up, from the loss of water; this is, however, not the case with the parts of the spinal marrow in question, the blood-vessels alone are accompanied by a little connective tissue. Moreover, connective tissue long resists putrefaction, while everyone knows how rapidly the spinal marrow after death becomes soft, and almost fluidifies.

In other respects, Bidder confirms nearly all my observations.

Stilling's work is uncommonly copious, three tolerably thick quarto volumes have appeared, and still it is not completed. It contains many observations and measurements, and a very complete history; but is also purely anatomical. Stilling, too, corroborates pretty closely all my remarks.

CHAPTER II.

ON THE METHODS OF INVESTIGATION.

If we inquire why, in the important study of the Spinal Cord, so many distinguished authors and able microscopists have arrived at such opposite conclusions, the reason appears to me to consist, in general, not merely in the great difficulty of obtaining suitable objects for microscopic examination, to which I have already alluded in the Introduction, but also in the variety of the modes employed by different authors to render the objects transparent and fitted for microscopic investigation.

Stilling endeavoured to obtain the degree of hardness necessary for making fine sections of the spinal cord, by placing the part in spirits of wine; for this purpose he employed tolerably strong alcohol. I have followed the same mode of operating, but experience has taught me that ordinary spirit, the specific gravity of which ranges between 903° and 917°, is better than stronger; the spinal cord is, indeed, more rapidly hardened by the latter, but the tissue is also more quickly changed, as the fat is extracted by the strong spirit, is deposited as irregular globules or in the granular form between the fibres, and finally collects in larger masses, rendering the medulla quite unfitted for minute examination; in weaker spirit, the change ensues much more slowly, and a hardened portion can be used for a much longer time.

Kölliker, following the mode proposed by Hannover, has strongly recommended chromic acid, by which a considerable degree of hardening is obtained, and he subsequently clears the medulla, which has been rendered very opaque by the acid, with a diluted solution of caustic soda,* a plan which has found pretty general acceptance. I also have tried this method, but cannot join in the great praise which Kölliker gives it. It is true we can prepare fine sections, and make them transparent with a solution of soda, but in general the object becomes too uniformly transparent, and we cannot satis-

* *Mikrosk. Anat.*, II Th., I Abth., p. 424.

factorily trace the filaments, especially those of the ganglionic cells, which are rendered invisible,—a defect made manifest by comparison with alcoholic preparations.

Schilling, too, complains that preparations treated with chromic acid are little adapted for the observation of these filaments,* and it has struck me very forcibly, that in his beautiful drawings, Tab. I. and II. Figs. 1 and 2, the ganglionic cells are everywhere represented without efferent filaments; although he has beautifully shown the nerve-roots. I suspect, too, that this is the principal reason why an observer, otherwise so accurate as Kölliker,—who may be classed among the first microscopists, and whose observations are generally highly characterized by correctness,—so completely differs on this point from later writers.

Clarke has adopted a totally different method in his preparations; he recommends that, after hardening in spirit, they shall be moistened on a glass with a mixture of three parts of spirit and one of acetic acid, which renders the grey matter more transparent. According to a second plan, he lets the thin section first macerate for one or two hours in the mixture of acetic acid and spirit, and then lie again for the same time in pure spirit; he next places it in turpentine, which expels the spirit in the form of dark drops, and quickly makes the section perfectly transparent. He afterwards immerses the latter in Canada balsam and covers it with a glass.† This plan did not succeed well with me; the preparation became only partially clear, and the ganglionic cells, from which the fat seemed to be removed, were rendered indistinct.

Wagner recommends a solution of sublimate.

When I next attempted to solve this difficult problem, I endeavoured to discover a method which should possess, in an increased degree, all the advantages of the former plans, without their disadvantages; after trying several saline solutions, acids, alkalies, and also glycerine, I had at least the good fortune to discover a mode of preparing these objects for the microscope, which, according to my experience, deserves to be preferred to all the others.

The spinal cord, divided into portions not too large, is first to be hardened in spirit, and as soon as it is sufficiently hard (for the shorter time it has lain in spirit the more distinct will the prepara-

* *l. c.* pp. 56 *et seq.*

† *Phil. Trans.* 1851, Part 2, pp. 607 *et seq.*

tions be), fine sections are to be made,* one of which is placed with a little distilled water on glass and covered with a thin plate of the same material. The two projecting edges of the latter are next to be very gently and alternately pressed, so as to force the water between the fibres of the section. The water very quickly becomes milky, and is to be washed away by constantly dropping a fresh supply at the edge of the covering glass, the alternate pressure being at the same time repeated, until the washings cease to be milky. Care should be taken to prevent the pressure being sufficient to alter the form of the object, as in that case the motion communicated to the covering glass would tear the medulla, and the connexion of the parts would be broken up by the water passing through it. In this manner, with some caution, we easily succeed in washing away the fat granules and loosened portions which interfere with the clearness of the object.

The same end may also be attained by placing the section for some moments in ether on a watch-glass; but if it be allowed to remain too long in the ether, for example, more than half an hour, the ganglionic cells become invisible, in consequence of the disappearance of the granular fat. I have always found washing with water satisfactory. By applying a good deal of water at the edge of the covering glass, and holding the glass obliquely, the covering glass glides, of its own accord off the object, without injuring the latter. The surrounding water is now wiped away, and a couple of drops of concentrated solution of chloride of calcium are brought by means of a glass rod upon the section, which is to be covered with the thin plate of glass; the latter is to be gently pressed and allowed to stand; after half an hour, or even sooner, it will be seen that the object is beginning to become transparent. After the lapse of eight or ten days the object will be extremely transparent, and all the fibres will be distinctly visible with sharp edges, a very great advantage being, that the minute capillary vessels become more distinctly visible and distinguishable from the nerve filaments. The fat, which is still present, sometimes begins to collect, here and there, into small granules, and to render some parts less clear, especially if the object

* For this purpose I make use of a broad sharp razor, supported on the forefinger of the left hand, by which the direction of the cut can be very accurately guided. It is of importance to moisten the upper surface of the instrument with spirit, otherwise the thin section adheres to the razor, and is torn.

has not in the first instance been sufficiently washed with water. If this is the case, solution of chloride of calcium is again to be applied to the edge of the covering glass, which takes it up, is loosened by the solution, and is now easily pushed off; the object is then washed on the glass with solution of chloride of calcium, covered as before, and allowed to remain for some days, after which the edges are luted.

A solution of chloride of magnesium also makes the sections clear, but does not produce this effect so quickly; subsequently, however, the fibres become exceedingly clear, although occasionally crystals form in them, and must be washed away. On the whole, I give the preference to the preparations with chloride of calcium, as presenting the greater degree of clearness.

A very great advantage of both methods is, that the objects need not be immediately luted, for as solutions of chloride of calcium, and also, but in a less degree, of chloride of magnesium, constantly attract moisture from the atmosphere, the preparations do not dry; we may therefore prepare a great number of objects, and subsequently select and lute the most beautiful with asphalt for preservation, while, for the same reason, the preparations never spoil, as the chloride of calcium does not dissipate. These preparations are therefore permanent, the filaments of the ganglionic cells and of the nerves are also very well shown; not only does the grey substance become clear, but the medullary matter exhibits its tissue clearly and distinctly.* Objects hardened in chromic acid acquire the same clearness by chloride of calcium, but subsequently small crystals form in them, and the ganglionic cells and their filaments are not so beautifully seen as in the objects hardened in spirit, although the nerve filaments are very beautifully visible. We may also subsequently try to wash off the crystals.

Placed by this means in a position to examine with greater clearness and certainty the minute structure of the spinal cord, and, if possible, to unravel nature's skilfully constructed tissue, I have once more, with the greatest care, repeated much of my former investigation, paying especial attention to those points in reference to which I was more or less in doubt.

* It appears that a concentrated solution of chloride of calcium withdraws from the nerve filaments and grey substance a portion of the water, and so produces the great transparency of these parts. We must, how-

It is now gratifying to me to be able to state, that I have not been obliged to withdraw anything which I before put forward, either as fully ascertained, or as still liable to some doubt; on the contrary, the results of my former investigations have been confirmed, and have received the support of some additional facts.

In order to see the ganglionic cells, their connexions, and the nerves arising from them, I can, however, finally, above all recommend, with some modification, a method proposed by Gerlach, which consists in colouring these parts by means of carmine. After some trials, I find that the following mode of making preparations is the most satisfactory, and it is in many respects still better than that with chloride of calcium. The spinal cord (and best that of a calf) is hardened for two or three days in spirit of from 849° to 872°, a very fine section is made and placed in a watch-glass with a saturated solution of pure carmine in water, and one or two drops of caustic ammonia; in this I do not allow the object to remain more than four or five seconds. The object, after being again placed in spirit, in order to wash off any redundancy, is laid upon a glass and allowed to dry a little, after which a couple of drops of spirit of turpentine are added. If it is now left for twenty-four or forty-eight hours, without a covering-glass, but protected from the dust, the spirit evaporates, the object becomes perfectly clear, and all the cylinder-axes and ganglionic cells are seen coloured red, but not the outer walls of the nerve tubes, which remain white; the blood-vessels and connective tissue also become coloured. The object is now covered with Canada balsam and a glass—Gerlach uses a dilute solution of carmine, and lets the object lie in it for twenty-four hours, but the colouring is then less sharply defined.*

ever, bear in mind, that if we allow the object to remain long in a solution of chloride of calcium without a covering glass, it will shrivel up.

* This paragraph, which does not appear in the original, is among the additional matter kindly sent me by the author for this edition of his work. The following note, which I have since received from him, is, however, still more recent.—TRANSLATOR.

"I now follow Gerlach's method of colouring preparations of the nerves (which at first did not succeed well with me), by placing the sections in a very dilute solution of carmine in spirit, and allowing them to remain in it from twelve to twenty-four hours. Formerly I was in the habit of laying them in a watery solution of carmine and ammonia, by which mode I obtained less beautiful preparations. I now add spirit to a few drops of a strong solution of carmine and ammonia, until it acquires a light rose colour, which I prefer."

CHAPTER III.

ON THE STUCTURE OF THE SPINAL CORD.

Having above quoted all that is stated on the subject by other writers, I shall not now enter upon a detailed description of the structure of the spinal cord; but shall content myself with recording the principal facts I have myself observed.

In the first place, I have demonstrated beyond all doubt, the mutual connexion of the multipolar ganglionic cells, by means of their connective filaments, in a considerable number of preparations, an inspection of which will, I think, be sufficient to convince the most incredulous. The subject is, however, not free from sources of fallacy; thus, in the grey substance, especially in the seat of these ganglionic cells, a very large number of extremely fine capillary blood-vessels are to be seen forming a most complicated network, and running round these cells, while their branches often very deceptively assume the appearance of passing into the latter. But it is a peculiar and not unimportant advantage possessed by a solution of chloride of calcium, that under its use the walls of the capillary vessels are distinguished from the filaments of the ganglionic cells by a particularly strongly-marked edge. My former preparations, which were kept in a dilute solution of arsenious acid, have occasionally misled me in this respect, although in these too the true connexion is plainly visible. Sometimes, two ganglionic cells near one another are connected by a tolerably thick filament;* almost always the connexion is visible, either between the adjoining, or between more remote ganglionic cells,† for, not unfrequently, a connecting fila-

* See Fig. 1 *a a′*, magnified one hundred times. I greatly prefer in general, but especially in these complicated tissues, a moderate magnifying power; at eighty or one hundred diameters we not only see the fibres better defined, but the larger field thus obtained exhibits the connexions more distinctly. It is only as an auxiliary and as a means of comparison that I make use of greater magnifying powers.

† Fig. 1 *b c*.

EXPLANATION OF PLATE I.

All the figures illustrating the Essay on the Spinal Cord are magnified one hundred times, except figure 5 and figure 8, which are magnified about sixty times, and figure 12, which is magnified ten times.

Fig. 1. Part of a Group of Ganglionic Cells from the Anterior Horn of the Lumbar Portion of the Spinal Cord of a Cow, in which the numerous filaments of communication, whereby these cells are connected with one another, are visible, page 35.

a a'. Two ganglionic cells, connected by short filaments; some communicating filaments are longer, as between *b*, *c*; others run over a ganglionic cell as *a'*, *e*; others appear to be connected by more than one filament, *a d*.

Fig. 2. A similar group of Ganglionic Cells, page 35.

a, *b*. Longer communicating filament.

Fig. 3. Transverse Section of a Portion of the Anterior Horn of Grey Matter, into which some Nerve-roots enter, page 38.

a. Grey matter of the anterior horn, in which are several multipolar cells, connected with one another by a network of communicating filaments. Among these, blood-vessels also run, of which two are shown at *a a*; from the cells several filaments are seen at *b b b b*, to pass into the nerve-roots.

Fig. 4. Longitudinal Section along the entrance of the Nerve-roots into the Anterior Horn, and origin of the Motor Nerves, page 39.

a a. Longitudinal filaments of the anterior medullary columns.

1, 1'. Two nerve-fibres, running into one cell and appearing to pass into two different bundles.

2. Two other nerve-fibres from the one side derived from one cell.

3, 4. Two nerve-fibres, passing obliquely under the others into the cell 4.

5, 6. Other cells, from which nerve-fibres issue.

7. Nerve-fibres which are lost in the more deeply-situated part of the horn.

8, 9. Communicating filaments between different cells, as they form themselves into groups.

[To face page 35.

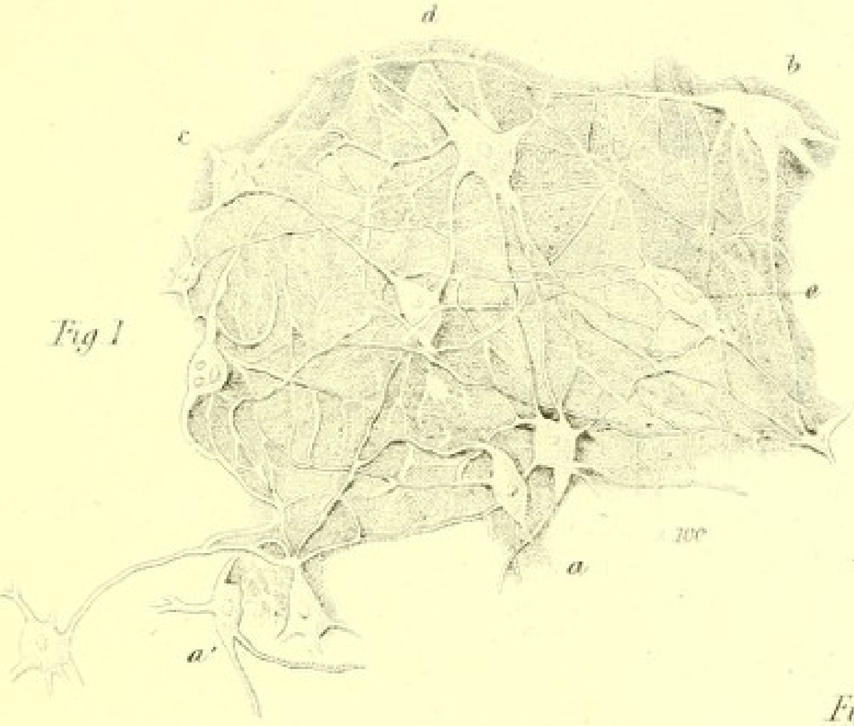


Fig. 1

Fig. 2

Fig. 3.

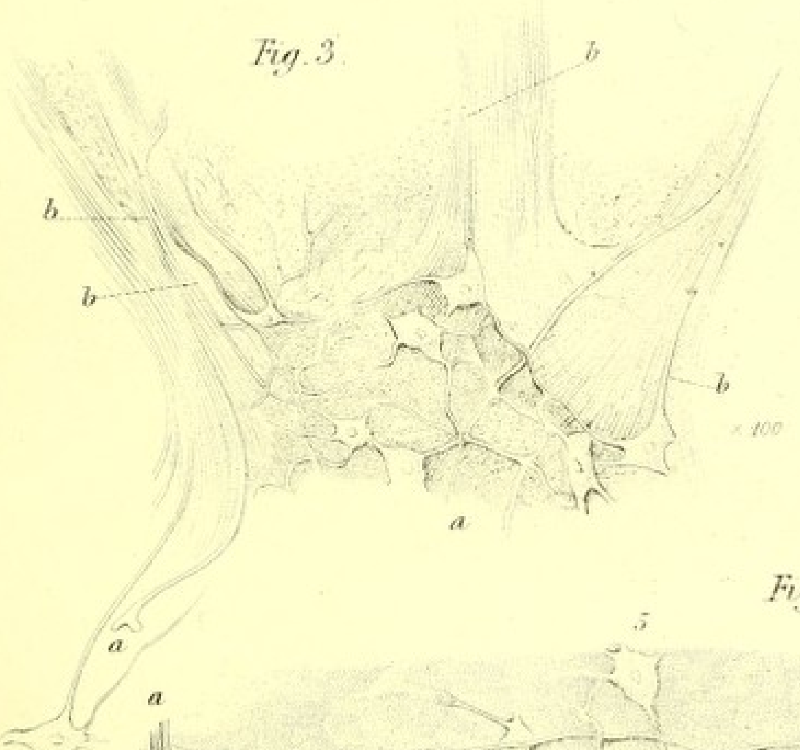
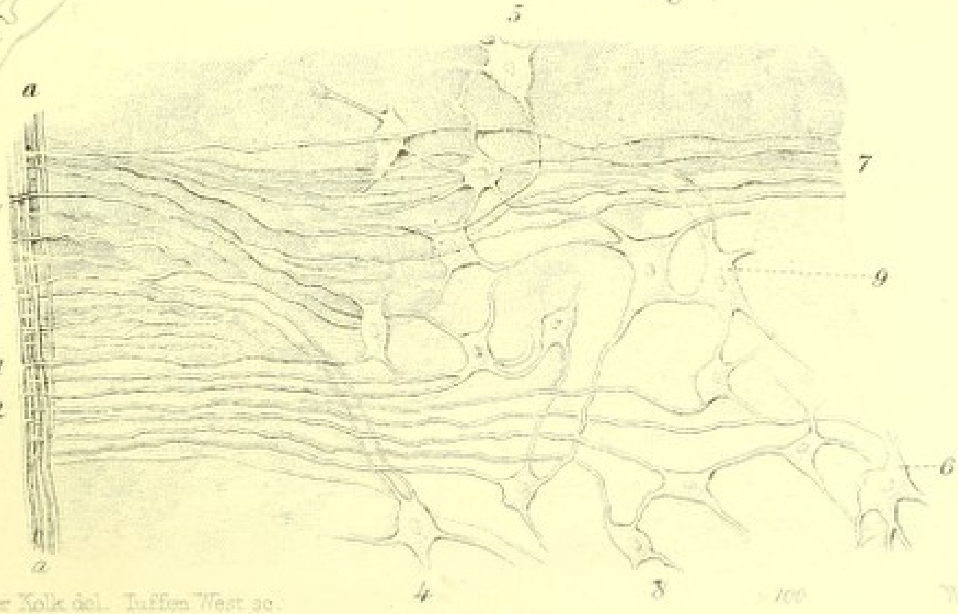


Fig. 4.



J. S. van der Kolk del. Tuffen West sc. W. West imp.

ment runs over the next ganglionic cell without being connected with it, in order to unite with a more distant cell;* sometimes the cells are connected by more than one filament.† But it is not possible to trace all the filaments; many are cut off, and a multitude of slender filaments of the most extreme delicacy appear in the meshes of the network, which cannot be further traced.‡ Both Figures 1 and 2 represent longitudinal sections through the anterior cornua. The relations in question are best seen in the lumbar bulb of the spinal cord of a cow, these groups of ganglionic cells being most distinct in large animals, while the number of the cells is in this particular portion of the spinal column greatest, the physiological reasons for which I shall subsequently endeavour to give.

I observed this connexion distinctly also in several transverse sections.

These ganglionic cells are most numerous in the anterior horns (as has been correctly remarked by most writers), and particularly at the entrance of the nerves. They also exist with their filaments in great numbers in the centre of the horns; there is, however, some diversity in this respect; in the lumbar and cervical bulbs the anterior horns of the grey matter are much broader, and the number of multipolar ganglionic cells is disproportionately much greater than in the dorsal part of the spinal cord; the number of multipolar ganglionic cells being, as Clarke,§ Schilling,‖ and Gratiolet¶ correctly observed (see above), in a direct ratio to the thickness of the nerves, arising from the spinal cord. Besides this general difference in the number of the ganglionic cells, I have also found the latter much more numerous in the situations where the nerve-roots enter into the cord, than in the intervening parts,—an observation quite in accordance with the theory of the origin of the nerves from these multipolar cells, of which I shall hereafter speak.

Besides these ganglionic cells in the anterior horns, which, as Kölliker observes, are distinguished by greater size, ganglionic cells also occur in the posterior cornua, but in smaller number. They differ, however, from one another; some more distinct, are situated near the entrance of the posterior nerve-roots in the cornua, and particularly in the fibres running round these horns, and sometimes

* Fig. 1 *e a′*. Fig. 2 *a b*.

† Fig. 1 *a d*.

‡ Fig. 1.

§ *Phil. Trans. l. c.* p. 614.

‖ Schilling, *l. c.* p. 39.

¶ Gratiolet, *l'Institut. l. c.*

encircling them as a girdle, which fibres are not mentioned by authors, and are most distinct in the lumbar bulb, passing to the middle part of the grey substance;* the cells are here more oblong, possess a smaller number of branched filaments, and resemble the cells, which, according to Kölliker, are met with in a more separate state, between the nerve filaments of the posterior horns. Of these cells he gives a very good representation.† Kölliker also represents ganglionic cells in the middle of the posterior horns in the gelatinous substance, which I likewise have met with, though I have often seen them larger than they are represented by him.‡ This depends, however, on the part of the spinal cord subjected to examination; the larger cells, the external, as well as those just described, occurring chiefly in the lumbar bulb, where both the posterior horns are broader and the ganglionic cells larger, than in the dorsal portion § of the spinal column.

Schilling appears not to have accurately observed these ganglionic cells; at least they are wanting in his otherwise beautiful representation of the spinal cord.

Lastly, I have constantly met with an apparently important group of ganglionic cells, which are not described by earlier writers, unless, as is very probable, Kölliker mentions them without giving their exact connexion.|| These cells lie very near one another in a small group, in the radiation of the posterior grey commissures, into which their filaments evidently pass.¶ Probably it is owing to defects in the mode of making the preparations, and to the hardening with chromic acid, that previous observers have been unable to discover them, and their connexion with the grey posterior commissure. Schilling does not represent them, and says, that he cannot ascertain whether these transverse fibres of the posterior commissure also serve to connect the cells with one another.**

However, they are very evident, although smaller than the cells in the anterior horns. They stand very closely together. This group also

* See my figure 8, *h g*.

† *Mikrosk. Anat.*, *l. c.* pp. 416 *et seq.* Fig. 128.

‡ *l. c.* p. 414, Fig. 126.

§ Bidder, *l. c.* p 674, denies that ganglionic cells exist in the posterior grey horns, of which, however, I possess several preparations. Stilling also confirms this. *Neue Untersuchungen*, 2 Lief., pp. 185 *et seq.*

|| *l. c.* p. 413, Fig. 125. In his drawing of the transverse section of the spinal cord, Tab. IV., Fig. 3, the ganglionic cells are indicated only by points, and very inaccurately; this is scarcely more than an outline figure.

¶ See Fig. 11, *g g.* ·Fig. 12, *k l.*

** *l. c.* p. 58.

is richer in cells and more distinct in the lumbar bulb. These cells are distinguished from those in the anterior cornua by having a smaller number of filaments; many are oblong, triangular, and the smaller ones commonly lie very near each other. When examining the spinal cord physiologically, I shall dwell more in detail upon these cells, which are connected exclusively with the posterior commissure,*

Lastly, there are also separate ganglionic cells amongst the white medullary matter or longitudinal filaments; they are situated in the lateral efferent filaments of the grey substance, which are seen on a transverse section, dividing among the medullary matter. Stilling was the first to give a representation of these rays,† and they are regarded by Todd and Bowman as processes of grey substance, into which blood-vessels penetrate from the pia mater.‡ Indeed, in these lateral rays a blood-vessel is often, but by no means constantly, found, and in sections placed in chloride of calcium, is very plainly distinguishable from the nerve filaments. These cells are few in number, and are always separate; they exist chiefly in the vicinity of the grey matter. Even Clarke, as we have above seen, observed these ganglionic cells;§ Kölliker, too, speaks of them, but gives no opinion as to their probable physiological signification.||

From all this I infer, that, as Clarke has correctly stated, several columns of multipolar ganglionic cells extend through the entire length of the spinal cord, those in the anterior cornua being the principal; next in importance are those at the side of the posterior commissure; then those in the middle of the grey matter, between the anterior and posterior horns, and, lastly, those in the posterior horns themselves, as the smallest. These columns are, however, not to be regarded as quite independent, on the contrary, they are all more or less connected. Those from the anterior horns in particular, extend nearly to the beginning or the basis of the anterior horns, or the

* As Bidder looks upon the entire posterior commissure as connective tissue, he denies the presence of ganglionic cells in it also, *l. c.* p. 48. Stilling has, however, confirmed the fact of their existence, *l. c.* 1 Lieferung, pp. 133 *et seq.*, but according to him they do not occur everywhere in the spinal cord, *l. c.* 2 Lief., p. 230.

† *Ueber die Medulla Oblongata*, p. 5. Plate II., Figs. 1–4.

‡ Todd, in the *Cyclopædia of Anatomy and Physiology*, art. Nervous System, p. 708. Todd and Bowman, *Anat. and Physiol.*, Part II., p. 259.

§ *Phil. Trans. l. c.* p. 610.

|| *Mikr. Anat. l. c.* p. 416. See these cells in a longitudinal section in Fig. 6 *g*.

mid-space between the two horns, and the ganglionic cells situated here are closely connected by their filaments with the group at the side of the commissures.*

These vertical columns are, however, when viewed in the longitudinal direction, of very unequal size; not only are they larger and richer in cells in the cervical and lumbar bulbs, but the number of cells increases where the roots of the nerves penetrate the spinal cord and the grey substance; they thus form more or less coherent groups, placed in a longitudinal direction above one another.

The physiological importance of these multipolar cells depends not only on their communications with one another, but especially on their connexions with the nerve-roots. We have above seen that although there has been much difference of opinion on this point, and although Kölliker totally denied their connexion with nerve-roots, the existence of such a connexion has by later writers been established beyond doubt.

Though I considered that I had formerly succeeded in demonstrating this connexion in some objects with sufficient certainty, I have recently, assisted by the greater clearness obtained in microscopic examinations by means of chloride of calcium, investigated this important question as fully as possible. In these investigations also I found the lumbar portion of the spinal cord of a cow the most satisfactory on account of the greater thickness of the nerve-roots. For this purpose both transverse and longitudinal sections should be made; the latter as close as possible to the entrance of the anterior roots, in the direction of the anterior horn of the grey matter, or rather parallel to the course of these nerve filaments.

In a transverse direction we often succeed in tracing the nerve-filaments very beautifully and uninterruptedly from without into the cornu; they are distinguished into thicker and slighter fasciculi, penetrating in a tolerably straight line into the grey substance. At their entrance into the latter usually lie some multipolar ganglionic cells, from which we can sometimes trace eccentric filaments into the nerve-roots or lateral radiations, as is very distinctly represented by Clarke,† although this writer did not recognize the importance of the fact.

Of this I have endeavoured to give as accurate a representation as possible in Fig. 3; where we see the network of intercommunicating

* Fig. 12, *l, k.*

† *Philosophical Transactions, l. c.* Fig. 15.

filaments, among which, however, a couple of blood-vessels, *a a*, are visible; while at *b b b b*, we see filaments derived from the ganglionic cells, spreading out in the nerve-roots. It is necessary to be careful not to confound minute blood-vessels, which usually accompany the nerve-roots on their entrance, with nerve filaments or efferent threads from the ganglionic cells. I may observe that I have succeeded much more satisfactorily, in some longitudinal sections, in finding the connexion of the nerves with the ganglionic cells, or rather their origin from them, on the anterior or motor side. After having first accurately determined in a transverse section the direction of the anterior horn and the entrance of the nerves, the knife should be placed as nearly as possible parallel to the entrance of the nerve; thin laminæ should then be made in that direction, which should both comprise the entrance of the nerve and should penetrate into the grey substance, when we shall very easily see the roots of the nerve filaments transversely between the longitudinal fibres penetrating to the anterior grey cornu. On account of the great number of ganglionic cells, however, we rarely succeed in this situation in observing the connexion with certainty; the nerve-roots for the most part run through the ganglionic cells and terminate without being connected with the latter, in other words, they have been cut off. But this is to be expected in consequence of the thinness of such a section, and the curved course of the nerve-roots. Sometimes, however, when we have by chance hit upon the exact direction, the connexion is so distinct as to leave no doubt upon the subject. From among several successful sections, I have given a faithful representation of one, in which the connexion had been very perfectly preserved and was very distinctly seen; so much so that by far the greater number of nerve filaments could in this situation be traced to their connexion with the ganglionic cells.

We see this represented in Fig. 4, only a few longitudinal medullary fibres, *a a*, being retained, in order to render the drawing not unnecessarily large. We here observe inferiorly, under 1, not less than eight filaments in connexion with ganglionic cells, while from the uppermost bundle four filaments can be traced to such bodies. Among these filaments those marked 1 1′ are both derived from the same ganglionic cell, the anterior in the centre, which gives off a filament to each fasciculus; at 2 we see two filaments, derived from the one end of a ganglionic cell, while the cell marked 4, likewise gives off two filaments, running out in an oblique direction under the other nerve filaments to the superior bundle at 3, just as the cell 5 likewise gives off a nerve filament, which passes obliquely over another ganglionic cell running near 1'. At 6 is the most remote ganglionic cell, connected with the nerve filaments; but from the fasciculus at 7, which is not traced, a filament was connected with a cell situated at a still greater distance, but which I have omitted, in order not to enlarge the drawing unnecessarily. The connexion of numerous ganglia with one another (as the cell 8, and the cells marked with 9) is here also very beautifully shown. Most of the connecting filaments of these cells are, however, cut off, while many filaments visible in the object, but which could not be traced, and which would only have made the drawing indistinct, are not included; as it is impossible to reproduce in a drawing the entire copiousness of nature. In several places, moreover, in this very successful preparation the passage of the nerve filaments into the ganglionic cells was clear to demonstration; the specimen was taken from the lumbar portion of a cow. The origin of the anterior nerve-roots from the ganglionic cells is here so evident as to leave no room for doubt on the subject.

If we take a transverse section, so successfully made (of which I possess several specimens) as to show exactly the entrance of a thicker nerve-root into the grey substance, I mostly find two nerve-roots together, which on entering the cornu extend laterally and towards the centre, and cross one another; many filaments run along the outer edge of the horn, others spread through its middle. Of this Schilling has given a very beautiful drawing,* exhibiting, however, only slender nerve-roots, while, as I have already remarked, no efferent filament or connexion of the ganglionic cells with the nerves is anywhere represented.

In one very beautiful preparation, among several others, the expansion of the nerve-roots in a transverse section was very evident, of which I have given in Fig. 5 a drawing as accurate as possible. We see here also a tolerably thick nerve, *a*, and a more slender one, *b*, passing through the medullary portion into the anterior grey substance, of which some filaments unite with ganglionic cells, *c c c*.†

* *De Med. Spin. text.*, Tab. I.

† A copious network of ganglionic cells was situated somewhat further from the edge of the grey substance towards the centre; but in order not to make the drawing too large and complicated, these have been omitted, and the ganglionic cells *c c c*, which belong to a very rich group, have been brought into the drawing, although they were situated at a somewhat greater

EXPLANATION OF PLATE II.

Fig. 5. Transverse Section through the Anterior Horn, and entrance of a Nerve-root, page 40.

A A A. Medullary matter or anterior columns, the longitudinal fibres of which are cut across.

B B. Grey matter of the anterior horn with its cells and nerve-fibres.

a, *b*. Two motor nerve-roots, dividing in the grey matter.

c c c. Multipolar cells into which the fibres of the nerve-roots pass.

d, *e*. Another group of cells, which are connected partly with the preceding, partly with one another, and receive numerous filaments from the marginal fibres surrounding the grey matter.

f, *g*, *h*, *i*. Grey radii, proceeding from the horn and the white medullary columns and here dividing; their fibres either pass at once into cells, as at *f*, or penetrate to the remote cells, as at *h*, or they form marginal fibres as at *i*, all of which appear to be lost in remote cells and decussate with the nerve-root *a*, without passing into it.

Fig. 6. Longitudinal Section at the Margin of the White and Grey Matter from the Anterior Horn, page 43.

a, *b*. Longitudinal medullary fibres, of which a few at the most internal at *a* and *g* pass over into multipolar cells; at *g* another cell is faintly seen between the longitudinal fibres.

c, *d*. Transverse fibres, as rays of the grey matter, which run along the medullary fibres, and bending appear at *e* and *f* to pass into these fibres. The cells themselves are again united by communicating filaments.

[To face page 40.

Fig. 5.

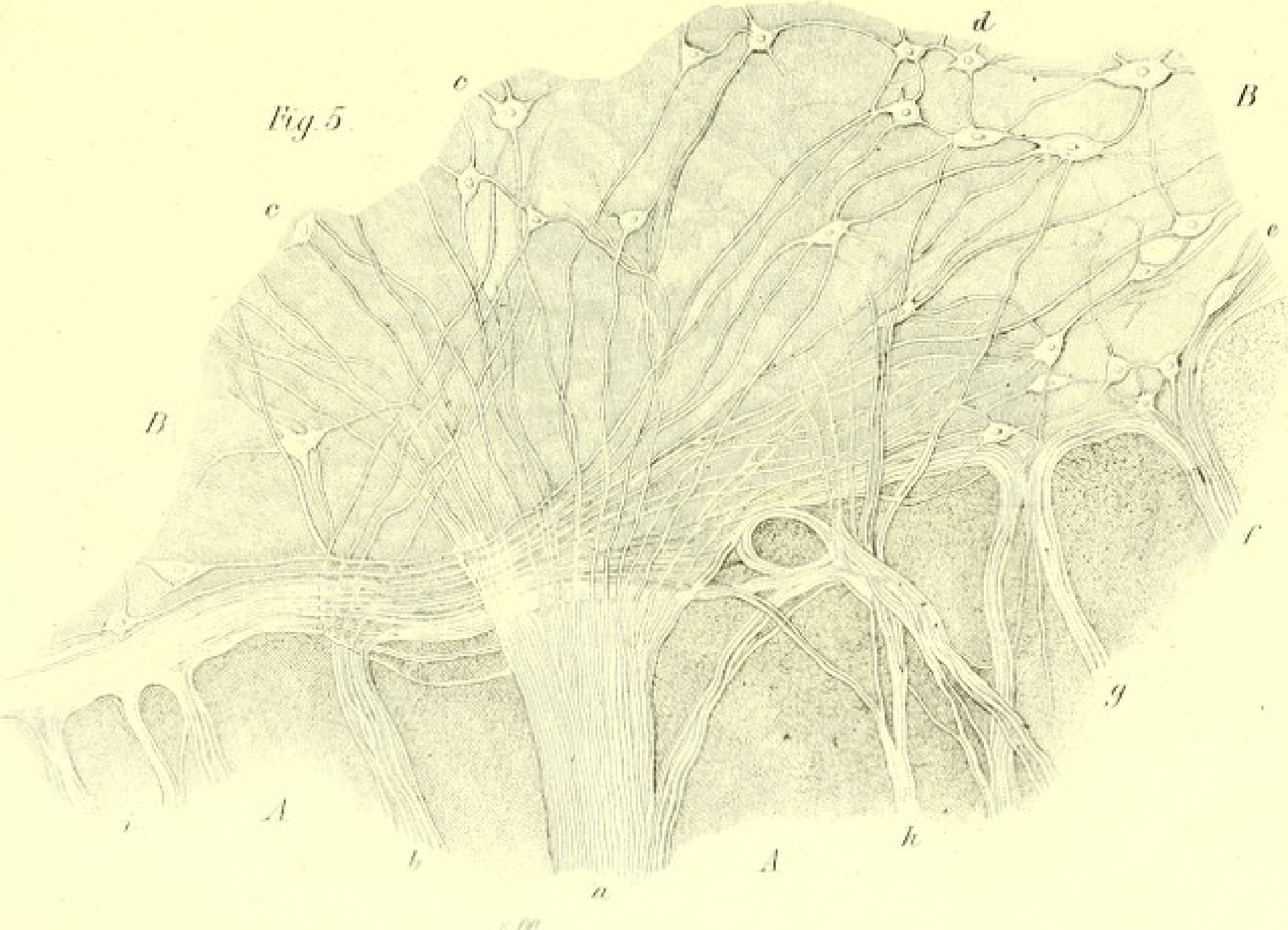
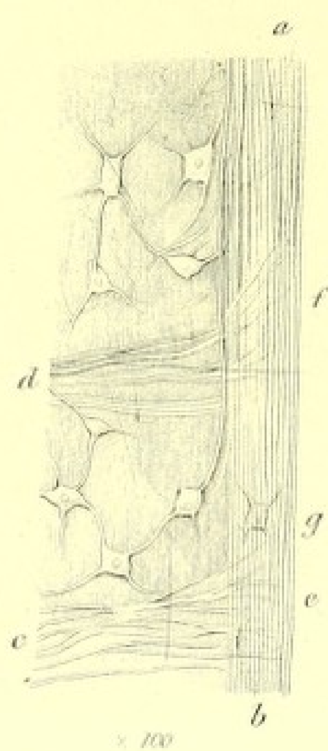


Fig. 6.



J. S. van der Kolk del. Tuffen West sc.

W. West imp.

There can therefore be no doubt that the roots of the motor nerves arise from the spinal cord, and more particularly from the ganglionic cells of the anterior horns, which unite to form a network, and often divide into more or less widely separated groups.*

The principal question therefore is, in what manner are these nerve-roots connected, by means of the ganglionic network into which they pass, with the brain?

That the anterior medullary filaments, which are represented in Fig. 5, as cut across at A A A, are the conductors of the orders of our will to the motor nerves, has been fully ascertained, and is admitted by all physiologists. The connexion stated to exist between these medullary filaments and the grey matter is, however, not so evident. In order to demonstrate this connexion, it is necessary to turn our attention to some other parts of the spinal cord, which, in my opinion, are immediately concerned in it; namely, the transverse fibres, found on all sides among the medullary longitudinal fibres, and radiating from the grey substance through the white. See Fig. 12, *f, g, h*.

Stilling was the first to represent these transverse fibres,† which he has done very beautifully. He describes them as extremely minute prolongations of grey transverse fibres, passing from within outwards, without combining at the periphery to form a nerve trunk. These minute fibres according to him almost always accompany prolongations of the pia mater and vessels, and are to be regarded as vascular nerves, providing for the nutrition of the spinal cord and its parts.‡ In the medulla oblongata these fibres are more numerous and more complicated, even participating in the formation of a very complex network, which, according to him, is constituted by a portion of the posterior nerve-roots, separately penetrating between the longitudinal fibres.§ That these radiating fibrous filaments are related principally to the blood-vessels, is admitted by most writers, as I have

distance, and the nerve-roots in these situations were consequently somewhat longer; the connexion can in some be distinctly followed.

* This origin of the motor nerves from the ganglionic cells of the anterior horns is now admitted by all. Stilling (2 Lief., p. 315), and Bidder (pp. 61 *et seq.*), confirm my observations on this subject.

† Stilling, *Ueber die Textur und Function der Med. obl.*, Pl. I., II.

‡ *l. c.* p. 5. He mentions these transverse fibres also in his former work, *Ueber die Textur des Rückenmarks*, but without distinctly representing them, pp. 21 *et seq.*

§ *l. c.* p. 8.

above stated.* Kölliker, however, regards them as the continuation of the motor nerve-roots, and more especially of the external radical fibres entering into the anterior horns, which, according to him, run mostly in smaller bundles, or even resolved into single fibres, and therefore less distinctly visible, in part backwards, partly in a curve outwards, and finally turn to the anterior half of the lateral columns, where they pass through the outer group of ganglionic cells (according to Kölliker, without becoming connected with them), and are lost in the lateral columns. He says further, that in longitudinal sections we see, not their connexion with the anterior roots, but (what is important) with the lateral columns. These transverse fibres penetrate to various distances into the lateral columns, to nearly the half or even farther, then curve upwards, and now proceed as longitudinal fibres.† In his outline figure he does not, however, delineate these transverse rays.‡

Clarke seems to regard these rays as consisting only of blood-vessels, probably in consequence of his mode of preparing the sections, which so completely alters the most minute nerve-fibres as to render them invisible, while the blood-vessels continue distinctly apparent; he consequently represents only blood-vessels with their numerous ramifications.§

Schilling speaks of the same transverse fibres and says, that the grey substance viewed under the microscope appears to be furnished as it were with numerous teeth and sharp needles, and sends out distinct prolongations, many of which run through the white matter to the circumference of the spinal cord.|| But it is very strange that this writer, who also admits that the nerve-roots terminate in the grey substance, and pass into ganglionic cells, should still look upon these lateral rays—although they are not at all connected with the nerve-roots—as nerve-fibres, entering obliquely, and therefore only partly visible on a transverse section and not reaching the periphery;¶ for these reasons he also, with Kölliker, considers all transverse filaments in the medullary portion to be nerve filaments.** But how it is possible to imagine these transverse rays in the lateral columns to be prolongations of the nerve-roots, which are said to terminate in the grey

* *l. c.* p. 30.

† Kölliker, *Mikrosk. Anat.*, p. 419. ‡ *l. c.* Tab. IV., Fig. 3.

§ *Phil. Trans.*, *l. c.* p. 615, Plates XXI., XXII., XXIV., XXV.

|| Schilling, *l. c.* p. 11. ¶ *l. c.* p. 26.

** *l. c.* p. 35.

matter in the ganglionic cells, I do not understand; we need consult only Schilling's own drawing to be convinced that the transverse rays in the lateral columns are unconnected with the anterior nerve-roots.* Todd and Bowman have already correctly refuted this idea, which was previously put forward by Stilling.†

From these statements, it is sufficiently evident that no clear idea has been formed as to the nature and essence of these transverse fibres; I think, however, that my investigations are capable of satisfactorily explaining what is apparently enigmatical in reference to them. In consequence of the curved and scattered course of these transverse fibres through the medulla, we seldom succeed in finding them or discovering their connexion with the longitudinal columns. I have, however, observed, that they curve and pass into the longitudinal fibres, as I have represented in Fig. 6, from a very successful longitudinal section, taken from the antero-lateral columns. We here see the transverse strands, *c d*, bending into the longitudinal fibres; yet at the same time the innermost longitudinal fibres curve towards the grey substance and pass into the ganglionic cells as at *a g*, a fact which Schilling also represents, and says he has only once observed.‡ I have often met with this, and in the preparation whence Fig. 6 was taken, only a part of which is represented, it occurred in several places.§

Even among the longitudinal columns we sometimes meet a ganglionic cell,‖ which probably serves to connect the longitudinal fibres with the more deeply penetrating transverse rays. These ganglionic cells are connected through their filaments of communication with other ganglionic cells, as is shown in the drawing. The connexion of these fibres is, however, very distinctly seen in the transverse section already given in Fig. 5. Thus two nerve-roots are here observed, *a b*, penetrating into the grey matter, which, from their entrance into the latter, were very beautifully seen, but of which, in order not to make the figure too large, only a small portion of the trunks is represented. On either side of these nerves we see at *f*, *g*, *h*, and *i*, the transverse fibre-rays passing from the grey substance into the white medulla A A A, where, after having given off several branches, they are lost before they have reached the outer boundary of the medulla. At *f* and *g* we see some of these fibres passing immediately

* *l.c.* Tab. I. † *Physiol. Anat.*, Part II., p. 259.

‡ Schilling, *l. c.* Tab. II., Fig. *a b*, p. 39.

§ Fig. 6 at *a* and *g*. ‖ Fig. 6 at *g*.

into ganglionic cells; others, however, curve right and left along the periphery of the grey matter. This is particularly evident in the fibres from the rays, *i*, some of which arise from the more distant lateral rays not taken into the figure, and almost all curve towards the nerve and between the fibres of the nerve-root without mingling, to terminate in the ganglionic cells at *e* and *d*; which was particularly well seen in this preparation. These ganglionic cells are again connected with the great ganglionic network, of which the cells *c c c*—whence the nerve-roots take their origin—constitute a small portion. A fasciculus from the nerve-root *a* is, however, seen to pass obliquely into the ray *h*, and hence to press further into the grey matter and end in ganglionic cells.

From the foregoing, the nature of these filaments may, without much difficulty, be explained. Thus the longitudinal white columns, for the most part, maintain, as all writers have observed, parallel courses, and present no apparent termination, while from the grey substance lateral transverse bundles radiate, which divide and are scattered among the white columns and take up their fibres, Fig. 6, *c e d f*. In this manner the longitudinal fibres, as conductors of our will pass into these transverse fibres, and thus the orders of our will are conveyed along these rays to the ganglionic net, whence the motor nerves take their origin. This of itself explains why so many ganglionic cells are situated at the outer edge of the grey matter, into which we do not see the nerve-roots pass;* these last arise rather from the centre of the anterior horn, namely, from the ganglionic group, which receives on all sides communicating filaments, arising themselves from the marginal ganglia or from the transverse rays.

It is, however, not always that such a decussation of the transverse radiating fibres with the nerve-root at its entrance is seen; sometimes the filaments of the nerve-root themselves appear in part to bend along the margin of the grey substance, and here to pass into cells which are connected with the radiating fibres, while other fibres keep more to the middle and penetrate to the principal group of the ganglionic cells.

* By this observation Clarke was, as we have above seen, misled; for, seeing that the elongated filaments of the ganglionic cells also ran into the lateral rays, which were connected with no nerve-roots, but, according to him, consisted chiefly of blood-vessels, he inferred that the elongated filaments of the cells in the nerves themselves, which he so beautifully represents, could not be connected with the nerve-roots, but served only to accompany the blood-vessels. See above, p. 16.

These transverse radiating fibres are, therefore, the means of communication between the anterior and lateral longitudinal columns and the grey substance, or rather the ganglionic cells, whence the nerve-roots arise. Hence is seen also why the longitudinal fibres of these white columns maintain such a parallel course. They would of necessity exhibit a more plaited appearance, if fasciculi of some of the fibres constantly passed from without between the others towards the centre in the grey substance; but it appears, on the contrary, that the grey matter sends off transverse rays, subdividing among the longitudinal fibres, and taking up these fibres, or, if we will, passing into them. It also follows from this, that these rays are most numerous where the thickest nerves arise, or where the most complex nervous connexions are situated; to be convinced of this it will be sufficient to compare the first three drawings in Stilling's work on the medulla oblongata, for example, Plate II., Fig. 1, from the dorsal portion, with Figs. 3 and 4 from the cervical bulb. I cannot, however, describe this connexion very fully, until I come to the physiological explanation of this wonderful tissue of fibres in the spinal cord, to which I refer the reader, but as preparatory to which I must first explain the structure of the spinal cord and of its tissue in its integrity.*

The examination of the structure of the posterior horns and the nerve-roots entering them is much more difficult; partly in consequence of the greater complexity of the fibres, the different directions they assume, and their connexion with one another; partly from the greater minuteness of the nerve filaments rendering it much harder to follow them with sufficient accuracy, at least separately; and partly on account of the remarkable phenomena of reflexion, which indisputably takes place in the spinal cord, a satisfactory explanation of which has constituted so great a stumbling-block to physiologists. It is therefore not surprising that various opinions should be put forward by different writers in reference to the structure of this part and the course of the sensitive roots.

We have already seen (pages 5 *et seq.*), that in order to explain these phenomena of reflexion, Volkmann resorted to the idea of a transverse conduction, describing the stimulus as leaping over from

* Both Bidder (*l. c.* pp. 81 *et seq.*) and Stilling (2 Lief., pp. 162 *et seq.*) have confirmed the fact of this connexion of the longitudinal medullary fibres with the ganglionic cells of the grey substance by means of the radiations curving into the longitudinal fibres, discovered by me.

a sensitive to a motor nerve.* Wagner proposed the very ingenious hypothesis, that the multipolar ganglionic cells constituted the connexion between these nerves, and that the irritation was conveyed through them from the sensitive to the motor nerves.† This simple and truth-like explanation was rejected by most subsequent writers. Marshall Hall suggested the existence of reflex or excito-motor nerves; but their presence was disputed by several authors, and especially, and at considerable length, by Todd.‡ Todd and Bowman assume, that both the anterior and posterior nerves terminate in the grey matter of the spinal cord, and assert, that after separating the columns of the cord along the line of sequence of the posterior roots, they found these roots to remain with the antero-lateral columns, and to have little or no connexion with the posterior columns.§ They state their belief that the anterior columns of the spinal cord serve at the same time both for sensation and motion, and that the posterior columns which, according to them, pass into the posterior horns, produce, as connecting fibres between the brain and the spinal cord, the coördination of movements.‖

Clarke likewise thinks, as we have above seen, that the roots of the posterior nerves are connected through the posterior horns of the grey substance with the anterior roots and the commissures. Some filaments, according to him, again leave the grey substance, and are then connected with the posterior and lateral columns.¶

Schilling, who, as we have seen, makes the anterior roots arise from the ganglionic cells, says that the posterior roots never penetrate into the anterior horns. He also acknowledges how extremely difficult it is to trace these minute filaments; but thinks, nevertheless, that the posterior longitudinal filaments consist of the fibres of the posterior roots.** In the gelatinous matter of the posterior horns, however, he never saw fibres or bundles pass into the longitudinal filaments,†† but he saw bundles of the posterior roots bend upwards, and, what is remarkable, also downwards, to be apparently prolonged into the longitudinal fibres.‡‡ According to him, all nerve-roots penetrate into the grey substance,§§ but the posterior form longitudinal bundles

* *Phys. Wört.*, *l. c.* p. 528.

† *l. c.* pp. 398 *et seq.* See above, p. 5.

‡ *Physiological Anatomy*, Part II., pp. 307 *et seq.*, and especially *Cyclopædia of Anatomy and Physiology*, art. 'Physiology of the Nervous System,' 721, U *et seq.*

§ Todd and Bowman, *Physiol. Anat.*, *l. c.* p. 302.

‖ *l. c.* p. 321.

¶ Clarke, *Phil. Trans.*, *l. c.* p. 616.

** Schilling, *l. c.* p. 40.

†† *l. c.* p. 31.

‡‡ *l. c.* p. 31, Tab. II., Fig. 1 *e.*

§§ *l. c.* p. 56.

in the grey posterior horn, into which they pass.* Gratiolet likewise laments that in the investigation of the origin of the posterior roots he has not been successful; he thinks, however, that these roots curve into the posterior longitudinal columns and mingle with them.†

I freely admit, that I have found the investigation of the origin and course of the posterior nerve-roots much more difficult than that of the anterior; but I think that by means of my clearer and more distinct preparations with chloride of calcium, I have made some progress in this direction. If we make a longitudinal thin section at the entrance of the posterior roots, we commonly see, that one or more roots enter the spinal cord, but immediately curve upwards into the longitudinal columns; so that it is evident that at least a portion of the nerve fibres pass directly into the posterior longitudinal columns.

Of this I have made a drawing, Fig. 7, where from *a* to *b* a root is seen to bend immediately into the longitudinal columns; these columns are again covered by others, and we can in successful sections follow them for some distance. They run upwards parallel to the white fibres, of which they then constitute a part, and are covered by sensitive nerves arising higher up, so that they are placed more or less in layers over one another (*imbricatim*). Of this mode of entrance of the sensitive nerve I possess several examples, and am surprised that it has not been observed by other writers, almost all of whom endeavoured to trace these nerve-roots into the posterior cornua, and have probably overlooked the curving directly under the pia mater, although Remak had already pointed out such a course in the frog in 1844,‡ and Ehrenberg, Valentin, and Budge, with the aid of the microscope, saw the sensitive fibres curve upwards.§ As I have already remarked, the inferior portion of the spinal cord in cows, where the sensitive nerves are so thick, is best adapted to this investigation; in other animals, where they are slighter, they are easily torn in making the section, and the connexion can no longer be distinctly traced. Besides these roots passing upwards into the longitudinal columns, transverse fibres also issue from distinct bundles in the posterior columns, and repair to the centre or the posterior horn,|| though, in consequence of the curved direction they assume, we scarcely ever succeed in tracing them far.¶

* Page 61, No. 5, Tab. I. *e.* † See above, p. 22.

‡ Müller, *Arch.* 1844, p. 177, Tab. VIII., Fig. 6 *q*, *u*, *s*.

§ Volkmann, *Nervenphys. l. c.* p. 511. || Fig. 7 *c*, *d*.

¶ In order to see both kinds of fibres, the longitudinal and transverse, it

This succeeds best in a transverse section taken exactly where the nerve-root enters the spinal cord; here we distinctly see it penetrating into the grey posterior horn, as has already been represented by Stilling and others. Nevertheless its fibres are so extremely minute and delicate, especially where they run through the gelatinous matter of the posterior horns, that it is very difficult to trace them.

In Fig. 8, I have given a drawing (as accurate as possible) of the course of these nerve-roots; but it would, in my opinion, be impossible to represent the nature and copiousness of all the interlacements and convolutions of the afferent roots. We here see a part of the spinal cord, in fact, the posterior horn from the lumbar portion of a cow, where at *a, b, c,* some nerve-roots enter the cord close to one another, some of which at *a* and *c,* after their entrance, assume a more transparent appearance, and seem to consist of transversely cut, ascending sensitive nerves. These roots very quickly divide into several bundles, in part connected with one another, and forming a sort of plexus, but of which I have given only the principal fasciculi; these bundles are therefore separated from one another by the posterior longitudinal fibres between which they penetrate. Finally, they reach the posterior horn of the grey substance, into which we see most of the roots penetrate as bundles of extremely minute fibres, *g g,* capable of being traced to the centre of the horn at *d* and *e,* and sometimes even a little farther, proceeding chiefly towards the ganglionic cells, which are here situated in groups, although more sparsely than in the anterior horns. Their extraordinary minuteness has prevented my being able with perfect certainty to decide whether they pass into the ganglionic cells; but I have often observed, that such a bundle or strand of these fine fibres can be traced into a group of ganglionic cells, though not farther; hence I suspect they pass into them, and that therefore they cannot be followed into the anterior horns, as some think.

is best to divide the lumbar portion of the spinal cord of a cow longitudinally into two equal halves, following the course of the fissures; so much of the medulla is now to be cut away at the posterior and under side, as to bring the section to the entrance of the sensitive roots; very thin laminæ are then to be taken, deviating somewhat, but very little from the longitudinal direction, that is:—we take a thin segment of the superior radical filament, while in the inferior part of the section we scarcely touch the nerve. As the transverse and longitudinal filaments proceed from different bundles, which do not lie in quite the same longitudinal direction, we can in this mode obtain both nerve filaments in one section.

EXPLANATION OF PLATE III.

Fig. 8. Transverse Section of the Posterior Horn with Nerves entering it, page 48.

a, *b*, *c*. Nerve-roots, the fibres of which, dividing into plexuses, run towards the grey matter, and penetrate between the longitudinal medullary fibres; at *a* and *c* we observe two roots, which do not proceed further, and appear to be truncated sensory filaments, the others are reflex filaments.

d, *e*. Group of ganglionic cells situated in the middle of the grey matter at the base of the posterior horn, in which most of the fibres appear to run together.

f. Portion of the posterior commissure, some of the fibres of which run across into the grey matter at *d* and *e* and are lost, while some pass into the horn at *k*, and others run into the marginal fibres *h h h* which surround the horn.

g g. Minute fibres of the reflex roots, which perforate the posterior horn in different bundles and appear to terminate in the central cells at *d*, *e*. In some we see a multipolar ganglionic cell lying close to their entrance.

h, *h*, *h*. Marginal fibres, which surround the horn on all sides, and appear to arise chiefly from the lateral rays at *l*, and which curve on either side towards the common central point at *d*, *e*. At the posterior surface of the horn and also in the neighbourhood of the commissure several cells are seen situated in these marginal fibres.

i, *i*. Two cells situated among the medullary cells, the connexion of which I could not discover.

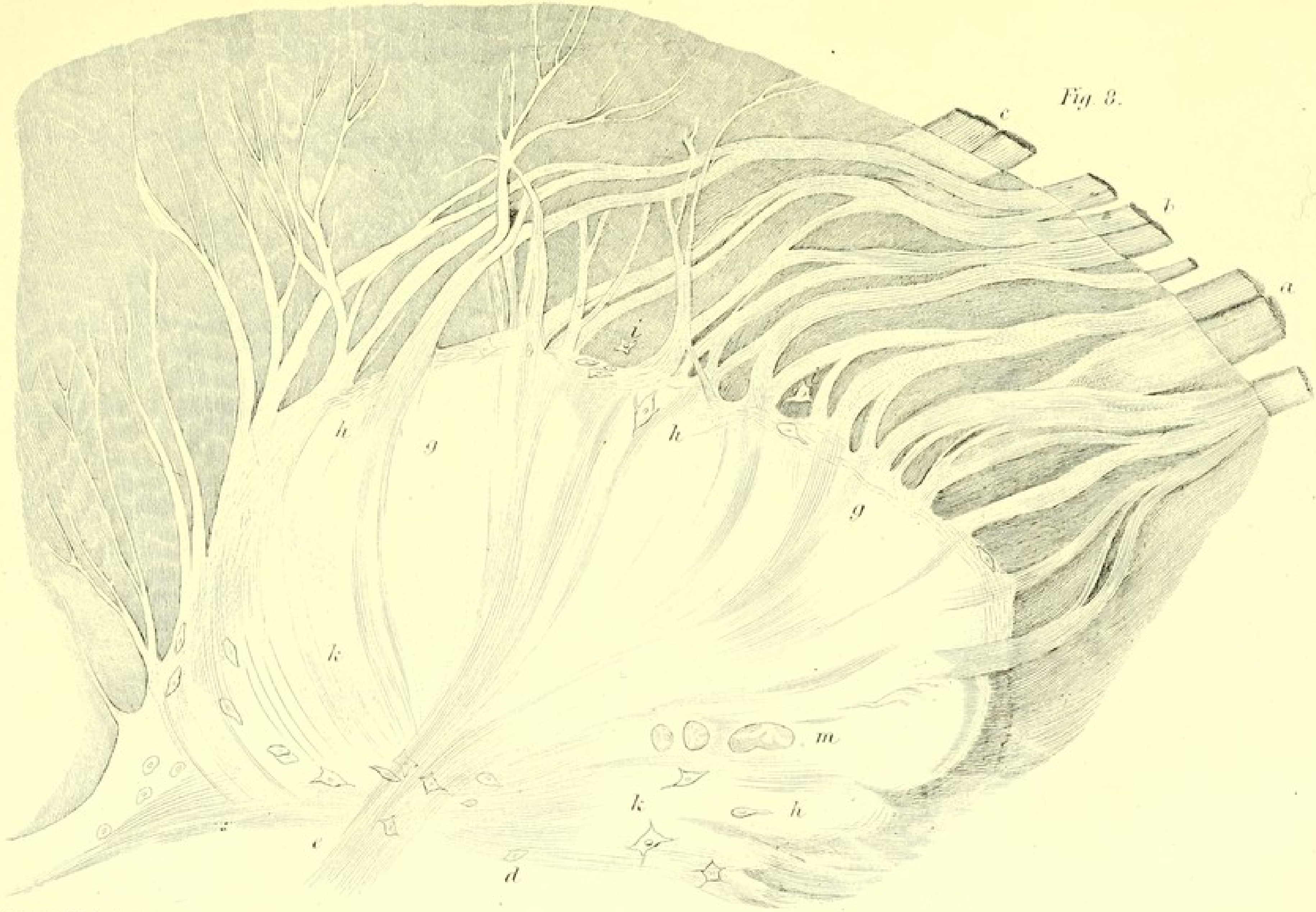
l. Lateral rays, which divide among the white medullary fibres, and pass into the marginal fibres of the grey matter.

k, *k*. Other scattered ganglionic cells, lying more dispersed in the grey matter, especially of the posterior horn.

m. Cut bundles of longitudinal fibres, which occur sometimes in great number, especially at the outer margin of the posterior horn.

[To face page 48.

Fig. 8.



x 60

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W. West imp.

But besides these nerve-roots, other fibres occur here, to which it seems to me the attention of writers has not been sufficiently directed; namely, the entire posterior horn is surrounded, as with a band or girdle, by a bundle of minute fibres of various degrees of thickness (also represented in the figure at *h h h*).* This layer of marginal fibres is constantly strengthened by the rays which we see ramifying particularly in that part of the medulla where the nerve does not enter, most of the filaments of which pass into these marginal fibres; but some filaments of the nerve-roots appear also to pass to these marginal fibres; although of these I do not feel perfectly certain. But that these marginal fibres are derived chiefly from the transverse rays—which, just as we saw in the anterior horns, cross in all directions through the longitudinal medullary columns—appears from the fact, that if we take a transverse section from this part of the spinal cord between two nerve-roots, where no nerve-root exists, the rays, although for the most part less complicated, are nevertheless present; and I have even found these marginal fibres very thick in such sections.†

It is particularly to be observed, that the marginal fibres possess many small, for the most part oblong, ganglionic cells, Fig. 8 *h h*; which ganglionic cells are not everywhere equally numerous, sometimes they are few, sometimes they are in tolerably considerable number; I even found in one section two distinct ganglionic cells in the white medulla external to the marginal cells, Fig. 8 *i i*, without any

* By these marginal fibres the posterior horn is, as it were, more separated from the longitudinal columns, and hence it is that in thin transverse sections these columns so easily part from the posterior horns on very slight pressure; especially where no reflex nerves enter the horn, and the connexion is maintained only by a few slight rays.

† The use of these posterior rays is not very evident: their course in the marginal fibres, and further, by means of these, towards the middle point of the posterior horn, Fig. 8 *h h h k k*, appears to indicate a connexion between the posterior columns of the spinal cord, or the conductors of sensation, and the centre of reflex action; the physiology of this is, however, not very clear, as reflex phenomena excite no internal sensation. Nor can they serve for the irradiation of sensation, that is, for the transference of the impression or of pain to an adjoining sensitive nerve, which, it is most probable, takes place higher up, where the sensitive nerves end, in the medulla oblongata. It appears to me most likely, that these posterior rays are connected with the reflex nerves entering from behind; but I think it best to refrain from all, perhaps perilous, hypotheses on this subject, until we shall be better acquainted with the connexion of these posterior rays.

apparent connexion with the nerve-roots. In the situation too, where the nerve-roots enter the grey horn, we sometimes meet a ganglionic cell, usually larger than those in the marginal fibres, and giving off several rays, Fig. 8 at *h*.

These marginal fibres, however, do not surround the posterior horn only on the outside, but arrange themselves in part at the basis of the horn internally, *k k*, where, from either side, they meet in the group of ganglionic cells at *d e*, and cross the nerve-roots which have penetrated to that point. All the fibres of the medullary rays do not pass into these marginal fibres; some enter, either with the nerve-roots, or separately, into the grey horn, and penetrate into the centre of the grey substance (see Fig. 8 *g*, *d*, *e*).

Lastly, with these marginal fibres are connected the fibres which, from the grey posterior commissures *f*, partly spread across towards the centre *d e*, and partly mingle with these marginal fibres at *k*.

From the foregoing it would therefore appear, that posteriorly not only is the tissue of the spinal cord more complicated, but contains two kinds of nerve-roots, one kind proceeding immediately upwards in the white medullary rays, Fig. 7 *a b*, and apparently passing to the brain. They are indisputably nerves of sensation; the other roots, however, Fig. 7 *c d*, Fig. 8 *a*, *b*, *c*, pass across through the white columns to the posterior horn, which they penetrate, and partly mingle with the marginal fibres, by which the horn is surrounded, and, as it were, enclosed, and which in the centre of the grey substance between the anterior and posterior horn appear to lose themselves in ganglionic cells, Fig. 8 *d e*, wherein at the same time both the major part of the marginal fibres and the posterior commissure, *f*, unite. These nerve filaments can scarcely be anything else than reflex nerves, conveying the stimulus into the network of ganglionic cells, wherewith they appear to be connected, whence the impression received can be communicated to the anterior groups of cells, from which the motor nerve-roots arise. These transverse roots, which have hitherto been regarded as sensitive roots, appear therefore to be reflex roots which accompany the sensitive nerves into the spinal cord, where they leave one another; the first to pass upwards to the brain, the others to unite with the common central point for motion, that is with one or other group of ganglionic cells in the commencement of the anterior horns. The posterior horn itself, which on account of its great transparency, is stated, although improperly, to consist of gelatinous matter, has, on a transverse section, an elegant and

EXPLANATION OF PLATE IV.

Fig. 7. Longitudinal Section from the Posterior Columns, in the place where a Nerve-root enters, page 47.

a, *b*. A sensory nerve-root, which immediately bends upwards, and passes into the longitudinal columns or fibres of sensation.

c, *d*. A second root, whose filaments run transversely through the white columns, more or less divided into bundles, to be lost as a nerve-root for reflex action in the posterior horn.

Fig. 9. Longitudinal Section at the Margin of the Posterior Horn, page 51.

a a a, *b b*. Grey matter, consisting of fine longitudinal fibres.

c. White medullary fibres of great thickness, passing upwards.

a a a. Transverse fibres, which run partly between the thicker medullary fibres, partly among the more slender grey fibres, portions of reflex bundles; at *a a a*, we also see several fibres cut across, into which these reflex filaments bend, as into the superior bundle.

Fig. 10. Longitudinal Section of a Portion of the long Fibres from the Grey Matter of the Posterior Horn with small oblong Cells, which here occur in separate groups, page 52.

Fig. 12. General View of a Transverse Section of the lower part of the Lumbar Bulb, magnified ten times, in order the better to show the connexion between the parts in Figure 11, which is drawn from the same object, page 55.

a, *b*, *c*. The one half of the spinal cord, drawn as accurately as possible, the other half *d*, *e*, being kept in outline to show the letters.

d d. Posterior nerve-root.

e e. Anterior nerve-root.

f. Rays derived from the anterior commissure, dividing in the medulla.

g. Rays which pass on all sides from the anterior horn into the medullary columns and are there lost.

h, *i*. Marginal fibres round the posterior horn, some of which curve inwards and take up posterior medullary rays.

k. Central ganglionic group, in which the transverse fibres of the posterior commissure, the marginal fibres, and the perforating reflex roots of the nerve *d*, seem to unite.

l. Ganglionic cells in the anterior horn, into which partly nerve-roots, partly the filaments of the marginal fibres, pass (of these cells only outline representations are given, as they cannot be seen with this magnifying power; the rest is faithfully copied from nature.)

m. Central canal.

[To face page 51.

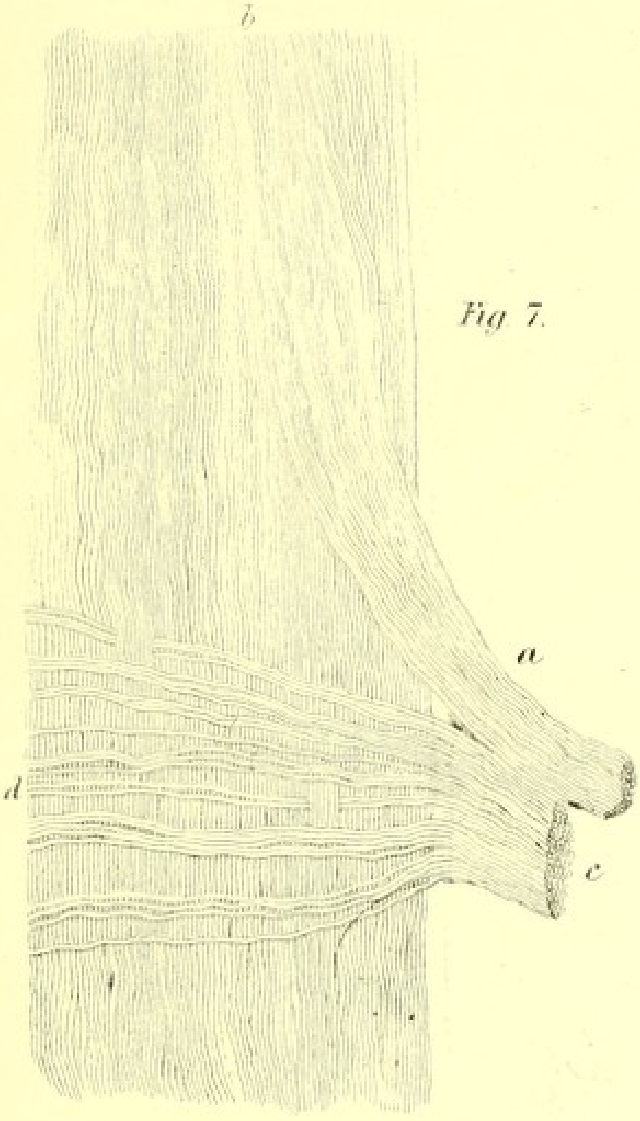
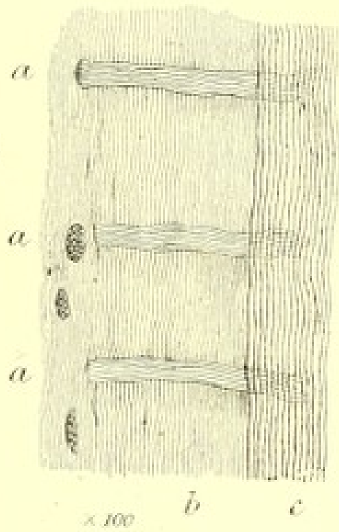


Fig 7.

× 100

Fig. 9.



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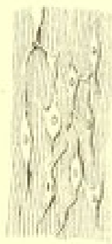
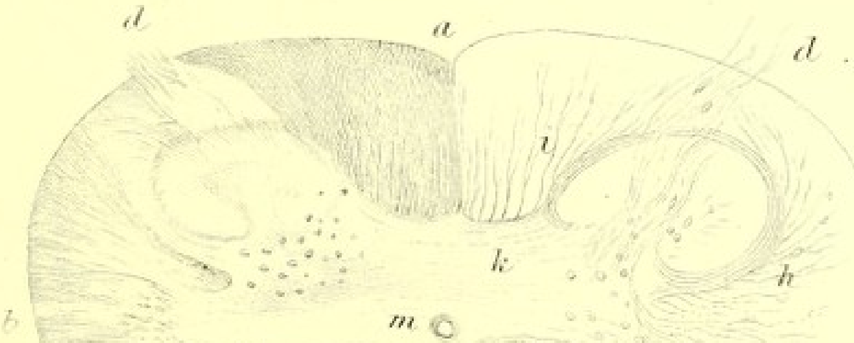


Fig. 10.

× 100

Fig. 12.



× 10

J. S. van der Kolk del. Tuffen West sc.

W. West imp.

wavy appearance, Fig. 8 *g g*, being very transparent towards the ends, with a dark marbled border. Several bundles, appearing as darker striæ, perforate this horn; its structure therefore differs very much from that of the anterior horn, which has a more uniform tint, and is more or less occupied with ganglionic cells, and the many decussating filaments, springing from them.*

If we now make a longitudinal section through the posterior horn, we see distinctly that this so-called gelatinous matter consists of minute, transparent, longitudinal fibres, Fig. 9 *b b*, which, for the most part, run a parallel course, and are very much slighter than the white ascending medullary filaments or sensitive threads. (See Fig. 9 *c*.) In successful sections we again see running between them the transverse fine bundles of the reflex nerves, Fig. 9 *a a a*, though of these, on account of their curved or convoluted course, we can usually trace only truncated fragments, always appearing as distinct fasciculi,

* The exact course of the sensitive and reflex roots in the spinal cord is certainly one of the most difficult subjects of investigation. Bidder says, that whatever trouble he took, he could not find the ascending fibres of the sensitive nerves which, according to my description, accompany the longitudinal medullary fibres upwards, *l. c.* pp. 84 *et seq.* This has surprised me, as I have distinctly observed them and drawn them from nature; I am therefore very glad to see my observations confirmed by Stilling. *Neue Untersuch.*, 2 Lief., pp. 285 *et seq.* Stilling, however, thinks that these ascending nerve filaments again penetrate the grey substance higher up, and that they do not run uninterruptedly to the brain, *l. c.* p. 284.

Since the publication of this Essay, my ideas on this subject have been somewhat modified by the well-known experiments of Brown-Sequard. I have myself seen that sensation decussates in the spinal cord, and not in the medulla oblongata, as I formerly believed; at least, if we cut through the one half of the spinal cord, the foot on the same side continues sensitive, and that on the other side becomes insensible, as I observed in a goat. My later investigations on the medulla oblongata have satisfied me, that the sensitive nerves do not themselves decussate, but that in the posterior horns they appear to terminate in ganglionic cells, whence other filaments arise which decussate. See my Essay on the Medulla Oblongata, pp. 27 *et seq.* [The translation of the Essay alluded to forms the second part of the present volume.] The posterior columns will therefore contain these decussated filaments, radiating from the posterior horns and curving upwards, and we thus obtain an explanation of these rays, the nature of which I had considered to be obscure. I freely admit, too, that in this Essay I have been so far in error, that what I took for sensitive nerves, are reflex nerves, which at various heights pass, according to Stilling, again into the grey matter, and that my reflex roots must in fact be regarded as nerves of sensation.

and nerves as perfect layers of transverse fibres, as they have been represented by Schilling.* Sometimes these transverse bundles appeared to bend into the longitudinal, which Schilling also observed. Occasionally, although rather rarely, we find, in addition, in the middle of this gelatinous matter or posterior horn, distinct ganglionic cells; these I have met with both in transverve and in longitudinal sections (see Fig. 10 in a longitudinal section.) They are extremely small, and form small circumscribed groups; in other places we sometimes see larger ganglionic cells lying separately in the middle of the posterior horn.

It is not easy to account physiologically for the occurrence of these longitudinal fibres in the posterior horn, which is almost wholly or, at all events, in by far the greater part, composed of them. They can scarcely be considered as sensitive filaments, situated more internally, and proceeding towards the brain; not only because they are much finer than the white fibres, Fig. 9 *c*, but, and indeed chiefly, on account of the varying size of the posterior horns themselves; thus the latter are largest in the lumbar and cervical bulbs, in these situations very much exceeding in breadth and extent the horns in the dorsal portion.† These minute fibres therefore do not run uninterruptedly upwards, as in this case the posterior horns in the dorsal portion could not be slighter than in the loins.

If, however, we bear in mind, that the motor nerves arise from groups of ganglionic cells, and recollect that these groups are reciprocally connected, in order to harmonize the movements of different muscles; that further, in a peculiarly irritated condition of the spinal cord one stimulus is capable of exciting very many or even all the nerves of the cord to convulsive actions, and so can make the reflex movements extend to very distant parts, it will appear more than probable that these longitudinal minute transparent fibres, of which the posterior horns consist, are fibres of communication, that is, fibres which connect with one another ganglionic groups situated at different heights of the spinal column, and so serve for the coördination of movements.‡ This view is still further corroborated by the

* Tab. 2, Fig. 1.

† See Stilling, *Med. Oblongata*, Pl. I., Fig. 1, compared with Pl. II., Fig. 2.

‡ It appears to me probable, that some of the transverse bundles or filaments of the reflex nerves pass into these, while other filaments seem to unite in the manner suggested with the central group of cells, whereby

fact that precisely as the anterior motor horns are much broader and richer in ganglionic groups in the lumbar and cervical portions,—whence the nerves for the complicated movements of the extremities arise,—so the posterior horns are also broader there, in order to connect the several groups with one another. In the back, however, the nerves serve to produce simpler movements, namely, those of the intercostal and dorsal muscles, where the several combinations are much fewer than between the numerous muscles of the extremities; and here accordingly both horns are much less extensive.

We shall, however, be able to see this more fully, when we have studied the commissures of the spinal cord, to which we now proceed.

The same difference of opinion exists with respect to these commissures as is the case with all other parts of the spinal cord. Kölliker makes the nerve-roots in part pass into the commissures, as Stilling had already taught; he thinks that the anterior commissure is in part a decussation of the anterior white fibres of the cord.* Schilling remarks that the two commissures consist of grey fibres, and not of white medullary filament; but later observations by Stilling,† and my own investigations, have shown me that the commissures consist of white matter. Blattman denies that the longitudinal white fibres pass directly into the commissures; these, according to the last named writer, only mingle with one another, without entering into any direct connexion.‡

Schilling has most fully and ably examined the structure and connexion of the commissures, and at the same time criticised the different opinions of authors upon the subject, and to his work I shall therefore more particularly refer.§

The anterior commissure is very remarkably distinguished from the posterior, by the crossing of the fibres in the former, as has been already represented by Stilling, of which decussation Schilling in particular gives a very beautiful drawing.|| I have constantly perceived this crossing, and have given a drawing of it from the lumbar portion of a cow.¶ The fibres, after crossing, turn round, run in

the connexion between the reflex nerves and these longitudinal fibres, and consequently the multilaterality of reflexion, appears to be promoted.

* *Mikrosk. Anat.*, *l. c.* p. 412.

† *Neue Untersuchungen über den Bau des Rückenmarks*, Frankfort, 1856. 1 Th. pp. 74 *et seq.*

‡ Blattman, *l. c.* pp. 12, 22.

§ *l. c.* pp. 44 *et seq.*

|| *l. c.* Tab. I.

¶ Fig. 11 *b*, *c*, *d*.

part, freely interlacing,* along the inner side of the anterior fissure into the white strands; † in part they pass into the inner margin of the anterior grey horn, where they mingle with the circular or marginal fibres which proceed from the numerous rays,‡ and from the grey matter, as we have above seen, divide in the white medullary strands, and take up the longitudinal fibres. It is certain that these fibres do not pass directly into the roots of the anterior nerves. The statement that they do so had already been denied by Schilling,§ and I, like him, have never been able to confirm it, although I have examined very many beautiful preparations, where I could trace the radical fibres of the nerves to a great distance. These fibres must, in fact, be regarded as transverse commissures: that is to say, their connexion with the fibres running from the rays along the margin of the horn, and the numerous rays spreading from the commissure along the anterior fissure directly into the white strands,|| indicate that they probably take up longitudinal fibres, the influence of which they convey to the opposite side of the spinal cord. Here they pass into a group of ganglionic cells,¶ which is not recognized by Schilling, but which I have above described, which group of ganglionic cells again seems to be more or less connected with the other groups present in the anterior horn. Through this anterior commissure, therefore, is probably established the connexion between the motions of the right and left sides, which exercise so much influence on one another, for example in walking; as well as the greater or less difference or harmony between the movements of both arms or hands, in consequence of which it is so difficult for commencing pianoforte-players to move the fingers of the two hands dissimilarly, the fingers of the one hand tending to perform the same movements as the other. Hence, also, we can explain why Stilling, on dividing the spinal cord longitudinally in the line of the fissures into two parts, saw voluntary movements take place in the frog, while the harmony between the motions of the extremities was interrupted.**

The difference is greater, especially as to breadth, between the posterior commissures. In the inferior lumbar portion of the spine this commissure is very broad, and consequently contains many

* Fig. 11 *d*. † Fig. 12, at *f*.
‡ Fig. 11 *l*, Fig. 12 *f*. § *l. c.* p. 50. || Fig. 12 *f*.
¶ Fig. 11 *f*, Fig. 12 *l*.
** *Untersuchungen über die Functionen des Rückenmarks*, p. 82.

fibres; higher in the back it is much slighter; in the superior cervical portion it again becomes broader.*

The fibres of this posterior transverse commissure run parallel without crossing; those which are next to the central opening pass into a ganglionic group,† and I have in several preparations observed these fibres to be of a somewhat lighter colour, as is represented in Figs. 11 and 12. The others run partly across from the centre of the one side to that of the opposite, where they appear to terminate in the central group of ganglionic cells.‡ Here, as in a common central point, the reflex filaments, the marginal fibres of the posterior horn and the posterior commissure unite, as we have above seen; the posterior fibres from this commissure pass directly into the marginal fibres, arising from the inner rays,§ so that something similar takes place here to what we have observed in the anterior commissure, without, however, the existence of any decussation.

The fibres of the posterior commissure appear here to run out into the different ganglionic cells, which in the spinal cord we may generally regard as points of union of dissimilarly acting fibres; as central points, where nervous action is excited, to radiate thence into connecting filaments and nerve fibres. Indeed, we have seen in the centre of the grey matter at the base of the posterior horn, a group of cells (Fig. 8 *d e*), which appears to be a common point for reflex action; in this group of cells, that is to say, the reflex nerves, radiate; into it converge the circular marginal fibres which surround the posterior horn (Fig. 8 *h h h*), and for the most part seem to spring from the external rays, *l;* and finally the fibres of the posterior commissure also run into it, *f, e, d.* If we now consider that the posterior horn itself consists of minute longitudinal fibres, which probably serve to unite various groups of cells, with which minute fibres this middle ganglionic group, *d e,* is at the same time in contact, we can form an opinion as to what an important point of union is established by these cells, which in their turn again seem to be connected with the group of cells in the anterior horn for motion (Fig. 12 *k l*).

Between these two commissures the central canal is situated. It is a prolongation of the fourth ventricle, lined internally with epi-

* See my Figs. 11 and 12, from the loins; also Clarke, *Phil. Trans., l. c.* Tab. XX., Fig. 1—5, from the inferior portion of the loins, and Tab. XXI.—XXV. Also Stilling, *Med. Oblong.*, Tab. II. and III.

† Fig. 11 *g*.

‡ Fig. 8 *f, e, d*. Fig. 12 *k*.

§ Fig. 8 *f, k*.

thelial cells.* Kölliker says that it does not occur in man as a hollow canal, as in the fœtus, but that its situation is occupied by a grey nucleus, formed of a central cylindrical or flattened streak of light-yellowish colour, constituted chiefly of nerve-cells.† Schilling states that he has sometimes distinctly seen a canal in man,‡ and I found it even in the spinal cord of a woman aged seventy. I suspect that Kölliker has been deceived by hardening the spinal marrow in chromic acid; thus I have sometimes in sheep, and even in cows, met with a coagulated substance, probably albumen, in the canal, and suspect, that in consequence of the strong action of chromic acid, the latter often either wholly contracts, or that its fluid contents (if it have such) become so firmly coagulated that the canal is no longer recognizable. In thin laminæ, after being somewhat hardened in spirit, and subsequently placed in chloride of calcium, I have always found a canal here, which is, moreover, wider and much more distinct in cows.

In now reflecting on what has been said, I think I may draw the following conclusions from my investigations:—

1. The ganglionic cells, especially in the anterior horn, are connected with one another by more or less ramified fibres of communication, and thus form more or less distinct groups.

2. From the ganglionic cells, especially in the middle and anterior parts of the anterior horn, arise the motor nerves, which unite at the margin of the grey matter into one, or commonly two or more nerve-roots close to one another, and now leave the spinal cord in a transverse direction, in order to compose the roots of the motor nerves.

3. Along the outer edge of the anterior horn run marginal fibres or filaments, which take their origin from the rays dividing among the longitudinal columns, and are connected with the ganglionic cells, situated in great number along the outer edge of the anterior horn. These cells are again connected with others more deeply placed, and so eventually with the group of ganglionic cells, whence the motor nerve arises.

4. The anterior longitudinal columns consist of white, mostly parallel, medullary fibres, which pass into the transverse rays just mentioned, and so convey the orders of the will to the ganglionic cells

* Fig. 11 *a*. Fig. 12.

† *Mikrosk. Anat.*, *l. c.* p. 411.

‡ *l. c.* p. 42.

in the grey matter; the longitudinal fibres, which are situated next the grey horn, curve directly, in order to pass into a ganglionic cell.

5. The posterior nerve-roots contain two sorts of filaments, those for proper sensation and those for reflex action. Hence the posterior nerve-roots are also much thicker than the anterior.

6. The nerve-roots for sensation pass, immediately after their entrance into the spinal cord, upwards along the posterior columns, in order to repair to the brain, or the seat of perception. They do not penetrate the grey matter.*

7. The other filaments for reflex action, pass across towards the posterior horn, and among the longitudinal fibres or columns form several plexuses; in part they press through the scattered gelatinous substance of the posterior horn, to the middle of the grey matter, where they appear to pass into ganglionic groups; perhaps they also give some filaments to the marginal fibres, which everywhere as a band surround the grey posterior horn.†

8. These marginal fibres arise in great part from the nerve rays, which from the posterior horn spread in the medulla; they surround the horn, and at its basis curve from either side towards the centre of the group of ganglionic cells, in which also the reflex nerves terminate. Among the marginal fibres, several, for the most part oblong ganglionic cells, are scattered; some ganglionic cells are met with also in the gelatinous substance, especially nearer to the centre.

9. The posterior horns of the grey matter consist chiefly of very fine longitudinal fibres. Now, as the former in the cervical and lumbar bulbs are at least five or six times thicker than in the dorsal portion of the spinal cord, it follows that the latter are in these parts present in much greater number; whence it would appear that they do not run through the whole spinal cord, but for the most part terminate in the cervical and lumbar expansions, where the majority of reflex actions and movements are excited and combined; they appear,

* It is, however, not improbable, that the sensitive nerves are lost towards the posterior horns in the grey matter in ganglionic cells; whence fibres arise, which cross through the posterior commissures, and on the opposite side as posterior rays repair in the medulla upwards as sensitive filaments to the brain.

† The reflex filaments are in this case, at least in part, the ascending fibres which at different heights again repair through the posterior horns to the ganglionic cells of the anterior horns.

therefore, through their longitudinal direction, more or less to unite several groups of cells placed above one another, and thus to form longitudinal filaments of communication.

10. The posterior commissure, consisting of white fibres, passes in part into adjoining ganglionic cells, partly into the cells which are present in the centre of the grey matter, while again some fibres are connected with the marginal fibres around the posterior horn.

11. The anterior commissure forms a decussation; its fibres push forward in order in part to terminate directly as rays among the inner and anterior longitudinal columns; in part they proceed towards the inner edge of the anterior horn, where they pass into the marginal fibres, which take, as we have above seen, their origin from the rays.

12. The fibres of both the anterior and posterior commissures are not directly connected with the nerve-roots, though they are probably indirectly connected with the anterior ones by means of the uniting filaments between the several ganglionic groups, and both commissures consist of white fibres.

13. In the spinal cord a central canal may always be found, lined internally with epithelial cells, and sometimes appearing to contain an albuminous fluid; in man it seems to be narrower than in most animals.

CHAPTER IV.

PHYSIOLOGICAL RESULTS.

Having endeavoured to explain, as accurately as possible, and to reduce to a system, the principal points relating to the structure and mutual connexion of the parts of which the spinal cord is composed, I believe it will not be unprofitable to refer to certain physiological principles in confirmation of what has been advanced, and at the same time to deduce and explain the mode of action in the medulla spinalis.

1. I have, by the most satisfactory observations, fully proved that the motor nerves take their origin in the spinal cord, and more particularly from the multipolar ganglionic cells of the anterior grey horns. The establishment of this fact was the more important as the valuable investigations of Wagner, illustrated by Ecker, referred to the electrical ray, and it has not yet been shown how far they can be applied to the spinal cord itself. Schilling's description is equally unsatisfactory, although he, as well as Gratiolet, states that he has clearly seen the connexion with the motor nerves. It is, however, not difficult to show that Kölliker's idea, referring the origin of the motor nerves to the brain, is liable to extraordinary difficulties, which make such an opinion in itself improbable.

If we examine a muscle, the biceps for example, or any other muscle of some size, and trace the motor nerves distributed to it, the slightest microscopic examination will suffice to show that the branches of the so-called perforans Casserii, which pass into the biceps, contain several hundreds, nay, thousands of primitive filaments; from the same nerve the brachialis anticus also receives its motor nerves, whereby this number is again considerably increased. The peculiarity, however, of these muscles is, that we cannot move either separately; they form one of those systems, of which some still more extensive examples are to be found in the body; it will suffice to mention the rectus, cruræus and vasti. When we bring the first-mentioned muscles into action, all the fibres belonging to the system to which they belong become proportionally tense; we are not able to flex the biceps and to leave the brachialis anticus relaxed, or *vice versâ;* but whether it be with slight force, or whether it be with a violent effort, the influence of our will is proportionately communicated to all the muscular fibres,—a coöperation absolutely necessary to enable the muscles to render us the service of which they are capable. The power of producing a partial contraction of some muscular bundles would have been perfectly useless; because, in these muscles a part could have no other action than the entire organ, namely, to flex the forearm; the orders of our will must, therefore, be uniformly distributed over all the muscular nerves entering into the brachialis anticus and biceps. Now, if all these muscular nerves proceed along the spinal cord to the brain, and, in fact, to the point where our will acts, the latter must always uniformly influence these thousands of nerve-fibres; but still it remains unexplained, why our will should not be able to act more strongly on some nerve-fibres than on others, as it can act on different muscular nerves, and why we should not have the power, for example, of bringing into action the one half of the biceps, or the biceps alone, leaving the brachialis anticus relaxed.

Nature has, however, in my opinion, arranged this with much greater simplicity and certainty. All the muscular nerves, destined for the biceps and brachialis anticus, arise from a group of multipolar ganglionic cells, which are mutually connected. If now this group receives an impression or stimulus from our will, by means of one or several conducting filaments derived from the brain, this impression appears to be destributed equally to, and to excite to the development of force, all the multipolar cells of the group, by means of numerous filaments of communication; the consequence of which is, that all the nerve fibres derived from the group are excited with an uniform force, which is transmitted to all muscular fibres receiving nerves from the same group, whence must result an uniform and simultaneous action and contraction of all muscular fibres of the biceps and brachialis anticus, so that we are unable during their contraction to leave a portion of these muscles inactive. We may, therefore, regard such a group of ganglionic cells as a battery of Leyden jars connected with one another; the electric force is divided uniformly over all the united jars, and all are at the same time uniformly discharged, as a conductor alone is necessary to enable all to be charged alike.*

2. According to this view, not only is the uniform and simultaneous action of all the fibres of a muscle explained, but the structure of the spinal cord is rendered plainer and more intelligible. Thus if a stimulus, communicated to such a group of ganglionic cells, diffuses itself uniformly over the whole group, the number of medullary filaments, which convey the orders of our will to the group, may be very small. Theoretically we might even imagine that there was but one conducting filament; I do not, however, believe that nature would intrust such an important action, as that of a considerable muscle, or even of a system of muscles, to one single and delicate nerve filament; but certainly we may suppose that the number of conducting filaments which arise from the brain and run downwards along the anterior and lateral columns, to unite with a group of ganglionic cells, need not be great; this number may therefore be extremely small in comparison with the number of nerve filaments, which arise from the group of cells and divide as a nerve in the muscle; and hence is at once explained the disparity between the mass of the anterior and lateral columns and that of all the motor roots together, which disparity is not adequately accounted for by Kölliker's calculations. If we only consider, as Todd and Bowman have already observed,† that in the fibres composing the anterior pyramids, and passing through the pons Varolii to the crura cerebri, all the nerve-filaments must be comprised which bring into action the muscular bundles and muscles of the entire body, a disparity presents itself which cannot be explained by the varying minuteness of nerve-fibres, since this difference is not nearly so great.

Hence it follows, therefore, that the number of medullary longitudinal fibres, passing as conductors of the orders of our will from

* Although it cannot be anatomically demonstrated, as we cannot trace all the multitudinous decussating filaments in the anterior horns of the grey matter, it must be inferred that such groups are, to a certain extent, isolated from the adjoining ones, as otherwise the separate movement of a muscle would be impossible. For this reason, we cannot consider the ganglionic cells as constituting connected columns, running along the whole length of the spinal cord; but they must be divided into so many different groups, as there are separate systems of muscles or muscular movements in the body.

† *Phys. Anat.*, Part II., p. 329, and *Cyclop. of Anat. and Phys.*, Vol. III., p. 722 D.

the brain to the several groups of ganglionic cells, may be relatively small. They must, in fact, be in proportion to the varying number of ganglionic groups in the anterior horns, and this number of different ganglionic groups must depend upon the several distinct movements which we can accomplish either with different muscles, or even sometimes with parts of a muscle, for example, the separate divisions of the pectoralis major. Consequently there will, according to my view, be one considerable group of ganglionic cells in the lumbar portion of the spinal cord for the rectus, the vasti, and the cruræus; one group for the gastrocnemius and soleus, &c.; and thus the number of ganglionic groups shall scarcely amount to much more than the number of muscles existing in the body. If we now compare the thickness of the antero-lateral columns of the spinal cord in transverse sections at different heights, we shall find that the small number of conducting filaments ascending from each group, will but slightly increase the thickness of the antero-lateral columns upwards.

Posteriorly we have, however, seen that the proper sensitive filaments, after their entrance into the spinal cord, immediately curve upwards to constitute a part of the posterior columns; the posterior and postero-lateral columns must consequently contain as many nerve filaments as there are nerves of sensation. In the ascending series of transverse sections, therefore, the posterior and postero-lateral columns must become much thicker as we proceed upwards, by the constant addition of sensitive nerves, than is the case with the anterior.

If we now compare from this point of view the plates of Arnold,* which are very accurate, we shall see that in the superior divisions of the spinal cord the postero-lateral columns are very much increased in mass, while the sections of the antero-lateral columns are only very little thicker, so that the structure of the spinal cord quite corroborates my theory.

3. I have considered it to be established that for every separate movement a special group of ganglionic cells must be present, whence all the nerve filaments arise which go to a muscle, or to a system of

* *Tabul Anat.*, Tab. I. and II. If we compare, for example, from Fig. 26 to 23, which contains the lumbar bulb, with from Fig. 20 to 16, containing the cervical portion of the spinal cord, the difference at once strikes the eye. Longet has also, though without mentioning Arnold, tolerably faithfully copied these figures. *Anat. et Physiol. du Système nerveux*, Tome I., Pl. II. See also Stilling, *Med. Oblongata*, Tab. I., Fig. 1, compared with Tab. II., Fig. 3 and 4.

muscles always acting simultaneously. The greater, therefore, the number of differently acting muscles is, so much the more numerous must be the various ganglionic groups in the anterior horns of the spinal cord, in order to represent these muscles and to produce their several actions. The consequence of this will be that in such situations the anterior horns of the grey matter must be broader and larger, and contain a greater number of multipolar cells, than where only a small number of different muscular actions is governed by the spinal cord, or where the number of muscles is less. In the lumbar bulb, whence the nerves for the legs, and in the cervical expansion, whence the nerves for the arms arise, the anterior horns must therefore be broader and more massive than in the dorsal portion, where the action of the intercostal and abdominal muscles does not comprise by any means so many different muscles, and where so many different movements do not take place as in the extremities. Accordingly, if we refer to Arnold's plates, we shall see that precisely in the lumbar bulb * and in the cervical portion † the anterior horns are broad, while those in the dorsal portion,‡ on the contrary, are remarkably slender and small.§ On microscopic examination, I have also found that in the dorsal portion the number of ganglionic cells is much less, or as Clarke has correctly observed, that the number of ganglionic cells is in a direct ratio to the size of the motor nerves passing from the spinal cord. ||

My suggestion as to the use and mode of union of the ganglionic cells in groups therefore at the same time explains the difference in

* Pl. II., from Fig. 26 to 23. † *l. c.* from 20 to 16.

‡ *l. c.* Fig. 22 and 21. See also Stilling, *Med. Obl.*, Tab. I., Fig. 1 and Tab. II., Fig. 3, contrasted with Tab. II., Fig. 2 and 4.

§ In accordance with this, the transverse rays from the anterior horns, in the white medulla, are more numerous in the lumbar and cervical expansions than in the dorsal portion of the spine; as a larger number of groups of ganglionic cells will require more numerous connexions with the antero-lateral columns as conductors of the orders of the will.

|| *Phil. Trans.*, *l. c.* p. 614. In like manner, it is easy to understand why, as Gratiolet already observed (see above, p. 22), the ganglionic cells in large animals are larger and more numerous in the anterior horns. If the special nerve-filaments for the muscles take their origin from these ganglionic groups, the ganglionic cells, whence they arise, must, as thicker muscles, receive more numerous nerve-filaments, give off a greater number of filaments, and therefore form larger and more distinct groups than in small animals, where the nerves are slighter and the ganglionic cells are consequently smaller and give off fewer filaments.

the thickness of the anterior horns and of the spinal cord in the several situations, and in connexion with the muscular nerves which leave the cord.

4. If we compare the spinal cord in different animals, we shall find a confirmation of what has been advanced. Although I had neither time nor opportunity to examine the spinal cord microscopically in any great number of animals,—an undertaking which might, indeed, be productive of extremely important results,—I have endeavoured to investigate this organ more closely in some animals, where it appeared to me a great difference existed. The slightness of the spinal cord in certain fishes especially attracted my attention. Having had the opportunity of dissecting a sturgeon (*Acipenser sturio*) of about one hundred and twenty pounds' weight, I was extremely surprised to meet with a spinal cord, which was scarcely thicker than that of a frog, while the muscles of the animal constituted by far the greater bulk of the body, and the thickness of the muscular mass far exceeded that of the thickest muscles of a man.* The roots, too, of the nerves, which proceed from the spinal cord, are in this fish extraordinarily slight, being only about equal to a bristle in thickness. I was very much surprised to meet scarcely any grey matter in its spinal cord, nor was it until after a lengthened search that I discovered some ganglionic cells; the nerve-fibres in the cord were, however, not very minute, they were even much thicker than in man.

This want of proportion between the thickness of the spinal cord, which was about equal to that of a frog, and the extraordinary size of the muscles, seems to show that no relation exists between the thickness of the cord and the muscular power of an animal, as I should have supposed. But the small number of ganglionic cells, and the small, scarcely distinguishable, quantity of grey matter present in the spinal cord of this fish, surprised me very much. If, however, we reflect on the mode of life and motions of the animal, this peculiarity

* The same tenuity is presented by the spinal cord in the shark, the plaice, the pike, and other fishes. On account of its softness and the great superabundance of fat, it is very difficult to examine the minute structure of the spinal cord in fishes; I found many thicker nerve-fibres with a distinct cylinder axis of 0·005 mm. and slighter ones of 0·0013 mm. in thickness. The ganglionic cells in the sturgeon were very transparent, connected by intermediate filaments; in this fish they were 0·0204 and 0·0255 mm. in breadth, by 0·0080 mm. in length. In the pike, too, I have met with those ganglionic cells in the spinal cord.

is immediately explained. The movements of the sturgeon, in fact, present but very little variety; it strikes to and fro with its tail as well as with its fins, it curves its body to one side or to the other, but the numerous combinations of the muscles of the extremities of the higher animals, and especially of man, where extensors and flexors are at the same time or alternately in action, do not here occur. The animal does not therefore need many groups of ganglionic cells and their several combinations for harmonized movements; while, moreover, in consequence of the considerable length of the spinal cord in these fishes, the cells appear to be very much separated in the longitudinal axis of the cord, so that often on a transverse section no ganglionic cells can be found.

If we compare, in this respect, the spinal cord of a frog, we shall find that the latter scarcely differs in thickness from the same organ in a sturgeon of one hundred and twenty pounds' weight. The grey matter with its four horns is here distinctly present, in which numerous, although small ganglionic cells, are found; but in the spring of this animal we meet a much more complicated play of muscular action, as many different muscles contribute to accomplish the jump.

Hence we see, that in animals likewise the statement is confirmed, that the more complicated their movements, the more numerous will be the ganglionic cells with their several groups, and the thicker will be the anterior horns and the mass of grey substance in the spinal cord.

5. I have above shown that the sensitive roots divide, after their entrance into the spinal cord, into ascending bundles, passing upwards with the longitudinal columns; and into transverse, which, dividing into different fasciculi, proceed towards the posterior horn of the grey matter, and after having perforated the latter, appear to be in great part gradually lost in the group of ganglionic cells, situated in the middle of the grey matter between the horns, and in these last I have in fact recognized reflex nerves. I cannot, however, wholly agree with Marshall Hall, who assumes excito-motor nerves, that is special nerves, said also to accomplish the motions caused by reflexion. This is an hypothesis which is based on no certain foundation; it is sufficient that the roots of the motor nerves receive the stimulus to action from the group of ganglionic cells, whether this be communicated through the will from before, or through the reflex movements from behind.

According to this idea we may therefore consider the groups of ganglionic cells as constituting a battery with two poles, or rather capable of being charged from two sides; the one pole is connected, by means of the lateral rays, with the filaments which conduct the orders of our will, the other pole, by means of different combinations of ganglionic cells, with the reflex nerves, so that a group is capable of receiving both psychical and physical stimuli. As, however, the posterior roots, in this case, contain two kinds of nerves, those for sensation and those for reflex action, it is not surprising that they should be thicker than the anterior roots, as is universally admitted. This thickness of the roots differs then by about the half; according to Kölliker the sum of the surfaces of transverse section of all the motor roots is to that of the sensitive roots in man as 6·9 to 15·6, in woman as 6·5 to 13·4,* which must depend on the different size of the body and thus on the extent of the sensitive skin.

According to this view, therefore, reflexion takes place not by springing over, or transverse conduction, but along fixed routes, whereby the reflex action is regulated.

By comparing this with what we have already stated as to Wagner's views, it will be seen that the latter writer differs from the opinion I have advanced only in assuming the existence of sensitive fibres, passing transversely in the posterior horns into ganglionic cells. It seems to me that there is little probability in this idea; as I have been unable to discover any difference in these transverse posterior roots, and as they perfectly resemble one another, it would naturally follow that they must all be classed either among reflex or among sensitive nerves. We can hardly admit the existence among them of two so different kinds of nerve filaments as those for sensation and for reflex action. Moreover, I doubt this connexion of proper sensitive fibres with the posterior horns, because irritation of the grey matter in the spinal cord by strychnia, which gives rise to great congestion in the posterior horns, excites no pain. Lastly, I have shown that the ascending grey fibres in the posterior horns, at least for by far the greater part, do not run through the brain, as the posterior horns become so slight in the middle of the back that most of the ascending fibres have in this situation disappeared. However, I freely admit that the question is still wholly undecided whether, when reflex sensation or sympathetic sensation takes place, the proper sensitive filaments first communicate their action to one another in

* *Mikrosk. Anat., l. c.* p. 433.

the seat of perception in the medulla oblongata by means of ganglionic cells, as appears to me to be most probable, or whether they stand in more intimate connexion with the posterior grey horns and the spinal cord. I should be rather inclined to assume, that the transverse rays which spread from the posterior horns into the posterior white columns, are capable of accomplishing some closer connexion between these parts, although, on account of the insensitive nature of reflex action, this is not clear to me; perhaps they give us the knowledge of reflex action. The very large number of slender ascending fibres in the posterior horns does not appear to me to render this explanation of the phenomena of reflex action improbable. We must remember that in a somewhat irritated condition of the spinal cord every sensitive point of the skin conveys its stimulus to all parts of the cord, and for this an infinite number of fibres is required, adequately to produce a proportionate connexion with the several ganglionic cells.

Finally, Wagner explains by the same reasoning the presence of reflex fibres in the posterior roots, whereby the thickness of the latter is increased, as I have above more fully considered. This point I have in my contributions published in 1848, on the structure of the spinal cord, endeavoured to confirm by the same and by additional proofs.* Wagner, therefore, also admits the reflex motor nerves of Marshall Hall.

Of the anterior columns this writer, too, assumes that all fibres enter into the great masses of ganglionic cells in the anterior horns, and are not in direct connexion with the brain. Thus also he lays down that the anterior columns arise from fibres of the anterior ganglia,† although he appears to me not to have recognized the exact connexion of the transverse rays. I cannot, however, wholly

* Notes of the Sectional Meetings of the *Provinciaal Utrechtsch Genootschap*, 1848, p. 13. See also above, p. 10.

I have not the least doubt that these contributions in the notes of the transactions of the section of the Provincial Society of Utrecht for 1848, were unknown to R. Wagner, although most of his ideas occur in them; as these notes are circulated only among the members, and their translations into the Swedish Journal probably did not come under the notice of this distinguished writer, whom I esteem much too highly to entertain for a moment the least doubt upon the subject. However, this independent and close agreement of ideas is a strong testimony in favour of their truth, and this is much more important than the questions of priority, so commonly agitated in our days.

† *l. c.* p. 38.

agree with Wagner's position that the reflex filaments pass from behind directly into the anterior multipolar ganglionic cells, whence the motor nerves arise. I think that they are first connected with smaller cells situated between both horns, and thus indirectly with the motor ganglionic cells, by which it is probable also that the too rapid development of reflex phenomena is restrained.

Subsequently Wagner adds the important proposition, that we never, or at least extremely rarely, can bring into action single primitive fibres; but that we always act upon groups of primitive fibres; several multipolar ganglia being in the case of larger muscles connected with a group,* a statement which quite agrees with that I have above advanced; yet even with respect to smaller muscles, I believe that a single ganglionic cell does not give out sufficient fibres.

Lastly, Wagner put it forward as doubtful, whether the fibres conveying voluntary stimulation to the muscles, and arising from the brain, unite with a peculiar system of ganglionic cells in the spinal cord and medulla oblongata, or whether the ganglionic cells with reflex motor fibres serve this purpose, of which he holds the latter opinion to be the more probable, inasmuch as the will can suppress the reflex phenomena. I believe that, by the discovery of the connexion of the transverse fibes radiating from the anterior horns with the longitudinal anterior columns, I have anatomically decided this question.

6. I have above remarked that most probably the longitudinal slender fibres of the posterior horns consist of filaments of communication, connecting the several groups of ganglionic cells with one another. In this manner, in my opinion, the difficult theory of reflex motion is much simplified, as the reflex nerves pass between these longitudinal filaments, perhaps partly pass into them, and the latter are probably connected with the same ganglionic groups, in which the reflex nerves terminate; for otherwise, as I have already observed, it is difficult to understand how the posterior horns should be so much slighter and smaller in the dorsal than in the lumbar region,† and consequently contain fewer longitudinal fibres, which applies also to the enlarged cervical tract and the higher part of the neck.‡ By reflex action the muscles are now first brought into

* *l. c.* p. 39, note X.

† See Stilling, *Med. Oblong.*, Pl. I., Fig. 1, compared with Pl. II., Figs. 1 and 2.

‡ Stilling, *l. c.*, Pl. II., Fig. 3, compare with Fig. 4.

motion, the nerves of which arise nearest to the reflex nerves, where, therefore, the excitation of the reflex nerve or of some of its filaments, has the shortest way to run from the posterior horn and the centre of the grey matter to the motor cells of the anterior root, both the anterior and posterior root uniting to form a mixed nerve.* Thus, in a very young child, not only does tickling the inside of the hand produce bending of the fingers, on account of the median nerve, which gives muscular branches to the flexors of the fingers and sensation to the inside of the hand, but in like manner tickling the back of the hand produces extension of the fingers, by reflex action on the musculo-spiral nerve, as I have elsewhere shown.† But if the irritation be more severe, or if the spinal cord be in a more irritable state, remote groups of muscles are also brought into action.

This last phenomenon appeared in fact to involve the explanation in almost insuperable difficulty, on which account Volkmann felt himself inclined to assume a transverse conduction or overleaping,‡ in the main points of which Kölliker coincides.§ It seems to me, that in the view I have proposed, these difficulties are for the most part removed, and that the explanation is rendered more easy. Let us suppose a simple case; for example, that a person unexpectedly burns his finger; so soon as he perceives it he will draw his hand quickly back; this is not altogether voluntary; he would do the same if in an unconscious state, for example, when under the influence of chloroform, or even in sleep. Now what takes place in this case? The forearm is flexed, and at the same time the humerus is drawn back, that is, the biceps and brachialis anticus enter

* See also Volkmann, *Nerven-phys. l. c.* p. 532. Thus reflex phenomena may take place, when the sensitive and motor nerves are connected with only a segment of the spinal cord. See Volkmann, *l. c.*, p. 543. This proves very clearly the close connexion between the anterior and posterior nerve-roots on the same level.

† On the connexion between the sensitive and motor nerves: *Tijdschrift der Wis- en Natuurk. Wetensch.* van de Eerste Klasse van het Kon. Ned. Inst. 1847. In this manner, the close connexion between the course of the sensitive and motor nerves which are united in the same trunk, is easily explained; so that, according to the above-described law of distribution, an irritation of the skin causes reflex action first in the muscles, with whose motor nerve that of the sensation unites into a trunk. See above, p. 7.

‡ *Nerven-physiol.*, *l. c.* pp. 528 *et seq.* and 547.

§ *Mikrosk. Anat.*, *l. c.* pp. 442 *et seq.*

into action for the first, the latissimus dorsi and teres major for the second movement. But there is now no difficulty in supposing that the reflex nerves, which are given off with the sensitive nerves of the finger, through their combination in the spinal cord, irritate the group of ganglionic cells whence the nerves are derived which excite the biceps and brachialis anticus, and at the same time the group of cells, from which the nerves for the latissimus dorsi and teres major arise. Thus through a combination of connecting filaments by means of ganglionic cells, wherein the reflex nerves terminate, both groups are simultaneously stimulated, and so both movements are combined. If the irritation is severe, or if the spinal cord be more than ordinarily sensitive, the stimulus may bring several muscles into action; for example, when a decapitated frog takes a jump on the application of a stimulus to the hind-foot or toe, several groups of ganglionic cells are brought into action through the reflex nerves, which groups are more or less connected with one another, and the movement becomes a combined or harmonized one, a jump. Here we must bear in mind, that a certain amount of irritation is necessary before reflex motion takes place; that is, the cells, wherein the reflex nerves appear to terminate, must be excited to a certain extent before they communicate the action which has been developed to the neighbouring group of cells, whence the muscular movement is immediately accomplished; they are like Leyden jars which must be charged before the spark passes. Remote or higher situated reflex cells, which probably are connected by means of longitudinal filaments of communication in the posterior horns with those which are directly stimulated, shall, therefore, not be so rapidly excited to action, or, to keep to the simile, become charged, as those which receive the stimulus directly from the reflex nerves; and hence it is that almost always, as Volkmann remarks, the next adjoining muscles are the first to be removed.* But if the whole spinal cord be in a more highly irritated condition, and if the reflex cells be, as it were, more highly charged, only a slight stimulus is necessary to produce a universal discharge, and more general reflex movements take place, as in convulsions, epilepsy, or after the administration of strychnia. This excitation occurs almost always in consequence of a greater determination of blood (congestion), or as a result of the blood being poisoned, for example, by strychnia. Now, if we give a dog strychnia, this drug, as is well known, and as I found in experiments made for

* *Nerven-phys. l. c.* p. 544, No. 10.

this special purpose, is taken up into the blood, and the blood so poisoned is in constant contact with the grey matter of the spinal cord, which is so rich in vessels,* and still the convulsions which take place are intermittent.

Suddenly, without any previous symptom, the dog falls, becomes convulsed, or makes involuntary movements; but these cease after some time, and now the animal appears to be again perfectly well. In such a case I have seen intervals of even more than an hour, in which I could touch and stroke the dog, while he ran round without any appearance of injury, until the sensibility had again become so great, that even the simple blowing of air upon him excited convulsions. Thus notwithstanding that the grey matter was incessantly in a state of interchange with the poisoned blood, the convulsions were not constant, and it was not until after a tolerably long interval that the susceptibility was sufficiently restored to reproduce them.

We see the same in epilepsy: if a severe attack has taken place, the patient is usually free for a long time, if a slight attack ensues, a second often occurs after a short interval; in the latter case only a partial discharge had, as it were, occurred, so that it was not until a second rapidly followed that the equilibrium could be restored.† If the excitability is exalted, as in children, only a slight stimulus is often required to produce general reflex phenomena, that is, convulsions; if a more remote group of ganglionic cells is excited to a higher degree, a remote stimulus through a reflex nerve, distantly connected with this group by means of filaments of communication, will be able to produce reflex movements in it, as is sometimes the case in hysterical affections.

7. We have, however, above seen, that the groups of motor cells—as I will designate them for distinction's sake—whence the motor nerves arise, possess as it were two poles, that is they are connected on the one side with the conducting filaments of our will (anterior columns), posteriorly with the reflex nerves by means of other ganglionic cells. Now if these reflex cells are connected through communicating filaments with several groups of motor cells, so that by reflex action a harmonized movement, for example a jump, takes

* See Ecker, *de Cerebri et Med. Spin. System. Vas. Capill. Traj. ad Rhen*, 1853, pp. 60 *et seq*. Fig. IX.

† It is perhaps to this cause that we should attribute the periodicity of so many phenomena which appear to stand in close connexion with the spinal cord, as agues, febris larvata, &c.

place, we may assume that by means of the anterior conducting filaments of volition, the groups are most easily brought harmoniously into action, whereby a combined or coördinated movement is produced. Now we have indeed the power of voluntarily moving a separate muscle, for which separate conducting filaments may exist, but we can with equally little exertion or consideration bring into action several groups of muscles, of which a step, a coördinated movement is the result, and this is probably produced by a prearranged connexion, by means of the communicating filaments of several groups, which are affected as by reflex action.* The cause of the coördination of muscular movement is therefore situated, as Volkmann correctly supposed, in the spinal cord, and it has always been incomprehensible to me how any one could ever have referred it to the cerebellum. If the cause of this coördination lay in the cerebellum, no harmonized reflex movements could take place in a decapitated frog.

The experiments of Flourens, Hertwich and others are, in my opinion, easily explained; the motor fibres pass from the corpora pyramidalia through the pons Varolii to the crura cerebri; they here decussate with the transverse fibres of the pons, and between both lies, as I have satisfied myself by microscopic investigations, a thin layer of grey matter,† containing small multipolar cells. If a part of

* That the production of harmonized movements, for example, taking a step, is referrible to the organization and action of the spinal cord, that is to different intimate connexions of certain groups of ganglionic cells, and therefore may be said to be prearranged in the structure of the cord, will appear extremely probable, if we watch a very young child, which when the mother takes it up in her lap, very early begins to make the regular movement of a step, alternately with the right and left foot; and we see this still more clearly in a young chicken, which runs off immediately after leaving the shell. Different combinations of muscular action are necessary for the taking a step, which are not learned by study and practice, ending after many failures in a successful election; but the combination which is required for the purpose must already exist, organized, and, as it were, prearranged in the spinal cord, so that a single impress is sufficient to bring this combination into action. Our mind knows neither the muscles or instruments, nor their number or situation, through whose combined action it produces a step. What study it would require if, out of all the possible irregular muscular movements of which the leg is capable, we were obliged by practice to learn to combine those which produce a step.

† Ecker, *Diss. de Cerebri et Med. Spin. Syst. Vas.*, 1, p. 58, Fig. VII.

the cerebellum be now taken away, the violent irritation so produced is reflected by means of the transverse fibres on the corpora pyramidalia, and irregular movements are the result. If the cerebellum were the seat of coördination, regular movements would of necessity ensue on irritation of that organ. But in ulceration of the cerebellum, when the irritation is more chronic and not so violent, I have never seen irregular movements arise.

I think, therefore, that the difficult phenomena of reflex action may be satisfactorily explained by the theory of special groups of motor cells and of reflex cells, and the varying degrees of connexion in which these are placed with one another by means of their communicating filaments.

This view also supplies an explanation of Schilling's singular observation, that of the transverse roots of the posterior nerves in the grey matter, some bundles curve upwards but others downwards.* Were these sensitive nerves, there could be no possible reason for their curving downwards; whereas if they are reflex nerves, it follows from the nature of the case that some bundles may and even must be in connexion with cell groups situated above, and others with cell groups placed beneath them, and consequently they must curve towards the latter.†

8. Lastly, we have seen that the commissures, connecting the right and left sides of the spinal cord, appear to participate more or less in the production of the reflex phenomena. It has, in fact, been shown, that the fibres from the posterior commissures run for by far the greatest part transversely, and in the middle between the two grey horns are lost partly in the same ganglionic groups, in which the reflex filaments also disappear, and seem partly to terminate in the small groups of ganglionic cells situated at the side of the central canal.‡ There is, therefore, every probability that the fibres of the posterior commissures serve for lateral reflex action, and are consequently capable of transferring to the opposite side the impression received in the groups of reflex cells, while those of the anterior

* Schilling, *l. c.* p. 31, Tab. II., Fig. 1 *e*.

† On this subject I would further remark, that the very division of the reflex nerves into slender fasciculi in the posterior horns, such as I have shown both in transverse sections, Fig. 8 *g g*, and in longitudinal, Fig. 9 *a a a*, appears to indicate their passage into different ganglionic groups, whereby the diversity and multiplicity of reflex phenomena is more fully explained.

‡ Fig. 11 *g g*, Fig. 8 *f*, *e*, *d*.

serve to produce in our voluntary movements harmony and agreement between the two sides, and so to preserve equilibrium. Hence we can, in a very simple mode, account for many phenomena which are otherwise difficult of explanation.

From the experiments of van Deen* and Stilling, it appears that all motion is not lost after one-half of the spinal cord of a frog is cut through; indeed, Stilling states explicitly, that if the spinal cord be cut across on both sides to the middle line, the incisions being at some distance from each other, the animal will still be in a state to produce voluntary motions and to jump.†

That reflex movements still take place in such frogs, was formerly demonstrated by van Deen to myself; the voluntary movements were, however, not very satisfactory, although a jump was certainly accomplished.‡

These experiments are indeed very strange, and are not explicable on the supposition of the rectilineal conduction of the impression of the will. But it may be imagined that if a group of ganglionic cells on the one side is stimulated by the will, in such an irritated spinal cord, the opposite side, cut through at a greater height, may be stimulated and set in motion through the medium of the commissures; the action is then a reflex one from above in consequence of the impression of the will, of which examples enough occur in the experiments of van Deen and Stilling. But it is in this case always difficult to distinguish properly and with certainty between voluntary and reflex movements. I have, however, myself observed that reflex movements may take place in the fore-feet, when the hind-feet are irritated where the spinal cord is in this manner half cut through at some distance on both sides. Now since, as we have seen, the posterior commissures pass into the same group of cells, in which the reflex nerves appear to terminate, the explanation is very simple, that the reflex movement is communicated to the other side.

But this is not possible, if we adopt the view of the course of the fibres in the spinal cord which Kölliker puts forward.§ This writer gets over the difficulty by simply saying, that if the section takes place at some distance on either side, all the filaments conducting the

* *Nadere ontdekkingen over de eigenschappen van het Ruggemerg*, 1839, p. 27, expt. 27, pp. 61 *et seq.*, expt. 47.

† Stilling, *Die Functionen des Rückenmarks, l. c.* pp. 153 *et seq.*, pp. 247 *et seq.* Fig. 19, 20.

‡ Van Deen, *l. c.* p. 62.

§ *Mikrosk. Anat. l. c.* p. 410. See also above, pp. 13 *et seq.*

motor influence of the brain are cut through and the extremities will be paralysed. So far at least as relates to the reflex movements, these cannot, according to Kölliker's theory, take place; for the fibres which are said to be situated next one another, and by transverse conduction to render reflex action possible, are likewise cut through; and thus the phenomena of reflex action should be even less possible than those of direct motion, which certainly is not the case, clearly proving the incorrectness of Kölliker's view of the course of the nerve fibres in the spinal cord. It is easily seen that the occurrence of convulsive movement on both sides of the body,—in cases where the remote cause, for example, hardening, or tubercles in the brain, was confined to one side,—must be explained by reference to these commissures.

But, as the decussated fibres of the anterior commissure pass either directly as transverse rays into the anterior medullary columns (Fig. 11 *d*, Fig. 12 *f*), or by means of the marginal fibres and cells are more directly connected on the inside of the anterior horn and the rays proceeding thence (Fig. 12 *c*, Fig. 5 *f g*) with these longitudinal columns, which we have recognized as conductors of the orders of our will,—the will must exercise more influence on the anterior commissure, and by this route must the given impression be conveyed to the other side. We can thus see, not only how the harmony of the movements of both sides is maintained, as we have already observed, but that this arrangement may also influence the muscles, which either always, or almost always, are in the healthy state moved similarly on both sides; for example, the muscles situated in the middle, the sphincters and levatores ani, the ischiocavernosi, as well as the abdominal and intercostal, and in great part the dorsal muscles, which hold the body in the erect or straight position; also the muscles for deglutition, those for the development of the voice, and others which always act symmetrically. Perhaps we may further refer to the same category the muscles engaged in the simultaneous movements of both wings in birds when flying. The posterior commissure seems to me to serve for the more involuntary lateral reflex actions; because as we have seen, its fibres appear to end in the middle of the grey matter, where I think I have also found the termination of the reflex nerves. However the connexion of the reflex nerves with the next anterior motor roots is much closer, than with the fibres of these transverse commissures, since, as Pfluger has shown, in extension of reflex movements the latter ascend exclusively on the one side, until the irritation, having reached the medulla oblongata, passes over and produces general convulsions.* The posterior commissure may also serve for involuntarily preserving the equilibrium between the two lateral portions of the body. These reflex movements bear so very much the character of coördinate, or, if we will, of voluntary movements, that they often cannot be entirely distinguished from them; for example, rubbing or scratching where itching is felt, which takes place likewise in sleep, and to avoid which in case of violent itching, even a powerful exertion of the will is necessary, just as a decapitated frog endeavours to remove with its foot the irritation of acetic acid applied to the side of its body, or if this is prevented, sometimes with the foot of the other side. Some, as E. Pfluger, observing such phenomena,† have been misled into assuming a sort of voluntary power or mind in the spinal cord, an error attributable solely to want of examination of the ingenious arrangement of the tissue and of the structure of the cord, in which all these harmonized movements appear to lie hidden, prearranged in the several combinations of the groups of ganglionic cells, and ready to be excited by any stimulus, whether voluntary or reflex, so that they are produced just as the harmonic tones of a piano under the fingers of the player. Such a view is sufficient to excite amazement at the ingenious nature of all these arrangements and wonderful combinations, but it is conceivable, and in my opinion not so difficult to imagine; while the idea of volition in the spinal cord, without consciousness, with the entire rejection of the existence of a soul, as Pfluger suggests, is an absurdity not to be thought of. On the contrary, the deeper we penetrate into the knowledge of the mechanism of our body, the more we shall be convinced that the whole is arranged as a perfect minister of our spirit and of our will, in which both the amazingly correct insertion, size and combination of the muscles, and certainly not less the combination of the ganglionic groups, whereby these muscles are harmoniously and suitably moved, are calculated with incomprehensible wisdom and fulness of purpose.

So there are, in fact, many involuntary actions, which we ordinarily regard as voluntary; for example, shrieking with pain. This shrieking appears to be merely the effect of a reflex action on the upper part of

* Pfluger, *Die Sensorischen Functionen des Rückenmarks.* Berlin, 1853, p. 76.

† *Die Sensorischen Functionen des Rückenmarks.* Berlin, 1853. Chapters II., III.

the spinal cord or medulla oblongata, where so many combinations lie concealed, and where such multitudinous reflex movements are developed; in violent pain it requires the greatest exertion to forbear screeching, or moaning: we are, as it were, constrained to it. This was strikingly illustrated in the remarkable case of a very intelligent lady, who came to ask me for an explanation of a phenomenon which had very much surprised her: her breast had been amputated under the influence of chloroform, so successfully applied, that she had felt nothing whatever of the operation, but on awaking she was perfectly conscious that she had heard herself screech, while the fact of her having skrieked was confirmed by the bystanders, and such shrieking indeed usually occurs in these cases; a proof of its involuntary nature, and that it is nothing but a reflex action. Hence it follows, that in vivisections so many incorrect inferences are drawn as to feeling and perception in animals. If the brain be cut off above the pons Varolii, and the fifth pair of nerves be strongly stimulated, the animal will cry out, although without consciousness, without perception, and without the feeling of pain.

Thus we often see such shrieking in convulsions; I have observed it in the most violent degree even in apoplexy, where there was no trace of consciousness.

9. There has been a great deal of controversy as to whether the grey matter, the antero-lateral or posterior columns are at all sensitive or not, and on this subject the most conflicting opinions have been broached, which are stated by Volkmann in a short review.* In my opinion the grey matter in the spinal cord serves solely for motion, the posterior rather for reflex action and the coördination of movement, while sensation is transmitted upwards exclusively through the posterior and lateral medullary columns. That such is the case, I inferred especially from the phenomena produced by strychnia in a dog: in slighter attacks the hind-feet acted first, and subsequently continued more rigid, the animal standing upon them, with the body inclined obliquely forward. Not only during these convulsions, but even when the animal lay more than once upon the ground, with its feet stretched out in tetanic rigidity, it had not lost consciousness, of which my audience were witnesses with me; thus, when a white cloth was accidentally drawn from one side of the apartment to the other, the dog followed it with his eyes and head, while it appeared from all that occurred, that he did not experience the least pain. We also

* *Nerven-phys. l. c.* p. 548.

know, that after excessive doses of strychnia, the patients, without feeling anything, are suddenly seized with abnormal movements and convulsions. After the death of the dog, I examined the spinal cord and brain, chiefly with a view to discover any congestion which might have existed in the several parts; in the brain I met no unusual degree of congestion, but I was particularly struck with a remarkable condition of the grey matter of the lumbar bulb; it presented in fact numerous small effusions of blood,* while in the medullary portion no abnormity was found. In another dog, killed under the influence of strychnia, I found, in the grey matter of the lumbar portion, aneurismal dilatation of the capillary vessels, which were in consequence on the verge of bursting. Perhaps similar effusions had taken place in this instance, but that in the sections I prepared I had not met with them. In both cases, however, the two horns of grey matter were most beautifully injected with blood, as was evident after the sections were dried and placed under Canada balsam. I think this observation sufficiently important to give a drawing of it (see Fig. 13). We here see magnified one hundred times the capillaries in the anterior horn of the grey matter, in which, at *a*, *b* and *c*, effusions of blood occur, presenting a speckled appearance; it is, however, remarkable, that in all these effusions there is a lighter-coloured central point, probably the point of effusion, where perhaps the blood is diluted by the subsequent issue of serum. Here, as well as at *d*, *e*, *f*, we see some dilated and aneurismal capillaries; in the more highly situated parts of the spinal cord these effusions did not occur, although the capillaries were also much congested, both in the anterior and posterior horns.

Hence, it would appear, that after the administration of strychnia great congestion and irritation take place in the grey matter, which in the situations where they are most fully developed, as in the loins, may pass into effusion or dilatation of the blood-vessels, and still all this occurs without any sensation, without any pain. Were the grey matter in the spinal cord sensitive, or did the sensitive nerves penetrate into the grey matter, such congestion and irritation as excites in a sensitive nerve itself the most intense pain, could not be conceived to exist without occasioning some sensation. Hence it follows also, that reflex movements cause no pain or sensation in the spinal cord, so that by this observation the direct ascent of the sensitive nerves in the spinal cord,—of which I possess the most satisfactory

* See also Ecker, *Diss. laud.*, pp. 119 *et seq.*

EXPLANATION OF PLATE V.

Fig. 11. Transverse Section of the Commissures, p. 55.

a. Central opening or canal, extending through the entire spinal cord; internally covered with conical epithelial cells.

b. Anterior fissure, *m*, posterior fissure.

c, *d*. Fibres of the anterior commissure, which divide in plexuses after the decussation, and separate as rays in the white medullary matter, or innermost tracts, between the fissure and the anterior horn. At the side of the decussation longitudinal columns *e*, which are cut across, constantly occur; there are also tolerably large blood-vessels cut through, both in these columns and close to the central opening.

f. Group of small multipolar cells, into which a portion of the fibres of the anterior commissure passes.

g g. Other groups of cells, into which the anterior (usually lighter coloured) portion of the posterior commissure passes.

h. Back part of the posterior commissure, whence the rays run out into the basis of the posterior horn.

i. Marginal fibres around the grey matter, into and through which a portion of the posterior rays run, whence some fibres are seen spreading outwards towards the central point of the horn in the direction of *k*.

m. Posterior fissure.

Fig. 13. Transverse Section of a part of the Anterior Horn, from the Lumbar Bulb of a Dog killed with Strychnia, dried under Canadian Balsam to show the distribution of the blood-vessels; magnified 100 times, page 78.

a, *b*, *c*. Three places where blood is effused from capillary vessels, and is seen in a speckled form. In all a brighter central part appears; the specks of blood exhibit themselves here and there in a longer and more filamentous form.

e, *d*, *f*. Dilated capillary vessels, aneurismatically distended.

[To face page 78.

Fig. 11.

Fig. 13.

W. West imp.

preparations,—is, physiologically or pathologically, if we will, confirmed.

A difficulty, however, still remains, namely, that if the sensitive nerves proceed directly upwards, along the posterior columns, into the medulla oblongata, the nerves of sensation of the right side should be situated, above the decussation, next the motor filaments of the left, which, as is well known, decussate beneath the corpora pyramidalia, and thus the perceptions of the right arm should fall at the side of the incitement to motion of the left, which must cause confusion. But we know from Foville's observations,* that on the posterior surface of the medulla oblongata behind and above the anterior decussation for motion, a decussation of fibres also takes place, through which probably the nerves of sensation are likewise conveyed to the opposite side. But as to the use of these decussations, and why the motor and sensitive filaments do not remain on the same side, we are not yet in a position even to form a probable conjecture.

The situation, too, where the impression of the sensation is observed, can scarcely be determined with any certainty; probably, however, it is in the medulla oblongata, whither the fifth pair runs, while in fishes, where the proper hemispheres of the brain are wanting, there is no higher situation to which the seat of sensation can with any reason be referred. Moreover, it is well known that injury of the more highly situated parts, especially of the cerebrum, occasions no pain, and that the cerebrum is insensible to pain.

If we may now, from what has been brought forward, lay it down, that both horns of grey matter in the spinal cord serve for motion, the anterior for more direct motion, the posterior for reflex action and coördination, it becomes intelligible why vivisections performed on animals, in which it has been attempted to cut through only the posterior or the anterior columns, have led to such discordant results. It is, indeed, evident that it is absolutely impossible to cut through these columns, without wounding the grey horns, which project across them, the necessary result whereof will be that different movements must be produced by this injury, whether of the anterior or of the posterior horns, according to the different groups of ganglionic cells, reflex nerves, or filaments of communication which are wounded; so that this question can never be solved in this way, and confusion,

* Foville, *Traité compl. de l'Anatomie et de la Physiol. du Syst. nerv. cer.* Paris, 1844. Pl. II., Fig. 4.

rather than light and knowledge, will have resulted to physiology from such experiments.

10. The laws of reflex action, which have been deduced as general results from a great number of observations by E. Pfluger,* are very important. In them this author shows that reflex action is at first strictly unilateral;† furthermore that, if reflex action arises from a stimulus in the brain or cerebral nerves, the reflex movements in their further progress extend to the nerves situated inferiorly, and thus to the medulla oblongata;‡ that, on the contrary, if reflex action arises from a spinal nerve, it extends in its further progress from below upwards towards the medulla oblongata, and not *vice versâ;* but that if the affection has reached the medulla oblongata the reflex movements may again extend in an inverse order to the lower parts, or pass into general convulsions;§ that lastly, if a reflex movement arises in motor nerves which are very remote from the insertion of the sensitive nerve primarily affected, these remote motor nerves are always such as arise from the medulla oblongata.||

Hence it appears that the medulla oblongata is the principal centre, whence the more general reflex movements and convulsions take their origin. Even some years ago I was in the habit of seeking in it the starting-point from which epileptic fits arise, and to which the attention of the physician should principally be directed. And though the primary irritation may be remote, for example, in the bowels, a morbidly exalted sensibility and irritation in the medulla oblongata will always exist, rendering it more capable of discharging itself, as it were, in involuntary reflex movements.¶

Experience has taught me that it is of the greatest importance for the physician to direct his attention in such diseases to the medulla oblongata. By following such a course, I have often succeeded in

* E. Pfluger, *Die Senorischen Functionen des Rückenmarks, u. s. w.* Berlin, 1853, pp. 62 *et seq.*

† *l. c.* p. 68.

‡ *l. c.* p 79.

§ *l. c.* p. 77.

|| *l. c.* p. 78.

¶ In accordance with this, we find that the means which render the spinal cord more capable of reflex movements, have also the power of exciting epileptic attacks: thus, for example, etherization is even recommended as a diagnostic, because in true epilepsy a fit almost always follows it,—an effect I have also observed produced by smelling chloroform; the brain is stupified by it; loss of consciousness ensues, and thus the patient's condition approaches in this respect to that of a decapitated frog, the reflex phenomena being likewise so much stronger.

cases which were not of too long standing, in overcoming the intractable disease first mentioned, by derivative applications to the neck.

A more accurate examination of the minute structure of the medulla oblongata, and especially of the pathological changes produced in it by long-continued epilepsy, which I have often observed in the form of hardening of the medulla oblongata, but in reference to which no microscopic investigations have as yet been made, may throw much light upon the subject. I have hitherto not had the opportunity of instituting these investigations, on which I had wished to fix the attention of physicians. It is only in this way it will ever be possible to escape from the unsuccessful, rude, empirical treatment which is still too generally in vogue in reference to epilepsy, and of which I have observed so many sad examples. A rational mode of treatment of this obstinate disease can be based only on a better acquaintance with the functions of the medulla spinalis, and especially of the medulla oblongata, whence we must endeavour to trace more fully the nature and essence of the disease. Perhaps I shall hereafter find opportunity to communicate the observations I have already made on the subject.*

If we now glance back on these physiological inferences, we may collate the principal points in the following propositions.

1. The several primitive fibres, which are lost as a motor nerve in a muscle or system of muscles, appear to arise from a group of mutually connected ganglionic cells; they receive the impression of our will along the anterior white columns, and the transverse fibres or rays connected therewith, passing into such a group; which stimulation, by being uniformly distributed over all the cells of the group, produces in all the motor filaments of the nerve arising from it a uniform and simultaneous action.

2. The number of these anterior conducting filaments of volition must thus be proportionate to the number of groups of cells and the several combinations of which they are capable, and must therefore be much less than the number of medullary filaments for the sensitive nerves in the posterior columns; so that by the constant accession of new sensitive nerves, the white medullary matter increases more in thickness upwards posteriorly than anteriorly, as is confirmed by the form of the spinal cord in transverse sections.

* These will be found in the second part of this volume, the original of which was published four years subsequently to that of the portion of the work we are at present engaged in.—TRANSLATOR.

3. Where numerous muscular nerves spring from the spinal cord, as for the extremities, more numerous groups of cells, whence they arise, must be present; hence it is, that the anterior grey horns in the lumbar and cervical bulbs are so much thicker than in the dorsal region, or the more highly situated portion of the cervical region.

4. In animals whose muscular movements are more simple, as in fishes, the spinal cord is slighter, and the grey matter, as well as the ganglionic cells, is much more scanty, as fewer combinations of movements are required.

5. Reflex movements take place, not by over-leaping or transverse conduction, but the reflex nerves appear to terminate, partly in a central group of ganglionic cells, which are more or less directly connected with the several groups of motor cells; and partly seem to pass into the minute longitudinal fibres of the posterior horns. Therefore, as the posterior nerve-roots contain at the same time sensitive and reflex nerves, it is easily explained why they are nearly twice as thick as the anterior roots.

6. The posterior horns of the grey matter, through which, probably, the several groups of ganglionic cells are mutually connected, appear to serve especially for the coördination of movements which take place in reflex action; the latter are more general in proportion to the more irritated condition of the grey matter of the ganglionic cells.

7. Through their connecting filaments the groups of motor cells appear to be so united, that as a stimulus applied to one of the toes is sufficient to excite in a frog, by reflex action, a harmonized movement, or a jump, so also, perhaps, only one impression is required to produce a coördinate movement (for example a step), which may then again be modified, according to circumstances, by special impressions on each of these groups of cells. The cause of the coördination of movements is situated in the spinal cord, and not in the cerebellum.

8. The transverse commissures appear to be designed to preserve the harmony of movements, between the two sides; the anterior, which seems to be connected more with the filaments conducting the orders of our will, for the harmony of the voluntary movements, and of the muscles acting simultaneously on each side of the body; the posterior for the involuntary harmony in reflex action, the equilibrium of the body, &c.

9. The two horns of grey matter appear to stand in the closest relation to motion: the anterior are the direct sources of motion, the posterior serve rather for reflex action and coördination. After the administration of strychnia, congestion, or effusion of blood takes place in both horns. The latter do not seem to be sensitive.

10. The medulla oblongata appears to be the common central point, where reflex action crosses to either side, and on the irritated state of which general spasms, as convulsions and epilepsy, seem to depend.

THE END.

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ON THE MINUTE STRUCTURE AND FUNCTIONS OF THE MEDULLA OBLONGATA, AND ON THE PROXIMATE CAUSE AND RATIONAL TREATMENT OF EPILEPSY.

BY

J. L. C. SCHROEDER VAN DER KOLK,

PROFESSOR IN THE UNIVERSITY OF UTRECHT.

Published by the Royal Academy of Sciences at Amsterdam.

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[WITH EMENDATIONS AND COPIOUS ADDITIONS FROM MANUSCRIPT NOTES OF THE AUTHOR.]

BY

WILLIAM DANIEL MOORE, A.B., M.B.,

OF TRINITY COLLEGE, DUBLIN, HONORARY MEMBER OF THE SWEDISH SOCIETY OF PHYSICIANS, AND OF THE NORWEGIAN MEDICAL-SOCIETY.

THE NEW SYDENHAM SOCIETY,

LONDON.

MDCCCLIX.

The grouping of the different Figures has been altered somewhat from that of the original work. In transference from the 4to. to the 8vo. form this was unavoidable. It is hoped that, with the help of the subjoined list, the reader will not experience any difficulty in finding the several displaced Figures.

ON THE

MINUTE STRUCTURE AND FUNCTIONS

OF THE

MEDULLA OBLONGATA,

ETC., ETC.

CHAPTER I.

INTRODUCTORY.

Of all the parts of the human body, there is not one which is of such great moment to existence and to the continuance of life, and to the maintenance of the most different and important functions of the system, uniting in a small space, and, as from a central point, directing so much that is various in aspect and really diverse, as the medulla oblongata; on which account it has long been called by Flourens and his followers the centre, or the middle point, and the knot of life. Indeed, in a limited portion of this organ, a simple puncture or injury suffices immediately and irrevocably to extinguish life, and, as with a stroke, to annihilate its principal phenomena, as respiration, voluntary motion, nay, all that constitutes existence.

Here is, in fact, the nucleus and the central point, whence most phenomena proceed; here the seat of perception, or of sensation, seems to lie; violent pain, by reflex action here, produces groaning; here reflex movements pass over to either side; here is the centre of automatic respiratory motions and of deglutition; hence the nervus vagus derives its remarkable influence upon the heart; and, finally, an irritated condition of this part produces excitation of the sexual organs; and even appears to have influence on the action of the kidneys.

It would seem that the very peculiar structure of the medulla oblongata has deterred the majority of physiologists and anatomists from venturing on such an inquiry as the present; they have almost always confined themselves to a rude inspection of various bundles of medullary filaments, and accumulations of grey matter, with the naked eye, or have endeavoured, by means of vivisections, to obtain a more accurate knowledge of the functions of its several parts. These vivisections have, however, often led to such opposite and sometimes perplexing results, that the nature of this important part has not unfrequently been rather rendered doubtful and obscured, than explained, by them.

It is, nevertheless, strange, that although Stilling, in his excellent treatise on the *Medulla Oblongata*,* and especially in his very diffuse, but at the same time, admirable work on the *Pons Varolii*,† has shed a completely new light upon this difficult part, and has broken the ground for all subsequent investigators—physiologists in general seem to have contented themselves with receiving some of his excellent delineations, without putting their own hands to the work. On the other hand, the peculiar prolixity and great size, and perhaps also the costliness of his book on the *Pons Varolii*, and its burdensome form, seem to have deterred most anatomists from reading it; for, of the many highly important facts contained therein, the majority appear to be quite unknown, and to be wholly neglected, not being even mentioned in the recent manuals. It is only very lately that the value of this work has begun to be appreciated. Although in my first investigations on the structure and tissue of the medulla oblongata, I, too, was deterred by the very complicated nature of its network of fibres, and despaired of being able to discover their course, yet, after an attentive perusal of Stilling's excellent works—of which the last, upon the *Pons Varolii*, in particular, is a remarkable monument of German industry and perseverance—I was encouraged to the task, and determined, under his guidance, to examine those parts for myself, to compare his delineations with the originals, and so to test them.

I soon discovered that the preparation of the sections represented by Stilling did not present so many difficulties as I had at first imagined, while as I went on I could not sufficiently admire the surprising skill and fidelity with which his delineations have been made.

* B. Stilling, *Ueber die Medulla Oblongata.* Erlangen, 1843.

† B. Stilling, *Ueber den Bau des Hirnknotens oder die Varolische Brücke.* Jena, 1846.

In this manner I have compared by far the greater number of Stilling's drawings with nature itself, and in most instances have had to admire their very great fidelity; although on closer examination, I have often felt compelled to differ considerably from him in describing and explaining the several parts. But as Stilling has confined himself chiefly to a purely anatomical exposition and description of the parts discovered by him, and of their mutual connexion, and has entered but little upon physiological disquisition, I found some remarkable peculiarities which appeared to have escaped his attention, and yet to be extremely important in a physiological point of view.

At first, these observations related only to a few, in my opinion, important connexions, and I did not intend to investigate the entire subject of the minute anatomy of the medulla oblongata; the more so as some pathological points constituted the proper aim of my research. However, the course of the investigation led me from one part to another; the solution of one question gave the key to another; what the structure of man did not reveal, I found demonstrated distinctly and clearly, and beyond my expectation, in animals, and thus under my hands the essay gradually became enlarged, and in it I think I have arrived at some, as I hope, not unimportant results, and have as far as possible solved most of the anatomical and physiological questions; upon which I have, in the third part, wholly rested my pathological views. That I have, throughout my examination of this complicated part, universally succeeded in discovering the exact truth, I can scarcely hope; others may hereafter follow up the subject, and confirm or reject my conclusions.

The delineations I have myself drawn from nature with the greatest care.

CHAPTER II.

GENERAL REMARKS ON THE MEDULLA OBLONGATA.

To enable the reader properly to comprehend my investigations, it is absolutely necessary to preface them with a brief explanation of the structure of the several parts of the medulla oblongata; and I shall therefore, in the first instance, make some general remarks on the difference between it and the spinal cord, partly taking Stilling as my guide, partly, where I have been obliged to differ from this excellent observer, following the results of my own examinations.

The first questions which occur to us in endeavouring to obtain a more accurate idea of the medulla oblongata, are:—What new parts, absent in the spinal cord itself, are to be found in the former? What parts end here? and what is their mutual connexion? Without entering on the present occasion, into a number of minute particulars, which are most fully discussed in Stilling's great work on the *Pons Varolii*, I shall in the first place, briefly consider and answer these questions, and subsequently pass to a more particular study of the principal parts of the organ in question.

We must first call to mind the known structure of the spinal cord, which is divided by an anterior and posterior fissure, as it were, into two lateral portions, connected to one another by more or less slender commissures, between which a very narrow canal runs through the whole cord, while the two halves of the latter consist internally of grey matter, extending into two anterior and posterior horns, and covered and enclosed by the white substance, consisting of longitudinal medullary filaments or columns.

Anteriorly, the roots of the motor nerves arise from the two anterior horns of grey matter; posteriorly, the posterior cornua consist in great part of very minute longitudinal fibres, which I have considered as threads of communication between the several reflex-nerves which appear to unite with them, and to convey the impressions they have received along these longitudinal filaments to the different groups of ganglionic cells, lying over one another in the anterior cornua, whereby the more complicated reflex movements may be explained.*

The white or medullary matter is distinguished anteriorly as consisting of the white columns, which, in my opinion, are the conductors of the orders of our will, and convey the same by means of numerous rays, spreading in a transverse direction between this medullary matter to the anterior ganglionic cells for the movement of the extremities; while the more lateral white columns appear, especially according to Schiff's experiments, to serve for the movement of the muscles of the trunk.† Finally, it would seem that the posterior columns are to be regarded rather as the bearers of impressions of sensation to the brain.

The canal, which runs through the whole spinal cord, occupies as nearly as possible, its centre; close to the medulla oblongata, however, it begins to incline backwards, until it finally opens into the fourth ventricle. The two anterior grey horns, whence the motor nerves take their origin, follow this backward direction of the canal; so that the groups of ganglionic cells, from which the hypoglossus arises, are situated quite posteriorly on the floor of the fourth ventricle.

The lateral and posterior columns, that is to say, of the spinal cord, divaricate at the opening of the central canal into the fourth ventricle, and thus come to lie at the side of the middle line; the relative order and position of the parts being thereby completely altered. The posterior columns, for example, deviate, according to Stilling, not only completely to the side, but they even turn forward into the higher parts of the medulla oblongata, and into the lowest part of the pons Varolii, so that they are said to be situated partly at the side of the anterior columns, and higher up even in front of these;‡ in reference to which, however, I differ in many respects from Stilling, as will hereafter appear. The so-called gelatinous matter, or posterior grey horns, likewise inclines more and more forwards.§

Thus, while the grey matter was at first situated like a wreath around the central canal, this arrangement is now completely altered; the posterior cornua spread themselves out to the side and towards

* Part I., p. 52.

† Schiff and Vierordt, *Arch. u. Phys. Heilkunde*, 1854, pp. 30 *et seq.*, and quoted in the present volume, pp. 27 *et seq.*

‡ Stilling, *Med. Oblong.* Pl. IV., Figs. 1 and 2 *f f*, Pl. V. and VI. *f f*, *Pons Varol.*, Pl. I. *g g*, *t*.

§ Stilling, *Med. Obl.*, Pl. IV., V., and VIII.

the front, and the several nuclei come to lie close to one another, and so form the floor of the fourth ventricle.* By this the nerve-roots too are displaced, the nuclei of the motor nerves now lie above one another close to the middle line; as for example, the nuclei of the hypoglossal and accessory nerves.† Above this spring the roots of the sixth pair,‡ the seventh pair,§ the fourth pair,|| and the third pair,¶ all close to the middle line. At the side, however, more externally, on the floor of the fourth ventricle of the brain, lie the nuclei whence the nerves of sensation take their origin, for example, that of the vagus;** higher up, those of the glosso-pharyngeus†† of the auditory nerve,‡‡ and of the sensitive root of the trigeminus.§§ We might even add, the optic nerve from the corpora quadrigemina, and the olfactory, both of which arise more to the side of the middle line.

There is thus a complete displacement or pushing away of the posterior columns; but at the same time new parts appear, which are most closely related to the nerves of sensation, and are not met with in the spinal cord. Thus, the nerves of sensation appear not to terminate in nuclei in the cord, but to proceed upwards, the seat of perception being by no means in the spinal cord. In the medulla oblongata, on the contrary, we see the roots of the vagus, of the glosso-pharyngeal, the auditory nerve, and the trigeminus, springing from their groups of nuclei, and taking their origin directly from a great number of ganglionic cells, which, according to my observations, differ, more or less, in size and form for the several sensitive nerves.

The explanation of this is, that the medulla oblongata appears probably to be the seat of perception, to which all the sensitive filaments of the spinal cord convey their impressions, and where the latter are perceived. Stilling even thought he had found, what I cannot admit, that the posterior columns of the spinal cord pass wholly

* Stilling, *Med. Obl.*, Pl. VI. *g*, *h*. Pl. VII., Figs. 1—6 *g*, *h*, *n*; my Fig. 1 B. *d*, *e*, *f*.

† Stilling, *Med. Obl.*, Pl. V. *g*, *h*; my Fig. 1 *d*, *e*, Fig. 2 A, *h*, *k'*, *a*, *k*.

‡ Stilling, *Pons Varol.*, Pl. XVIII, Fig. 1; my Fig. 4 *e*, *f*.

§ Stilling, *loc. cit.*, Plate XVIII., Fig. 2; my Fig. 4 *f f'*.

|| Stilling, *l. c.*, Pl. XVIII., Fig. 3.

¶ Stilling, *l. c.*, Pl. XI.

** Stilling, *Med. Obl.*, Pl. VI. *h*; my Fig. 1 *e f*.

†† Stilling, *Med. Obl.*, Pl. VII., Fig. 1—6 *n*, *n*.

‡‡ Stilling, *Pons. Varol.*, Pl. I., *n n*; my Fig. 4 *g g'*, *h*.

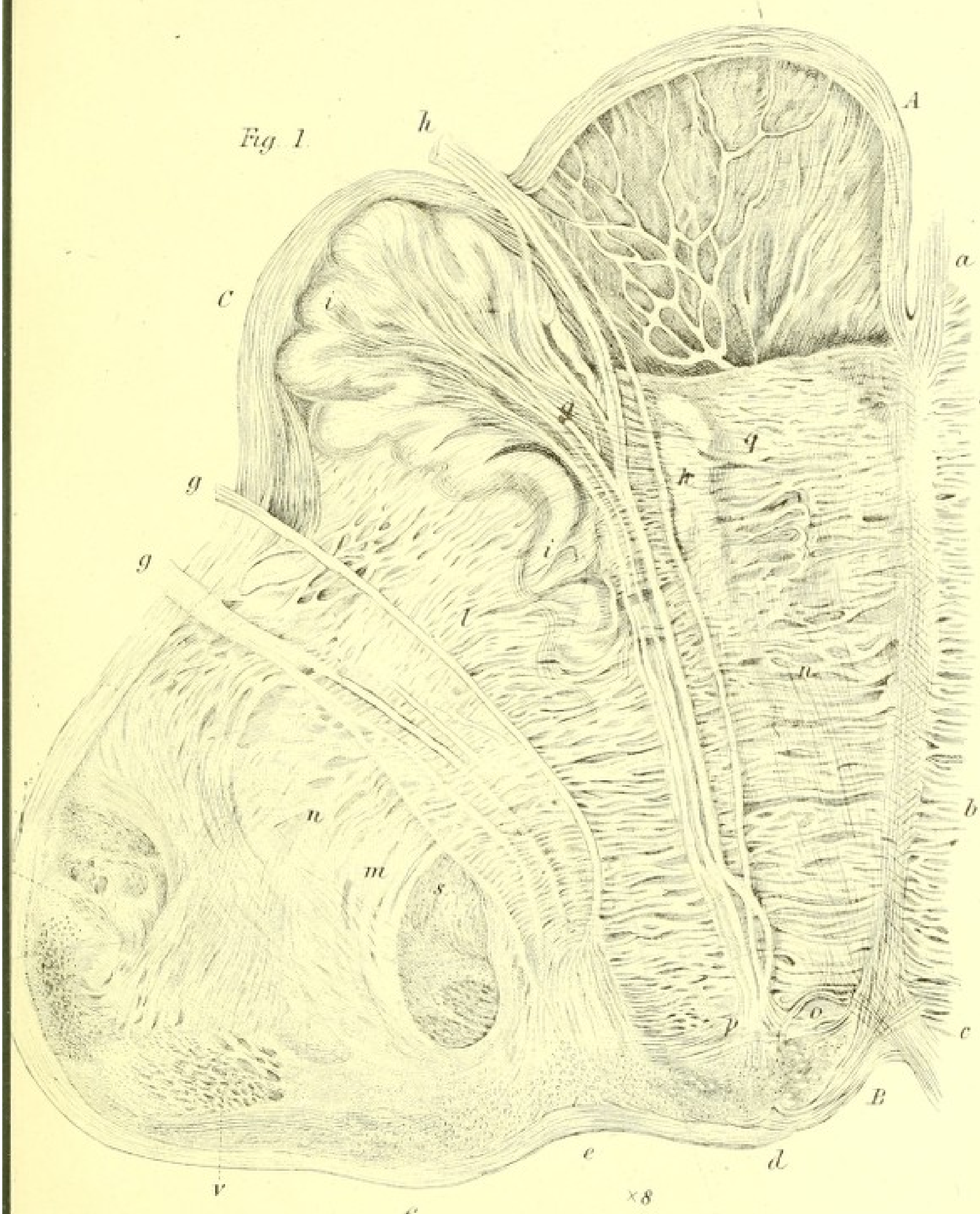
§§ Stilling, *l. c.*, Pl. XV. TT, *t*; my Fig. 4 *r*.

EXPLANATION OF PLATE I.

Fig. 1. Medulla Oblongata.

A, *B*, *C*, *D*. Left half of the medulla oblongata.
A, *B*. Raphe or septum, in which the fibres decussate.
A. Corpora pyramidalia.
C. Corpora olivaria.
D. Corpora restiformia, and root of the fifth nerve.
a, *b*, *c*. Transverse fibres (fibræ arciformes) as they are passing through the raphe or septum.
d. Ganglionic nucleus for the nervus hypoglossus, and the root of this nerve passing into the nucleus.
e. Root of the nervus vagus or accessorius in its nucleus, *e*, *f*.
f. Nucleus for the vagus.
g g. Nervus vagus.
h. Nervus hypoglossus.
i i. Corpus olivare.
k. Accessory nucleus of the corpus olivare.
l. Same on the outside.
m, *n n*. Transverse fibres (fibræ arciformes), which, in connexion with the centrum of the vagus, connect both sides for bilateral action.
o, *p*. Transverse fibres for the ganglionic nucleus of the hypoglossus and vagus, which pass to the septum, cross one another, and so accomplish the decussation of the nervous influence of the hypoglossus and accessory.
q q, *r*. Fibres passing from the corpora olivaria, towards the raphe, to the decussation.
i, *q*, *p*. Fibres from the corpus olivare to the nucleus of the hypoglossus.
s. Longitudinal fibres, into which filaments of the vagus pass. They constitute the superior portion of the lateral columns of the medulla spinalis, and terminate here.
t. Root of the nervus trigeminus.
v. Longitudinal fibres from the corpus restiforme.

[To face page 92.



J. S. van der Kolk del. Tuffen West sc.

W. West imp.

into the trigeminus;* it seems to me that they end about where the trigeminus begins, namely, at the seat of perception.†

If we now compare the spinal cord with the medulla oblongata, we shall see, that not only the direction and the mutual relation of the parts are very much altered, but that the medulla oblongata is considerably increased in thickness. While the anterior cornua of the grey matter were formerly placed behind the anterior white columns in the spinal cord, and were covered by a comparatively thin layer of white medullary matter, in the medulla oblongata these have passed entirely backwards on the floor of the fourth ventricle, and in place of the anterior columns a very considerable mass of interlaced fibres here exhibits itself, the roots of the facial, hypoglossal, and vagus nerves perforating the entire thickness of the medulla oblongata, in order to pass from their nuclei outwards to the nerve-trunk.‡ The fissures, by which the spinal cord was divided from before backwards, have almost wholly disappeared, and the two sides are most closely connected by the partition or raphe of Stilling.

* Stilling, *Pons Varol.*, pp. 45, 133, and especially 168, Pl. VI. *g g*, compared with Pl. V. *g g*, and Pl. XV.

† That the medulla oblongata is the seat of perception can scarcely be any longer a subject of doubt. Not only is it known that the brain itself is insensible, but while the nerves of sensation in the spinal cord pass upwards, the trigeminus descends to the medulla oblongata, that is to the seat of perception. In fishes, the sensitive nerves run in the same direction to the medulla oblongata, and in them there is no higher place to which to ascribe the seat of sensation. In like manner the formation of the brain begins in the fœtus with the parts situated at the base of the skull; the cerebrum is still wanting just as in the fish; but nature commences its formation with the parts which place us in relation to the external world, that is with the centres for smell, the corpora quadrigemina for sight, and the medulla oblongata for hearing, taste, and feeling. It is not until afterwards that the hemispheres are developed as organs, which are connected with the parts mentioned by special bundles of fibres, as has been so beautifully represented by Foville, *Anat. et Phys. du Syst. nerveux*, Pl. XVIII., Fig. 1 N N N″ and *q* C L B B B, and which further elaborate the observed impressions and act as organs of the higher faculties. In like manner nature begins with the corpora striata in the fœtus and in the fish, as the instruments by which the will acquires the power of producing motion. In the fish there is no other part to which we could ascribe this power, and in the ascending scale of animals, all these fundamental parts retain their proper functions; only others are added which are more closely connected with the higher faculties.

‡ Stilling, *Med. Obl.*, Pl. II. *l l*, compared with Pl. V. *g*, *l*; see also my first Fig., letters *d*, *h*,—*e*, *g g*.

This increased quantity of nervous substance, whereby the medulla oblongata is rendered so very much thicker, cannot, therefore, be due simply to a prolongation of the white nervous fibres or columns of the spinal cord; many new parts are, on the contrary, added, which did not exist in the cord. It is chiefly the connexion of these new parts with the medullary filaments and grey matter, extending upwards from the spinal cord, which makes the study of the medulla oblongata of such importance, and at the same time so complicated and difficult.

Stilling has carefully described and represented these various bundles of ascending longitudinal fibres in the medulla oblongata, and has endeavoured to follow the white columns of the cord through the medulla to their final terminations; in this, however, notwithstanding the fulness of his description and the fidelity of his drawings, he has, in my opinion, not wholly succeeded.

According to Stilling, not only does the grey matter pass backwards in the medulla oblongata, but the white anterior columns also follow the same course, and these are said to be again covered by other new parts.

In the first place, Stilling introduces the corpora pyramidalia, which he regards as entirely new bodies, stated to take their origin in this situation, from grey matter, and which are said to cover the anterior columns.* He even considers it doubtful, whether fibres of the anterior white columns of the spinal cord are connected with the pyramids.†

In this I can by no means agree with Stilling. It is true that on making a longitudinal section we see some thicker bundles, especially under the corpora olivaria, passing straight upwards, but these, pro-

* *Medulla Oblongata*, pp. 27 *et seq.* Pl. VII., Fig. 11.

† *l. c.*, p. 28. It is indeed true, that on a longitudinal section at the seat of decussation the fibres of the pyramids appear to arise obliquely, like the feather of a quill, as Stilling expresses himself; but this is only apparent; they run like fingers interlaced, and are bent laterally, in order to pass to the opposite side of the medulla oblongata, as is strikingly represented especially by Lenhosseck (*Untersuchungen ueber den feinen Bau des centralen Nervensystems*, Wien, 1855, Pl. I. Fig. 2, Pl. IV., Fig. 1). In consequence of this oblique course, they are cut through on a longitudinal section. Kölliker too considers the pyramids to be not an independent system, but a prolongation of the lateral columns of the spinal cord, *Mikrosk. Anat.*, 2 B. 1 H. p. 455. I doubt whether Stilling himself would further defend his hypothesis.

bably decussate higher up. The anterior columns, however, of the spinal cord undoubtedly pass, after the decussation into the corpora pyramidalia. This is acknowledged by all anatomists. But I willingly admit that the number of fibres in the pyramids increases in a marked degree, superiorly in the pons Varolii, which may partly give rise to the increased thickness and augmented bulk of these parts.*

The principal cause, however, of the increased thickness of the medulla oblongata is to be found in numerous parts, which either arise in it as perfectly new bodies, consisting both of white and grey matter, or come from elsewhere, and, consequently, were not present in the spinal cord.

To these belong, in the first place, the corpora restiformia and the posterior pyramidal bodies, the soft and wedge-like columns of Stilling, on the outer edge of the fourth ventricle, which, as Stilling correctly remarks, are not, as was thought, and is still maintained by many anatomists, the continuation of the posterior or sensitive columns of the spinal cord, but are derived from the cerebellum, and descend in the medulla oblongata from behind to the side, where they terminate by, at least for the greatest part, resolving themselves into transverse fibres, which in such great numbers pervade the medulla oblongata.†

According to Stilling, a portion of the former posterior white columns, namely, the anterior portion, passes upwards in company with the foregoing, in order to unite with the corpora restiformia, to which, therefore, these columns probably impart sensation.‡

* This is particularly clearly explained by Stilling in his great work on the *Pons Varolii*. These new fibres, from the corpora pyramidalia, appear always to stop at the outside of the ascending bundles of these bodies, which are much interlaced in the pons (*l. c.*, p. 99, No. 6, Pl. VII., VIII., IX., P. x, P. x). It is still uncertain what connexion exists between these descending fibres derived from the brain, and those of the corpora pyramidalia; but I suspect that they become connected with the grey matter and little multipolar ganglionic cells situated between these bundles, and in this manner perhaps unite in the corpora pyramidalia with the fibres derived from the anterior columns of the spinal cord.

† Stilling, *Pons Varolii*, pp. 151 *et seq.* This descent of the corpora restiformia is very beautifully delineated by Stilling, *Pons Varolii*, Pl. XII., Fig. 12—16, and in the outline Figs. Pl. XXI., Figs. 12—16.

‡ Stilling, *Pons Varolii*, pp. 26, 45 *et seq.* Tab. i. O, *t t.*

If Brown-Sequard had been acquainted with this course of the sensory filaments, described by Stilling so early as 1846, he would not have announced as a new discovery the singular fact put forward so prominently, that on cutting through the one half of the medulla oblongata

To this we should add, that, as will hereafter be seen, the root of the trigeminus runs downwards in the medulla oblongata, even to the level of the origin of the hypoglossal and accessosy nerves. During its course, this root, however, gradually becomes slighter by giving off numerous filaments, and it appears, according to Stilling, to unite with the descending corpora restiformia.

The increased thickness of the medulla oblongata is also occasioned to a great extent by the corpora olivaria, which, as is well known, are situated on the outer side of the corpora pyramidalia, and enclose the so-called corpora ciliara or dentata; they constitute a wholly new mass in the medulla oblongata, on which subject we shall hereafter speak at greater length.

Besides these parts, the grey matter of the medulla oblongata is likewise greatly increased by the nuclei and ganglionic groups, whence we have already seen the nerves of sensation arise; which appears not to be so much the case with the sensitive nerves of the spinal cord, and seems to be closely connected with the fact of the medulla oblongata being the seat of sensation.

Furthermore, a very important system of transverse fibres exhibits itself in this situation,* whereby the two sides of the medulla oblongata are intimately connected, and to a degree that cannot be seen in any other part, whether in the brain above, or in the spinal cord beneath. The two sides of the medulla oblongata appear to be reciprocally so intimately united by these transverse filaments, that we may suppose that influences acting on the one side must also be communicated to the other.

Finally, we have here an important system of fibres, which in my opinion have, at least in great part, been incorrectly explained by

the upper or central portion of the corpus restiforme was rendered devoid of feeling, and that therefore the sensory filaments could not in this situation proceed from above downwards. *Recherches expérimentales sur la transmission croisée des impressions sensitives*, Paris, 1855, pp. 6 *et seq*. The sensibility of the corpus restiforme would seem to be due to the portion of the posterior white sensitive columns, described by Stilling, which accompany the corpora restiformia to the cerebellum, and which were, therefore, cut through in Brown-Sequard's experiment. The merit of this writer on this point therefore consists, in his having confirmed by a physiological experiment, which is also important in other respects, the anatomical connexion of these parts already much earlier pointed out by Stilling. Furthermore, the fact is, in my opinion, in favour of the view that the seat of proper sensation is to be sought in the medulla oblongata.

* See Fig. 1, *m*, *n*, *n*.

Stilling, and which contribute very much to the augmentation of the medulla oblongata.

Stilling's opinion is, that the numerous longitudinal bundles in the medulla oblongata, which are separated from one another by an incalculable number of transverse and radiating fibres, are almost all prolongations of the anterior, lateral, and posterior white columns of the spinal cord. But if this were the case, it would follow that they must be considerably increased in number, as the size of the medulla oblongata, which is perforated by the roots of the nerves, is so much greater than that of the spinal cord itself.

Stilling, having once expressed the opinion that the pyramids were new bodies, originally arising in the medulla oblongata from nuclei, and therefore not considering them to be the continuation of the anterior white columns of the spinal cord, it was natural that he should seek the latter elsewhere, and he now placed them behind the pyramids. It appears to me, however, that much confusion has consequently been created in his determination of the course of the several columns of the spinal cord in the medulla oblongata, as their limits are difficult to define.*

Thus the pyramids are the prolongations of the anterior columns of the spinal cord, which seem to me to serve especially for the movement of the extremities; these decussate before they pass into the medulla oblongata.† In this discussation, however, the longitudinal

* See also Lenhossek, *Neue Untersuch.*, pp. 64 *et seq.*

† If we observe the further course and division of the pyramids through the pons Varolii into four principal columns, as is represented by Foville (*Traité complet de l'anat. physiol. du Système cerebro-spinal*, Pl. 5, Fig. 1, lett. 1, 2), which deeper columns of Foville appear to agree with the anterior columns of Stilling (Pons Varolii, Pl. I., II., III., IV. *d d*), we can scarcely suppress the suspicion, that these four columns of the pyramids may serve for the four extremities. It must be left to subsequent investigations to decide this point.

Meanwhile it has struck me very forcibly that the pyramids in the medulla oblongata in hoofed animals, as the horse, ass, and calf (see Fig. 4 *n*, in the calf), are much slighter than in beasts of prey, apes, and man (Figs. 11, 12, in the cat A, Fig. 1, in man A). Perhaps this is connected with the absence of the special movement of the hand and fingers in the hoofed animals, where the mechanism of motion is consequently much more simple. It is indeed natural, that for movements so complicated as those of the fingers on the extremities of a man, a much greater number of fibres should be required in the pyramids, and accordingly on a transverse section of the medulla oblongata the thickness of the pyramids in man is disproportionately much greater than in the calf or horse, notwithfibres, which are situated behind and to the sides of the pyramids, do not at all participate; they therefore constitute another system of fibres. They are, at least in great part, not prolongations of the white lateral and posterior columns, but commence as an entirely new system of fibres in the medulla oblongata.

There are, in fact, fibres which, derived from the brain, or rather from the corpora striata, thalami, and crura cerebri, descend and terminate in the several nuclei and ganglionic groups, whence the nerves of the medulla oblongata arise; as there are also those which pass into the corpora olivaria and other ganglionic groups, of which several occur in the medulla oblongata, in order to convey to them the orders of our will.

In my opinion, therefore, these longitudinal columns, divided into so many slender bundles, are, in part, descending fibres, terminating in the medulla oblongata, and so contributing much to its augmented bulk.

The nerves, in fact, as the hypoglossus, vagus, glosso-pharyngeus, &c., all arise above the decussation of the pyramids, and neither the nuclei, nor the fibres conveying to them the orders of our will, can participate in the decussation of the pyramids, above which they are situated; but they constitute a new system, the decussation of which is accomplished in another manner, as I shall hereafter point out.

The lateral and posterior columns of the spinal cord pass, indeed, into the medulla oblongata, but by far the greatest part would appear to me to end here; that is to say, if we may adopt Schiff's opinion, that the lateral columns of the cord serve rather for the movement of the trunk, and therefore especially for respiration.* And, as it is well known that the centre for the function of respiration has its seat in the medulla oblongata, and that if the brain be cut off above that point respiration still continues, it follows that a great number of the fibres constituting the lateral columns in the spinal cord would appear to terminate here.† From this centre of the function of respiration new fibres must, however, again commence, which ascend,

standing that the entire thickness of the medulla oblongata is much more considerable in the latter. A part of the corpora pyramidalia appears, however, in the calf, horse, and ass to separate into thin fibres in the substance of the corpus trapezoides and to be lost, as otherwise these bodies would here be disproportionately small.

* Vierordt, *Arch. für Physiol. Heilkunde*, 13 Jahrg. 1 Heft. 1854, pp. 30 *et seq.* See also my Essay on the Spinal Cord, pp. 26 *et seq.*

† Of this hereafter. Stilling assumes an uninterrupted continuity of

in order to serve as conductors of volition whereby we can also voluntarily control respiration.

As, further, the medulla oblongata appears to be the seat of sensation,* and at least the brain itself to be insensible, only parts situated somewhat higher than the former (as the corpora quadrigemina) seeming to participate, to a certain extent, in this sensibility; it would follow, that the posterior columns of the spinal cord, so far as these can be regarded as conductors of sensation, likewise find their termination in the medulla oblongata, and partly, perhaps, somewhat higher among the groups of ganglionic cells, which are there so numerous.

Yet, on the other hand, new fibres appear to ascend from the medulla, so as to place the brain in closer connexion with the centre of perception, the course of which is particularly given by Foville, and which betake themselves to the so-called cribriform space (his *espace quadrilatère perforé*),† in order hence to radiate out through the antero-posterior arch of fibres, under its internal convolutions, into the grey matter of the hemispheres.‡

We may thus correctly regard the medulla oblongata as the nodus vitæ, or as a central point, where many different bundles of fibres end, or take their origin in various ganglionic groups, which hence diffuse their influence over so many different parts of the body.

Above all, however, the number of transverse fibres in the medulla oblongata, which I have already referred to, is of great significance and importance; as in no other situation do they occur to the same extent, and they appear to have a tendency, at least for the greater part, to bring the two sides of the medulla oblongata into

all the columns into the brain. *Neue Untersuchungen ueber den Bau des Rückenmarks*, 1857, 3 Liefer. p. 630.

* Szokalski removed in young dogs, rabbits, &c., the anterior hemispheres, the corpora striata and thalami, the corpora quadrigemina and the cerebellum, and notwithstanding this mutilation the animals cried when he pinched their tails; they rubbed their noses on every mechanical or chemical irritation of the mucous membrane of the organ; they ground their teeth when anything bitter or acid was put into their mouth; so that he regarded these rather as instinctive than reflex movements, in which I cannot altogether agree with him. See *Prager Vierteljahrschrift*, 1854, 1 B, p. 79.

† Foville, *Traité complet de l'Anatomie et de la Physiologie du Système Nerveux Cerebro-spinal*, Pl. 18, Fig. 1 Y Y″ G, L.

‡ *l. c.*, Pl. XVIII., Fig. 1, L, B, B, B, B, *b*, *b*, *b*, *b*, also Pl. XIV., Fig. 1, D, B, B, B, B, *b*, *b*, *b*, *b*.

more intimate union with one another,—a circumstance which is most closely connected with the functions of that organ.

As the spinal cord is divided by an anterior and a posterior groove or channel, as it were, into two corresponding lateral potions, connected only by its comparatively slender commissures, we see that the muscular actions of each half of the cord take place independently, that is, unilaterally; the movements of the muscles of the extremities and the trunk, on the one side, being capable of being performed separately. From the medulla oblongata, however, many compound muscular movements are produced, which are bilateral, that is, which are performed simultaneously on both sides with the same force; as, for example, those of the tongue and pharynx in deglutition, as also the movements accompanying speech, the voice, respiration, coughing, &c.

In order that such important movements may always be performed uniformly on both sides, a system of transverse arched fibres appears to be placed in the medulla oblongata, reciprocally connecting most of the parts met with in that organ. These fibres are wanting in the spinal cord. They pass from opposite sides to the septum or raphe of Stilling, where they distinctly decussate at more or less right angles.*

A few of these transverse fibres arise from the nuclei of the facial nerve;† a much greater number come from the trigeminus,‡ from the nuclei of the accessory, the vagus,§ the glosso-pharyngeal, and auditory nerves,|| some connect the two corpora olivaria with one another.¶ A considerable portion, however, of these arched transverse fibres take their origin from the corpora restiformia and the so-called soft columns, which, as Stilling has very correctly pointed out,** and resolved†† partly into these arched fibres, partly into the external circular marginal fibres of the medulla oblongata, the so-called fibræ arciformes of Arnold, or the stratum zonale.

Through this system of fibres, the corpora restiformia and the soft columns appear to effect a union of the two sides of the medulla oblongata.

But as these corpora restiformia and the soft columns are derived

* Fig. 1, *a*, *b*, *c*.
† Fig. 4, *f*, *c*, at the front.
‡ Fig. 1, *t*, *n*, *l*, *n*, *k*, *r*, *b*.
§ Fig. 1, *f*, *m*, *s*, *n*, *b*.
|| Fig. 4, *h*, *d*.
¶ Fig. 1, *i*, *q q*, *r*.
** Stilling, *Med. Oblong.*, pp. 35 *et seq.*
†† Fig. 1, *v*, *n*, *l*, *q*, *n*, and D, C, A.

from the cerebellum, and as another part of the cerebellum, namely, the pons Varolii, likewise establishes a union of the two sides, we can scarcely suppress the suspicion that a principal object of the cerebellum, whose functions still appear enveloped in so much mystery, is to accomplish an intimate union of the two sides of the nervous system in the medulla oblongata and the pons Varolii.*

Above the medulla oblongata in the brain, most functions appear again to become unilateral; we know that at least so far as motion is concerned, an effusion of blood in the corpora striata produces hemiplegia or unilateral paralysis: so that in this respect the brain agrees with the spinal cord, and the medulla oblongata alone is distinguished from the other parts of the cerebro-spinal system, by its peculiar system of transverse fibres, rendering it, in many functions, a bilaterally working organ.

Besides these arched fibres, uniting the right and left sides, there are also other transverse commissures, especially between the nuclei of the nerves, the action of which is mostly bilateral; thus, for example, between the facial nuclei, and also the nerve-trunks themselves. Fig. 3, *f′*, *d*, *b*. Fig. 4, *f*, *b*, between the two accessory nuclei, Fig. 2, A, *a′*, *k′*, *d*, *a*, *k*, and those of the hypoglossus, Fig, 2, A, before C. Fig. 1, *d*, B. Fig. 12, *d*, B; to which subject I shall hereafter return more particularly.

* We might even add the so-called crura cerebelli ad corpora quadrigemina, which, according to Stilling, have been incorrectly thus denominated (*Pons Varolii*, p. 70), as their fibres pass aside to the pons Varolii, where they likewise decussate in front of the crura cerebri, and pass into the so-called Haube, or *integumenta pendunculorum cerebri* of Stilling (*Pons Varolii*, Pl. XIX., Fig. 10 D).

It appears to me that the well-known experiments of Flourens and Hertwich are quite consistent with the opinion which makes the cerebellum an organ of union (which, however, I put forward merely as a conjecture), as irritation of the cerebellum by means of these arched filaments of union, which everywhere appear to be connected through interspersed ganglionic cells with the longitudinal fibres, must necessarily have a disturbing influence on the activity and conduction of the orders of our will. Indeed, in my opinion, we can hardly look upon the cerebellum as an organ for the coördination of movements, as, if the brain and cerebellum are removed in an animal, all movements harmonized by reflexion, as leaping, &c., still take place.

CHAPTER III.

ON THE DECUSSATION OF THE NERVES OF THE MEDULLA OBLONGATA.

When we reflect, that the anterior, and perhaps partly the lateral columns of the spinal cord, so far as they are to be regarded as conductors of the orders of our will to the several motor nerves, arising from the anterior cornua of the cord, undergo a decussation in the corpora pyramidalia, the question presents itself:—How are the nerves circumstanced, which take their origin above this decussation, and consequently do not participate therein?

This important, and, indeed, very difficult question, has been in general too much neglected by physiologists. From pathological observations, however, it appeared to be clear, that a decussation must also take place in the nerves alluded to, at least in part, for all observations do not agree even on this point. Such a decussation of these nerves is, *à priori*, probable; for without it we can scarcely imagine how, when the will acts on the right side of the body, it can at the same time set in motion, not the left, but the right side of the face or tongue, and yet after apoplexy in one hemisphere of the brain we almost always see paralysis of the opposite side, as well in the face and tongue as in the extremities.

But the manner in which, and the situation where, this decussation takes place, is a question by no means easily solved; as the very complicated nature of the network of thousands of fibres interlaced in different directions makes it very hard always to follow the true course of the latter; while the minuteness of these fibres and nerve-filaments often renders it extremely difficult to trace them with certainty.

Kölliker is the principal advocate of the theory, that the nervous trunks of the medulla oblongata all decussate,* and he believes that

* *Mikroskop. Anat.*, 2 B., H, p. 467.

*

EXPLANATION OF PLATE II.

Fig. 2, *A*. Decussation of the Hypoglossal and Accessory Nerves.

C. Central canal of the medulla, exactly under the extremity of the fourth ventricle.
c. Epithelial cells in the central canal.
R. Raphe or septum, in which the decussation takes place.
H H'. Nervi hypoglossi, terminating in their nuclei or ganglionic groups, and ramifying therein.
1, 2, 3. Right side: the expansion of the nerve-fibres of the hypoglossus in the nucleus.
A A'. Accessory nerve, passing into its nuclei *a'*, *k'* and *a*, *k*.
a a a a, at the left, and *a' a' a' a*, at the right. Fibres which arise from the nucleus of the accessory, *a k*, on the outside and inside, and pass into the raphe, *R*, in order again to radiate at *a* and *a'*.
h' h' h', at the right. Fibres from the hypoglossal nucleus, *h*, *k'*, on the outside, passing towards the raphe.
h'' h''. Fibres passing from the inside of the nucleus, towards the raphe, to the decussation.
h'' h'''. Fasciculus from the inside, which extends in front of the central canal towards the other side, through the hypoglossus, *H*, and is here lost in longitudinal fibres on the outside of the latter.
l. Longitudinal tract, passing into the lateral columns of the medulla spinalis. —*a a*, *l*, fibres, which, in place of radiating inwards in the nucleus of the accessory, radiate towards the longitudinal tract, *l*. Close to *l* a multipolar ganglion is seen.
m, *d*. Transverse fibres, whereby these columns communicate with one another. In front of the central canal before *c*, transverse fibres are likewise seen, by which the hypoglossal nuclei are in part mutually connected.

Fig. 2, B. Longitudinal Section of the Medulla Oblongata of a Cow, nearly parallel with the Raphe, but more to the side close to the path of the Hypoglossus.

a a. Longitudinal bundles of fibres which, derived from the brain, pass downwards (conductors of the orders of our will, or of impressions of sensation).
a, *b*, *c*. Oblique fibres, crossing one another in every situation, and in the most varied manner, and surrounding the transverse fibres, which here appear obscure.
d, *e*, *f*, *g*. Multipolar ganglionic cells, mostly situated in or on the border of the transverse fibres, and giving off transverse fibres, *e*, *f*, *g*. They are connected with the longitudinal fibres, *d*, *e*, which bend into them, and appear to lead to the nuclei of the nerves.
d, *e'*. Other longitudinal fibres, which bend across without passing into a ganglion.
h h. Transverse bundles of fibres (fibræ arciformes), cut across in this longitudinal section, and now obscurely seen. It would appear that they are connected with ganglionic cells.

Fig. 3. Section of the Medulla Oblongata, on a level with the Facial Nerve in a Cat.

a, *b*. Raphe.
e, *i*. Abducent nerve, which, at *i*, *d*, bends outwards and does not decussate.
f f', *d*, *b*. Facial nerve. At *f'*, *d*, its fibres surround one of the posterior cut roots of the auditory nerve in the fourth ventricles, and pass, in *b*, partly obliquely into the raphe, to radiate on the other side (see *d*, *b*, *k*); partly in transverse fibres to the other side (see *b*).
g, *h*. Nervus auditorius, which at *h* passes into its nucleus, whence numerous transverse fibres arise, which, as fibræ arciformes, in the course *f'*, *i*, *k*, *c*, repair to the other side, and here pass through the raphe, to connect the two nuclei of the auditory.
l l. Transversely cut root of the trigeminus, which is situated between the facial and auditory nerves.
m m. Corpus olivare superius.

Fig. 5. Small portion of the Corpus Ciliare, from the Corpora Olivaria, magnified 450 times.

a a. Unipolar ganglionic cells, whence a fibre proceeds. Probably the other filaments are cut off, and are, therefore, not seen.
b. Bipolar ganglionic cell, whence the one filament passes into another ganglionic cell, *c*, and connects the two.
d d. Two ganglionic cells, giving off two filaments on the one side.

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Fig. 2 A.

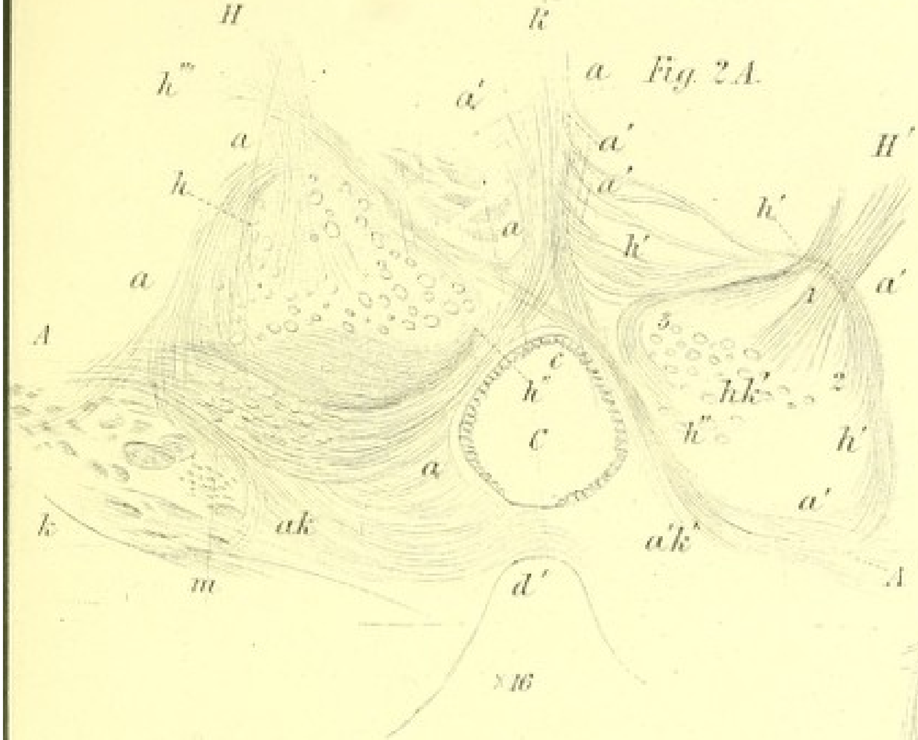


Fig. 2 B.

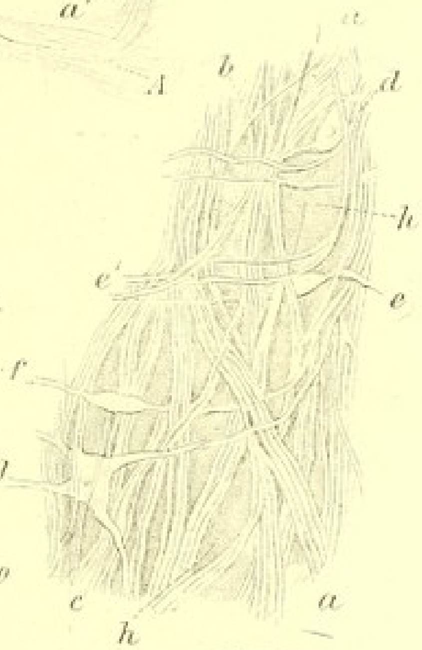


Fig. 5.

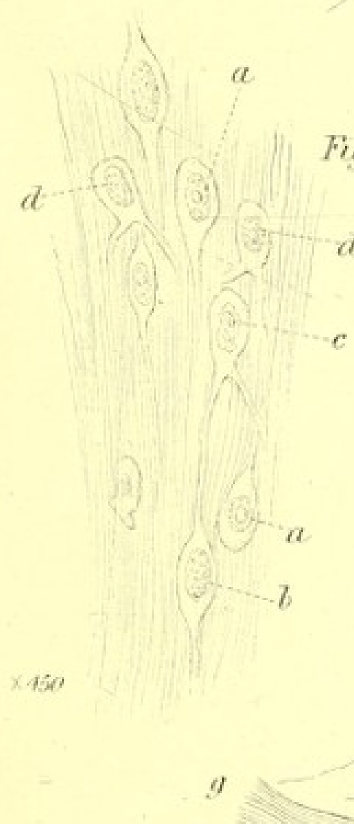
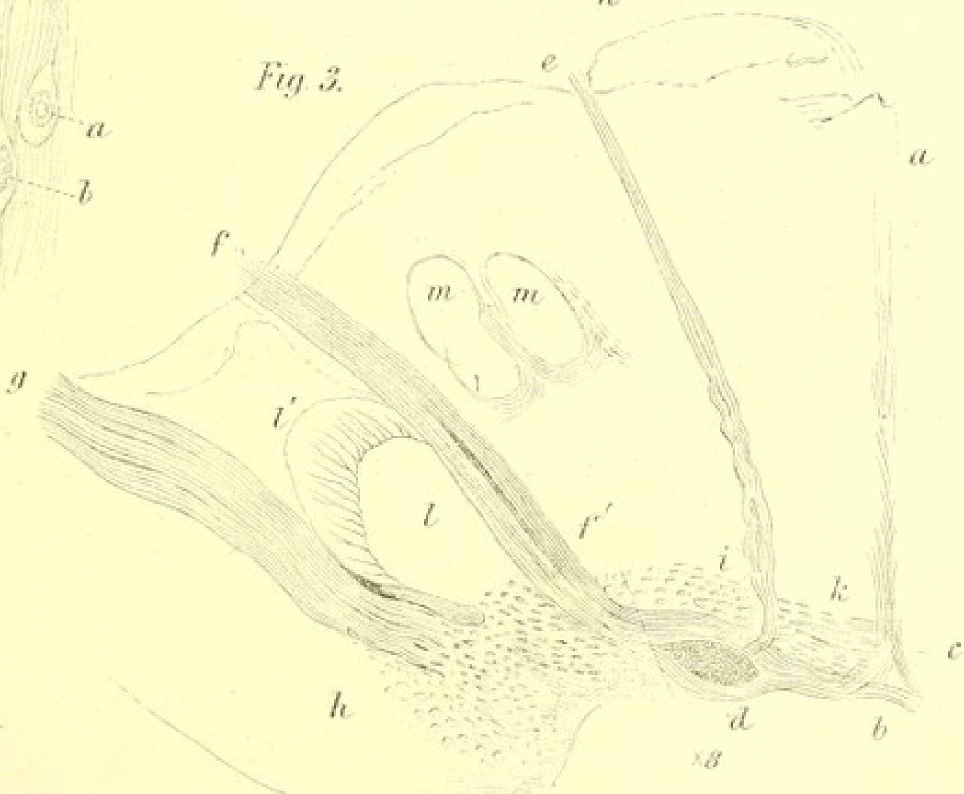


Fig. 3.



J. S. van der Kolk del. Tuffen West sc.

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he has actually observed this decussation in the hypoglossal* and accessory† nerves.

According to the position he had assumed (which may now be regarded as completely abandoned), the nerves do not terminate in the anterior grey cornua of the spinal cord, but pass upwards through the pyramids directly to the brain.‡ Kölliker thought the same view ought also to apply in this instance, and he consequently supposes, notwithstanding the contradictory observations of Stilling, that the commencement of these nerves is not to be sought in the medulla oblongata; but that they derive their origin from the head in the corpora striata or optic thalami.§

On account of the importance of the matter, I have instituted many investigations of this subject, not only in man, but also in the ape, ass, horse, cow, dog, cat, and several other animals, which have led me, after careful examination with very different magnifying powers, to a definite result.

First, as to the hypoglossus, it was evident that this nerve does not itself decussate, but that it is wholly lost in the hypoglossal nucleus and spreads out into numerous fibres, which pass over into the multipolar ganglia.

In order to make this really very complicated course of the several fibres clear, I have prepared, with as much accuracy as possible, a representation of the hypoglossal and accessory nerves in the calf, (see Fig. 2, A); which differs from nature only in this, that very many of these different nerve-fibres do not become visible until they are magnified from two hundred and fifty to three hundred times, when I have accurately traced them, and have subsequently reduced the drawing to about ten times the natural size, though at the latter, many of these fibres are not at all distinguishable. The section is taken immediately under the fourth ventricle, where the lateral walls begin to close to form a canal.

This canal is seen in Fig. 2 C, everywhere invested with a conical epithelium. R, is the raphe of Stilling; on each side the hypoglossal nerve H′ and H is seen passing with its fibres into the hypoglossal nucleus *h*, *k*, possessing a quantity of multipolar ganglionic cells, which are merely indicated in the drawing. These fibres of the hypoglossus after entering the nucleus, spread out in a fan-shape, both outwardly

* *l. c.* p. 458 and p. 453, Fig. 136 *f.* Lenhossek states the same, *l. c.* p. 3 *a*.

† *l. c.* p. 458.

‡ *l. c.* p. 440, Fig. 131.

§ *l. c.* pp. 466 *et seq.*

from the nucleus 1, 2, and towards the middle and inside 1, 3, where some fibres even lead to a tolerably great distance backwards.

In addition to these fibres spreading from the hypoglossus through the whole nucleus, in order to unite with the ganglionic cells, others leave the nucleus, to pass along its outside to the raphe *h'*, *h'*, *h'*, and to the other side of the nucleus *h*.

The latter fibres arise in fact, first, on the outside of the nucleus *h'*, *h'*, *h'*, and *h*, and partly on the inside *h''*, *h''*, so that the nucleus is surrounded on all sides, and, as it were, enclosed. Both bundles proceed to the raphe, in which they run at first more or less forward, to leave it again at the outer edge of the opposite side, where we can follow them for a little between the network of longitudinal bundles and transverse fibres, until they are lost at different distances, and we can trace them no further; as, perhaps from taking a curved direction, they here appear to be truncated. Some fasciculi follow a somewhat different course; a few, that is to say, as is represented at one side of the object, and which in this preparation occurred only on the one side, arise internally at *h''*, strike over in front of the canal to the opposite side, run nearly parallel with the anterior marginal fibres of the opposite nucleus; but in the neighbourhood of the hypoglossal nerve pass more forward, and run obliquely through the hypoglossus, to be lost in the ascending longitudinal bundles at the side of the hypoglossus, *h''*, *h''*.

This last fasciculus, which I have met with in many preparations, presents at first sight the appearance of having been derived directly from the hypoglossus, so that I at first thought that Kölliker was partly correct in thinking he had seen that the hypoglossal nerve itself decussated.

Repeated and accurate examination with higher magnifying powers completely convinced me, that this fasciculus is not derived from the hypoglossus itself, but that it penetrates through the fibres of the nerve, to be lost in the longitudinal bundles, or perhaps to be reflected among them. From the hypoglossus itself no filaments pass to the other side, but all are lost in the nucleus of its own side, H' 1, 2, 3.

This is completely confirmed by the remarkable experiment performed by Stilling, who says that he has undoubtedly seen, that if the skull of an animal be opened, the cerebellum removed, and a couching-needle passed superficially or deeply into the hypoglossal nucleus, movements arise in the tongue, and more particularly on the left or right side of the tongue, accordingly as the left or right hypoglossal nucleus is irritated.*

But if the hypoglossus itself decussated, passing to the nucleus of the opposite side, the reverse should have taken place, and when the left nucleus was irritated, the right side of the tongue should have been set in motion. I admit, however, that extreme accuracy and great attention are required, to follow these filaments with certainty, among other fibres running a nearly parallel course, and to arrive at the true state of the case, the more so, as between these fibres others run which are not under the control of the hypoglossus, but are derived from the accessory nucleus. Besides these, fibres run also from the postero-internal side of the nuclei of the hypoglossus, and pass transversely from the one nucleus to the other, thus forming transverse commissures (Fig. 2 C, in front of the central canal). I have found this distinctly and unmistakably in other sections taken higher up from the ass, where the hypoglossal nuclei lie on the floor of the fourth ventricle, and are united to one another by transverse nerve fibres, which, as I saw satisfactorily with strong magnifying powers, consist of true nerve filaments, and not of connective tissue, as Bidder thinks.†

I have, on account of the close connexion, represented this in the same drawing.

Thus, we see the accessory nerve, Fig. 2 A′ A, entering its nucleus, which is stretched out, and consequently appears slighter and longer, but is very rich in ganglionic cells, *a′*, *k′*, *a*, *k*.

From this nucleus likewise arise at each side fibres, decussating in the raphe, both from the inside, *a*, *k*, *a′*, *k′*, and from the outside, *a*, *a′*, which last pass forward and surround the entire hypoglossal nucleus, *a′ a′ a′*, *a a a*. Arrived at the front of this nucleus, several fasciculi leave these anterior marginal fibres, to pass more forward, and to betake themselves to the raphe, and to disperse through it, *a′ a′ a′*, *a a a*, passing in their course to it, with several windings, between longitudinal fasciculi situated here, by which they are separated from one another. Other fibres, derived from the accessory nucleus, continue to follow the course of the marginal fibres of the hypoglossal nucleus, and constitute the outside of these fibres.

* Stilling, *Med. Obl.*, p. 57.

† Bidder (*Untersuchungen ueber den Textur des Rückenmarks*, Leips. 1857, p. 97) thinks that the posterior commissure consists wholly of connective tissue, which I cannot admit.

On the front of the hypoglossal nucleus, therefore, marginal fibres exist, derived from the outside of that nucleus, *a′ h′*, *h a*; furthermore, fibres derived from the other nucleus, but running more or less parallel to these on the opposite side, to traverse the hypoglossus and to be lost in the longitudinal bundles, *h″ h‴*, and, lastly, fibres from the outside of the accessory nucleus, which pass as external marginal fibres around those just described as belonging to the hypoglossal nucleus, and with these repair to the raphe, *a′ a′ a′*, *a a a*. Lastly, there are on the inside some fibres from the hypoglossus itself, which are lost in the nucleus, H′ 3.

In a sufficiently clear preparation, however, we can, with the requisite magnifying power, satisfy ourselves as to the course of these several fibres; the fibres of the hypoglossus lie, in fact, rather more internally in the nucleus itself.

In addition to these fibres, I found on the inside of the hypoglossal nucleus, where the latter appears somewhat darker and seems to possess no ganglionic cells, as is indicated on one side in the figure, that some fibres radiate through this part of the nucleus, some of which bend forwards and outwards, to be lost in the hypoglossal nucleus, *h″*. Others make a curve in the opposite direction, and pass into the nucleus of the accessory nerve at *a*, *k*.

In sections taken higher up, the nucleus for the accessory and vagus nerves lies more on the outside of the hypoglossal nucleus, and in this situation the fibres proceed from the nucleus of the vagus in a rather straight direction in front of the hypoglossal nucleus to the adjoining nucleus of the vagus. The posterior marginal fibres run, then, quite behind the hypoglossal nucleus towards the posterior edge of the vagus nucleus, so that the hypoglossal nucleus is also bounded anteriorly and posteriorly by marginal fibres, Fig. 1, *o*, *p*, *o*, *d*, *e*.

In lower sections, the accessory nucleus goes, on the contrary, still further inwards behind the hypoglossal nucleus, the central canal becomes smaller, and passes more forwards, the hypoglossal nucleus is directed likewise at an acute angle more forwards and outwards, and now the marginal fibres of the accessory nucleus make along the entrance of the hypoglossus such an acute angle, that I was long under the incorrect impression that some marginal fibres derived from the accessory nucleus passed into the hypoglossus itself. Repeated and accurate examination, however, of the calf, the ass, the dog, the cat, and the paradoxurus musonga, have convinced me that this is not the case; but that they all bend forward at an acute angle in front of the hypoglossal nucleus, to betake themselves to the raphe, and afterwards to radiate again on the other side.

While, however, the central canal passes more forwards, the fasciculi derived from the inner and posterior side of the accessory nucleus begin to pass behind the central canal to the other side, where they run internally to the opposite hypoglossal nucleus, to be lost anteriorly among the longitudinal bundles of the medulla oblongata. Here, therefore, both before and behind the central canal, a decussation takes place, which latter, however, is always smaller and more difficult to observe, and wherein transverse fibres also appear to be present, passing from one accessory or vagus nucleus to the other. See Fig. 2 *d*.

On the outside, too, of the accessory nucleus, a somewhat different course is occasionally observed in these lower sections. Thus, some fibres from the accessory nucleus do not here join the marginal fibres of the hypoglossal nucleus, but first pass outwards and forwards, and in their course make a much greater curve forwards between the longitudinal fibres, wander over the hypoglossus, and repair to the raphe, in order to pass on the opposite side into the longitudinal fasciculi. These fibres quite agree with the semicircular fibres, delineated and described by Stilling in the medulla oblongata.*

In following the course of these decussating fibres, which arise from the nuclei of the hypoglossal and accessory nerves, and are lost in the ascending or cerebral longitudinal bundles of the opposite side, I have no doubt that they are the conductors of the orders of our will from the brain; that is, they run forwards between the longitudinal fasciculi (which, as we have already seen,† derived from the brain, end here), to curve into these fibres, and so to accomplish the decussation. In the medulla oblongata, therefore the same thing takes place as in the spinal cord; here, too, the nerves end in the anterior grey cornua of their own side, whence marginal fibres and radii pass outwards, and bend upwards into the longitudinal fasciculi,‡ decussating in the pyramids. These longitudinal bundles are likewise the conductors of the orders of our will, which they have received from the brain and probably from the corpora striata. The only difference, therefore, consists in this, that in the medulla ob-

* Stilling, *Med. Obl.*, p. 20. See also my Fig. 1, *e*, *s*, fibres passing to the raphe between *b*, *c*

† See above, p. 98.

‡ See my *Treatise on the Spinal Cord*, p. 43, Fig. 6.

longata the fibres from the nuclei decussate immediately, while in the spinal cord they first run upwards, each on its own side, to accomplish the decussation in the corpora pyramidalia. To demonstrate this as plainly as possible, I have—following up longitudinal sections I formerly made of the spinal cord in reference to the reflexion of the longitudinal fibres*—endeavoured to prepare similar sections of the medulla oblongata, for which purpose, on account of the greater thickness of the individual filaments and the much larger size of the interspersed ganglionic cells, the medulla oblongata of a cow appeared to be the most suitable. A small portion of this is seen in Fig. 2 B, in a longitudinal section nearly parallel with the raphe, and on a level with, but anterior to, the hypoglossal nucleus. We here see the longitudinal bundles, *a a, b, c,* which, on a transverse section, appear as dark intervening spaces, passing in different directions from above downwards, and interlaced in the most varied manner.

The dark spaces, *h h,* situated between these fasciculi, are the fibræ arciformes cut across, passing to decussate in the raphe.

Besides these bundles, we see numerous multipolar ganglionic cells, *d, e, f, g,* almost all of which appear to be connected with longitudinal fibres curving to assume a transverse direction; while from their other side numerous transverse fibres radiate, but for the most part cannot be followed to any distance. A few longitudinal fibres also assume a transverse direction without intervening ganglia, *d, e′, d, b.*

Hence it is sufficiently evident that many, and, probably, in my opinion, by far the greater number, if not all, the longitudinal fibres, derived from the brain bend in the medulla oblongata into transverse fibres. Many of these transverse fibres were directed forwards, others backwards, to pass over into the accessory ganglia lying in front, or posteriorly to the raphe, to decussate in the manner above described.

In reference to this subject, I was struck with the fact, that the interspersed ganglionic cells were almost always situated close to, or between the fibræ arciformes, which were here cut across. It seems to me to be not unlikely that these ganglionic cells might also connect the ascending or cerebral longitudinal fasciculi with fibræ arciformes for lateral action or decussation; yet I put this forward only as a conjecture to be verified by subsequent special investigations.

* *Treatise on the Spinal Cord*, Pl. II., Fig. 6.

That a decussation takes place between the hypoglossus and the brain has long been known, from numerous pathological observations of hemiplegia after apoplexy. The remarkable point, however, in this form of paralysis, which has given rise to many theories, consists in this, that the tip of the tongue is inclined to the paralyzed side of the body, as we should expect if the paralysis existed on the opposite side, making it appear, in hemiplegia of the right side of the body, that the action of the right side of the tongue drew the tip to the right from the opposite paralyzed side. This is, however, by no means the case: thus, if the left hypoglossal nerve be cut through, the tongue is inclined to the left side.* Lallemand, who, in his excellent *Recherches sur l'Encephale*, quotes many examples of paralysis of one half of the tongue, and obliquity of its point towards the paralyzed side, endeavours to explain the fact, by observing, that as the genioglossus of the healthy side protrudes the tongue, the latter must be inclined to the paralyzed side, on account of paralysis of the other genioglossus.† However, the tongue is often oblique, when it lies at rest in the mouth, without being protruded.

Bidder attempts to account for this obliquity of the tongue by showing, that as one side of the os hyoides is drawn upwards, the bone must stand obliquely, and so communicate an oblique direction to the tongue.‡

It is, in fact, not easy to explain this obliquity; as we should expect, that especially the styloglossus, which runs along the outer edge of the tongue, and also the lingualis, should in hemiplegia necessarily draw the tip of the organ to the sound side.

But it appears, that the genioglossus, which passes from the superior genoid process of the under jaw obliquely upwards and outwards to the tongue, in consequence of its oblique direction, draws the organ in hemiplegia to the other side; in addition to which, the transverse muscular fibres, which in hemiplegia can hardly be semi-paralyzed, are able to contribute their part towards drawing the paralyzed weaker side of the organ more into the middle, and so to coöperate in inclining the tongue. As the obliquity of the os hyoides is not always present, it appears to me that we cannot refer the

* Panizza, *Versuche ueber die Verrichtungen der Nerven*, Erlangen, 1840, p. 101. Bidder, *Versuche*, in Müller, *Archiv*, 1842, p. 110.

† Lallemand, *Recherches*, Lettre 1, obs. 7, p. 23.

‡ Müller, *Archiv*, *l. c.*, p. 111.

inclination of the tip of it, but the paralysis of the one hyoglossus would occasion the other to draw the middle and posterior part of the tongue to the sound side, and so indirectly in connexion with the action of the genioglossus, to inflect the point of the organ towards the paralyzed side. But it is not always the case in hemiplegia that the tongue is inclined to the paralyzed side, and thus the explanation is rendered still more difficult.*

Such a condition, I myself witnessed last autumn in the Meerenberg Institution for the Insane, in an idiot with incomplete hemiplegia and atrophy, in whom I immediately recognized an analogous case to one I formerly described and delineated in the works of the Royal Netherlands Institute.†

The right forearm was in this instance about three inches shorter than the left, and was very much atrophied, while on the contrary, the head was greatly awry with atrophy of its opposite side, that is, of the left half, just as in the case formerly described by me, of which, at the time, I endeavoured to give a satisfactory explanation.

On requesting the patient to put out his tongue, I saw to my surprise, that the tip was directed towards the left side, that is, towards the sound half of the body, even when the organ was not protruded. The power of articulation, although interfered with, was not entirely lost.

As I was on the point of leaving the Institution some new patients were brought in, and among them was a girl, in whom I immediately recognized a similar case; but in this instance, the left forearm was atrophied, and was upwards of three inches shorter than the right, while the right side of the head was very much wasted, so that the inequality struck the eye at once. On examining the tongue, I found it likewise curved and lying obliquely in the mouth, but with the tip to the right side; consequently, again in opposition to the paralyzed

* See a case of this kind in Lallemand, *Recherches sur l'Encephale*, Lett. vii., p. 45. In this instance the paralysis was on the left, and the tongue was inclined to the right side. In irritation, too, the same side of the tongue and face may be affected; as occurred, amongst others, in a case where the tongue was, by spasms, rendered as hard as wood, and was drawn upwards and to the left side, while the mouth was also drawn to the left side. *Medico-Chirurgical Transactions*, Vol. IV., p. 25. Also in Pfluger, *Functionen des Rückenmarks*, Berlin, 1853, p. 84.

† Case of atrophy of the left hemisphere of the brain. *Verhand. der Eerste Klasse van het Kon. Ned. Inst.*, 3rd Series, Part V., 1852. Amsterdam. Sulpke.

half of the body. The paralysis was, however, in both cases incomplete, especially in the legs, the two patients being able to walk; but it was worse in one arm, which, in either instance, was held in a curved position.

These two cases having been accurately observed at the same time, and exhibiting the atrophy in opposite sides of the body, were sufficient to show a manifest connexion between this affection and the obliquity of the tongue.

I believe, however, that we must seek another explanation of these cases. Thus, in both instances, atrophy of the one-half of the brain existed, and on the opposite side from the atrophy of the body. In these cases, too, as I have mentioned in the communication quoted above, atrophy of the medulla oblongata was present, above the decussation on the side of the atrophy of the brain; below the decussation on the opposite side.*

The hypoglossus, however, arises close to, or even above the decussation, consequently from the part of the medulla oblongata where the atrophy still existed on the same side as that of the brain. In the case of atrophy of the right cerebral lobes, therefore, the hypoglossus of the right side participated in the paralysis. Now, as the tongue is curved towards the side of the paralyzed hypoglossus, it must incline to that of the atrophy of the brain, that is, to the side opposite to that on which the atrophy of the body exists.

However this may be, it is enough that in paralysis without atrophy, in consequence of an attack of hemiplegia, the point of the tongue is always turned to the paralyzed side, and that the paralysis of the tongue is, in these cases, on the same side as that of the body; sufficiently proving that the orders of our will pass from the brain along decussating nerve filaments, which quite agrees with the results of my anatomical investigations.

Finally, the transverse commissures, uniting the nuclei of the hypoglossal and accessory nerves, on the floor of the fourth ventricle, will contribute to the simultaneous bilateral effects, which are in so high a degree peculiar to these nerves. Lastly, I found in some sections, behind the nuclei of the hypoglossal and vagus or accessory nerves, on the floor of the fourth ventricle, several slender longitudinal minute fasciculi, which appear to connect these nuclei with parts situated higher up.

What I have said of the vagus, accessory, and hypoglossus, is also

* *l. c.*, p. 6, Pl. II. Fig. 3.

true of the glosso-pharyngeal nerve. From its nucleus, likewise, fibres arise, which proceed to the raphe, and turn more or less forward, to be lost in the longitudinal fasciculi on the other side. It is, however, very remarkable, that the trunk of the nerve, according to my observation in several preparations in man and some animals, as in the ass, passes through the middle of the trunk or root of the trigeminus.

From the foregoing, however, it appears, that these marginal fibres, which terminate in the nuclei of the nerves, and, after the decussation, pass upwards to the brain, are not peculiar to the motor nerves. They occur also around the nucleus of the vagus and glosso-pharyngeus, and, as these are nerves of sensation or centripetal influence, their marginal fibres must have similar functions; that is, they must convey the impression produced in the nuclei of the nerves to the opposite side of the brain, so that a decussation accordingly takes place in the action of the nerves of sensation, as well as in those of motion.

From this we at once clearly perceive, that the nerves of sensation do not themselves decussate, but terminate in nuclei on their own side, while the impression produced in them is conveyed to the opposite side. This will, perhaps, be rendered still more apparent by observing the course of the great root of the trigeminus, which indisputably descends on the same side into the medulla oblongata, and, as we shall hereafter see, terminates on a level with the inferior edge of the corpus olivare, or of the inferior radical filaments of the hypoglossus. This is a fact so generally acknowledged, that no anatomist has ever asserted that the sensitive root of the trigeminus itself arises from the opposite side of the medulla oblongata, since we can, with great facility, trace it downwards along the same side.

It is, however, evident, that the sensitive influence must be conveyed to the other side, just as occurs in the nerves of motion, as, otherwise, no harmony could exist between the two sides. Indeed, as I have already elsewhere remarked, "if the nerves of sensation pass directly upwards along the posterior columns into the medulla oblongata, the nerves of sensation of the right side would, above the decussation, be situated next the motor filaments of the left side, which, as is well known, decussate below the corpora pyramidalia, and thus the sensations of the right arm would fall on the side of the incitement to motion of the left, which must cause confusion."* The

* Essay on the Spinal Cord, p. 79.

same is true also of the nerves of the medulla oblongata; the sensations of the right lingualis would be situated on the same side as the conductors of the orders of our will to the left hypoglossus.

Hence it appears, that the perception of sensation cannot be situated in the nuclei of the sensory nerves themselves, as those of the vagus, glosso-pharyngeus, and trigeminus; but that the impressions excited here must be conveyed by other fibres, which, as we have seen, decussate to the other side, and to a point or part which is, in fact, as yet unknown. As we have above remarked,* the medulla oblongata and some parts situated a little higher up, perhaps as far as, or even in, the thalami optici, which are, as it were, the upper extremities of the posterior grey horns of the spinal cord, appear to be the seat of sensation, as the corpora quadrigemina are the seat of the perception of light. But the optic nerves present this exception to the others, that they themselves decussate, causing perception from the left eye to take place in the corpora quadrigemina of the right side; so the rule holds good for both the nerves of motion and sensation, that everywhere the seats of the impression of our will and of perception are situated on the side opposite to the nerves. Where, however, this point of perception is, we cannot venture to guess.

I formerly supposed that the point of decussation of the nerves of sensation, should be situated in the medulla oblongata.† The experiments of Brown-Sequard have subsequently shown, that the decussation of sensation occurs in the spinal cord itself, the right side of the cord being, for example, the conductor of the impression of the sensory nerves ramifying in the left or opposite side of the body.‡ Through the kindness of my friend J. A. Fles, Lecturer at the Military Hospital in Utrecht, I have been able to convince myself of the correctness of this position, and have seen, that on cutting through the right half of the spinal cord of a goat, the left leg became devoid of feeling, and the right paralyzed as to motion, while a high degree of sensibility remained in the latter.

Some have been inclined to infer from this, that the nerves of sensation themselves decussate, and do not terminate on the same side, and Stilling says expressly, that a portion of the posterior

* Page 93, *note* †.

† Essay on the Spinal Cord, p. 79.

‡ E. Brown-Sequard, *Recherches expérimentales sur la transmission des impressions sensitives dans la Moelle épinière. Gazette Hebdom. de Méd.*, 1855, t. II., Nos. 31, 36.

nerve-roots passes into the commissures,* and that they thus appear to decussate directly, while this is said not to be the case with other sensory filaments. But as Stilling himself promises hereafter to communicate his ideas on the true origin of the nerves,† I will not dwell longer on the subject.

From the great analogy, however, which exists between the sensitive nerves of the spinal cord and of the medulla oblongata, I think we must for the present infer, that the nerves of sensation in the cord also arise from the ganglionic cells in the posterior grey cornua, whence, probably, filaments are derived, which decussate in the commissures and pass farther upwards. Such a view would afford the best explanation of Brown-Sequard's experiments, and would reconcile them with the indisputable facts of the course of the sensory nerves in the medulla oblongata. From these experiments it would appear to follow as a necessary consequence, that the decussation for the nerves of sensation takes place in the spinal cord, in the neighbourhood of the origin of the sensory root.‡

As, however, the posterior grey cornua, as I have observed in my Essay on the Spinal Cord, pages 52 and 68, are much more slender in the back and above the cervical bulb, and therefore contain a much smaller number of the fine ascending fibres, than exist in the lumbar and cervical expansions, these fibres cannot, in my opinion, serve for

* Stilling, *Neue Untersuchungen ueber den Bau des Rückenmarks.* Cassel, 1857, Part II, p. 265 C, pp. 268 *et seq.* See also Part I., pp. 119, 131.

† Stilling, *l. c.*, Part III., p. 628. I observed in one of my patients, that pressure on the anterior surface of the left thigh, a hand's breadth above the knee, immediately excited a very painful sensation in the ankle of the right foot. This would seem to indicate an intimate connexion between the nerves of sensation of each side. The reflex action would, in this instance, however, take place, from the left crural nerve to the root of the right sciatic. The phenomenon has lasted many months. Pressure on the ankle, however, does not in return produce any pain in the thigh.

‡ I readily admit, that in my former essay on the spinal cord, I may perhaps have erred in my theory of the sensitive nerves, and may have mistaken nerves of sensation for nerves of reflexion and *vice versâ*, and that, therefore, probably the sensitive nerves are the transverse roots, and the reflex nerves the ascending filaments, which, according to Stilling (*Neue Untersuchungen*, Part II., p. 265, and pp. 285 *et seq.*), are said again to turn towards the grey matter. As Bidder declares that he could not, after a careful examination, discover these ascending fibres of the posterior nerve-roots (*Untersuchungen ueber die Textur des Rückenmarks*, Leipzig, 1837, p. 89), I am glad to see my observations confirmed by so accurate an investigator as Stilling.

the conduction of perception; on the contrary, while the proper sensory filaments appear to pass over into the ganglionic cells of the spinal cord, other conducting filaments spring from this origin of the nerves of sensation, which, as in the medulla oblongata, seem to pass to the opposite side, to turn upwards into the posterior columns, and so to convey the impression to the brain. Hence it also follows, that we cause insensibility, according to the experiments of Brown-Sequard, by a longitudinal incision into the middle, or by destroying the grey matter. Brown-Sequard appears, however, not to have, in every instance, accurately distinguished reflex impressions from the perception of feeling.

If, however, we trace the mode in which, according to the experience of Ludwig Turck, degeneration advances in the spinal cord, that is, in compression or any other morbid condition of the cord, the extension will be found to take place always in the posterior white columns above, and in the anterior beneath the seat of lesion (See Ludwig Turck in Froriep's *Notizen*, 1857, u. B. No. 9, p. 157), whence we must infer that the posterior columns exercise a centripetal influence towards the brain, and the anterior a centrifugal influence, and that, consequently, the posterior columns are most closely connected with sensation. I consider it impossible to attain to certainty on this subject by the performance of vivisections, and Brown-Sequard's experiments do not appear to me to be in every instance satisfactory.

CHAPTER IV.

ON THE ORIGIN OF THE NERVES FROM THE MEDULLA OBLONGATA.

THE FACIAL NERVE.

Among the nerves of the medulla oblongata there is probably not one the origin of which is so difficult to define with certainty as the facial nerve.

In the human subject, the course of this nerve is, as has been correctly shown by Stilling, very much curved or inclined downwards, just as is also the case with the abducent nerve.* It is very clear that both these nerves are pressed downwards in their course through the medulla oblongata, in consequence of the great breadth of the pons Varolii altering the transverse direction peculiar to the other nerves of the medulla oblongata. In animals, however, where the pons Varolii is narrower, these nerves maintain a straighter direction, and can, on a transverse section, easily be exposed throughout their whole transit: on the other hand, in many animals their course is inclined, more or less obliquely, forwards and downwards.†

This nerve is specially distinguished by a peculiar white tint of its fibres, which run very parallel to one another. It is hence easily recognizable. In its course the trunk bends inwards in front of the fourth ventricle, and appears, after it has approached the floor of the latter, to run transversely inwards to the raphe, into which most of its fibres seem to pass,‡ in order again to radiate forwards on the opposite side.§

In this course, however, along the floor of the fourth ventricle,

* Stilling, *Pons Varolii*, p. 154, Plate XVIII, Fig. 2, facialis, Fig. 1, abducens.

† In consequence of the greater thickness of this nerve in the larger animals, its entire course through the medulla oblongata is very beautifully and distinctly seen, even with the naked eye, especially in the calf, horse, and ass. Fig. 3, *f f'*, Fig. 4, *f f'*.

‡ Fig. 3, *f f'*, *d*. See also Stilling, *Pons Varolii*, Plates III., IV., V.

§ Fig. 3, *f f'*, *d*, *b*, *k k*.

EXPLANATION OF PLATE III.

Fig. 4. Section of the Medulla Oblongata in the Calf, on a level with the Facial Nerve.

a, *b*. Raphe.

c, *d*. Transverse fibres, passing through the raphe to the decussation.

e, *f*. Nervus abducens. At *f*, it curves outwards through the nucleus of the facial nerve.

f′ f. Nervus facialis, terminating at *f*, in its nucleus.

g g′. Nervus auditorius; at *g′* furnished with large ganglionic cells.

h. Nucleus of the auditory nerve; *h*, *d*, transverse fibres passing from this nucleus through the raphe to the other side.

i, *k*. Transverse fibres from the nucleus *h*, and from the auditory itself at *g′*, which radiate posteriorly to pass into the cerebellum.

m. Fibres from the nucleus of the auditory *h*, to the nucleus of the facial nerve, for reflex influence through the latter on the stapedius muscle, the tensor tympani, and on the motions of the concha.

n. Very slender fasciculi of the corpora pyramidalia, which in herbivora are very small.

l, *r*. Transversely cut root of the trigeminus, which is closely connected with the nucleus of the auditory by fibres *r*, *h*.

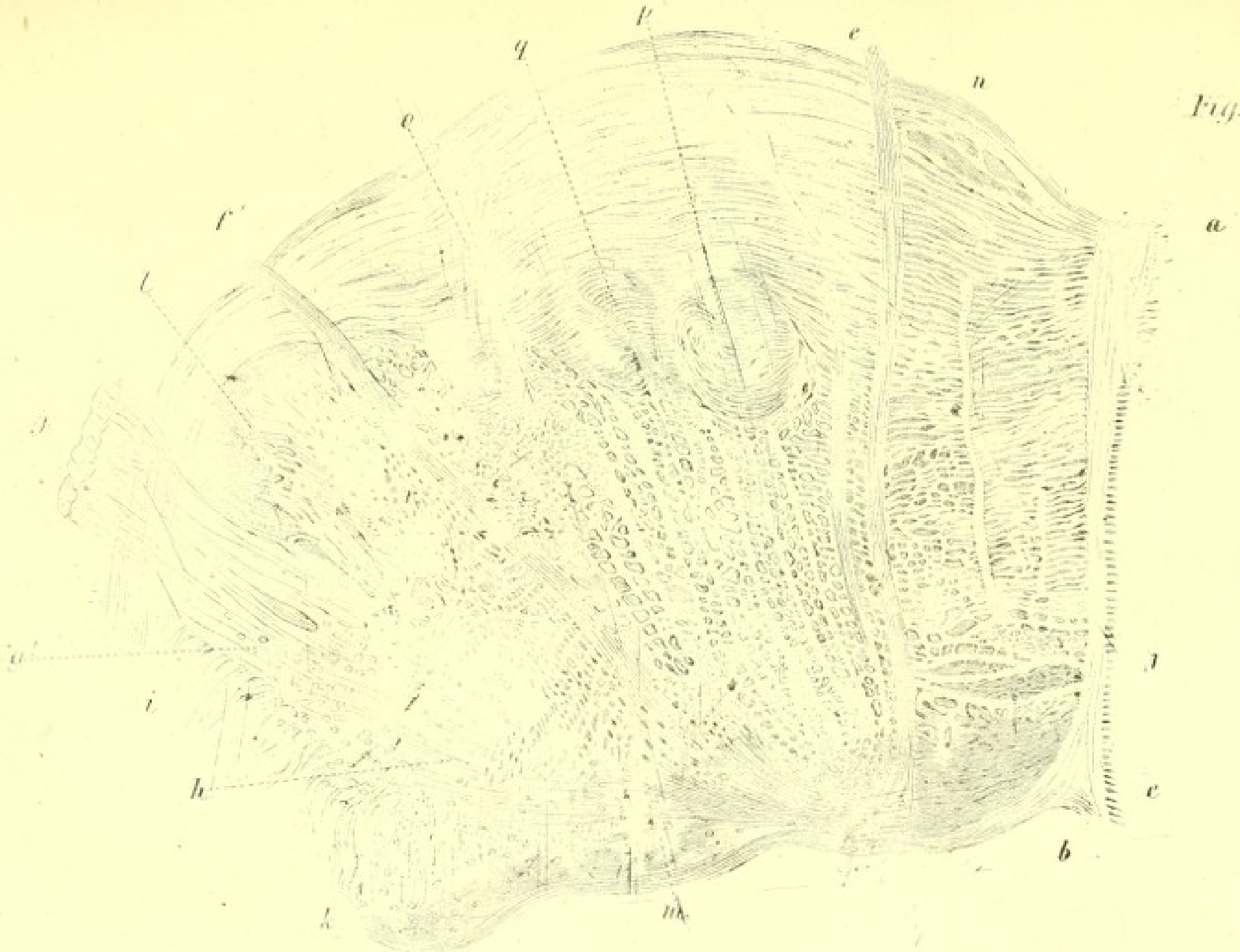
o. Accessory nucleus, with large ganglionic cells, connected by radiating fibres *o*, *f*, with the facial nucleus, and by tranverse fibres *r*, *o*, with the root of the trigeminus, for reflex action in winking.

p, *q*. Corpora olivaria superiora in the calf, whence fibres radiate to the facial nucleus *f*, for reflex action, and the expression of mental emotions.

a, *n*, *q*, *o*, *f′*. Transverse fibres from the corpus trapezoides, under the pons Varolii, to connect the two sides of the medulla oblongata.

[To face page 117.

Fig. 4.



J. S. van der Kolk del.t Tuffen West sc.

it exhibits many peculiarities, still further distinguishing it from other nerves.

Stilling observes, and I have myself confirmed his statement, that the trunk of the facial nerve is for the most part united into a single fasciculus; rarely do any filaments of longitudinal fibres intervene, in which case the nerve presents the appearance of consisting, more or less, of two divisions.* In its course through the medulla it is situated to the inside of the trigeminus, without decidedly mingling with it.†

What Stilling remarks of the difference between the inferior and superior portions of the facial nerve, is, however, of great importance. Thus, while its lower parts terminate in a proper nucleus,‡ the superior fibres exhibit a different relation. These latter appear to pass directly into the raphe, without being lost in the nucleus, and to decussate in it; their further course this writer could not distinctly trace. In their transit they enclose a bundle of longitudinal fibres, which Stilling considers to be a root of the trigeminus, the fibres of the facial nerve passing anteriorly and posteriorly along this fasiculus.§

In still higher parts, according to the same author, we see no further trace of a nucleus; but the fibres of the facial, in his opinion, bend downwards to pass into the nucleus situated inferiorly, while other fibres of the same pass through the raphe to the columns of the spinal cord, of which they are said to be prolongations, thus giving to the facial nerve a double origin. Stilling acknowledges, however, that this would require to be confirmed by more accurate investigations.‖.

Although I can yield a general assent to the description of the

* Stilling, *Pons Varolii*, p. 37. This is also in some measure represented in my Fig. 3. It occurs to a greater extent in the abducent nerve, Fig. 4, *e*, *f*.

† Fig. 3, *f f'*, *l l'*, Fig. 4, *f*, *l*, *r*. Stilling considers this part to be the continuation of the former gelatinous matter from the posterior horns of the spinal cord, and the adjoining posterior white columns, in which I cannot agree with this writer (*l. c.* p. 37). I shall hereafter return to this subject more fully.

‡ Stilling, Plates III., IV., *n n'*, *h*, and my Fig. IV., *f f*.

§ Stilling, *l. c.* p. 37, Pl. V., *n n*, *a*. See also my Fig. 3, *f f'*, *d*, *b*. We shall hereafter see that this fasciculus of longitudinal fibres, which is enclosed by the trunk of the facial nerve at the fourth ventricle, has nothing in common with the trigeminus, but is one of the cut posterior roots of the auditory nerve. In the horse and ass, where these roots follow a more oblique course upwards, they seem not to decussate with the facial.

‖ *l. c.* p. 38.

course of the facial nerve given by Stilling, and though I also have, in most animals, met many cut fibres in the superior tracts of the nerve, yet in the horse and ass the individual fibres of the facial nerve, which is in these animals so large, are so thick and plainly recognizable that, strange as it appeared to me, and much as I felt the difficulty of explaining the fact, I was compelled to adopt the opinion, that many of its fibres run directly into the raphe, without being interrupted by a nucleus. I have, however, at the same time observed, that in this course many isolated little ganglionic groups, and even separate ganglionic cells, were met with between the fibres of the nerve; so that although I thought I could trace some of these fibres uninterruptedly into the raphe, I cannot state positively that I did so; there can, however, I think, be no doubt, that all the fibres of the facial nerve do not arise from one and the same ganglionic group; whether it be that some fibres pass immediately through the raphe to the other side, or arise from separate ganglionic cells.

It is moreover remarkable that, at least in the ass, the trunk of the facial nerve passes through the middle of the great root of the trigeminus; nevertheless, I have not succeeded in discovering any immediate connexion between these two nerves.

The principal nucleus for the facial nerve, after having received on the outside many fibres from these nerves, gives off on the inner side a number of fibres, which, as we have seen in the nucleus of the hypoglossus, pass over into the raphe, to leave it again more anteriorly.* It is, however, remarkable, that some fibres pass completely behind the raphe to the other side.† But the same is also the case with the superior portions of the facial, where no nucleus is any longer visible.‡ That these fibres do not—as Bidder, in his very recent work on the spinal cord,§ states respecting the posterior commissures—consist of connective tissue I have succeeded in determining with certainty in the the horse, the ass, and other animals, as I could distinctly trace them into the facial nerve. It is certain, that of all the nerves of the medulla oblongata, not one has such an intimate connexion with the nerve of the other side, whether directly or indirectly, through the intervention of ganglionic cells, as the facial.

* Fig. 4, *f*, *b*, *c*. † Fig. 4, *b*. ‡ Fig. 3, *b*.

§ Bidder, *Untersuchungen ueber die Textur des Rückenmarks*, Leipzig, 1857, pp. 47 and 95, No. 11. With reference also to the spinal cord itself, I can by no means admit this opinion of Bidder as to the presence of so much connective tissue.

If, however, we reflect upon the functions of the facial nerve, we cannot be so very much surprised at the variety of its origin, and the close connexion between the nerve of the one side and that of the other. The function of the facial nerve is, for the most part, bilateral. We can, it is true, move the muscles of one side of the face more or less separately, but in animals this power, except in the movements of the ears and eyelids, appears to be almost entirely wanting. In fact, I very much doubt whether a dog, cat, horse, or ass, possesses the power of drawing the mouth awry, of moving only one ala nasi, or of voluntarily shutting one eye closely, for which, even in man, a certain amount of practice and exertion is required.*

But the fibres of the facial nerve which, without entering into the facial nucleus, pass immediately to the raphe, are proportionally much more numerous and considerable in the horse and ass than in man, or even than in the higher animals; while the proper nucleus is, on the contrary, much larger in man. Hence we may probably infer, that that portion of the facial nerve which arises from the nucleus, or perhaps, also, even from superior smaller nuclei and ganglionic cells, admits of movements more or less independent. As, however, a part of the nucleus appears to be united posteriorly, by means of transverse fibres, with the nucleus of the other side,† those parts alone of the facial nerve which arise from ganglionic cells, not immediately connected with those of the opposite side, should admit of a unilateral movement. And as these fasciculi of transverse fibres behind the raphe seem to be proportionally much larger in animals, particularly in the horse and the ass, and even in the dog and cat, than in man, while the proper nucleus for the facial nerve is smaller in animals, the unilateral action of the facial nerve should be much less in these animals than in man. But the fibres which pass from the ganglion into the raphe, and radiate to the other side must—just as we have seen in the hypoglossal and accessory nerves—be considered as conductors of the orders of our will, so that a decussation takes place here also; as it is known,

* It is, however, remarkable, that in dogs and rabbits, when an object is approximated to the eye, nictitation of the eyelids takes place only on the one side, while in man the closing occurs in both eyes. But this closing of the eye is involuntary, and is not to be confounded with the voluntary action of the facial nerve. I shall hereafter endeavour to give an explanation of this phenomenon, which is produced by reflex action.

† Fig. 3, *d*, *b*, Fig. 4, *f*, *b*.

that in paralysis after apoplexy the side of the face is paralyzed, which is opposite to the lesion of the brain.*

The nucleus of the facial nerve is, however, connected with many other parts; in the first place, with the nucleus of the auditory nerve, subsequently with the great root of the trigeminus, and again with some remote ganglionic groups, to which the corpora olivaria also belong. But as the latter are also very closely connected with the nucleus of the hypoglossal and accessory nerves, I will hereafter consider these more remote ganglia separately under the name of accessory ganglia, which exercise a more complicated reflex action on the nerves, and shall confine myself, in this portion of the work, to the proximate origin

† Almost all observations of paralysis of the face show that in hemiplegia the facial nerve is paralyzed on the side opposite to the lesion of the brain, causing the mouth to be drawn to the healthy side of the body. Of this we find very many examples in, among others, Lallemand, *Recherches sur l'Encephale.* In cases in which one side of the body is affected with rigidity, the mouth is drawn to the same or the affected side, in consequence of the facial nerve of that side acting more strongly. Paralysis of the side of the face opposite to that of the body, seems to be an extremely rare occurrence. A short time ago, a very remarkable example of this lesion occurred to me, where the mouth was drawn very strongly to the left side, in consequence of paralysis of the right facial nerve, so that the lids of the right eye could not be closed, and where a paralytic affection with partial insensibility of the left extremities existed. Here, therefore, the right facial nerve was paralyzed in opposition to the paralysis of the extremities; in this case, too, the tongue was inclined to the right side.

A remarkable case of paralysis of the face on the side opposite to that of the paralysis of the body, is to be found in Schmidt's *Jahrbuch*, 1857, No. 3, p. 297. In this instance the right side of the body was paralyzed, and the mouth was drawn to the right; the left eye could be only half closed; on dissection, the cerebrum was found to be softened. In the pons Varolii, chiefly on the left side, was a reddish depressed spot, and a hard tumour of the size of a walnut, tapering backwards. The whole process had extended further in the left side of the pons than in the right. In front of the pons, the membranes of the brain were thickened and adherent to one another, and in the left half they were attached to the groove between the pons and the left convolutions of the brain. The left nervus trigeminus was softened, the left facial nerve was normal. In this case there was, therefore, evidently paralysis of the right side of the body, with paralysis of the left facial nerve.

The writer seeks the explanation and the seat of the disease in the pons, in which he thinks the facial nerve decussates. In man, the facial nerve, in consequence of its high course, and its oblique direction upwards, runs partly through the pons Varolii. The opposition in the paralysis of the nerves from their nuclei, and the intimate connexions of these last with adjoining nerves.

For these reasons, I now proceed to the auditory nerve, which leaves the spinal cord close to the facial nerve.

THE AUDITORY NERVE.

In the medulla oblongata the two nerves, the facial and the auditory, are immediately separated from one another by the prolongation of the root of the trigeminus, which is situated between the two.* In order to observe this course of the auditory nerve, I should par-

must therefore be explained, in this instance, by the corpora pyramidalia being impaired in the pons above the decussation, the facial nerve below its decussation; whence the author draws the conclusion, that this case at the same time shows that the facial nerve decussates not partially, but perfectly, as otherwise complete paralysis could not take place on the one side: which, however, if the trunk of the facial nerve was injured, according to his opinion, in its passage through the medulla, would not be proved, as in that case, of course, only the one facial nerve could be paralyzed.

I believe that in this and the other cases, the writer's explanation is pretty nearly correct; that is to say, when the pons is affected on the left side, the corpora pyramidalia may at the same time be injured, producing paralysis of the right side of the body, and of the left facial nerve where it runs through the inferior part of the pons. Such a crossing of paralysis should, therefore, indicate that the seat of the disease is in the pons Varolii. See also Romberg, *Lehrbuch der Nervenkrankheiten*, 1840, 1 B., p. 225. Whether, however, we may infer, that in hemiplegia, where the face is not affected, the seat of lesion is always below the facial nerve, I cannot say; as the fibres from the brain, conveying the orders of our will to the facial nerve, probably arise from a different point in the brain or corpora striata, from those which conduct them along the corpora pyramidalia to the extremities, and which may, therefore, also be separately affected. By accurate pathological observations and dissections alone shall we be able to discover these different points.

It is also possible that two distinct lesions may exist in the brain, one of which shall be situated on the side opposite to the other; that on the one side affecting the extremities, and that on the other the facial nerve and the tongue. See, further, a case of paralysis of the right half of the face, and of the left side of the body, by Romberg, *Lehrbuch*, 1. B., 3 Abth., pp. 808 *et seq.*

* Figs. 3 and 4, *l l*, between the auditory nerve, *g*, and the facial, *f*, which is erroneously designated by Stilling as gelatinous matter, and posterior white column of the spinal cord.

ticularly recommend the calf, horse or ass, where the nerve is very thick, and its origin extremely beautiful and distinctly seen.

The auditory nerve also belongs to the rather compound nerves. Its roots are generally known; they proceed from the fourth ventricle, more or less obliquely outwards, to turn round the corpus restiforme, and so to pass over into the trunk of the nerve. Stilling found near the point where these fibres emerge to constitute the auditory, a peculiar group of ganglionic cells, which appear to be closely connected with them.* The nerve itself penetrates obliquely between the corpus restiforme and the root of the trigeminus (Stilling's white posterior columns of the spinal cord), in somewhat of a curved form, towards the fourth ventricle, from which, however, as Stilling very justly observes, it continues further removed than the facial nerve, in the direction of the so-called locus coeruleus,† in which he still distinguishes some divisions.

It is particularly remarkable that the fibres of the auditory nerve lie by no means so close to one another as is the case with other nerves; but that their fasciculi are separated by several columns of longitudinal fibres, passing upwards between the filaments of the nerve into more distinct fibres.‡

In no other case is it so easy to see the connexion between the filaments of the nerve and the ganglionic cells whence they arise. This is particularly evident in the calf. These ganglionic cells are of the largest kind, being plainly distinguishable even when magnified only eight or ten times,§ and with a magnifying power of 40 or 50 it can be satisfactorily seen, that the filaments of the auditory nerve arise from them. These cells are again connected with one another by several filaments, and subsequently give off central filaments, passing to a group of ganglionic cells or nucleus situated more deeply near the fourth ventricle.‖ This nucleus, which is very distinct, particularly in the calf, consists of a number of ganglionic cells, between which fibres run in all directions. In the first place, it receives

* Stilling, *Pons Varolii*, pp. 28 and 162 *et seq.*, Plates I. and II. *z*, and p. 153.

† Stilling, *l. c.*, p. 38, Plate I. *l*, *m*, *n n*, Plates II., III., IV., *m m*, and Plate XVIII., Figs. 13, 14, 15, pp. 122 *et seq.* See also my Fig. 4, *g*, *h*.

‡ Fig. 4, *g g''*. Also Stilling, Plate II., *m m''*.

§ Fig. 4, *g*.

‖ Fig. 4, *h*. Stilling has certainly not examined this origin of the auditory nerve from these ganglionic cells in the calf; as he considers it to be uncertain, *l. c.*, p. 159, and even denies the existence of a distinct nucleus to the nerve, *l. c.*, p. 158, *b*, although he describes the connexion of very large ganglionic cells with its fibres.

the fibres of the auditory nerve;* next a number of fibres, derived from the corpus restiforme and from the cerebellum, spread through it, exhibiting a peculiar waving curve, especially in the calf.† In other places these fibres run a straighter course from the cerebellum.‡ It appeared to me evident, that some fibres of the auditory nerve, arising from large ganglionic cells of the auditory, bend down transversely into these fibres, and pass with them to the cerebellum.§ In some sections I distinctly saw several large ganglionic cells, perfectly uniform with those of the trunk of the auditory nerve and connected with them, extending between these fibres which come from the cerebellum; leaving no doubt that the auditory nerve is very closely connected with the cerebellum; the design and explanation of which connexion is, however, in my opinion, obscure.||

It is known, that Foville has described a connexion between the auditory nerve and the flocculus.¶ This connexion I have confirmed, and to it have attributed the peculiarly large size of the flocculus in the rodentia, which are possessed of acute hearing.** At the same time, I do not pretend to decide what part the cerebellum plays in the perception of sound; on the contrary, I admit that the use of this connexion is still unknown to me.

In several preparations, especially those taken from the ass and calf, I satisfied myself, that between the auditory and trigeminal nerves, where the former encircles the trunk of the great root of the latter, there is a community of fibres, all of which possess ganglionic cells. I have endeavoured to exhibit this connexion in my drawing, Fig. 4, on the inside of the auditory nerve *g*.

On the other side of the nucleus (Fig. 4 *h*) a number of large bundles of fibres radiate, which are, particularly in the calf, extraordinarily large, and turn in the most beautiful manner round the

* Fig. 4, *g'*, *h*. † Fig 4, *i*, *k*.

‡ Stilling, Plates II., III., *f f*. § Fig. 4, *i*, *g''*.

|| In the ass, I found in the radiations of the auditory nerve, towards the cerebellum, many ganglionic cells strongly tinged with pigment. In lower sections, where the trunk of the auditory nerve is no longer visible, this nucleus is still present with radiations towards the cerebellum, and at the same time large fasciculi pass hence towards the raphe.

¶ Foville, *Traité complet de l'Anatomie et Physiologie du Syst. Cerebr. Spi.* Plate IV., Fig. 3, *o*, *h*. Plate IV., Fig. 1, E E, X.

** *Recherches d'Anatomie Comparée sur le Genre Stenops d'Illiger*, by J. L. C. Schroeder van der Kolk and W. Vrolik, p. 33. In *Bijdragen tot de Dierkunde* published by *Natura Artis Magistra*, D. I. Amsterdam, 1848-1854.

longitudinal fasciculi, passing as more or less divided fibræ arciformes to the raphe, whither they run in a transverse direction, to reunite with other similar fibres from the other side, or to pass into them.*

Many of these fibræ arciformes encircle the trunk or root of the facial nerve (Fig. 4, *ff*) in the most varied manner, and in some places I thought I observed long fibres, assuming the course of the nerve, and passing with its fibres in the trunk periphericaIly outwards. After repeated examinations, however, with stronger magnifying powers, I always succeeded in discovering, that although some of these fibres are directed for a short space outwards with the fibres of the facial nerve, a little further on they again leave this course to pass over into other fibræ arciformes; so that, notwithstanding the manner in which they encircle the nerve, I was quite unable to satisfy myself of the existence of any direct connexion between them.†

The case is, however, quite different with the nuclei. From the same central nucleus, namely, that of the auditory nerve, Fig. 4 *h*, many slight fibres pass to the nucleus of the facial nerve,‡ leaving no doubt of a connexion between these two nuclei.

This connexion I consider to be extremely important. It indicates a reflex action or influence of the auditory nerve on some parts of the facial. Of the existence of such an influence there is, in fact, no doubt.§ The stapedius muscle receives a branch from the facial nerve, and it is certainly to be inferred, that strong impressions on the auditory nerve, such as more or less acute or dull sounds, must exercise a reflex influence on the movements of the bones of the ear, and therefore also especially on the stapedius.

The central connexion, whereby the auditory nerve most probably exercises a reflex action on the otic ganglion, and so by means of the tensor tympani on the tension of the membrana tympani, is more difficult of demonstration. This difficulty arises from the numerous

* Fig. 4, *h*, *d*.

† In the calf, these fibres are so distinct and large, that it is not difficult in many places to trace them uninterruptedly into and through the raphe. This proves the existence of an immediate connexion between the two auditory nuclei; and thus, perhaps, the sympathy of the two nerves, and the occurrence of deafness in both ears, for example, in consequence of apoplexy, which I have myself observed, may be explained. Perhaps it is also in consequence of this connexion, that with two ears we hear but a single sound.

‡ Fig. 4, *m*, *f*.

§ Todd and Bowman, *Physiol. Anat.*, vol. II., p. 87.

connexions of this ganglion with several nerves. The otic ganglion is, in fact, connected with the pterygoid, glosso-pharyngeal and facial nerves, and the question therefore is—by what way does the reflex impression probably pass from the auditory nerve to this ganglion? With respect to the pterygoid nerve, the intimate connexion between it and the otic ganglion appears to be not absolutely constant, and is denied by several investigators;* by later writers, however, the mutual connexion of these parts has been admitted. But as the pterygoid nerve arises as a lateral branch of the portio minor trigemini, from a central nucleus, situated considerably higher than the nucleus of the auditory nerve,† it would be nearly impossible, with any certainty, to trace anatomically the connexion between the two nerves; and for the same reason it is improbable that the reflex action should follow this route. On the other hand, the glosso-pharyngeal nerve arises much lower than the auditory, as is particularly well seen in the long medulla oblongata of the ass;‡ so that neither is it very probable that a central connexion exists between these two nerves. There thus remains the connexion of the otic ganglion, by means of the nervus petrosus superficialis minor, with the knee-shaped curve of the facial nerve.§ Perhaps this connexion may also be accomplished through the chorda tympani, which is often, as I have myself observed, closely connected with the otic ganglion. Hence it appears, that this reflex action of the auditory nerve upon the otic ganglion and on the tensor tympani is most probably achieved through the facial nerve along the central connexion I have described, which thus becomes still more important.

It is, however, probable, that we ought to admit a still more extensive reflex influence of the auditory nerve upon the facial, namely, on the motions of the ear. Although in animals, especially in the horse, these movements of the ears are voluntary, yet we see the organ so instantaneously directed to the side whence the sound is heard, that the action would seem to be not always entirely voluntary, but rather reflex. Everything in the body is so perfectly

* Müller and Meckel, *Arch.* 1832, p. 72.

† Stilling, *Pons Varolii*, Plate XXII., Fig. 3.

‡ See my Fig. 10, letters 8, 9. The distances between these several nerves have here been accurately measured and represented.

§ Valentin, *Hirn und Nervenlehre von Soemmering*, p. 406, Litt. X. Longet, *Anat. et Phys. du Syst. nerveux*, t. II., p. 143. The latter writer decidedly regards this filament as the motor root of the otic ganglion.

adapted and brought into harmony, that we must, in fact, assign no small space to involuntary reflex actions. Thus, in terror we make a very rapid inspiration, raise the humerus from the body by the action of the deltoid, so as to be able, through the abdominal muscles, to act with great power on the chest, which is drawn up, and to fix it, and thus to use the pectoral muscles with greater force in our defence. This also is an involuntary reflex action, produced wholly by the reflex influence of different nerves on various groups of ganglia, bringing the body involuntarily into an attitude of self-defence. Just so it appears to me that the motion of the ears in animals is very often attributable to reflex action. In man, as is well-known, there is scarcely any movement of the ears; but the reflex action of terror on the facial nerve, whereby even the frontal and occipital muscles can be rendered extremely tense, and the hairs, as we say, stand on end, has long since been, as well as the retention of the voice from rapid inspiration, graphically described by Virgil in the well-known line—*Steteruntque comæ, vox faucibus hæsit.* Besides, it is generally admitted that an unexpected sound terrifies us more violently than an unexpected sight. In violent terror, however, the reflex action is not confined to the facial nerve, but the whole nervous system is greatly affected; in the first place, disturbances of the respiratory organs come on, aphonia, and sometimes convulsions, which, as they act bilaterally, as we shall hereafter see, originate in the medulla oblongata.

Under this more extensive influence and reflex action of the auditory nerve, I would now bring the posterior roots, which run over the fourth ventricle, and of which I have already briefly spoken. That these roots from the fourth ventricle are connected, for the most part, and often exclusively, with the auditory nerve, and appear to pass immediately into it, is beyond all doubt; yet I do not believe that they are strictly to be included among its proper filaments. Sometimes they are even wanting, although hearing exists; as the learned Dr. Martini, director of the Institution for the Insane at Leubus, in Silesia, informed me he had unmistakably observed. Longet,* and J. F. Meckel,† and Proschaska,‡ quoted by him, testify the same.

Sometimes these medullary striæ are not all connected with the

* *Anatom. et Physiol. du Syst. Nerv.*, t. II., p. 83.

† *Mém. de l'Acad. des Sciences de Berlin*, 1765, p. 99.

‡ *De Structura nervorum Vindobonæ*, 1779, p. 119.

auditory nerve itself,* as I also have seen; moreover, they are liable to very many varieties in course, division, and thickness; in one deaf and dumb subject, I scarcely found them; in another, they were very fully developed. In the dog, cat, rabbit, the paradoxurus, and the cavia cobaya, I found them very well developed, although in the ass and calf they were scarcely to be seen. They run along the floor of the fourth ventricle obliquely upwards to the middle line, where they disappear. Now, as we have seen that the origin of the nerves of motion is situated very near the middle line or raphe, but the nuclei of the nerves of sensation, as the vagus, trigeminus, and the auditory nerve itself, are situated more at the side, we cannot well suppose that the seat of hearing should be found exactly in the raphe, in which all the decussating filaments unite.

But the groups of ganglia are important, which, according to Stilling, are situated in these medullary striæ near their passage into the trunk of the auditory nerve.† Burdach, too, speaks of a ganglion, lying on the corpus geniculatum, and into which these striæ are said to pass.‡ I also have met with this ganglion on the outside of the auditory nerve, and suspect that many filaments of the latter, which serve to produce reflex action, pass into it. Stilling thinks that these posterior roots cross in the raphe and pass to the other side, but he himself considers this observation to be uncertain.§ Neither have I succeeded in tracing the course of these fibres further than the raphe. If, however, we bear in mind, as I have already remarked, the strong impression which an unexpected sound makes on the medulla spinalis, and through it on the whole muscular system, it appears to me that these fibres in the fourth ventricle, in consequence of their connexion with the auditory nerve, must be most useful as nerves of reflexion. When the mind, confused with terror, would not be in a condition to place the body rapidly in the best position for self-defence, this is accomplished precisely through these medullary striæ, which convey the impression either into the raphe, where all the nervous filaments meet, and where the proper nodus vitalis is situated, or they decussate there to bend on the opposite side into longitudinal fibres, which set the ganglionic groups in action, whence the movements of the abdomen, chest, and arms spring, which, as has been already explained, we involuntarily exert in terror.

* See also Burdach, *vom Baue des Gehirns*, 2 Band, p. 311.

† Stilling, *Pons Varolii*, pp. 28 *et seq.*, Plate I., *m*, *z*, Plate II., *z*.

‡ Burdach, *l. c.*, p. 84, 147, *c*.

§ *l. c.*, p. 28.

That with our two ears we hear but one sound cannot, in my opinion, be due altogether to these medullary striæ, but is rather the result of the connexion of the proper auditory ganglia through the striæ arciformes, which I have above described and delineated,* and of the simultaneous perception of sound. As I have already remarked,† it is these posterior so-called roots of the auditory nerve, exhibiting themselves in transverse sections as dark, oblong, obliquely-divided medullary fasciculi, which Stilling has incorrectly described as the constant and inconstant root of the trigeminus.‡ According to my observations, they are not at all connected with the trigeminus;§ in the horse and in the ass I have in vain sought these fasciculi in the tract of the facial nerve, and in such animals these reflex roots of the auditory nerve do not ramify so much as in man. They are even difficult to recognize, being formed by a thicker, tolerably broad root, which passes obliquely upwards.

THE ABDUCENT NERVE.

From the course and connexion of the nerves we have hitherto considered, it appears, that all the nerves of the medulla oblongata decussate indirectly through the fibres which arise from their nuclei, and, penetrating through the raphe, are lost on the opposite side, or rather, bend into the longitudinal fibres. On this account, the course of the abducent nerve, which appears to constitute an exception in this respect, is the more remarkable, although I am not yet able to demonstrate its exact origin.

Its course is in general very well shown by Stilling.|| This nerve perforates the medulla oblongata exactly in the same direction as the

* Plate 4, *h*, *d*. † Page 117, Note §.

‡ Stilling, *l. c.* Plate 3, 4, *a′ a′ a″*. See my Fig. 3, *d*.

§ If we compare the situation and height of these posterior reflex roots of the auditory nerve in Stilling's excellent representations, *Pons Varolii*, Plate XIX., Fig. 13-15, it will strike us that they are situated exactly on a level with the facial nerve, and far beneath the root of the portio minor trigemini, which is much higher than the facial nerve, and, consequently, cannot be encircled by the latter, while the portio major trigemini, according to Stilling's own drawings, is not situated so near the floor of the fourth ventricle, but previously bends downwards. See especially *l. c.* Figs. 15 and 16.

|| Stilling, *l. c.* pp. 36 and 115, Plates III., IV., V., *u u′*.

inferiorly situated hypoglossal nerve, and is, as well as the facial nerve in man, pressed obliquely downwards by the broad pons Varolii.* In animals, where the pons is narrower, the nerve runs transversely through the medulla, just as the roots of the hypoglossus do, and by a section can very easily be exposed in its whole course.† It is, however, very remarkable, that while all other nerves of the medulla oblongata bend inwards or towards the raphe, this nerve alone takes an opposite direction, and when it has approached the fourth ventricle, curves outwards.‡

According to Stilling, the abducent nerve arises from the same nucleus, whence the facial nerve on the opposite side takes its origin.§ In fact, at the first glance it appears as if the former arose on the inside of the facial nucleus; but I have ascertained on more accurate examination with higher magnifying powers, that this is not the case; the truth is, the radical filaments of this nerve perforate the nucleus, to disappear on the other or posterior surface, on the floor of the fourth ventricle.||

In higher sections also I succeeded, especially in the calf, horse and ass, in seeing that the fibres of the abducent nerve here penetrate those of the facial, to terminate on the floor of the fourth ventricle.¶ I cannot, therefore, admit that the abducent nerve takes its origin from the same nucleus whence the facial arises. Were this the case, it would, indeed, be very remarkable, that two nerves, arising from a common nucleus, should be so very distinct and without

* Stilling, *l. c.* Plate XVIII., Fig. 1.

† My Fig. 4, *e, f.*

‡ Fig. 4, *e, f.* Stilling, Plates III., IV., V.

§ Stilling, *l. c.* pp. 36 *et seq.*, and 153.

|| Fig. 4, *e, f.* I here found in several sections a thin layer of longitudinal fibres cut across, into which, in the ass, I distinctly saw filaments of the abducent nerve passing, after they had been pushed away by the facial nerve.

¶ Fig. 3, *d.* In the rabbit, the silver-grey facial nerve, which is in this animal very thick, is very plainly distinguishable from the rest of the tissue, and it appeared in one preparation distinctly to end in its nucleus. Some fibres of the abducent here very evidently cross the facial nerve, to pass to a rather considerable group of ganglionic cells, situated on the outside of the facial nerve. This appears to me to be, at least in part, the true origin of the abducent nerve; the more so, as I have met with something of the kind in the horse. The fibres of the abducent nerve, especially on its upper surface, become very much divided into numerous fasciculi, previously to its passage through the facial.

harmony in their action; while the connexion with the oculo-motor nerve, which is situated higher up, must be considered to be very intimate, as one branch of the oculo-motor, the internal, always works together with the abducent of the opposite eye, and the motions of the muscles of the face, through the facial nerve, are without any influence on the condition of the eyes. It even appears, that Stilling himself has seen something of the kind, although he makes no mention of it, as in a longitudinal section he distinctly represents these fibres of the abducent nerve perforating the nucleus.* But with a sufficient magnifying power it is evident, that these nervous filaments of the abducent by no means end in the nucleus of the facial nerve; they all appear to be cut through in different situations; seeming to bend, and, in my opinion, upwards, as they apparently pass over into longitudinal fasciculi situated here, or rather, after an upward curve, into a nucleus of ganglionic groups, placed externally and superiorly to the facial nerve, whence no fibres appear to pass towards the raphe; this nucleus, therefore, does not participate in the decussation. The foregoing seems to be, in some measure confirmed by the observations of Szokalski, who witnessed paralysis of the abducent in a man in consequence of a blow on the occiput; in this instance the roots of the abducent were found very much thickened and developed, and could be traced through the pons dividing into several fasciculi. Szokalski thought he saw a decussation of one fasciculus, which I very much doubt; but the others curved upwards.† He thinks, in consequence of his investigations, that the abducent nerve is connected with the cerebrum, the tubercula quadrigemina, and the cerebellum, whence he endeavours to explain the antagonistic action with the musculus rectus internus.‡

But as these investigations are not microscopic, and the nervous filaments appear to have been traced only with the knife, they are not conclusive, as it is impossible to follow the minute fasciculi of such a nerve in the peculiarities of its origin with the naked eye, unless they are rendered more or less distinct through morbid degeneration, and have thus become capable of being traced.

If, however, we consider the intimate relation between the abducent and the oculo-motor nerves, it will be at once apparent, that

* *l. c.* Plate XIII., and Diagram XXII., Fig. 1, *m*, *h*. In the diagram, these perforating fibres are not given.

† Szokalski, *Ueber die Cerebralstörungen der Gesichtsfunctionen*, in *Prager Vierteljahrschrift*, 1854, 1 B., p. 88. ‡ *l. c.* pp. 89 *et seq.*

there must be a close connexion between them. The fact that we cannot move the rectus externus muscle without at the same time bringing into action the internus of the other side, is strongly confirmatory of the view that the abducent bends upwards, and so enters into a close connexion with the higher-situated nucleus of the oculomotor nerve.*

It appears to me to be very important in reference to this point, that the abducent, in opposition to the other nerves of the spinal cord, a little in front of the floor of the fourth ventricle, turns outwards, and therefore from the raphe; whence it would appear, that this nerve does not decussate, especially as the nucleus, in which we consider the abducent to terminate, is thus placed further from the raphe, and appears to give no fibres to the latter. Should this last point be confirmed by subsequent investigations, and should it therefore appear that the right abducent nerve passing upwards is connected with the fibres from the brain, which stimulate the left nucleus of the oculo-motor nerve after decussation, and whence the abducent nerve of the left eye arises—we should immediately be able to explain in a simple manner, the antagonism between these muscles of the eye; since, in that case, the same stimulus should simultaneously bring into action the left internal and the right abducent muscles, and *vice versâ*.† This is, however, merely a conjecture.

* In this respect, perhaps, the longitudinal tract, which is very beautifully represented by Stilling, and which appears partly to connect the origin of the abducent with the nucleus of the oculo-motor, although this office is not attributed to it by that writer, deserves a closer examination. See Plate XIII. in the diagram, Plate XXII., *h*, *e e′*, H. That this fasciculus, however, is partly lost in the nucleus of the oculo-motor nerve, is distinctly stated by Stilling, *l. c.* pp. 107 and 174.

† As the nucleus of the oculo-motor nerve, which is very well represented by Stilling, is situated so near the mesian line that their parts are nearly confluent (see Stilling, *l. c.* Plate XI.), while it is surrounded by longitudinal fasciculi, which appear to be connected with it and to penetrate the nuclei,—we can very easily imagine such a connexion between these nerves. I have also found this nucleus in several sections, as it is represented by Stilling; yet I do not wish to go beyond the medulla oblongata, which in itself presents so rich a field for observation, and I therefore leave this important point to the investigations of others.

THE FIFTH NERVE (TRIGEMINUS).

Of all the nerves, this is, perhaps, on account of its numerous voluntary and involuntary functions, and of its extensive distribution (being most closely connected with all the senses), the nerve, the origin of which is most important, and at the same time most difficult to explain.

There has been much controversy as to its various origins; I do not intend, however, to enter into an historical account of the several opinions in reference to this point.* Let it suffice to remember, that this nerve is double, consisting of a thicker sensitive part, and a portion which, as a motor nerve, forms a slighter trunk, and supplies the masticating muscles. Longet very accurately delineates the root of the sensory nerve, which penetrates the pons Varolii on the outside of the corpus olivare and the inside of the corpus restiforme in the medulla oblongata, and then passes to the inferior edge of the corpus olivare.† The origin of the lesser root, however, he did not profess to give with certainty. According to Foville, this nerve is also connected with the cerebellum.‡ Stilling is uncommonly diffuse in his description of the central origin of the trigeminal nerve.§ Of the portio major alone he describes not less than six different points of origin,|| advancing the singular idea, that the previously white posterior columns of the spinal cord pass uninterruptedly into the portio major of this nerve.¶ In other respects, Stilling gives a very clear delineation of the origin and course of the nerve.**

Of these drawings I can in general speak very favourably; the

* See the earlier opinions in Burdach, *Ueber das Gehirn*, 2 Theil, CLXXIII., Note.

† Longet, *Anat. et Phys. du Syst. Nerveux*, t. II., pp. 95 *et seq.*, Plate I., Fig. 9, C, D.

‡ Foville, *Traité compl., etc.*, Plate V., Fig. 4, H H'. He delineates the origin of the great as well as of the lesser root; Plate II., Fig. 3, R R, the great, and H' the lesser root. The latter, however, appears to me to be inaccurate.

§ *Pons Varolii*, pp. 120-134.

|| *l. c.* p. 155.

¶ *l. c.* p. 45, No. C. Stilling thinks he has found in this passage of the posterior columns of the spinal cord into the root of the trigeminus, the foundation of a new physiology of the nerves, which I, however, suspect he has since abandoned. See, further, his work, pp. 51, 130, 145.

** Plate XIX., Fig. 13-16, Plate XVII., in a longitudinal section; Plates XV. and XVI., section made in an oblique direction.

portio minor leaves the portio major in front of the fourth ventricle, passing inwards towards the raphe, whither we have seen that all the motor nerves were directed, and where there is also a central nucleus; this appears to me to be in many places confounded by Stilling with the posterior reflex root of the auditory nerve above described. Hence, too, fibres pass into the raphe, so that these also, as Stilling correctly observes, decussate.* These are, as I have shown of the other motor nerves, not fibres of the trigeminus itself, but fibres passing from its nucleus through the raphe to the other side, there to bend into the longitudinal fasciculi, as conductors of the orders of our will.

The portio major, however, deviates in its course from that of all other nerves. Thus the other nerves, as we have seen, pass transversely or in a somewhat oblique direction upwards through the medulla; the portio major inclines downwards.†

I have particularly studied the course of the portio major in a series of consecutive transverse sections in man and several animals, beginning at its exit from the pons Varolii. From these investigations it appeared to me, that this part in its course downwards to near the inferior boundary of the corpus olivare where it terminates, undergoes many changes, which, although important, would lead me too far, and would require a considerable number of drawings, were I to enter into all particulars relating to them.

Let it therefore be sufficient to state the principal changes which this great root of the trigeminus undergoes in its passage through the medulla oblongata, and to mention its various connexions with the adjoining nerves.

In the upper parts, immediately below where it emerges from the pons Varolii, it exhibits on a transverse section fibres running inwards or backwards, which again pass in part outwards towards the cerebellum. A little lower down these fibres begin, in consequence of the interposition of groups of nuclei and ganglionic cells, to assume a less regular course, and to spread out laterally; this is particularly the case a little above the origin of the auditory nerve; its trunk is everywhere surrounded by marginal fibres, definitely separating it on the outer surface from the neighbouring parts.‡ These ganglionic groups increase in number, and, at the same time, strong and thick fasciculi of longitudinal fibres form, especially on the outer and anterior edge, exhibiting themselves as dark spots. Soon,

* Stilling, Plate XV., t. t. *a' a*, p. 123.

† Stilling, Plate XIX., Fig. 13-16. Plate XVII., Foville, *l. c.* Plate II., Fig. 3; Longet, *l. c.* Plate 1, Fig. 9.

‡ Fig. 4, *l*, *r*.

we discover, to the inside of the trunk of the trigeminus, the first bundles of white, silver-grey fibres of the facial nerve. This is most evident in animals, and I have accordingly in this description followed the course of the trigeminus, chiefly in the ass and calf.

The auditory nerve now places itself on the outside, and enters into connexions with the trunk of the trigeminus, while the ganglionic groups in this last nerve become more distinctly separate,* and towards the fourth ventricle forms radiations, giving off very many filaments to the nucleus of the auditory nerve.† In like manner it also sends, as I could see very beautifully, particularly in some preparations from the ass, filaments to the nucleus of the facial, which run along this nerve. Especially in the ass, the root of the facial is clearly seen to run nearly through the middle of the trigeminus. No connecting fibres are, however, visible between the two nerves; the facial appears simply to perforate the trigeminus. Nearer the fourth ventricle fibres from the trunk of the trigeminus again perforate the trunk of the facial nerve to pass to the raphe, while other fibres from the trigeminus pass into the facial nucleus.

In the lower divisions we constantly see numerous thick fibres passing in a very beautifully curved course, through the trunk of the nucleus of the trigeminus.

The nerve likewise gives off a number of fibres to the nucleus of the glosso-pharyngeal, which in the ass and some other animals also runs through the middle of the trigeminus, just as the facial nerve does. Its connexion with the nucleus of the vagus is still more intimate, several thick fasciculi of fibres passing from the latter through the middle of the trunk of the trigeminus, and being partly lost there, while, in part, they pass through it and cross into the exterior marginal fibres. Here the ganglionic mass of the trigeminus, which is constantly renewed by the appearance of fresh groups of nuclei, passes more and more backwards and inwards towards the nucleus of the vagus, seemingly ready to unite with it.‡ Similar connexions also take place, although in a less marked degree, between the trigeminus and the nucleus of the accessory nerve. With respect to the nucleus of the hypoglossus, its connexion with the inferior part of the trigemi-

* Fig. 4, *g*, *l*. In the ass, I found these ganglionic cells tinged with pigment. Long after the auditory nerve has disappeared in the successive sections, we see these ganglia behind the root of the trigeminus also connected with the corpus restiforme.

† Fig. 4, in the course from *l* to *m*.

‡ Fig. 1, *t*, D, *f*. Fig. 12, D, *l*, *e*.

EXPLANATION OF PLATE V.

Fig. 11. Transverse Section of the Medulla Oblongata, on a level with the Facial Nerve and Corpora Olivaria Superiora, in the Cat.

A, B, C, D. Half of the medulla oblongata.

a, b, c. Raphe. At *a* the fibres of the corpus trapezoides traverse the raphe, and cover the antero-posterior fibres.

d, e. Nucleus for the facial nerve.

e, d, c. Fibres from this nucleus, which pass across to the other side.

f. Blood-vessel in the course of the facial nerve, whose fibres are here scarcely visible.

g. Root of the nervus trigeminus, whence numerous fibræ arciformes repair to the raphe, *b*.

h. Two fasciculi of the abducent nerve, the central termination of which, in front of the facial nucleus *d*, is not visible.

i, k. Superior corpora olivaria, with numerous marginal fibres, which, partly from *k*, pass into the raphe to unite the two corpora olivaria. Other central fibres pass from these corpora olivaria to the nucleus of the facial nerve. They are much more developed and larger than the same corpora olivaria superiora in the calf, Fig. 4, *p*, *q*. At *A* we see the corpora pyramidalia, which are here much larger than in the calf, Fig. 4, *n*.

Fig. 12. Transverse Section of the Medulla Oblongata in a Cat, at the level of the Corpora Olivaria Inferiora.

A, B, C, D. Medulla oblongata, externally and anteriorly surrounded with marginal fibres.

a, b, c. Raphe.

d. Nucleus of the hypoglossus, into which this nerve passes by different roots, *h*, *g′*.

e. Nucleus of the vagus, and dark longitudinal bundle of fibres from the lateral columns of the medulla.

i, l. Corpus restiforme and root of the trigeminus. From *i* many fibræ arciformes arise, which pass partly through the corpora olivaria, and proceed through the raphe.

k, C. Corpora olivaria inferiora; in animals, for the most part, separated into three more or less coherent parts, which are situated behind the corpora pyramidalia, *k*. Many striæ pass hence to the nucleus of the hypoglossus, *d*.

They are perforated by other fibrous fasciculi, which pass to the raphe.

[To face page 134.

Fig. 12.

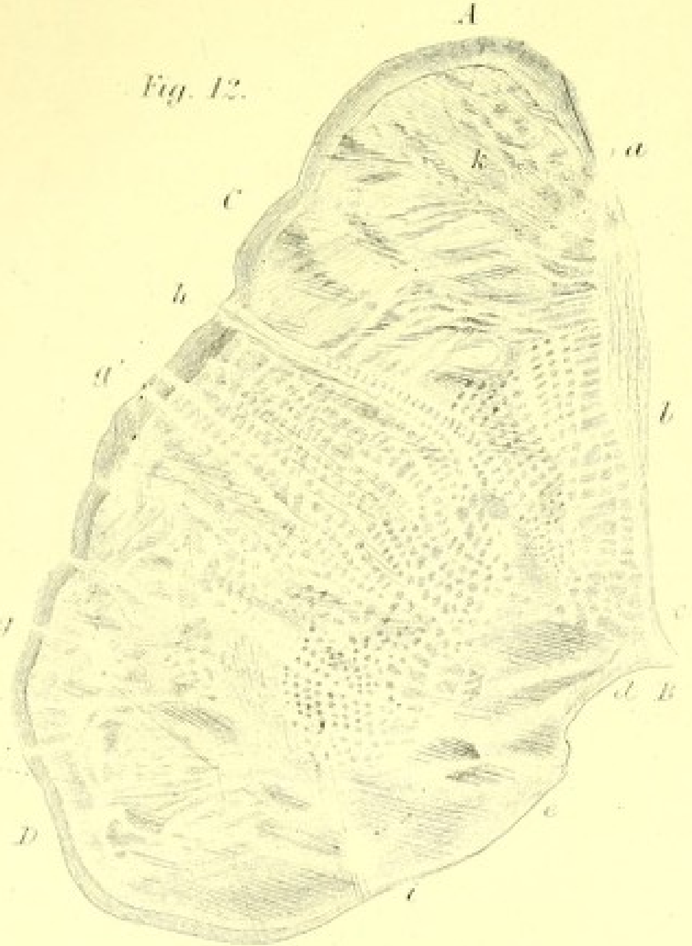
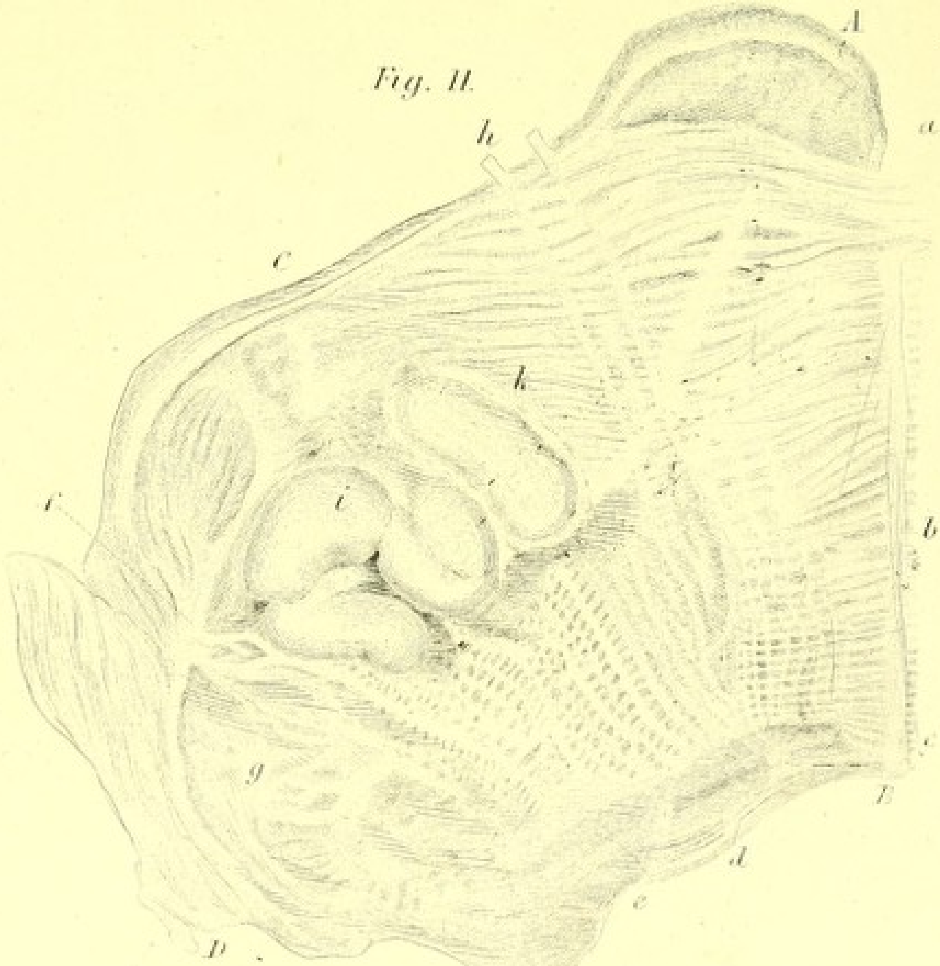


Fig. 11.



J. S. van der Kolk del. Tuffen West, sc.

W. West imp.

nus appeared to me to be more doubtful, although here and there fibres from the trigeminus also seem to pass, chiefly on the front, through the trunk of the vagus to the nucleus of the hypoglossus. The trigeminus, however, is particularly connected with a bundle of longitudinal fibres, exhibiting itself on the first appearance of the nucleus of the vagus and its trunk; on which subject I shall hereafter speak more fully.

Besides these connexions with the nuclei of all the nerves of the medulla oblongata, the trunk of the trigeminus is likewise closely connected with the accessory ganglia and the corpora olivaria, as I shall subsequently show. In its course under the auditory nerve, the corpus restiforme lies to the outside of the trunk of the trigeminus, and from this many very beautifully curved fasciculi commence to perforate the latter towards the front, to pass as fibræ arciformes in a curve forwards and inwards to the raphe, in which course they radiate with a great number of fibrous bundles through the corpora olivaria, especially in the posterior parts.* These fibræ arciformes arise in great part from the corpus restiforme, but here and there partly from the trunk of the trigeminus itself.

At the inferior part of this root of the trigeminus, it coalesces more with the corpus restiforme, whilst its own fasiculi becoming more and more divided, appear to dissolve into little ganglionic groups, and to be lost in the lateral radiations. It begins, united to the corpus restiforme, to turn more backwards, and the separate groups of grey matter, enveloped in and perforated by numerous transverse fibres, finally give way to the posterior grey horns or gelatinous matter, on which account, Stilling thinks that they pass uninterruptedly into the trigeminus, though this appears to me to be very improbable.

After this brief sketch, which comprises only the general points, attention to the course of the nerve will show, that in this great root of the trigeminus new ganglionic groups arise, wherever fresh radiations are formed, or new connexions with the successive nervous nuclei of the medulla oblongata are established, a state of things which would appear to indicate separate actions and distinct reflex functions.†

* Fig. 1, *m*, *n n*, *l*, *i*, *k*. Fig. 11, *g*, *b*. Fig. 12, *i*, *l*, *b*.

† I have not been able to discover any connexions between the trigeminus and the abducent nerve; but neither am I aware of any reflex phenomena of the trigeminus on the abducent.

If we now examine the influence of the trigeminus on the other nerves, we shall discover in its functions a full explanation of the connexions I have described. The trigemiuus is, in fact, the reflex nerve *par excellence;* for stimuli, applied to its different branches, everywhere give rise to reflex phenomena in the neighbouring nerves. That the trigeminus forms connexions with the nucleus of the facial nerve may be inferred, *à priori,* as every irritation of the face, for example in pain, immediately produces a reflex action in the muscles of the face, betraying an intimate connexion between the facial nerve and the trigeminus. What use there is in the connexion between this last nerve and the auditory, I cannot clearly see; we know too little of the action of the bones of the ear and of hearing itself to explain it. It is scarcely necessary to dwell upon the use of the connexions of the trigeminus, considered as a reflex nerve, with the glosso-pharyngeal vagus, accessory, and hypoglossal nerves in swallowing, inspiration, coughing, and sneezing. I shall hereafter return to this point.

These connexions, are, however, sufficient to explain the peculiar course of this root of the trigeminus, which alone of all the nerves extends from above downwards through the medulla oblongata. Its downward direction, in fact, enables it to form reflex connexions successfully with all the nerves of the medulla oblongata, according as it approaches the level of their nuclei.*

Finally, I think it a very important fact, that, as a general rule, in every place where fibres are given off, performing any special function, such as reflex action, fresh groups of ganglionic cells invariably appear, giving origin to these fibres. We have, for example, seen this above; where the posterior roots of the auditory nerve, which seem to have a reflex action, pass from the outside into the fourth ventricle, there is a ganglionic group. This is again always the case, where the trigeminus enters into new combinations; indeed, even the corpus restiforme exhibits a great number of ganglionic cells, where the principal fibræ arciformes arise from these bodies, to pass in a curve through the trigeminus to the raphe. These cells I have in the ass found very beautifully tinged with pigment.† If we follow up this

* As I have above remarked, the abducent, which lies more remote from the trigeminus, and probably arises higher up, appears to make an exception to this rule.

† Perhaps this ass was an old animal, as the pigment in the ganglionic cells increases with age.

idea, I believe that it is capable of very great extension, and that it will afford an explanation of many phenomena. Indeed, if we assume it as a general rule, that in the nervous system wherever a particular action is to be excited through nervous filaments, special ganglionic cells are required, producing the peculiar nervous action, we shall find but few exceptions to the rule.

Thus it is, for example, known, that the staff-like bodies in the retina are sensitive to light, but not the nerve-fibres themselves. The peculiar action of the staff-like bodies appears, when excited, to be communicated to the nervous filaments of the retina through ganglionic cells placed in the junction between the two.* The nervous filaments of the optic nerve in their central termination again pass into nuclei, whence further filaments take on themselves the distribution of the sensation to the brain.

The same appears to be true of the cells discovered by Corti in the cochlea of the ear, which are affected by the vibrations of sound, and, according to Kölliker's discovery, communicate their action to ganglionic cells,† with which the auditory nerve in its ultimate filaments is provided. This appears to be quite confirmed by the discoveries of Ecker in reference to the olfactory nerve, which terminates in ganglionic cells, wherewith the epithelial cells of the mucous membrane of the upper nares are apparently connected through slender filaments.‡ Both nerves also have central ganglia, whence the cerebral fibres arise, which convey to the brain the impressions they have received.

In like manner, the orders of our will do not pass directly into the motor nerves, but into ganglionic cells, whence the peripheric action arises for the movement of the muscles.

Greater difficulty appears, at first sight, to be connected with this subject in reference to the nerves of sensation. This is, however, not really the case. Indeed, according to the recent investigations of Wagner and Meisner, the cutaneous nerves appear to end in the tactile papillæ and in vesicles filled with granular matter,§ again

* See particularly J. C. Müller, *Anat. physiol. Untersuchungen ueber die Retina*, Leipzig, 1856.

† Kölliker, *Ueber die letzte Eindigungen des Nervus cochlea und die Functionen der Schnecke. Glückwünsche an* Tiedemann. Wurzburg, 1854.

‡ Ecker, *Ueberdas Epithelium der Riechschleimhaut*, and *Berichte ueber die Verhandl. d. Gesellschaft zu Freyburg*, Nov. 1855. Plate IV.

§ Wagner, *Nerv. Unters.* p. 133. Funk, *Physiol.* 2e Lief. p. 584.

strongly resembling ganglionic cells, through which the sensation, not only of warmth and cold, but also of the tactile properties of bodies, is excited. It appears also from the experiments of Weber and others, that the trunks or branches of the sensitive nerves, for example when the skin is removed, give no sensation of warmth, or cold, nor the peculiar tactile perceptions, but only a feeling of pain. As we may, therefore, assume the existence of ganglionic cells in the tactile papillæ of the skin, which appears to me very probable indeed, we may regard these as peculiar galvanic batteries, exciting a special action in the sensitive nerve. Further, we should not, in reference to this point, overlook the fact, that in the trunks of these sensitive nerves ganglia are everywhere placed before their entrance into the spinal cord, so that every sensitive filament appears in its course to pass through a ganglionic cell. These cells must also exercise a peculiar action on the nervous filaments, as they all appear to be bipolar, and therefore scarcely enter into connexion with other filaments.

Further, I consider the fact to be of great importance, that the ganglionic cells for the several nerves also vary among themselves in form and size. Thus, the cells of the hypoglossus are different from those of the accessory nerve, and the latter from those of the auditory, the vagus, the trigeminus, the retina, the nervus cochlearis, &c. Again, they are quite different in the corpora olivaria and in the cortical matter of the cerebellum, and these again differ from those of the cerebrum.*

From all this we may infer, that the ganglionic cells are peculiar nervous workshops or batteries, which, through an electric excitation of the nerves, produce a peculiar current in the nervous filaments

* Jacubowitsch distinguishes only three sorts of cells: 1, large multipolar cells, named by him motor cells, with from one to eight filaments; 2, sensory cells, which are smaller, with generally three, and at most four, filaments; and 3, sympathetic cells, which are still smaller. *Mittheilungen ueber die feinere Structur des Gehirns und Rückenmarks*, Breslau, 1857, pp. 2 *et seq.* According to him, the motor cells are almost entirely wanting in the medulla oblongata, *l. c.* p. 41. The nuclei, however, of the hypoglossal, accessory, and facial nerves show, that motor cells are really present in that part, and therefore his distinction is not correct, although the cells in these nuclei are somewhat smaller than those in the anterior horns of the spinal cord. But the cells in the nuclei of the auditory nerve are again much larger, and in form are more like his motor cells, although they exercise quite a different function. His physiological distinction, to which, however, he does not strictly adhere, *l. c.* p. 2, appears to me to be incorrect.

themselves, by which their specific action is performed. I shall again return to this idea.

It remains to speak of the fibræ arciformes, and of the radiating fibres which occur in the medulla oblongata in such considerable number; but as these appear to have more relation to the mutual connexion between different parts of this organ and not to belong to any particular nerve, we shall be better able to explain them when we have first traced the several ganglionic groups, whence nerves do not directly arise, but which we regard as auxiliary organs for producing a combined action of many nerves of the medulla oblongata.

CHAPTER V.

ON THE ACCESSORY GANGLIA IN THE MEDULLA OBLONGATA.

In my consideration of the medulla oblongata I have confined myself chiefly to the longitudinal fibres which arise in it *de novo,* posterior to the corpora pyramidalia and which proceed to the brain, as well as to the origin of the nerves from the organ in question, and to the manner in which decussation is produced, not through the trunks of the nerves themselves, but through the conducting filaments arising from the ganglionic nuclei, and passing to the other side, to turn into the longitudinal fasciculi.

I have, however, designedly been silent as to the numerous ganglionic groups occurring in the medulla oblongata. Among these the well-known corpora olivaria occupy the first place; yet, besides them, most nerves have also special ganglionic groups very closely connected by means of a great number of fibres with the nuclei whence they arise, and thus, probably, exercising a more or less extensive influence on their mode of action. These groups of ganglionic cells exhibit themselves for the most part in sections taken before the trunk of the nerve to which they belong is visible, and give very many connecting filaments to the nucleus whence the nerve arises.

This is particularly the case with the facial and glosso-pharyngeal nerves. Some time after the trunk of the nerve to which they are related has disappeared in the successive sections, these ganglionic groups are also lost, in order subsequently in their turn to make way for others. Such a special ganglionic group is seen in my Fig, 4, *o,* already dividing into two parts, situated on the inside of the facial nerve, and containing very many large ganglionic cells. The most important however of all, are the corpora olivaria, with the consideration of which we shall, in the first place, occupy ourselves.

The corpora olivaria are, as has already been remarked, two wholly new bodies, occurring for the first time in the medulla oblongata. They consist internally, in great part, of grey matter arranged in different curves, and consequently presenting in transverse or longitudinal sections the appearance of a serpentine lamina seen on its edge, resembling a kind of plaited capsule open from behind, called corpus ciliare or dentatum.

As is well known, they are situated on the outside and partly behind the corpora pyramidalia, between these and the lateral columns and corpora restiformia of the medulla oblongata, while anteriorly they are covered by transverse fibres, the fibræ arciformes of Arnold.* When we examine this grey matter in transverse or longitudinal sections, we see that it consists, in great part, of an infinite number of very small ganglionic cells, which are of a more or less yellow-brown colour, with interspersed pigment granules and nuclei. On most of these ganglionic cells a filament is distinctly observable;† on several, however, I saw two filaments, constituting them bipolar ganglia.‡ Finally, some occurred to me which were connected § by communicating filaments with adjoining cells, or laterally gave off a branch.|| But as these ganglionic cells present much the same appearance either on a longitudinal or transverse section, that is, some passing in a round, but most of them in an oblong form, into one or two filaments, I readily assent to Kölliker's opinion, when he ascribes from three to five ramified filaments to each:¶ hence they would appear to belong to the class of small multipolar cells.** The nucleus-filled lamina or corpus ciliare, is perforated, as Stilling first pointed out,†† by many transverse fibres passing into the raphe, and decussating at more or less acute angles.‡‡

Kölliker says that he could discover no connexion between these fibres and the ganglionic cells of the corpus ciliare;§§ in which case the corpus ciliare would be isolated, and would exercise no influence on neighbouring parts. But I distinctly saw, that very many fibres which penetrate the corpus ciliare from behind through the hilus, or

* Fig. 1, C. † Fig. 5, *a a*. ‡ Fig. 5, *b*.

§ Fig. 5, *b*, *c*. || Fig. 5, *d d*.

¶ Kölliker, *Mikrosk. Anat.*, pp. 455.

** According to Kölliker these cells possess a diameter of from 0·008‴ to 0·012‴. This agrees tolerably well with my measurements; thus I found it 0·007‴ to 0·013‴. We cannot, however, judge accurately of their true size, as those examined were probably more or less shrivelled, both by chromic acid and spirit. Much depends, also, on the direction in which the section is made. By a solution of carmine, they are very beautifully coloured, and rendered much more distinct.

†† *Medulla Oblongata*, Plate V., *g*. ‡‡ Fig. 1, *q q*, *r*.

§§ *l. c.* p. 456.

opening, all terminate in it; many others, however, perforate this grey matter, to pass out again on the opposite side.

Thus, if we make a very fine transverse lamina or section of the corpus ciliare, we see that, both from within and from the outside of the cavities of the plait, fibres pass into the corpus ciliare. Some appear to penetrate exactly into the hollow curve of these windings, and in part to come out again as marginal rays at the convex end;* but a great number of the fibres which penetrate into the cavity, bend laterally to the grey matter,† in which they decussate in various modes. Both on the outer and inner sides run marginal fibres, which continue as a layer more or less parallel to the curves, and appear to take up the fibres from the corpus ciliare, and further on to give them off externally.‡ These are in different situations in various states of development, but, as we shall subsequently see, they occur everywhere, both in the more highly developed corpora olivaria in man, and in the more simple corpora olivaria in animals. These marginal fibres appear to be connected with the ganglionic cells in the corpus ciliare, and to conduct their influence to other parts, as they collect externally in larger or smaller fasciculi.§ They are, however, often so completely covered by other marginal fibres, as to be only indistinctly visible. Sometimes fasciculi pass from the most external marginal fibres through the corpus ciliare, and join other bundles derived from the hilus.|| A great proportion of the fibres which enter the cavity of the corpus olivare, appear evidently to take their origin from these ganglionic cells.¶ Very many fibres, however, especially the so-called fibræ arciformes, penetrate the corpus ciliare without our being able with certainty to discover whether they are connected with the ganglionic cells, a connexion which, nevertheless, appears to me to be probable, as otherwise we cannot see any use in so many fibres penetrating this body.** But in other situations we see few

* Fig. 6, *a*, *b*, *c*, *d*. † Fig. 6, *a*, *b*, *c*.

‡ Fig. 6, *a*, *d*, Lenhossek, *Neue Untersuchungen ueber den feineren Bau des centralen Nervensystems*, Wien, 1855. Plate II., Fig. 3, *c*, Fig. 1, *g g*.

§ See this Fig. 4, *p*, in the corpus olivare of a calf.

|| Fig. 6, *e*, *f*. ¶ Fig. 1, *i*, *q*.

** Fig. 1, *l*, *k*, Fig. 12, C, *k*, in a cat. Lenhossek represents only fibres entering the hilus from the inside, but not one penetrating the corpus ciliare, which is not correct. See *Neue Untersuchungen des feineren Bau des centralen Nervensystems*, Wien, 1855. Plate II., Fig. 1. Stilling had previously stated this much more correctly in his work on the *Medulla Oblongata*, Plates V. and VI. I subsequently observed, on inspecting

EXPLANATION OF PLATE IV.

Fig. 6. Portion of the Corpus Ciliare from the Corpus Olivare.

a, *b*, *c*. Fasciculi of fibres, radiating from the concavities of the curves of the corpus ciliare.
a a', *f*. Fasciculi from the inside, which, as marginal fibres, at *a'* constantly receive fresh fibres from the ganglionic cells, and at *f* further radiate outwards through the hilus.
e, *d*. Marginal fibres on the outside of the corpus olivare.
e, *f*. Bundle of fibres, passing transversely through the corpus ciliare from without inwards.
d. Most external marginal fibres, which everywhere receive fibres from the ganglionic cells of the corpus ciliare.

Fig. 7, *A*. Remarkable example of Atrophy of the Corpora Olivaria, in a Case of the Loss of the Power of Articulation.

a. Pons Varolii.
b. Medulla oblongata, at the level of the decussation.
c. Left corpus olivare, appearing as a little tubercle.
d. Uncommonly thick fibræ arciformes, curving backwards under the small corpus olivare.
e. Right corpus olivare, over which longitudinal fibres run. Internally there was only a mere trace of corpus ciliare.
V-XI. Different nerves, arising in this situation.

B. Example of Obliquity of the Medulla Oblongata, with very unequal Corpora Olivaria.

a, *b*. Corpora pyramidalia. The right, *a*, is distinguished from the left, which is somewhat broader, by a thick bundle of longitudinal fibres, running over it, and passing outwards under the corpus olivare.
c c. Boundaries of the right corpus olivare, 15mm. long.
d d. Small left corpus olivare, 11mm. long.
e. Strange lateral curve in the anterior groove between the corpora pyramidalia. Somewhat above this curve a great section of fibres passes to the other side, completely filling the groove of decussation.
V V. The two vagi. That of the right side is nearly half as broad again as the left, 7mm. against from $4\frac{1}{2}$ to 5.
A A. Accessory nerves. That of the left side appears somewhat thicker.
H H. Hypoglossi.

Fig. 8. Medulla Oblongata of a Dog.

5—12. The nerves of the medulla oblongata.
a a. Corpora olivaria superiora, on a level with the facial nerve, behind the corpus trapezoides.
b b. Corpus olivare inferius, exactly at the roots of the hypoglossus, and not extending above or below these roots.

Fig. 9. Medulla Oblongata of a Cat.

a a. Corpora olivaria superiora, at the level of the facial nerve.
b b. Corpora olivaria inferiora, at the level of the hypoglossus.

Fig. 10. Medulla Oblongata of the Ass.

5—12. The several nerves.
a a. The two little corpora olivaria superiora, distinct from one another, on the outside of the abducent nerve, on a level with the facial nerve.
b b. Corpus olivare inferius, from the expansion of the roots of the hypoglossus more inwards, behind the corpora pyramidalia.

[To face page 142.

Fig. 6.

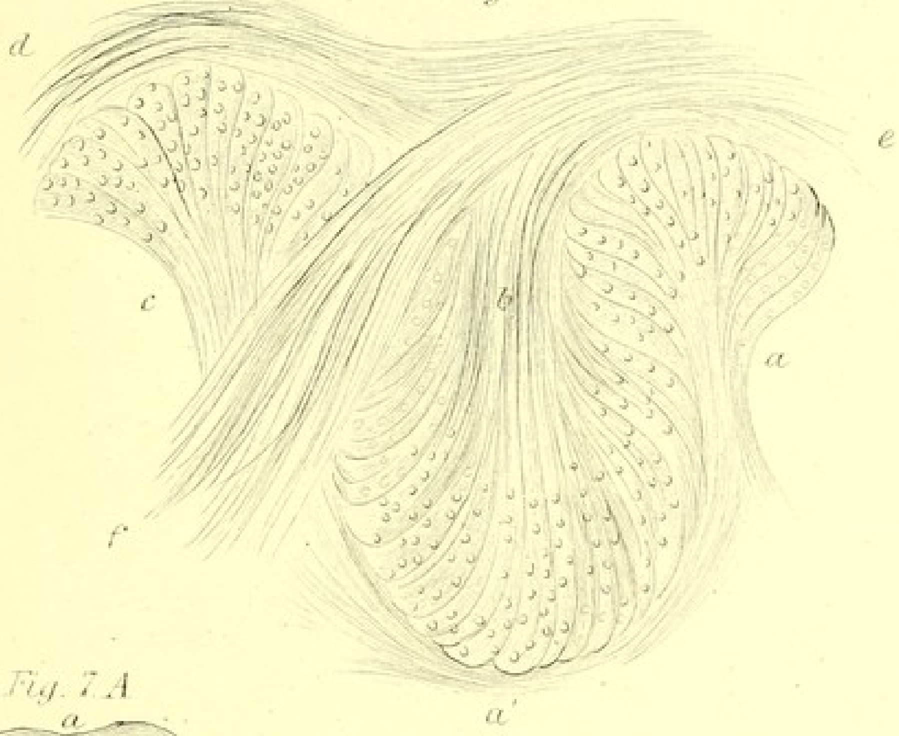


Fig. 7. A.

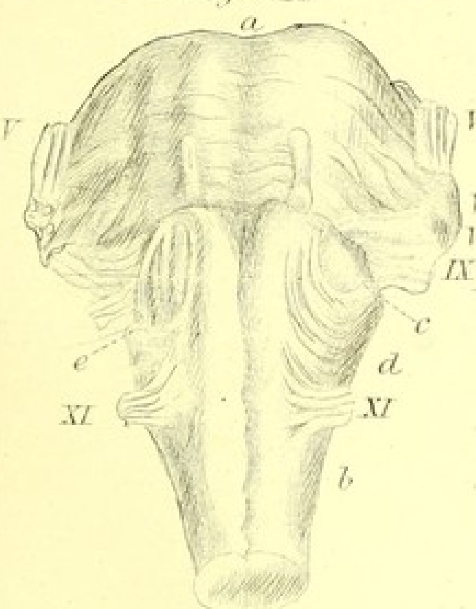


Fig. 7. B.

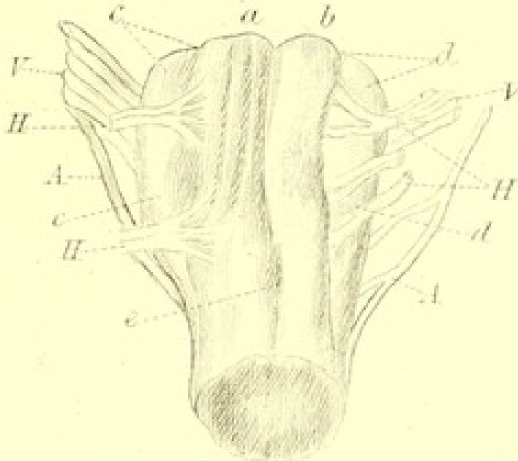


Fig. 8.

Fig. 10.

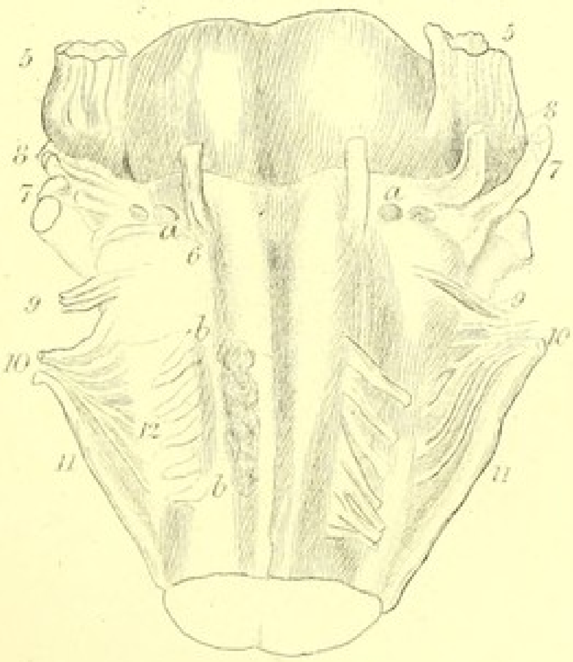
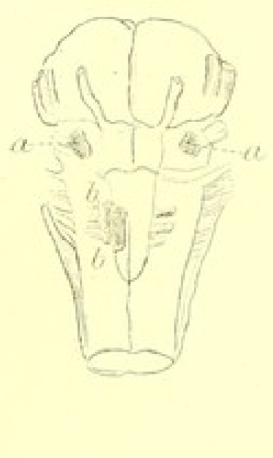


Fig. 9.



or no fibres penetrating the corpus ciliare, although on the one side they pass in great number between the ganglionic cells. These must, therefore, take their origin from the ganglionic cells. But on account of the extraordinary minuteness of these fibres and the small size of the cells, we can sometimes follow a filament in its connexion with a cell to a little distance; but the fibre is soon covered by others, so that we lose sight of it.

Stilling describes on the inside of the corpus olivare a second nucleus, which he denominates the great pyramidal nucleus, and he thinks that the pyramids arise from it.*

I have already reminded the reader, that the pyramids are the continuations of the anterior columns of the spinal cord, and do not originate in the medulla oblongata. These accessory nuclei agree, however, so completely in structure and composition with the corpora ciliaria, that we may look upon them as exactly similar to the latter. Even this innermost nucleus is not everywhere isolated; on the contrary, if we make a series of successive transverse sections, we shall see that in some it is connected with the proper corpus ciliare, while in others it is separated from that body; it is therefore merely an offshoot of the corpus ciliare. On the outside, too, such a body usually occurs, and Lenhossek represents several;† but he has, in my opinion, confounded some with ordinary ganglionic groups, which are, however, distinguished from these corpora olivaria by the greater size of the cells. It is very remarkable that, as Stilling first stated, the hypoglossal nerve passes between the corpora olivaria and the so-called pyramidal nucleus of Stilling.‡ In many parts, however, of the corpus ciliare isolated tracts of the root of the hypoglossus perforate the corpus olivare itself, and penetrate between the ganglionic cells,§ leading us to suspect the existence of a closer connexion between the corpus olivare and the muscular nerve of the tongue.

This supposition I found confirmed in the fullest manner by my further investigations.

Stilling represents several transverse fibres apparently escaping out

Lenhossek's preparations at Bonn, that this is in a great measure the result of his mode of making the preparations, as, by too great transparency, many of the more minute fibres are rendered difficult to see.

* *Medulla Oblongata*, p. 30, Plates V. and VI., *r*, also my Fig. 1, *k*.

† Lenhossek, *l. c.* Plate II., Fig. I, *h*. See also my drawing, Fig. 1, *h*, *i*, *k*.

‡ *Medulla Oblongata*, Plates V. VI., *l*, *r*.

§ Fig. 1, *q*.

of the hilus from the corpus olivare, and passing into the partition or raphe,* giving the two corpora olivaria the appearance of being connected with one another; but he did not observe that whole bundles of fibres, derived from the hilus, bend from the corpora olivaria close to the hypoglossal nerve, to terminate with the latter in the nucleus of this nerve.

These fibres arise from the grey substance of the corpus ciliare, and form a tolerably large bundle, which does not differ much in thickness from the roots of the hypoglossus, and which we can follow uninterruptedly into the nucleus of this nerve. The fasciculi in question seem not to perforate the corpus ciliare, as they do not appear on the other side; but it can be easily shown that they arise from the ganglionic cells of the corpus olivare itself. They pass through the hilus, and collect in bundles, which run into the nucleus of the hypoglossus.† From the same place, and especially from the bottom of the corpus olivare, a quantity of fibres simultaneously radiate, which make for the middle line or raphe, perforate the latter,‡ and appear to communicate with the corresponding fibres of the other side, connecting the corpora olivaria with one another. It is, however, also possible, that some of these minute transverse fibres, which proceed from the corpora olivaria towards the raphe, and radiate again on the other side, may bend partly upwards into the minute longitudinal fasciculi, coming from the brain, and so, as conductors of the orders of our will, decussate, just as we have above seen of the nuclei of the nerves. As, however, a number of longitudinal fibres appear to spring from the top of the corpora olivaria, and from their sides, and pass to the crura cerebri and corpora quadrigemina, the so-called fasciculi olivares and laqueus,§ we may also assume that these latter tracts serve to bring the corpora olivaria into connexion with the brain, and thus with our will, and that the transverse fibres

* Stilling, *Medulla Oblongata*, Fig. VI., *q*.

† Fig. 1, *i, p*. Lenhossek, *l. c.* Plate II., Fig. 1, *e*. I discovered this remarkable connexion in the spring of 1855, with my Swedish friend Liedholm. In the autumn of 1856 I received the essay of Lenhossek, who had, quite independently, accurately described and represented the same connexion, giving it the name of pedunculus olivæ, *l. c.* p. 34. The discovery was made known in a short paper in the Swedish Journal, the *Hygiea* (Professor Schroeder van der Kolk's Views on Epilepsy, communicated by J. F. Liedholm, Hospital Physician at Wexio, 1856).

‡ Fig. 1, *i, q q*.

§ Arnoldi, *Icones cerebri*, Plate IX., Fig. 5, *r, s, t*.

must be regarded only as commissures. In the one case, the conductors of the orders of our will would be considered as decussating, just as occurs in the nerves; in the other case they would not be supposed to decussate. Both opinions might even be true in case of an impression from the one side acting simultaneously on both corpora olivaria. Moreover, it is in many places evident, that these commissures pass from the one corpus olivare to the other, and serve to unite both, although I have not found the connexions so well marked as they have been represented by Lenhossek.* This intimate connexion, both between the corpora olivaria reciprocally, and with the nucleus of the hypoglossus, particularly struck me, and I thought that a more accurate investigation of it might, perhaps, lead to some explanation of the use and action of the corpus olivare itself.

Let us keep in view, as starting-points, the two following facts:—

1. The two corpora olivaria are reciprocally united by a considerable number of fibres, arising from their ganglionic cells, and perforating the raphe.†

2. The corpus olivare of each side is closely connected with the nucleus, from which the hypoglossal nerve of the same side derives its origin.‡

Hence we may infer that there is most probably an intimate physiological connexion between their actions. In what, then, can this connexion consist?

I have already, in my Essay on the Spinal Cord, endeavoured to prove, that all motor nerves take their origin from certain groups of multipolar ganglionic cells; that these groups are more numerous where a greater number of muscular nerves arise, as in the brachial and crural plexuses, and in proportion as more numerous combinations of different muscular actions, as, for example, in walking, are to be accomplished and brought into harmonious coöperation.§ Now, we possess no part which is capable of such various motions as the tongue, which is certainly the most moveable part of the body.

If we now examine the nucleus of the hypoglossus, I must acknowledge that I am acquainted with no other part of the entire spinal cord or brain where the multipolar ganglionic cells are so densely

* *l. c.* Plate II., Fig. 2, *e.*

† Fig. 1, *p*, Lenhossek, *l. c.* Plate II., Fig. 2, *c.*

‡ Fig. 1, *p*, Lenhossek, Plate II., Fig. 1, *e.*

§ See above, pp. 62 *et seq.*

accumulated as in it,—a fact confirmatory of the opinion just alluded to.*

But we also see that the corpus olivare is in the closest connexion with this nucleus, a considerable number of fasciculi of fibres passing from the former into the latter. It would therefore appear that the corpus olivare is, at least in part, an auxiliary ganglion of the hypoglossus (for, as we shall find, it is connected with other nerves), and as such is joined to the hypoglossus for the production of certain special combinations of movements.

It is, further, very remarkable, that the corpus olivare occurs in but a small number of animals, and, indeed, only in the mammalia. Birds possess, as I shall hereafter show, only a remote type of this body, and lower animals seem no longer to exhibit any trace of it. But if we compare the corpus olivare among the mammalia themselves, it will at once strike us that these organs occur nowhere on so extensive a scale, and so fully developed, or presenting so strongly-plaited a corpus ciliare as in man. Its numerous plaits have undoubtedly the advantage of containing a very great number of ganglionic cells in a small compass, and of affording a very extensive surface in a limited space, whereby the multiplied connexions between its cells and the surrounding fibres, or those which arise in the corpus ciliare, are rendered possible. This narrow-plaited form, moreover, renders easy the entrance and exit of the in-coming and out-going fibres.

Again, in the higher mammalia, as the apes, the corpora olivaria are most like those in man; in the lower they are, as I shall hereafter more fully explain, smaller, and divided into several parts; in man they are, however, so much larger, that they exceed in circumference by two or three times those of the chimpanzee; and this difference is still more remarkable in lower, though much larger animals, as in the horse, the cow, and the ass.

This at once suggests the idea that the corpora olivaria have a much more important function to discharge in man than in animals, and that in the mammalia in general some more highly-developed or complex action has to be performed, in which these bodies coöperate, and which does not occur, at least in the same manner, in the am-

* This is particularly well marked in the hypoglossal nucleus of the cow, where, on account of the greater size of the tongue, and the consequently increased amount of muscular fasciculi, the number of ganglionic cells in the nucleus is uncommonly great, and is in proportion to the increased thickness of the nerve itself.

phibia and in fishes, as in these the corpora olivaria are wholly absent.

Immediately after I had discovered the special fasciculi, connecting the corpora olivaria with the nuclei of the hypoglossus, I suspected that the very delicate combinations of motion in the human tongue in articulation and speech might afford an explanation of the much greater size of the olivary bodies, and of their more intimate connexion with the nuclei of the hypoglossus. For speech and the articulation of words require such a multitude of peculiar motions of the tongue, and such an infinite number of varying combinations of its muscular movements, that it cannot appear strange that two auxiliary ganglia should be required for the performance of these functions.

If we attend to the situation of the hypoglossal nuclei, it will appear that these are located close to one another, adjoining the middle line or raphe.*

They are here separated from one another by the longitudinal fibres which pass from before backwards through the raphe, and on the floor of the fourth ventricle cover these nuclei from behind,† and which are formed partly by proper nerve-fibres, as we have above seen, and partly by connective tissue from the pia mater. It is only in a limited portion that the two nuclei appear to be connected with one another by transverse filaments. The greater part of each nucleus seems to be isolated in its action, and not to be connected with that of the other side; the result of which is, that each hypoglossal nucleus can act separately, so that we are able to move the tongue to one side or the other. In speaking, however, the tongue must be moved equally and simultaneously on both sides, as appears from the fact, that when one side of the organ is paralyzed, speech is impaired.‡

It seems to me that the corpora olivaria serve to accomplish these uniform and simultaneous movements of the tongue, intimately connected as they appear to be by the above-described proper transverse fibres, passing through the raphe from one corpus ciliare to the

* Fig. 1, *o*, *p*, *d*.

† Fig. 1, B, *d*.

‡ Among others, we may find many proofs of this in Lallemand's excellent work, *Recherches sur l'Encephale et ses dépendances*, Paris, 1824. Thus, a patient often got angry and violent, because she could no express herself in words; she uttered only a confused sound and inarticulate noises; the tongue, as well as the whole body, was half paralyzed. Lett. I., Obs. 7, p. 19. It is self-evident that where the paralysis is less complete, as often occurs, the impediment in speech will be less.

other, in consequence of which the action of the one corpus olivare always takes place simultaneously with that of the other. According to this view, the orders of our will should, in the articulation of speech, be conveyed by the corpora olivaria on both sides simultaneously and uniformly to the two hypoglossal nuclei, so that in this case the corpora olivaria must be regarded as auxiliary ganglia, communicating the multitudinous combinations of muscular movements required in speech, simultaneously to the two hypoglossal nuclei, and thence to the tongue, the result being the uniform movement of both sides of this organ. The hypoglossal nuclei appear, therefore, to be in themselves unilateral, that is, each can act separately for itself, in virtue of which we are able to move the tongue to either side. The corpora olivaria on the other hand are bilateral; that is, they are so connected in their operation by the transverse fibres, that the action of both is always excited uniformly and simultaneously, and is communicated to the muscles of the tongue on both sides, which, as I have already observed, is necessary for speech and the articulation of words.*

* The idea that the corpora olivaria are closely connected with speech is not new. Even Willis says :—" In homine infra paris octavi (Hypoglossi) originem protuberantia quædam utrique medullæ lateri adnascitur. Ex illa fibræ quatuor aut quinque distinctæ prodeunt, quarum una aut altera arteriam vertebralem pertranseuntem circumligat, omnes autem in eundem truncum, qui prædicti paris nervus est, coalescunt. Protuberantia isthæc, pia matre avulsa, facile conspicitur, et peculiaris spirituum, huic nervo destinatorum condus videtur.

" Cum enim hic nervus *linguæ ejusque musculis* impendatur, adeoque *loquelæ peragendæ* potissimum conducat, in homine, cui vocis et major usus et frequentior exercitatio, spirituum penu ingente, quorum copiæ semper in promptu sint, opus esse videtur. *Brutis* vero, quibus nulla aut rarior vocis necessitas, talis *protuberantia* deest, quippe illis haud requiritur, ut spiritus ante vocis organa, quasi in vestibulo quodam catervatim aggregentur, quin sufficiat eos e communi medullæ oblongatæ tractu paulatim accieri."—Th. Willis, *Cerebri Anatomia*, cap. 18 in Opera omnia Genevæ, 1676, p. 90. It would appear that this remarkable part has but little attracted the attention of subsequent writers. Professor Retzius, however, who discovered the intimate connexion between the corpora olivaria and the facial nerve, and admitted the connexion previously stated by Burdach to exist between the corpora olivaria and the nervus hypoglossus, infers that, " as comparative, as well as experimental and pathological anatomy, has afforded me full proof that the seventh pair of nerves is destined for the expressive (mimischen) movements of the countenance, and as again the latter, as well as the movements produced by speech, are the peculiar attributes of the human race, and, by means of the facial and lingual nerves, proceed from the

That the notion that the corpora olivaria are organs for the articulation of the voice, is no mere conjecture, but that it can be confirmed by facts will appear from the following very remarkable case, which fell under my own observation.

G. van A. was received into the Institution for the Insane in Utrecht, in May, 1854. She had then attained the age of twenty-two years, although, from her small and youthful figure, she seemed scarcely to have passed the period of childhood. Almost from her birth she had given signs of defective powers of mind, and it subsequently appeared that she was dumb, but not deaf. Two of her brothers were educated as deaf-mutes in the Institution for the Deaf and Dumb at Groningen. Pinching poverty induced the mother (whose mental powers had likewise suffered much in consequence of a former illness, after the death of her husband) to place her daughter in the Institution for the Insane; especially as the young woman had become malicious and passionate. Probably this was the result of the want of proper food: as a little care in the Institution soon restored her former tranquillity, which continued during the whole of her stay there until her death in August, 1855.

From her mother we learned that she had always enjoyed good health, and had menstruated regularly; only suffering occasionally from a spasmodic cough. The most remarkable point, however, was that, notwithstanding all the trouble which had been taken with her,

olivary bodies, we might regard the olivary bodies as central organs for the movements of expression and speech." See Müller, *Archiv für Physiol.* 1836, p. 363. Duges also says, in his *Physiologie Comparée*, 1838, t. I., p. 360, " Les olives offrent un degré d'intérêt de plus, comme centre nerveux particulier. Le singulier kyste, formé de substance ferme et grisâtre, qui leur sert de noyau (corps rhomboide), tout semblable à celui qu'on trouve au milieu de chaque hémisphère du cervelet, semble indiquer des fonctions spéciales. Nous nous sommes figuré que son aptitude particulière pourrait bien se rapporter à l'exercice de la voix, comme moyen d'expression des idées. Il est bon de noter à ce sujet, que les olives sont plus volumineuses chez l'homme que chez tout autre animal, que les nerves du larynx, de la langue et du pharynx naissent des faisceaux olivaires ; " and furthermore, at p. 262 :—" L'hypoglosse, moteur de la langue, vient des faisceaux sous-spinaux et peut-être des olives qui agiraient, par leur intermédiare, sur la langue comme organe de prononciation."

I have not found these ideas in other writers, and as they are not confirmed by any cases, they cannot be looked upon as more than mere conjectures. Only very recently have the corpora olivaria been occasionally mentioned by some authors as being connected with speech, though this theory is not supported by the production of any proof.

she had never been able to form an articulate sound, but only now and then uttered a squeak. She was almost always very mild and contented, but habitually thrust her thick tongue out between her teeth, without its inclining to one side or the other. She usually understood all that was said to her, and although idiotic, was of a very gentle disposition. She attended when she was called by name, but could never answer. She in general exhibited a smiling countenance, especially when she was addressed by name, and when her attention was excited; she almost always let her tongue hang out of her mouth, and only rarely gave occasional utterance to a low, mournful sound. During her stay in the house, all her functions were normal, menstruation was regular; now and then, however, her cough returned without any expectoration. But in July, 1855, she was again attacked with violent cough, on which diarrhœa supervened, she rapidly lost all appetite, and, very much emaciated and wasted, sank in the following month.

At the post-mortem examination, the body was found to be slender and but ill-developed; the head was small, the forehead but slightly arched and sloping backwards; the chest was very flat. On removing the hard, but thin and small skull, the cerebrum appeared little and ill-developed; the convolutions, especially on the anterior lobes, were slight and not numerous; in consequence of the diminished arching of the anterior lobes, the so-called convolutions of the third rank of Foville, were scarcely shown on the inner longitudinal surface of the hemispheres, and were very small; the convolutions on the posterior cerebral lobes were but little developed. On the anterior cerebral lobes, beneath the os frontis, was seen a spot, of the size of the palm of a small hand, with bloody exudation under the arachnoid, in which situation the pia mater was adherent to the cortical substance, which was in many parts softened. On section, the grey and white substances were here and there thickly studded with red sanguineous points; the thalami optici presented a strikingly yellow colour. The thoracic and abdominal cavities were not opened.

On taking out the brain, however, the medulla oblongata immediately attracted my attention; not only because the pons Varolii was smaller and narrower than usual, but chiefly on account of the very unusual minuteness and slight development of the corpora olivaria. Such an example had never before occurred to me, and I have accordingly represented this remarkable deviation with the greatest accuracy in Fig. 7, A.

We see here, *a*, the pons Varolii; *b*, a section of the medulla cervicalis at the lower extremity of the decussation of the pyramids, which are tolerably well developed; at *c* and *e* we observe the small corpora olivaria, of which the left at *c* exhibits only a small nodule,* surrounded internally and inferiorly by uncommonly thick fibræ arciformes at *d*. These fibres are thicker than I have ever observed in any other case, and after descending vertically from the pyramids, curve outwards in eight or nine bundles.

But at the lower extremity, on a level on the left side with *d*, we see some fasciculi passing in an opposite direction to the anterior sulcus, which is not the case on the right side, where the fibræ arciformes are also very thick, although somewhat less highly developed.

This deviation of these fibres inwards appears to occur very rarely. I found only one similar abnormity in Arnold's plates, likewise represented on the left side.† However, this writer, though in other respects so accurate, makes no mention of this point in the explanation of the plates, nor in his *Bemerkungen ueber den Bau des Hirns und Rückenmarks*, Zurich, 1838. Neither does Valentin‡ nor Foville§ speak of it.

Of the transverse fibres over the corpora olivaria, the so-called stratum zonale of Arnold,‖ we can in this instance, as is often the case, see no trace with the naked eye.

On the right side, the form of the corpus olivare is not less remarkable; here, at the first glance, it appears to be wholly absent. Thus, there is in this situation a depression with a slightly raised floor, on which the thick fibræ arciformes are placed; while in the seat of the corpus olivare tolerably broad longitudinal fasciculi of fibres are seen.¶

In order to ascertain whether the corpus olivare was present at all or not on the right side, I made, without destroying the preparation, a longitudinal incision with a very sharp knife in the direction of that

* The vertical diameter of this amounted to exactly four millimetres, the breadth to 3·46; in the normal condition the length amounts to from thirteen to fifteen millimetres, the breadth to four millimetres.

† *Icones cerebri*, Pl. II., Fig. 5, lett. *g*. Also Pl. III., Fig. 1 *h* on both sides.

‡ Sömmering. *Hirn- und Nervenlehre von* Valentin, 1841.

§ *Traité complet de l'Anatomie du Système Nerveux*. Paris, 1844.

‖ *Bemerkungen, &c.*, p. 82. *Icones cerebri*, Pl. II., Fig. 5 *c c*.

¶ Fig. 7, A *e*.

body, and then took from one wall of the section as thin a lamina as possible. On submitting the latter to a magnifying power of from 250 to 450 diameters, I found in it, almost exclusively, longitudinal fibres, decussating with one another; on the one side of the section, I found some grey substance, and in it scattered ganglionic cells of the corpus ciliare, but in a straighter line, not so highly convoluted; whence I concluded that the corpus olivare was even much less developed on the right side than on the left.

The posterior roots of the auditory nerve in the fourth ventricle were, although only in the upper half, distinctly present, and evidently passed over into the auditory nerve itself.

The cerebellum appeared normal, but not highly developed.

From this remarkable case it therefore appears:—that in this instance there was complete inability to articulate, and consequent absence of speech, without deafness and without proper paralysis of the tongue, which the patient could move, although perhaps not very quickly, with an extremely defective development of the corpora olivaria; so that the influence of these bodies on the complicated movements of the tongue in speech seems scarcely to admit of doubt. Deglutition was, however, well performed.

I am indebted to my esteemed friend, Roëll, physician to the Institution for the Insane at Dordrecht, for a second very important case. He sent me in April, 1856, the head of an epileptic patient, aged thirty-two, who had died the previous evening, and who had for nine months been under treatment in the Institution at Dordrecht. My friend at the same time transmitted the following report:—

"The patient was deaf and dumb from youth, and subsequently became epileptic. He uttered only a croaking hard sound, which, nevertheless, he endeavoured to articulate; the word *tabak* (as it appeared to me), being alone intelligible. He always sat quietly, assisted himself, could make known his desire for tobacco, and was glad when it was complied with.

"His hands were drawn inwards by the flexors; his digestion was good; the last eight days he was confined to bed, ate little, and gradually pined away without consciousness."

Immediately after receiving the head, I opened the cranium, which was thin; the os frontis was small, sloped backwards, and was but little developed; on the removal of the cranium, the dura mater presented a very sanguineous appearance.

On the upper surface of the cerebrum, especially at the vertex, there was intense meningitis, with a greenish-yellow purulent effusion between the pia mater and arachnoid, extending over the cerebral lobes. At the vertex, the arachnoid was, through a limited space, adherent to the dura mater. The pia mater was very firmly attached to the brain, and could only with very great difficulty be separated from its surface, and scarcely even from the depressions between the convolutions, which seldom occurs; consequently, in several places, thin layers of cortical substance continued hanging to the inside of the pia mater. The convolutions on the anterior lobes were small and ill-developed. On pulling off the pia mater, and washing with water, the colour of some convolutions was observed to be very white, and this was also the case where attachments to the pia mater had existed. Other points of attachment, on the contrary, exhibited a light-rose colour, a proof that the inflammation had penetrated into the cortical substance, as constantly occurs in idiopathic mania, unless the condition has already passed into dementia, when the convolutions are pale, and the pia mater easily separated. In the present instance, the change of colour was the result of the inflammation of the brain, which seems to have set in shortly before death. The venæ magnæ Galeni, at their passage into the straight sinus, were covered with a purulent exudation, which extended to a certain depth between the posterior lobes and the cerebellum. The fluid, however, in the lateral ventricles was clear, and the pia mater was not thickened, so that the inflammation had not extended to the whole of the interior cavities of the brain. The pia mater, too, could be separated from the corpora striata, without laceration of the cerebral substance, which is, under other circumstances, not usually the case.

The fornix, however, and the thalami, especially on the right side, were softened; the corpora striata were healthy; the corpus dentatum cerebelli was pale; the brain, especially the medullary substance, exhibited many red points on section.

The pia mater and arachnoid, on the medulla oblongata, also, were thickened, and exhibited traces of inflammation; the corpora olivaria were small; the posterior so-called roots of the auditory nerve in the fourth ventricle were even strongly developed; they passed distinctly into the auditory nerve, which was, however, on both sides very thin and atrophied.

The cerebellum was not red from inflammation, but on its inner surface it presented, between the pia mater and arachnoid, some purulent infiltration. The soft commissure between the thalami was healthy; in the pineal gland were large sand-like particles.

After I had allowed the medulla oblongata to harden sufficiently, I prepared thin microscopic sections of it. It appeared to me, that the blood-vessels, especially in the corpora olivaria and the raphe, were very much dilated; a point to which I shall hereafter return at greater length.

In addition to a red or brown discoloration of the white and grey substance, occupying some extent, and caused by exudation from a very highly distended blood-vessel in front of the nucleus of the hypoglossus on the right side, about in the situation indicated in Fig. 1 by the letter *p*, I particularly observed that the inner and posterior part of the floor of the fourth ventricle (see Fig. 1, from *o* to beyond *p*), was yellow, hard, and granular, and was evidently more or less degenerated on the same side. There were also yellow, hardened spots close to and in the corpus olivare, nearly in the situation marked *i* and *l* in Fig. 1; and another at *m*. On the left side, the affection was less marked, though here, too, a similar degeneration existed in the corpus olivare, but somewhat more anteriorly. The corpora olivaria, moreover, on both sides, had less of yellow transparency than usual; in some places they were very dark and opaque, so that under the microscope I could scarcely distinguish their structure, which was granular, probably in consequence of a chronic deposition of albumen, such as I have frequently seen, under the form of coagulated granular matter, in hardening of the brain.

In this case, therefore, we see that with difficulty of speech and articulation, degeneration existed in the ganglionic groups whence the hypoglossal nerve arises on the right side, while spots of degeneration exhibited themselves in the corpora olivaria on both sides.

But it appears to me probable, that as the great imbibition of blood must have been of recent occurrence, the red exudation and dilatation of the blood-vessel near the nucleus of the hypoglossus were of later date, and were, perhaps, connected with the recent inflammation of the brain, of which the patient had died; and that they were, perhaps, also promoted by the former epileptic attacks; a point to which I shall again allude. The vessels in the neighbourhood of the corpora olivaria were much smaller, and were not so highly distended with blood. On micrometric determination, the vessel near the hypoglossus appeared to amount in diameter to 0·261 millimetre, the widest, somewhat to the outside of the corpora olivaria, to 0·305 millimetre. It is not stated whether there was paralysis of the tongue during life, probably, therefore, it did not exist. The epileptic attacks had not been frequent.

A third case of this nature was communicated to me by my esteemed friend, Ramaer, physician to the Zutphen Insitution for the Insane, who, at the same time, with the greatest kindness, sent me the preparation. Of the history of the case, I received the following report :—

"Last week I dissected the body of an idiot, whom I had always considered to be dumb; but I now heard that he used to utter a couple of words, namely *vrydag*, when he had eaten anything to his liking, and *botje*, by which he designated the little bones he got here and there to pick, while he was still at liberty. However, these words were so indistinctly uttered that I never could understand them. In other respects the unfortunate being was cunning enough; he assisted in mangling and bed-making, and could hear well. His brain was very well-developed for an idiot; but the medulla oblongata was turned in the strangest manner, one corpus olivare appearing to be pushed upwards, while beneath was a deep depression."

I was unable to ascertain whether this depression was produced by a bony excrescence from the skull, or from what cause it proceeded; but as we have only few examples of mal-position of the corpora olivaria, I thought it worth while to give a drawing of the specimen. We see the strangely-turned corpora pyramidalia, Fig. 7, B; the left corpus olivare, *d d*, is much smaller than the right, *c c*, in the proportion of eleven to fifteen millimetres; the left vagus, V′, also, is much slighter than the right, nearly as five to seven; between the hypoglossal nerves there is but little difference. The decussation is turned quite obliquely. According to reports subsequently obtained, there appeared to have been no atrophy of the one hemisphere of the brain, nor was there any paralysis of the tongue.

On the left side, the inferior roots of the hypoglossus, H, come much lower than the inferior border of the corpus olivare. It is not improbable that for want of harmony in the corpora olivaria, the bilateral actions in the motions of the tongue, which are necessary to articulation, could not be accomplished.

In the foregoing instances, the patients never had the power of speech and of the articulation of words; it is, therefore, important that I am able to add a case in which the difficulty of articulation commenced during the last period of life, in consequence of a morbid affection of the central parts.

B., aged 30 years, was admitted on the 11th of January, 1855, into the Utrecht Institution for the Insane.

Formerly of a sound constitution and regular mode of life, he was very much thought of for his peculiar ability in the commission trade, and was consequently often obliged to undertake fatiguing journeys. For these, however, he was very well able. He suffered only from habitual constipation and a torpid state of the bowels, a condition which appeared to inconvenience him but little, though he might have had no motion for several days. In 1853, he was long affected with boils, and had an anthrax on the back; he seemed often to suffer from nocturnal pollutions, and most probably had in his youth been addicted to onanism.

In 1854, he married, and entirely changed his mode of life; he was now occupied in book-keeping and writing in his extensive business, and adopted sedentary habits.

In the commencement of December of the same year, he began to complain of headach, while the constipation had greatly increased. The headach, which was extremely violent, and occasionally intermitting, was probably, as I have often observed it, the consequence of congestion and chronic inflammation of the dura mater, in which intermissions are very usual.

On the administration of strong purgatives and tartar emetic, and the application of cupping-glasses, with scarifications to the neck, the headach completely gave way. The patient was now to have gone on a journey; when he suddenly became excited, a state which rapidly led to the development of all sorts of foolish and exaggerated ideas; he thought he was exceedingly wealthy, bought a country place, wasted much money in useless purchases; in consequence of which he was brought into the Institution, and placed under my care.

At first, he was in a state of continual perturbation, under the constant influence of various dreams and phantasies, which at times he recognized as deceptions, but which quickly returned and promised him a golden future. (Incipient inflammation of the pia mater and irritation of the cortical substance of the brain.)

Under the use of tartar emetic and the employment of cupping-glasses, with scarifications to the neck, and the subsequent application of leeches to the nose and anus, his state improved so much that he not only became quiet, but appeared to be restored to complete clearness of intellect, when unexpectedly his condition again became quickly worse, and day and night was liable to sudden exacerbations. He had usually wide pupils, and the latter, if his bowels were confined—to prevent which care had constantly to be taken—became still more dilated. The transition to dementia was now gradually more apparent, and neither a seton in the neck, nor an issue on the scalp, was effectual in preventing this change. The patient's gait became unsteady, he was more and more out of his mind, and especially began to exhibit much difficulty in the articulation of words, which he frequently could not enunciate without exertion. Deglutition also began to be defective, he took his food with difficulty, slobbered his drink, and used to let the saliva run out of his mouth. These phenomena steadily increased, while now and then a peculiar sense of oppression was manifested, at which times he could not bear any pressure on his neck or chest, and often, especially at night, he stripped these parts; sometimes he grasped his neck so forcibly that he became blue in the face.

The difficulty of speech and deglutition remarkably augmented; he often held his food long in his mouth, then hurt himself in the attempt to swallow, on which severe attacks of cough usually ensued. His legs and arms had become œdematous. He was, however, still occasionally excited, and full of plans of travelling. Finally, he grew more and more oppressed and short-breathed, the pulse became small and quick, his sleep was disturbed; râles were heard in the chest, and one evening, after having eaten with relish, he died with symptoms of paralysis of the lungs.

On post-mortem examination, it was found that the skull was uncommonly thick, and that the dura mater was firmly adherent to it, a consequence, no doubt, of the former chronic inflammation which had been attended with headach. The brain appeared smaller than I had expected, not entirely filling the cranium, while the arachnoid membrane, loose and wrinkled, covered the cerebral mass, and the cavity was occupied by a great quantity of yellow serum. (*Atrophia Cerebri.*) On removing this membrane, much effused blood was seen as a thin layer beneath the pia mater, in the regions of the os frontis and parietal bones. On drawing away the pia mater, great flakes of grey substance were separated with it from the antero-superior surface of the hemispheres, the admitted result of inflammation of the pia mater and cortical substance, which had produced the phenomena of idiopathic mania (pride, &c.), with the subsequent paralytic symptoms. The pia mater and arachnoid were thickened; the quantity of serum in the ventricles was small, probably in consequence of the pressure on the brain from the large amount of fluid in the skull; there were many bloody points, and a marbled colour of the medullary substance; the septum was very much softened.

In the cavity of the thorax, there was much fluid; the bronchial glands were very dark-coloured; the left bronchus was quite filled with purulent mucus, the right less so; the right lung, especially the inferior lobe, was hepatized, in the left was lobular pneumonia. It appears to me probable, that in consequence of the impaired action of the muscles, the portions of food often went wrong, and so gave rise to this inflammation. Perhaps a semi-paralytic condition of the vagus contributed to this result.* The mucous membrane of the air-passages was also very red-coloured; the heart, particularly the right ventricle, was greatly dilated, probably in consequence of the obstructed circulation through the lungs.

In the abdominal cavity, the stomach was found very large and distended, most likely a result of the semi-paralysis of the vagi, as I have often observed. The gall-bladder was empty; the spleen and liver were normal; the colon was uncommonly long, and the transverse colon and cæcum in particular were amazingly distended and dilated; a great portion of the left colon, on the contrary, as is usually the case in constipation, was very much contracted, and at the same time very much lengthened, which must be considered as the first predisposing cause of the patient's illness. I allowed the medulla oblongata to harden in spirit, in order to be able to submit thin sections of it to microscopic examination.

In this investigation I discovered, in the first place, an unusual quantity of fat everywhere infiltrating and obscuring the tissue of the medulla oblongata, and rendering it necessary to wash some sections repeatedly for its removal; a condition indicative of incipient softening. This was principally the case in the two corpora olivaria, which were very highly impregnated with fat; the ganglionic cells appeared to be unusually loaded with the latter; the colour, too, of the corpus ciliare had not everywhere preserved its peculiar yellow tint, but was in parts very white. This change pervaded about half of that body; the left corpus ciliare in particular, appeared to be

* Dr Gaye, *Einige Bemerkungen über Lungenentzündungen bei Irren. In Allgem. Zeitschrift für Psychiatrie.* Berlin, 1853, pp. 580 *et seq.*

much atrophied, curving at very acute angles. In the situation of the nuclei of the accessory, vagus, and especially of the glosso-pharyngeus, there was on the floor of the ventricle sharply-defined yellow degeneration, in which no particular tissue was discoverable, extending as a layer to near the nucleus of the hypoglossus, of 0.54 of a millimetre in thickness.*

I likewise encountered a round dark spot in the course of the hypoglossus, between its roots.† From this examination, therefore, it appears, that not only the medulla oblongata, but particularly the corpora olivaria, had undergone fatty degeneration, exhibiting several degenerated dark spots, probably consisting of more or less highly-organized albumen; in the corpora olivaria, the course of the hypoglossus, and particularly of the accessory, vagus and glosso-pharyngeal nerves. These changes fully account for the very difficult articulation and obstructed deglutition which had existed during life.

A similar instance was communicated to me some time ago, during his short stay in this city, by my esteemed friend, Dr. Martini, physician to, and director of, the Leubus Institution for the Insane in Silesia. Dr. Martini had, in a case of total loss of speech, met with induration of the corpora olivaria.

Similar examples of loss of speech or of the power of articulating words, occur in many authors, without the writers having connected the affection of the corpora olivaria with the loss of speech. Thus, Olivier relates a remarkable case of paralysis and dementia of long standing, where at last the voice was all but wholly lost, the patient being scarcely able to utter a few inarticulate sounds; the corpora olivaria and pyramidalia were softened and changed into a grey

* About the situation marked in my first Fig. from *e* to beyond *f*.

† I have designedly reported this case somewhat at length, because the whole course of the disease is strikingly illustrated by the results of the post-mortem examination, on which account it is of practical importance.

Since the original edition of this Essay was printed, I received, a short time ago, through the kindness of my friend Dr Röell, the medulla oblongata of a woman aged 50, who had been for twenty-five years insane and completely demented, and could only indistinctly utter the single word "snuif" (snuff). There was paralysis of the right side of the face. I found in the medulla very decided fatty degeneration; the right corpus olivare was more slender and somewhat smaller than the left, although both were slender and atrophied; in the corpora pyramidalia were numerous wide vessels, of 0·276 mm., in the raphe = 0·305. There was no vascular dilatation in the other parts. The patient had not been epileptic.

semi-fluid pulp.* In another case, in consequence of an aneurism of the basilar artery, the pyramids were nearly annihilated; the corpora olivaria were pressed outwards and indented; the roots of the hypoglossus were in part destroyed; the vagus and glosso-pharyngeus were compressed,† with loss of voice and of the power of articulation, and with dysphagia.‡ The same phenomena occurred in another case, with red speckling and great softening of the medulla oblongata after a fracture of the first cervical vertebra.§ Several similar observations of loss of speech and of the power of articulation, with softening of the medulla oblongata to near the pons Varolii,|| or of the inferior part of the pons, in which, consequently, the corpora olivaria must have participated, occur in the same author.¶ Thus, likewise, we have a case of difficulty of speech with induration of the medulla oblongata,** from which Olivier infers, that in affections of the medulla oblongata speech is lost;†† he was not, however, aware of the importance of the corpora olivaria in this respect.‡‡

Two cases, communicated by Cruveilhier, are still more important in this point of view. The one was that of a lady, aged thirty-seven, who, from some unknown cause, had for six years been paralyzed in the legs; the paralysis had originally begun in the left, and had subsequently attacked the right leg. For the last two years she was under Cruveilhier's observation in the Salpetrière. Latterly, the paralysis had also invaded the arms; the sensibility of the parts was not diminished; the intellectual powers were unimpaired; but one of the principal symptoms was difficulty of articulation. Cruveilhier says:—"Elle souriait à mon approche et me saluait avec expression; mais quand je lui addressais la parole, elle était prise d'une émotion

* *Traité des Maladies de la Moëlle épinière.* Paris, 1837, 3e edition, t. II., Obs. 123, pp. 382 *et seq.*

† *l. c.* t. I. p. 460, Obs. 52.

‡ *l. c.* p. 457.

§ *l. c.* t. I., pp. 400 *et seq.*, Obs. 39.

|| *l. c.* t. II., Obs. 97, p. 187.

¶ *l. c.* t. II., Obs. 109, p. 310, Obs. 111, p. 315.

** *l. c.* t. II., Obs. 126, p. 398.

†† T. I., p. 365, t. II. p. 423.

‡‡ The case from Professor Oppolzer's *Klinik*, communicated by Romberg, also belongs to the same class. In this instance the power both of swallowing and of speech was lost, and, in addition to the existence of a grey tuberculous mass in the left half of the pons Varolii, the left side of the medulla oblongata, from below the pons to beneath the origin of the vagus, was found firmly adherent to the base of the skull, while a portion of lardaceous tubercle, of the size of a pea, had penetrated into the superficial substance of the right corpus olivare, compressing the hypoglossal and facial nerves. Romberg, *Lehrb. der Nervenl.*, 1846, 1 B. 3 Abth., p. 814.

difficile à rendre. Elle rougissait, riait, pleurait, ses membres et son tronc étaient saisis de mouvemens involontaires, qui la faisaient s'agiter sur sa chaise percée; les muscles faciaux agités des grimaces et l'articulation de sons beaucoup plus difficile que lorsqu'elle était revenue de cet état de trouble. Du reste, elle finissait par se faire entendre. La difficulté dans l'articulation des sons tenait surtout aux mouvemens de la langue, qui n'y prenait presque aucune part. Déglutition difficile, ce qui supposait une diminution dans l'action musculaire de la langue et de l'arrière bouche. Point de céphalalgie, jamais de céphalalgie; la malade entendait à merveille, mais elle se plaignait d'avoir la vue très-affaiblie.

"Cinq mois avant sa mort dépérissement notable, fièvre, respiration fréquente, toux incomplète, jamais suivie d'expectoration; d'où engouement des bronches, qui se debarrassent par momens. L'articulation des sons devient très-difficile, de même que la déglutition. L'intelligence persiste jusqu'au dernier moment."

At the *post-mortem* examination, Cruveilhier found, besides a change into a grey condition in the crura cerebri, that the great commissure, thalamus and fornix, and the corpora pyramidalia in the medulla oblongata were also grey. The left corpus olivare was healthy, the right was, like the parts above mentioned, grey, except a little point on its upper surface, which still appeared as an insulated spot of white. The corpora restiformia had undergone a similar alteration. A transverse section through the centre of the corpora olivaria showed that the grey change had invaded the entire thickness of the corpora pyramidalia and of the right corpus olivare, with the corpora restiformia. The roots of the nerves arising in this situation, namely, those of the hypoglossus, the vagus, and glosso-pharyngeus were grey, and externally appeared to be reduced to the neurilemma.*

The following case, likewise communicated by Cruveilhier, is, however, still more important.

A child, of four years, had fallen into a state of such general weakness that he could not stand, and had to be carried or laid on a bed; he could, however, move all his limbs, but could not guide his movements with precision, nor could he exercise any force. Deglutition was very difficult, especially of fluids, only a small quantity of which reached his stomach, while the rest was rejected by the mouth, and sometimes through the nose. The articulation of sounds was exceedingly slow; the voice was low and stammering; the little patient

* Cruveilhier, *Anat. Pathol.*, Livr. 32, p. 22, Pl. II., Fig. 4 O. D.

still articulated distinctly, but only syllable by syllable; the respiration was slow, often oppressed and sighing, and in a recumbent position was impossible, even when the head was supported by several pillows. The intellectual powers of the child were developed very much beyond his time of life; nutrition was perfectly well performed, the patient being even stout and fat. The illness was the result of convulsions, with which the child had been attacked three years previously, and which had since returned repeatedly at irregular intervals, causing him to be considered epileptic. Five or six months later he died asphyxiated, although in the full possession of his intellect, but no longer able to utter a sound.

On examining the body, Cruveilhier found both corpora oilvaria as hard as cartilage; in other respects they exhibited no change, nor was there any abnormity of colour or extent; one of the crura cerebelli (the author had forgotten which) and the tubercula mammillaria participated in the induration; the entire of the remaining cerebral mass was sound. He was able to examine only so much of the medulla oblongata as could be taken out by the foramen magnum; the medulla was perfectly healthy below, and at the sides of the corpora olivaria.* It is to be regretted that in so remarkable a case no more accurate examination could be made as to the exact limits of the lesion; neither does Cruveilhier state,whether decided paralysis of the tongue was present or not.

The case, however, taken in connexion with others, proves a great deal, as the affection was so definitely circumscribed in the two corpora olivaria; and I am, in fact, much surprised that Cruveilhier has not drawn from it any inference as to the connexion of the corpora olivaria with the articulation of words, as well as with deglutition.

A case of a very acute affection of the corpora olivaria, observed and communicated by C. C. W. Maudt, Officer of Health in the Dutch Indies, also appears to me to be of extreme importance.†

A native gunner under treatment in the Hospital, was bitten, while out for the purpose of evacuating his bowels, by a serpent, called by the natives, Oeloer. Scarcely had he returned to his sleeping-place from which he had risen, when he became giddy, fell in a faint, and in ten minutes had lost the power of swallowing.

* Cruveilhier, *l. c.* Livr. 35. *Maladies de la protubérance annulaire*, p. 2.

† See *Geneesk. Tijdschrift voor Neêrl. Indië*, V. Jaarg. Afd. V. en VI. p. 956.

Diluted liquid ammonia put into his mouth flowed out again mixed with saliva; the cervical muscles, and especially those of the larynx and os hyoides, were stiff and tense; respiration was laboured and sighing.

There was *total loss of speech* with unimpaired consciousness; the patient at every question applied his hand to his throat, as if to signify that the part was constricted; the pulse was very slow, 59, small, weak; the skin was cold.

A small and superficial wound, which perforated only the epidermis, without any discoloration or swelling of the surrounding parts, was with difficulty discovered. This wound was immediately cut out. On account of the inability to swallow, no internal remedies could be given; but external derivants, rubbing the neck and throat with caustic ammonia, creosote, blisters, inhalations of chloroform, were all in vain; respiration became more and more difficult, and death occurred in four and a half hours after the receipt of the injury.

Post-mortem examination four hours after death :—

Enormous tumefaction of the whole body from emphysema. No local phenomena in the neighbourhood of the wound.

Head.—Great distention of the sinus of the dura mater; extraordinary development of the blood-vessels under the arachnoid; no particular change in the cerebral substance; slight increase of serous fluid and collapse (?) of the choroid plexuses in the ventricles.

The medulla oblongata was greatly congested under the arachnoid, especially between the corpus olivare and corpus restiforme. Its internal texture perfectly normal; the spinal cavity presented no morbid changes.

Thorax.—Great rigidity of all the muscles of the throat and neck, with strongly-marked hyperemia of their tissue, which was uncommonly dark-coloured. Little œdema of the epiglottis, *perfect closing of the glottis,* the mucous membrane of the larynx and trachea pale and covered with thin mucus.

This case is extremely important in many respects, as well because the first commencement of the symptoms was observed by a well-informed physician, as on account of the post-mortem examination having been performed so soon after death, by which the phenomena witnessed during life seem to be completely explained.

In this instance, also, the only actual abnormity was the great redness of the medulla oblongata about the corpora olivaria, and the accompanying hyperemia and tension of the cervical muscles, which are supplied by the accessory and hypoglossal nerves. Now, as this condition appears to have been alike on both sides, we can scarcely avoid inferring, that the corpora olivaria were affected, whereby the nuclei of these two nerves were injured, particularly in their bilateral relations, and consequently the powers of deglutition, voice and speech, were completely lost.

Lastly, we may add the testimony of Pinel, who says, that as alterations of speech are characteristic in general paralysis, and changes in the corpora olivaria are equally constant, the latter organs must be connected with the articulation of the sounds formed in speech, and consequently with the development of voice.*

Many cases of impairment of speech occur in various writers, which I might bring forward in confirmation of the opinion I have advanced, where the medulla oblongata or the inferior portion of the pons Varolii was hardened, or softened, or in some other way affected, but in which reports the corpora olivaria are not expressly, or are only cursorily mentioned; although it is not to be doubted, that the impairment of speech was fairly attributable to their morbid condition.†

* *Séances de l'Académie de Médecine*, Sept. 1854, quoted in the *Neue Med. Chir. Zeitung*, 7 Feb., 1855, p. 116.

As I have not had the opportunity of reading this Essay, I cannot fairly judge of the premises whence Pinel draws this inference. I have, indeed, in my third case, reported above, found this view confirmed, but without a microscopic examination, I should certainly not have ventured in that instance to infer a definite abnormity in the corpora olivaria or in the medulla oblongata in general, as formerly, in dissections of such cases, I have not remarked any change in the corpora olivaria. However, these observations of Pinel, and my conclusions previously formed on anatomico-physiological grounds as to the use of the corpora olivaria in the articulation of the voice, reciprocally confirm one another the more strikingly as they were arrived at quite independently of each other.

† Morgagni, *Epist.* IX., Art. 25, Plura corpuscula per medullæ oblongatæ crura cum aphonia. *Epist.* XIV., Art. 35, softening of the medulla oblongata with aphonia. *Epist.* LXII., Art. 5, softening, and where, on some pressure, blood issued from the septum and the parts at the side of the sixth pair (that is the corpora olivaria), with aphonia. Serres and Magendie, *Journal de Physiol.*, t. II., p. 178, Pl. I., Fig. 2, lett. 4. Loss of speech with inflammation of the pons Varolii, and of the corpus olivare. See also several cases in W. Nasse's dissertation, *De Singularum Cerebri Partium Functionibus.* Bonnæ, 1845, p. 47 *et seq.*; Longet, *Anat. et Physiol. du Système Nerveux*, t. I., pp. 406 *et seq.*

We must, however, in estimating the value of cases with difficulty or loss of speech from a central cause, distinguish those in which the peculiar mechanism of the movements of the tongue necessary for articulation is impaired—from the diseased condition of the corpora olivaria—from those where the cause is situated higher up.

Thus, many years ago, Bouillaud thought that impairment of speech was to be ascribed to an affection of the anterior lobes of the brain, in opposition to which Pinel stated, that in several cases of difficulty of speech no morbid changes were discoverable in the anterior cerebral lobes.* Bouillaud, has, however, correctly remarked on this point, that we must carefully distinguish the examples in which the memory of words was paralytically lost, from those in which the mechanism of expression was impaired from paralysis of the tongue; as he had spoken only of the former cases of loss of memory of words.†

This lesion of speech occasionally occurs, where the patients have forgotten the signification of words and designate a thing by a term which has not the least connexion with it. Generally speaking, the patients are quite aware that they are using a wrong word; such instances I have often observed: if we suggest the term intended, they immediately recognize it, and rejoice at having recovered it.‡

There is, however, a third cause of loss of the power of articulation and of speech, which must be borne in mind in the examination of affections of the brain.

* Pinel and Magendie, *Journal de Physiol.*, t. V. pp. 340 *et seq.*

† Magendie, *Journal, l. c.* t. VI. pp. 19 *et seq.* See a very remarkable instance of this recently recorded, where, in consequence of a wound, a bony splinter from the os frontis, above the left eye, compressed the anterior part of the hemisphere, subsequently causing loss of speech, which faculty was completely regained after the removal of the fragment by the trepan.—*Gazette Médicale de Paris,* 1857, No. 36, 5th September, p. 567.

‡ Marcé has recently collected several cases of loss of the power of uttering words, or of combining sounds to form words, and even of the loss of the power of writing, and has attempted to show that the organ for these psychical combinations is situated in the cerebrum. See *Gazette Médicale*, 1856, Nos. 48 and 50, December, pp. 777 *et seq.* A case of this kind occurred to me some time ago, in a person who constantly used a different word from that he wished to articulate; although he was perfectly conscious that the word he uttered was not the right one, and was, in consequence, fretful and dejected. To my amazement, he was unable to read, even with large printed letters; and he was equally unable to write; the letters he placed upside down, or made illegible figures, although as an experienced merchant he had been able to read and write very well. There

Thus, we regard the corpora olivaria merely as auxiliary organs, or auxiliary ganglia, which, by their connexions with the nuclei of several nerves of the medulla oblongata, bilaterally produce a number of combinations of muscular movements. To these belong the combinations required for the articulation of words, for which, especially the hypoglossus, and partly also the facial nerve, likewise connected with the corpora olivaria, must be excited. We by no means, however, consider the corpora olivaria to be organs whereon our will directly acts; this takes place, I am convinced, chiefly in the corpora striata, an injury of which is also invariably followed by paralysis.

Therefore, if these organs, on which the will appears more immediately to act, be disturbed, paralysis of the tongue and neighbouring parts renders the utterance of words wholly impossible. In slighter degrees of affection, inflammation of the pia mater in the ventricle, above the corpora striata, with more or less softening, I saw stammering and difficulty of utterance produced in mania idiopathica.*

Hence it would appear, that the medulla oblongata and corpora olivaria may be perfectly sound in cases of loss of speech, without our being justified in supposing that they are not most intimately connected with the mechanism of speech and the articulation of words. It is self-evident, that in affections of the pons Varolii, with loss of speech or voice, of which many cases are on record, the lesion may have destroyed the conducting filaments connecting the corpora olivaria with the parts situated higher, as corpora striata.

was no defect in his sight, but he had lost the faculty of combining letters so as to form a word, and consequently, could not indicate his name. It appeared to me very strange that he retained the power of adding up figures. As in many cases quoted by Marcé, the tongue was not paralyzed in this instance. The defect in this patient was evidently situated in the cerebrum, and I readily admit, with Marcé, the existence of a combinative organ for these psychical operations in the brain, but we are still far from being able to define with certainty the exact situation of this organ, although it is probably to be sought under the os frontis.

* To show this connexion between the corpora striata and spinal cord, it is scarcely necessary to quote the observations of Turck, that after apoplexy in or about the corpora striata, granular cells form and follow the course of the fibres in a downward direction, so that they are met with in the spinal cord, below the decussation, on the opposite side from the seat of disease in the brain. See *Zeitschrift der k. k. Gesellschaft der Aerzte zu Wien*, January 1850. Also in Donder's *Lancet*, 1850, 5e Jaarg., pp. 584 *et seq.*

Sometimes the defect lies in the nuclei of the nerves themselves. Of this a very remarkable example occurred to me not long ago, in the medulla oblongata of a maniac, who, in consequence of long-continued idiopathic mania, had fallen into a state of complete dementia, and began progressively to stammer, his speech at last becoming at times nearly unintelligible; he was also affected in his deglutition, which became difficult. Besides the results of inflammation of the pia mater on the upper surface of the brain, I found, in the medulla oblongata, the ganglionic cells in the nuclei of the hypoglossus, and also partly, although not so numerously, in those of the accessory nerve, in a state of blackish-brown degeneration, which I at first mistook for little points of blood. On closer examination, however, it appeared, as Professor Nasse of Giessen, who was accidentally with me, also observed, that they were degenerated ganglionic cells. On many we could distinctly recognize the external neurilemma, passing over into the filaments. Among these dark ganglionic cells, which appeared quite filled with granular, very dark-brown pigment, we could discover some lighter-coloured and some healthy cells. In the rest of the medulla, and in the corpora olivaria, similar morbid ganglionic cells did not exist; the colour was much darker than sometimes occurs in very old persons, and the cells were quite filled with the colouring matter. In this case, therefore, the stammering and difficulty of swallowing had probably arisen from disease of the ganglionic cells in the nuclei of the hypoglossal and accessory nerves; but as the ganglionic cells were not all degenerated, the paralysis was not complete. The cause of the latter is consequently not invariably situated in the corpora olivaria; in partial destruction of the nuclei of the hypoglossal and accessory nerves the effect must, however, be the same, as the corpora olivaria in this case cannot excite the latter to action. The statement of the younger Pinel, which I have above quoted, that in the stammering of mania the corpora olivaria are always degenerated, is therefore not correct.*

* These morbidly affected parts may be very limited. In this respect, a case communicated by Dr. Panthel is remarkable, of a youth of twelve years, who, in consequence of violent mental emotion, had suddenly lost his speech and voice, although he could make all the motions of the tongue and lips regularly, and in all possible directions. Deglutition and respiration, too, were quite free. Every attempt to speak, however, immediately produced spasms in the muscles of the larynx, governed by the hypoglossal nerve, in the sterno and hyothyroid and sternohyoid muscles. On compressing these parts with the hand, the spasms were

Perhaps we may refer to the central causes in the brain and corpora striata, a case communicated by Andral, of an old woman, who, in consequence of an attack of apoplexy had lost her speech, while she perfectly retained her intellectual powers. There was in her case paralysis of the tongue, without any other lesion of motion or sensation.

In this case, on the postero-external surface of the left corpus striatum and in the centrum ovale of Vieussens, on the right side, two very much softened and discoloured spots were found, while all the other parts of the brain were healthy.* In most instances, this central affection is not limited exclusively to the corpora striata, but extends also to the neighbouring parts, for example, in the centrum semi-ovale of Vieussens, through which the fibres connecting the corpora striata with the convolutions and cortical substance pass:

instantly controlled and the speech restored. See *Geneesk. Courant* of the 16th December, 1855, No 50, translated from the *Deutsche Klinik.*

Hence it appears that the ganglionic cells of the hypoglossal nerve, which minister to the motions of the tongue, were undisturbed, but the centres by which the bilateral combinations for speech and voice are governed, were morbidly affected, while those for deglutition and respiration were sound.

A second case lately sent to me by Dr Roëll, was that of a woman aged twenty-eight, who, within two years, had become epileptic and quite silly. She spoke indeed, but there was in her tone and accent something strange, which she could not control. The sound of her voice varied without any reason nearly an octave up and down, and often ended in a sharp, high, discordant tone. Latterly, both speech and deglutition were difficult, apparently from paralysis of the right side of the tongue. In this case, I found atrophy of the right corpus olivare, and likewise scattered dark ganglionic cells in and around the nuclei of the hypoglossi, especially that of the right hypoglossus. The entire medulla oblongata had fallen into a state of decided fatty degeneration. In the fits, the patient often bit her tongue. It is not probable that the dark degeneration of the ganglionic cells was of very recent occurrence, though this would certainly closely correspond to the symptoms above detailed.

On the 10th of February, 1859, I had an opportunity of examining the medulla oblongata of an epileptic patient who died in a fit, and who had never bitten her tongue; in this instance, however, an apoplectic attack had occurred some time previously, with degeneration in one corpus striatum. It was remarkable, that on this side the materies nigra in the crura cerebri had become perfectly orange-coloured. I found also, in the nucleus of the hypoglossus, some dark cells similar to those above mentioned. The speech, too, had in this case been affected.

* Andral, *Clinique Médicale*, Chap. IV., Observ. XVII.

a change which may be attended with paralysis of the tongue and loss of speech.*

From the foregoing, I think we may reasonably infer, that the corpora olivaria are to be regarded as auxiliary ganglia, which, by their mutual connexion, produce a bilateral action, and by their intimate connexion with the nuclei of the hypoglossi, develop, while their influence on other nerves is undiminished, the numerous combinations required for the articulation of words. This view is greatly confirmed, both by my own pathological observations of affections of the corpora olivaria with loss of speech, as well as by those derived from the works of other authors.

Hence, too, we can explain the greater size of the corpora olivaria in man than in other animals; and at the same time we obtain a proof that these organs also discharge other important functions, and bring into action complicated muscular movements, as I shall endeavour more fully to point out in the two following chapters.

* See many examples of this in Lallemand, *Recherches sur l'Encephale*, in the index under the word *Aphonie*.

CHAPTER VI.

ON THE CORPORA OLIVARIA IN ANIMALS.

I HAVE already remarked, that the corpora olivaria in animals are much smaller than in man, and that they occur only in the mammalia. This observation is to be found in several authors, although, so far as I am aware, the subject has not been accurately investigated.

Serres describes olivary tracts not only in the mammalia, but also in birds, reptiles, and fishes.* He, however, acknowledges that the grey substance of the corpora olivaria occurs only in the mammalia, and that it is much less in apes than in man; but, according to the order in which he names the animals, it would appear as if they were larger in the Cetacea and Phocæ than in the Ruminantia and Rodentia; in which last, according to him, they are no longer plaited.† It is, however, well known, how little reliance can often be placed on these investigations of Serres. Magendie and Desmoulins assert, that in the ruminantia and the pig the corpora olivaria no longer exhibit any trace of a corpus dentatum.‡

Rolando says, that, after a careful examination of the place where the corpora olivaria should be situated, he thinks he can assert, that it is impossible in the cow, pig, sheep, and goat, to find anything at all resembling the yellow plaited or dentated lamina of the corpus olivare to be seen in man. Sometimes it is even difficult to see the tubercula olivaria externally.§

According to Tiedemann the corpora olivaria in the orang-outang are very large, five lines long and one and-a-half broad.|| In the

* *Anatomie comparée du Cerveau.* Paris, 1826, t. II. pp. 197 *et seq.*

† *l. c.* p. 196.

‡ Magendie et Desmoulins, *Anatomie des System. Nerveux des Animaux à Vertèbres.* Paris, 1825, t. I. pp. 226 *et seq.*

§ Magendie, *Journal de Physiologie*, t. IV. p. 337.

|| *Untersuchungen ueber die Natur des Menschen, Zeitschrift für Physiol.*, 2 B, p. 22. As this measurement, however, is taken only from the external

Chimpanzee I found the corpora olivaria much smaller, only two French lines in length, and very slightly prominent.

Of the semnopithecus nasicus, Tiedemann says :—" Olivæ vix prominentes."* Also in the lemur mongos they seem to be very small.† Tiedemann states, that in the lion the corpora olivaria are so small that they are not visible externally; but that he has, however, seen them in the centrum.‡ In the cavia aguti, he says, they do not project externally; but that internally there is a grey mass, that gives the appearance of a corpus dentatum.§ In the phoca he found the corpora olivaria so small that he could scarcely discover them,|| which is confirmed by W. Vrolik.¶ In the dolphin, according to Tiedemann, the corpora olivaria exhibit no external elevation ; but internally he found enclosed in the medulla an accumulation of grey substance (corpus dentatum olivæ).** According to Carus, they are remarkably large in the dolphin, in which he finds an approximation to the human brain.††

Cuvier speaks only very briefly of the corpora olivaria, stating that in the bear they exhibit scarcely any elevation, and that in the lynx, the melas and phoca they completely coalesce with the corpora pyramidalia, and can be distinguished only by the line of origin of the twelfth cerebral nerve.‡‡.

On the whole, the corpora olivaria have attracted very little atten-

swelling, and is therefore very indefinite, we cannot rely on it with certainty. In the drawing given by Tiedemann of the brain of the orang-outang, from which he has taken his measurement, the corpora olivaria amount scarcely to four French lines, of which standard Tiedemann has made use.

According to Valentin, the corpora olivaria in man are five Parisian lines in length and three in breadth. See *Hirn- und Nervenlehre*, p. 234.

* Tiedemann, *Icones Cerebri Simiarum, etc.*, Tab. IV., Fig. 6, p. 27.

† *l. c.*, Tab. IV., Fig. 2. W. Vrolik and I found them very slightly arched in the stenops. *Recherches d'anat. comparée sur le genre Stenops d'Illiger in Bijdragen tot de Dierkunde, uitgegeven door het Genootschap Nat. Art. Mag.* 2e Afl., p. 31. Amsterdam, 1851.

‡ *l. c.* Tab. III., Fig. 4, *d d*, p. 21.

§ *l. c.* Tab. IV., Fig. 12, p. 30.

|| *l. c.* Tab. II., Fig. 8, *c c*, p. 16.

¶ W. Vrolik, *Specimen anat. zöologicum de Phocis*, 1822, p. 57. I have since found the corpora olivaria in the phoca not smaller than in the ass.

** *Zeitschrift für Physiol.*, t. 2, p. 254.

†† C. G. Carus, *Versuch einen Darstellung des Nervensystems*, Leipsic, 1814, p. 244. This is so strange that a confirmation of the observation appears to me to be very necessary.

‡‡ *Leçons d'anatomie comparée* de Cuvier, 2 édition, Paris, 1845, t. III. p. 105.

tion, and so far as I am aware, have not been accurately microscopically examined in animals.

Having, however, endeavoured to show, especially from numerous pathological observations, and also from the close connexion between the corpora olivaria and the hypoglossal nuclei, that these bodies are to be regarded as auxiliary ganglia for the numerous motions of the tongue in the articulation of speech, I thought it of the greatest importance to trace accurately the difference between them, as they occur in man and in animals. Indeed, their presence in the mammalia distinctly shows that they cannot serve exclusively for the articulation of words, which is peculiar to man alone, but that they must be closely connected also with other functions. This appears even from their situation in the human subject; the corpora olivaria reach much higher than the roots of the hypoglossal nerve, even to the inferior boundary of the pons Varolii,* and as far as the roots of the facial nerve; their superior part cannot, therefore, be connected with the hypoglossus, but must be subservient to other functions.

In my first examination of the corpora olivaria in a cow, I was very much surprised to find, in transverse sections, under the microscope, no trace at all of corpora olivaria in the situation where they occur in man; until I observed that, while the hypoglossal nerve in this animal arises much lower down, the corpora olivaria are in like manner placed in the situation of the origin of this nerve, but possess only few convolutions. It, however, struck me as remarkable, that in these animals I found the corpora olivaria situated between the hypoglossus and the septum or raphe of Stilling, behind the corpora pyramidalia, while in man they are, for the most part, located externally to these parts.

Now on examining the whole medulla oblongata more accurately, I discovered to my surprise that in these animals two corpora olivaria exist on each side, the one very high, immediately under the pons Varolii, on a level with the facial and abducent nerves, and situated to the outside of the course of the latter, and a second, much lower, but placed to the inside of the trunk of the hypoglossus, without any distinct communication being traceable between these two corpora olivaria.

For such reasons I thought it important to examine accurately and compare the latter organs in several animals.†

* Stilling, *Pons Varolii,* Tab. I.

† I gladly take this opportunity of returning my special thanks to

In two apes (the Cercopithecus cynomolgus and Cynocephalus papio), I found the corpora olivaria single on each side, just as in man. They are here, although smaller, still tolerably well-developed; they also exhibit a hilus and several convolutions; they commence high up in the medulla, between the facial and abducent nerves, to the outside of this last nerve, or, if we will, to the outside of the corpora pyramidalia, while the upper part of the corpus ciliare in man is, for the most part, situated more internally behind the corpora pyramidalia.*

They extend also in apes to the inferior roots of the hypoglossus, of which some fasciculi, just as in man, perforate the corpora olivaria; others are, in this case likewise, situated to the inside of the latter. Here, also, therefore, accessory nuclei occur on a level with the hypoglossus, especially on the inside.

The close connexion between these corpora olivaria and the hypoglossus is, in this instance also, very evidently seen to take place through numerous fasciculi of fibres, by far the majority of which pass into the external marginal fibres of the corpora olivaria; some few, also, go inwards into the hilus, and thereby, although they are less developed, agree very closely with those connecting fibres between the corpora olivaria and the hypoglossal nuclei, which I have pointed out in man,† the pedunculi olivæ of Lenhossek.

Hence it appears, that these fasciculi—which, however, in apes appear in a few sections only, as closely connecting filaments between the corpus olivare and the hypoglossal nucleus—are subservient to other functions than the articulation of the voice, as I shall subsequently endeavour to show. These fasciculi do not occur in other mammalia, although in those also the corpora olivaria are intimately connected with the hypoglossal nuclei.

In all the following animals examined by me, as the cat and dog, as types of beasts of prey, and also in the paradoxurus musonga; further in the rodentia, as the rabbit and cavia aguti; in the herbivora, as the horse, the ass, the cow, double corpora olivaria occur, namely, two on each side, the superior of which is situated immediately on a level with the origin of the facial nerve,‡ between this

Westermann, Director of the Zoological Gardens at Amsterdam, for his kindness in complying with my request, and sending me several animals, whereby he has enabled me to pursue this investigation.

* Stilling, *Pons Varolii*, Tab. 1, *s*.

† Fig. 1, *i*, *q*, *p*.

‡ Fig. 11 *i*, in the cat; Fig. 4, *p*, *q*, in the calf. The height I have indicated in Fig. 8, in the dog; Fig. 9, in the cat, Fig. 10 in the ass, *a a*.

nerve and the abducent, that is, somewhat more outwardly. They commence with the first traces of the facial nerve and disappear in lower sections, where these roots also cease to show themselves. They differ in extent, however (as we shall more fully see), in different animals.

Without being in any direct connexion with these corpora olivaria, which from their situation I shall call *corpora olivaria superiora* or *externa*, others are placed lower down, but are situated much more to the inside and adjoining the raphe, mostly behind the corpora pyramidalia.* These last commence and terminate with the roots of the hypoglossus, to the inside of which they are located, several roots of this nerve penetrating through the middle of the corpora olivaria. With the inferior roots of the hypoglossus these corpora olivaria also terminate, and, so far as relates to their lateral situation, therefore, coincide most closely with the inner accessory nuclei or corpora olivaria of man; although the latter are smaller, and are properly only ramifications issuing from the corpus ciliare.

In their internal structure, both the superior and inferior corpora olivaria quite agree with those of man; they both possess an innumerable multitude of very small multipolar cells; they are similarly bounded by marginal fibres, which are connected with these cells, and radiate externally in various directions;† they make, however, a much smaller number of convolutions than in man, and present only a feeble trace of hilus. Although there are no such thick connecting fibres (pedunculus olivæ) as in man, there are, in the decussating network of fibres, very many rays or radiating fibres of Stilling, which connect these corpora olivaria with the nuclei situated on the floor of the fourth ventricle, namely, the superior with the nucleus of the facial nerve,‡ the inferior with the nucleus of the hypoglossus.§

The superior are situated behind the so-called trapezoid body, beneath the pons Varolii,|| the transverse fibres of which pass through the anterior part of these corpora olivaria to unite more or less with their marginal fibres, and are thus connected, through the raphe with those of the other side.¶ From the marginal fibres too, more posteriorly, several fibres radiate in a transverve direction, towards the

* Fig. 12, behind *k*, *b*, in the cat. See the height in Figs. 8, 9, and 10 *b b*.

† Fig. 2 *k*, Fig. 11 *k*.

‡ Fig. 2 *i*, *k*, *d*, with the nucleus of the facial nerve in the cat; and Fig. 4, *p*, *q*, *f*, in the calf.

§ Fig. 12, *k*, *d*.

|| Figs. 8, 9, 10 *a a*.

¶ Fig. 4, *q*, *p*, *a*; Fig. 11 *k*, *a*. These fibres of the corpus trapezoides radiate transversely through the raphe; in the cat they cover almost completely the longitudinal fibres of the raphe. Fig. 2 *a*, also Fig. 4 *a*.

raphe.* They are themselves interwoven with very minute fibres, mostly in a transverse direction.†

The inferior consist of three bodies, placed obliquely and adjoining one another, which are situated in an oblique direction behind the corpora pyramidalia. They are much more strongly interwoven with transverse fibres belonging to the fibræ arciformes, and thus exhibit a striking similarity to the inner corpora olivaria or accessory nuclei in man.‡

The superior corpora olivaria vary, however, considerably in different animals; I have found them most highly developed in the beasts of prey, as the dog and cat, as also, though somewhat less so, in the paradoxurus musonga. They are smaller in the rodentia, the rabbit, and the Cavia aguti; still smaller in the herbivora, the calf, horse, and especially the ass, where they are very slightly developed, lie more anteriorly in the corpus trapezoides, and consist at most of two or three oblong round nuclei, which, on a superficial inspection, might easily be overlooked.

For these reasons I have made an accurate drawing of them in the cat and calf.

We see them as they are in the cat in Fig. 11, *i*, *k*.§ At the inner side, two roots of the abducent nerve, *h*, *d*, are visible. The corpora olivaria here form a double curve, like an S (see *i*), a process being connected with it and situated on the same side, *k*, and are surrounded by numerous marginal fibres, although they are sharply defined from the surrounding tissue. Many radiating fibres, which in other sections were still more numerous, connect these corpora olivaria with the facial nucleus, *d*, while, as we have above seen, other transverse fibres connect them through the raphe with those of the opposite side.

In the calf they are less developed and smaller; they are here not so coherent, and are divided into three separate bodies,‖ which, although unconnected, nevertheless exhibit exactly the same struc-

* Fig. 4 and 11. † Fig. 4 *p*, *q*; Fig. 11 *i*, *k*. ‡ Fig. 1 *k*.

§ In this drawing only a trace of the facial nerve occurs in the nucleus at *d*. The section was taken exactly between two bundles of the facial nerve, where a blood-vessel, *f*, is visible in its course; in higher, and particularly in lower sections, numerous roots of the facial were again visible. I may take this opportunity of observing, that above and below the course of a nerve in the medulla oblongata, especially of the abducent, facial, glosso-pharyngeal, vagus, and hypoglossal nerves, a blood-vessel is usually situated, which follows the course of the nerve into the nucleus. I shall subsequently show the importance of this.

‖ Fig. 4, *p*, *q*.

ture. But in some sections the two smaller, *q*, were connected and formed but one fold. From the top of these two, fibres also radiate anteriorly into the trapezoid body, *p*, *q*, *f*, and are connected by many radiating fibres with the facial nucleus. On the outside, somewhat more posteriorly, we see again two groups of nuclei, or ganglionic cells, which, however, do not belong to the corpora olivaria, are distinguished from the latter by very large multipolar ganglionic cells, and belong to the facial nerve.* These also are of general occurrence, though they are not always found exactly on a level with the corpora olivaria; most usually they are a little above the facial nerve. To this point I shall again advert.

As I have remarked, these superior corpora olivaria are covered by the transverse fibres of the so-called trapezoid body,† which form very thick fasciculi, and unite through the raphe with those of the other side. In its transverse course the trapezoid body surrounds the facial and auditory nerves, and appears to be closely connected with the latter nerve. Serres, however, shows from several comparisons, that this trapezoid body bears no fixed relation in size to the development of the auditory nerve, the latter being, in some animals, large, where the trapezoid body is small, and *vice versâ*.‡ On the contrary, this body appears to be broader, in proportion as the pons Varolii is slighter in animals.§ Sometimes a trace of it occurs also in man.‖

The other or inferior corpus olivare varies much less in size and shape in different animals, so that I have been unable to observe anything characteristic in it. As we have above seen, it lies to the inside of the hypoglossus behind the corpora pyramidalia,¶ and is connected both with the nucleus of the latter by radiating fibres, and with the raphe by transverse fibres. The radiating fibres are very numerous, especially in the rabbit.

The general opinion is, that the corpora olivaria are wholly wanting in birds. I too thought I had seen this established from several

* Fig. 4 *o*, *f*.

† Fig. 4, *p*, *q*, *o*. Fig. 11 C, and Figs. 8, 9, 10. See also Tiedemann, *Icones Cerebri Simiarum*. Tab. I., Fig. 5 *n*, in the Simia nemestrina, Tab. III., Fig. 4 *e*, in the Lion. So also Serres, *Anatomie Comparée du Cerveau*, Tab. XI., Fig. 231, T. Tab. XIII., Fig. 249, T, and in several drawings. In animals in which the pons is slighter, this body appears more uncovered.

‡ Serres, *l. c.* t. I., p. 331.

§ Serres, *l. c.* t. II., p. 209.

‖ Arnold, *Icones Cerebri*, Tab. II., Fig. 5, *b*, and *Bemerkungen ueber den Bau des Gehirns*, Zurich, 1838, p. 21.

¶ Fig. 12, *c*, *k*.

sections of the medulla oblongata, until, on carefully examining a series of consecutive sections of the whole medulla oblongata, I found that in birds also we meet analogous forms, although less elaborately constructed. Thus, on the level with the hypoglossus are very dense groups of ganglia on the front of the medulla, partly to the inside, partly to the outside of the hypoglossus, which, consisting of two or even three oval groups of ganglionic cells, are here and there confluent, and thus present a complete analogy to the inferior corpora olivaria, and also quite agree with them in situation. But they differ in their tissue; as they are composed of large multipolar ganglionic cells, which in the corpora olivaria are smaller.

Similar, but smaller groups occur on a level with the facial nerve, of which one group is situated within the abducent nerve and raphe, and another externally to this nerve, consisting of large ganglionic cells, so that we must consider these bodies to be analogous to corpora olivaria.

To what nerves these corpora olivaria are more closely related, is a question of especial importance. In man this is more difficult to decide, since the corpora olivaria in the human subject extend as a continuous track through the greatest part, or nearly the whole of the medulla oblongata, and may, therefore, be connected with all the nerves of the medulla.

In the lower mammalia, the medulla oblongata is, however, extended to a proportionally much greater length: the nerves in these stand further from one another, and the corpora olivaria, which in man and in the apes are connected to form one compound body, are separated in these animals into distinct groups, belonging to particular nerves.

Thus, in all animals, the inferior corpus olivare is contained exactly within the limits of the roots of the hypoglossus,* and as, especially in the dog, and also in the ass, the glosso-pharyngeal nerve,† together with the vagus and accessory,‡ reach much higher than the top of the inferior corpus olivare, we may suppose that this body is in no way connected with these last nerves.

The limitation of the superior corpora olivaria may appear somewhat more difficult; indeed three nerves, the abducent, facial, and

* Figs. 8, 9, 10, *b b*, 12. I can guarantee the accuracy of these drawings, as I have determined the relative distances of the nerves and other parts with a pair of line compasses, which easily show even the one-fiftieth of a millimetre.

† Figs. 8, 9, 10, see 9.

‡ Figs. 8, 9, 10, see 10, 11.

auditory, occur on a level with these bodies. As they, however, are very closely connected by radiating fibres exclusively with the facial, we must assume that they are auxiliary ganglia of this nerve.

We shall, therefore, now proceed, after these more purely anatomical considerations, to an accurate examination of the action of the auxiliary ganglia.

CHAPTER VII.

ON THE FUNCTIONS OF THE CORPORA OLIVARIA, AND ON THE DIFFERENT AUXILIARY GANGLIA IN THEIR CONNEXION WITH THE SEVERAL NERVE-NUCLEI.

SINCE, as we have seen, the corpora olivaria are, in animals, divided into two groups, the superior, connected with the facial, the inferior with the hypoglossal nerve, I shall now proceed to examine each separately, as well as the particular auxiliary ganglia, occurring in addition to these bodies.

With respect, in the first place, to the superior corpora olivaria, they are, as I have shown, most intimately connected with the facial nerve; but as they are also connected with one another by transverse filaments passing through the raphe and through the corpus trapezoides, it may be inferred that their influence on the facial nuclei, and through them on the nerves, must be bilateral. We have, indeed, found that the two facial nuclei are reciprocally connected on the floor of the fourth ventricle by transverse fibres, while it is still uncertain whether a mutual connexion exists also between the superior fibres of the nerve itself, which run directly over the nucleus.* Thus to secure bilateral action, no need of corpora olivaria or accessory ganglia should apparently exist. The effect of these last on the facial nuclei can be only an indirect reflex action, whether produced by the will, or by other stimuli, while the will, acting directly on the facial nuclei, is capable of producing separate movements. The reciprocal and close connexion between the nuclei of the facial nerve appears to me, as I have already remarked, to be related to the bilateral action of most of the facial muscles; thus, we usually move the eyelids, the alæ nasi, and the orbicular muscle of the mouth simultaneously on both sides, and as this bilateral action appears to be stronger in animals than in man, we find in the former a correspondingly greater quantity of transverse fibres, apparently uniting from behind the nuclei of the facial nerve.

* See above, pp. 117 *et seq.*

To the corpora olivaria would therefore belong the more complicated actions in the expression of the passions, which may be reduced to a species of reflex actions, as in them we bring our face into motion almost without being conscious of so doing, and particularly as this expression is the same in all men.* We may, indeed, voluntarily produce the same movements, and so artificially imitate the passions, showing that in this instance the superior portions of the corpora olivaria are not wholly withdrawn from the influence of our will, and that in every case the stimulus will be communicated from the brain to these bodies; but we do this rather by mentally exciting in ourselves the feelings we wish to express, than by any special influence on the muscles of the eyes, the mouth, &c.†

The above-described difference between the corpora olivaria superiora in different families of the animal kingdom appears to me to be particularly remarkable.

Thus we saw that in beasts of prey these bodies are more highly developed than in herbivorous animals. In the latter, the trunk of the facial nerve itself is, it is true, very thick and large, but this depends upon the extent and volume of the several muscles it has to set in motion. But the expression of the passions, especially of anger, is much stronger in the faces of the carnivora than in the herbivora, which, as Bell correctly remarks, scarcely express their passions in the face.‡ In passion, in the bull, the eye sparkles and

* That these movements of the face in passions, laughing, &c., are, in fact, reflex movements, and by no means excited by the direct influence of our will, appears among others, from the remarkable case related by Romberg, of total loss of all voluntary movement of the face, while the patient laughed with all the complicated movements which attend the act in the healthy subject. *Lehrbuch der Nervenkrankheiten*, 1846, 1 B. 3 Abth., p. 661. Nor is the opposite case less remarkable, where the voluntary movement of the face was undisturbed, while the reflex motion of the right side was lost. Romberg, *l. c.*, p. 662.

† It might indeed appear, that in man the corpora olivaria are not in connexion with the facial nerve, since, according to Stilling, the superior fibres of the latter seem to arise somewhat above the former; but this is not the case. The top of the corpus olivare in the human subject occurs in the same sections as the lowest fasciculi of the facial nerve, and is, moreover, lost in a vertical and upward direction in distinct ganglionic cells, apparently in connexion with the nerve. The upper part of the corpora olivaria in man must therefore correspond in action to the corpora olivaria superiora in animals.

‡ Charles Bell, *Essay on the Anatomy and Philosophy of Expression*, 2nd edition, London, 1824.

the nostrils are dilated; but in the carnivora, the lips are retracted, the canine tooth is bared, the flashing of the eye is terrific, and the peculiar snarling expression is presented.* The muscles which co-operate in the production of the latter, called by Bell the musculi ringentes, are wholly wanting in the herbivora; the slight development of the corpora olivaria superiora of the latter, therefore, quite corresponds to the trifling degree of expression in the face. These bodies, too, in the ass, which has scarcely any expression in its face, are accordingly much smaller than in the bull or cow.

I have lately had an opportunity of examining the corpora olivaria in a seal; I found the inferior corpora olivaria nearly as in the dog, cat, &c.; but the superior were entirely absent. This is very important, as in the seal, in consequence of the unyielding nature of the skin, no expressive movements can take place.

In birds, the superior corpora olivaria on a level with the facial nerve, are still less developed than the lower, and consist only, as I found in the hen, of a few small groups of large ganglionic cells, within and on the outside of the abducent nerve; they are also connected by radiating fibres with the nucleus of the facial. This exactly corresponds to the slight development of this nerve, of which Longet correctly says:—"Les oiseaux, chez qui les muscles de la face sont si peu nombreux, offrent un nerf facial rudimentaire; les filets peuvent servir dans l'expression des passions, en faisant contracter les muscles qui, chez certains oiseaux, redressent les plumes mobiles de leurs oreilles et celles de leur cou. C'est évidemment le nerf facial qui influence l'érection des plumes du cou chez le coq de combat, se préparant à la lutte."†

In addition to these corpora olivaria superiora, other ganglionic groups, however, occur, which are closely connected with the facial nerve, and of which I have already spoken.‡ These are met with in all the animals I have examined; they are intimately related to the trunk of the nervus trigeminus, so that Stilling even thinks he sees in them, in the human subject, the inferior nucleus of the trigeminus.§ But in this view I cannot at all agree with him, since the trigeminus, as we have seen, is situated between the auditory and facial nerves,

* *l. c.* † Longet, *Anat. et Phys. du Syst. Nerv.*, t. II., p. 170.

‡ See above, p. 176, Fig. 4 *o*, *f*. In other sections, a little higher or lower, this ganglionic group is usually larger, and has coalesced into a round mass, as is represented by Stilling in the human subject.

§ *Pons Varolii*, Tab. III. *r*, p. 33.

and is separated by the facial from these groups, while the root of the trigeminus, moreover, descends much lower.*

I have already spoken of the influence of the trigeminus on the facial nerve, and from the filaments passing from the fifth nerve to the facial nucleus, I have sought to explain the multitudinous reflex actions elicited by the application of stimuli to the face, or often, for example, in toothache. The use of these ganglionic groups might, therefore appear to be doubtful—but as they are connected posteriorly with the facial nucleus,† externally by several fibres with the root of the trigeminus, and especially with a ganglious mass present in that root,‡ we may suppose that they, too, are capable of producing a reflex influence on the facial nerve.

Among the actions developed by the influence of the trigeminus on the facial nerve, winking alone remains to be considered. This is absolutely a reflex action, produced by the trigeminus. It is well known, that after divison or paralysis of the first branch of the trigeminus, winking, on the application of stimuli to the eye, ceases.§

Yet here, too, comparative anatomy comes to our assistance. We have above seen that in birds, where there is little expression of passions depending on the facial nerve, the corpora olivaria superiora are also extremely slightly developed; but birds, in common with the mammalia, possess the power of winking, and it surprised me very much to find this same group of ganglionic cells to which we have ascribed the act of winking, as strongly developed, and equally closely connected with the facial nucleus by numerous fibres in birds as in the mammalia, confirming the idea I have put forward as to the use of this accessory ganglion.||

An analogous formation of an accessory nucleus or auxiliary gan-

* See above, pp. 133 *et seq.* † Fig. 4 *o, f.* ‡ Fig. 4 *r, o.*

§ Thus also the above-mentioned patient, in Romberg's case, could not voluntarily close the eyelids; but if the hand were quickly moved towards the eyes, or if the latter were suddenly directed towards a bright light, the eyelids were closed. And this took place also in sneezing. Romberg, *Nerv. Krankh.*, p. 659.

Still stronger is the case described by Romberg, of a patient with anæsthesia of the fifth nerve on the left side, in whom rough contact, even pricking the globe, did not produce winking, while he could, at will, powerfully close the eyelids, *l. c.* pp. 200 *et seq.* Here, therefore, the reflex action was cut off, while the direct influence of the will from the brain remained.

|| Winking, however, proceeds from a twofold cause; it arises in consequence of a strong impression of light on the optic nerve, and also from

glion occurs with the glosso-pharyngeal nerve, and consequently lower in the medulla, where it, therefore, appears to be in no direct connexion with the auxiliary nucleus of the facial nerve. In other respects the auxiliary ganglion is placed in the same direction, on the inside of the trigeminus, to which it is very closely connected by numerous fibres; so that we might regard it more correctly than the preceding almost as a part of the trigeminus, which, however, is not very probable. It is situated more anteriorly than that of the facial nerve, and is very closely connected with the nucleus of the glosso-pharyngeal by many more central fibres, which divide into a number of beautiful fasciculi. As, however, the glosso-pharyngeal nerve, according to my observations, perforates the root of the trigeminus itself, this auxiliary nucleus, which splits into two divisions, and contains larger multipolar ganglionic cells, is not separated from the root of the trigeminus by the glosso-pharyngeal nerve, as is the case with the facial.

As the glosso-pharyngeal nerve is, for the most part, a nerve of taste, and as its remaining motor branches are distributed to the pharynx and the soft palate, its muscular influence appears to be closely connected, perhaps, with deglutition, or in my opinion, rather with the sensation of loathing and squeamishness.

It is, therefore, not improbable that the accessory nucleus for the

touching the eye or eyelid. It is very important that, as Snellen shows in his very valuable dissertation, the stimulus of feeble light causes only a reflex action of the eyelid on the same side in a rabbit, while from the action of very strong light on one eye, both eyelids wink. In a healthy rabbit, on the other hand, the most violent pinching of one eyelid produces only motion on the same side. The optic nerve, as the author infers, therefore reflects bilaterally in the rabbit, the trigeminus only unilaterally. See H. Snellen, *De invloed der zenuwen op de ontsteking proefondervindelijk getoetst.* Utrecht, 1857, p. 24. Hence it would appear, that in the rabbit the above-described ganglionic groups, which are subservient to the act of winking, are not connected with one another by transverse fibres. In other respects, this writer goes too far, in wishing to apply what is true of one branch of the trigeminus in the rabbit to the entire of this nerve; as the reflex action of the trigeminus in deglutition is certainly bilateral. Involuntary winking, too, in man is bilateral, also in cases where it is not excited by the stimulus of light.

However, it is important that Heer Snellen has shown by an experiment (*l. c.*, p. 24), that winking continues to be excited by the action of light on the optic nerve, after the trigeminus is cut through, consequently a connexion must exist also between the roots of the optic nerves and the nuclei of the facial nerve.

glosso-pharyngeal also stands in the same close relation to this bilateral muscular action, in retching and other movements of the pharynx, as we have seen of the accessory nucleus with the facial nerve, namely, as a reflex ganglion.

The course of the nervus vagus and its connexion with different parts in the medulla oblongata, are, however, of extreme importance. We know, indeed, that the nervus vagus in particular exercises an extraordinary influence on respiration, and the discovery of the centre for the movements of the respiratory muscles is, in fact, a most important problem.

We have above spoken only very briefly of this nerve, and have seen that it arises from a nucleus, to the outside of the nucleus of the hypoglossus.* In proportion as we descend lower in the medulla oblongata, where the accessory appears as a motor nerve, this ganglion passes further backwards and towards the raphe, so that it is situated behind the nucleus of the hypoglossus;† bearing out the remark I have already made, that the nuclei for the motor nerves are situated nearer the raphe, and those for sensation or centripetal action more to the side.

My attention was, however, much attracted by a bundle of longitudinal fibres, which is situated to the outside of the nervus vagus, near its entrance into the nucleus, and which disappears in higher parts, where the vagus no longer shows itself in transverse sections.‡ This fasciculus of longitudinal fibres becomes larger and interwoven with more numerous transverse fibres the lower we take the sections, until it finally passes into the lateral columns of the spinal cord.§

It appeared to me, from accurate investigations, that from this fasciculus of longitudinal fibres different nervous filaments pass into the vagus itself,|| and proceed, with the trunk of the nerve, outwards. Between these longitudinal fasciculi several ganglionic cells also occur. The fasciculus is, commonly, closely circumscribed by marginal fibres which are given off as curved fibres, to decussate in the raphe;¶ other fibres radiate more anteriorly, where they disappear in the root of the nervus trigeminus,** which thus influences respiration.

* Fig. 1 *g g*, *e*, *f*, p. 92. † Fig. 2 *a*, *k*.

‡ Fig. 1, at *s*, Fig. 2 A, *l*, *m*, Fig. 12 at *e*. See also Stilling, *Medulla Oblongata*, Pl. V. VI. *m*.

§ Stilling, *Medulla Oblongata*, Pl. VI. V. *n*. Pl. IV., Fig. 2 at *n*. Pl. III. and II. *e e*, pp. 23 *et seq*.

|| Fig. 1 *s*. ¶ Fig. 1 *m*, *n*, *b*. ** Fig. 1 to the outside of *m*, *n*

In parts situated lower down, a number of fibres were distinctly seen, which, running transversely behind the central canal, united as a commissure with the corresponding fasciculus of the other side,* to confer on respiration its invariably bilateral character. Anteriorly, too, fibres ended herein, which appeared to arise from the above-described marginal fibres, around the hypoglossal nucleus in front of the accessory nerve.†

Hence it appears satisfactorily established, that this fasciculus of longitudinal fibres is most closely connected with the vagus and accessory nerves, fibres from these nerves passing into it. Now, I have, in the first part of this volume, endeavoured to show, from experiments by Schiff, that the lateral columns of the spinal cord serve for the motions of the trunk, and therefore for respiration, the anterior columns for the movements of the extremities.‡

It is therefore extremely remarkable, that not only do these lateral columns terminate on a level with the nervus vagus, which is so closely connected with respiration, but also, that fibres from the vagus and accessory nerves appear to pass into them.

Hence it is easy to explain why, if the nervus vagus be centripetally excited, for example, by means of a rotary apparatus, respiration ceases, as the stimulus is now conveyed along the nervus vagus to the lateral columns of the medulla, which curve through cross rays again into the anterior grey horns of the spinal cord, to pass into the nuclei, whence the respiratory nerves arise.§

In this manner also, the ordinary mode of respiration is explicable. The nervi vagi appear to convey stimuli from the lungs, perhaps from the superabundant carbonic acid, to the lateral columns, whereby the phrenic nerve is in the first instance excited, and so inspiration

* Fig. 2 A, *a*, *k*, *d*. † Fig. 2 *a*, A. ‡ Essay on the Spinal Cord, p. 26.

§ It has been a subject of much dispute, whether in this experiment respiration stops in the inspiratory or expiratory stage. See Snellen, *Onderzoekingen over den invloed van den N. vagus op de ademhalingsbewegingen*, in the *Nederlandsch Lancet*, 1854-55, p. 421.

My esteemed friend Donders showed me, that during an experiment with needles inserted into the diaphragm, and then inclined forwards, an arrest of respiration took place in the inspiratory stage. I suspect, however, that the experiment in question does not fully establish this point, for the stimulus acts as well on that part of the longitudinal columns whence the phrenic nerve arises, as on that from which the intercostal and lumbar nerves spring. The diaphragm must therefore descend, but at the same time the thoracic and abdominal muscles are put upon the stretch ; whence it appears to me, that the muscles of inspiration and expiration are ensues. In the ordinary course of breathing, expiration follows on the cessation of this reflex action of the vagus on the phrenic nerve, in consequence of the elasticity of the lungs, as particularly observed in the remarkable case I formerly described of complete compression of the spinal cord, immediately beneath the root of the phrenic nerve, in which all respiratory movements and even speech were preserved intact. See *Nederlandsch Lancet*, 1851-52, page 52.

On the application of a stronger stimulus, a brief excitement arises in the phrenic nerve, and passes rapidly to the expiratory muscles, as in sneezing, coughing, &c.

Lastly, in birds, where the mechanism of respiration is the same as in the mammalia, a similar bundle of longitudinal fibres occurs on the outside of the vagus, although other parts are scarcely visible, as corpora olivaria; so that here too, the same relation is manifested between these fasciculi and the nervus vagus, to meet a like necessity in the mechanism of respiration.*

Hence appears clearly what I have above remarked, that the lateral columns of the spinal cord terminate in the medulla oblongata. At the same time, other new longitudinal fasciculi must be present to convey the orders of our will to the point of union for respiration, already described, enabling us voluntarily to quicken or to modify our breathing as may be necessary. These nervous filaments through which our will acts on the longitudinal columns, and through the

simultaneously contracted, perhaps in different degrees, according as one or other set has the predominance. This was subsequently confirmed by Snellen himself, who stated to me that he had often seen vomiting ensue in dogs during central irritation of the vagus, and arrest of respiration, thus indicating a simultaneous contraction of the abdomen. The same apears also from the investigations of A. von Helmolt, *Ueber die reflectorischen Beziehungen des Nervus vagus*, Giessen, 1856, who on strong irritation observed powerful contractions, also of the abdominal muscles. *l. c.*, p. 27 and 32, *note*.

* Dr. Stich relates a case, where perfect anæsthesia, not only of all the nerves of the trunk, but also of the accessory, vagus, glosso-pharyngeal, and fifth nerve was said to exist; so that the inhalation of acid vapours or mechanical irritation in the parts under the control of the vagus, glosso-pharyngeal, and trigeminus nerves produced no reaction. How respiration could continue and deglutition take place in this case, I cannot understand. See Schmidt's *Jahrbücher*, 1857, No. 3, pp. 355 *et seq.*

Unfortunately, no remark is made on this point. It appears to me, that the anæsthesia can have affected only the majority of the branches of the fifth and of the superior laryngeal nerves; but the case is too superficially reported to admit of any conclusion being drawn from it.

latter on respiration, we can, in fact plainly distinguish. Thus we have above described the fibres, which decussate and as conductors of the orders of our will, are lost in the nuclei, whence the nerves take their origin. We have also seen how these fibres run as marginal fibres round the nucleus of the hypoglossus, while some of them penetrate into that of the accessory more posteriorly situated.* But it struck me very forcibly, that on using a sufficient magnifying power, I saw some of these marginal fibres, and indeed the most external, along the outside of the hypoglossus, *a, a,* perforating the trunk of the accessory, A, and passing into the longitudinal tracts or fasciculi, *a, k, l,* which are situated behind and to the side of the accessory, and being lost there, while several multipolar ganglionic cells made their appearance.† I was long uncertain what function I should attribute to these marginal fibres, and at first suspected, that in them some closer connexion was to be sought between the accessory as a vocal nerve and respiration. As, however, all these marginal fibres which terminate in the nerve nuclei, and decussating with the other side, appear to curve upwards into longitudinal fibres, must be regarded as conductors of our will, it seems to me scarcely to admit of a doubt, that the fibres—which terminate in the longitudinal columns *a, k, l,* and appear to be connected with them by means of multipolar ganglionic cells, and to pursue exactly the same course with the above—are likewise routes whereby our will is enabled to convey its orders to the respiratory apparatus, and according to our will to modify its action. We do not, however, in the situation of this union, meet with any aggregated group of ganglionic cells; the latter are rather scattered and isolated in the summit of this longitudinal fasciculus.

Moreover, it is an important fact, that these conductors of our will, whereby we influence respiration, decussate, just as I have shown in the other marginal fibres, which pass into the nuclei of the nerves. At the same time, these fibres afford a fresh proof, that the lateral columns of the spinal cord really end here. Thus from the spinal cord, the corpora pyramidalia, which serve for the movements of the extremities, alone pass anteriorly, as a continuation of the anterior columns, upwards into the brain; the lateral columns do not take this course. Hence it follows, that in hemiplegia after cerebral apoplexy, the arm and leg of the same side are paralyzed. We call this, however very incorrectly, unilateral paralysis, as if the

* Fig. 2, A, *a a a.* † Fig. 2, A, *a, l.*

entire half of the body were paralyzed; this is not the case: only the muscles of the one half of the face, of the arm, and leg are affected; but the intercostal muscles, the abdominal muscles, and the one half of the diaphragm are in hemiplegia undisturbed in their functions. Sometimes, I have observed that the one side of the chest was, in consequence of paralysis of the pectoralis, less powerfully drawn upwards; but still respiration is not unilaterally disturbed.* This peculiarity, to which in my opinion sufficient attention has not been paid, is to me a powerful proof, that the lateral columns of the spinal cord do not run into the brain, as they should then in apoplexy likewise participate in the subsequent paralysis, which never is the case. As they are brought into action specially by the stimulus received from the nervus vagus, their function does not depend directly on our will, although it may be to a certain extent influenced by the latter.†

The close connexion between the nucleus of the vagus and the nervus trigeminus which I have above merely alluded to, is, however, extremely remarkable. With no one nerve-nucleus does the trigeminus appear to be so intimately connected as with that of the vagus, so much is this the case, that in some sections the vagus-nucleus seems to coalesce with the root of the trigeminus.

How completely the phenomena during life correspond to this, scarcely needs to be demonstrated; thus irritation of the trigeminus acts most powerfully on respiration, for example, in sneezing; thus also, sprinkling cold water on the face produces a rapid inspiration.

* Only one case do I find in Virchow's *Archiv für path. Anatomie*, B. II., Heft. 5, 1857, p. 413, where, after apoplexy, in consequence of an aneurismal clot in the cerebral portion of the left carotid artery, hemiphlegia occurred, and where the abdominal muscles from time to time contracted only on the left side. Dissection exhibited not only complete softening of the left middle hemisphere, but also two recent extravasations of blood of the size of a bean; the second somewhat smaller under the aqueduct of Sylvius, in the pons Varolii, and in the neighbourhood numerous small capillary extravasations, p. 417. Probably the latter had injured the longitudinal columns, near the vagus. In a diagnostic point of view also this may be important.

† Helmolt's observations quite accords with this also. *Ueber reflect. Bezieh. d. Nerv. vagus, etc., l. c.*, p. 30, that in central irritation of the two terminations of the nervus vagus reflex motions never arise in the muscles of the extremities. As the corpora pyramidalia are very far removed from the origin of the vagus and the longitudinal fasciculi accompanying it, the impossibility of reflex action taking place between the two, can be maintained on anatomical grounds also.

Lastly, I must add that, as I have shown above, from the nucleus of the vagus, but especially lower down from the accessory, transverse filaments, forming a commissure, run behind the central canal to the nucleus of the other side. This commissure unites, particularly in the lower sections where it is stronger, not only the two nuclei of the accessory, but also the longitudinal columns, where these deviate more and more to the side, and pass into the lateral tracks of the spinal cord.* This commissure is here, just as is the case with the facial nerve, very strong, it even exceeds that of the facial. As to its function, it appears that, as we have seen above, most branches of the facial work bilaterally, as is probably, in a still greater degree, true of the accessory which moves the muscles of the larynx and pharynx, and perhaps, with the exception of its branch to the trapezius, acts bilaterally in all its ramifications. Such an influence would quite accord with the greater breadth of its posterior commissure, connecting the two nuclei, and would be necessary for the bilateral action of the muscles of the larynx in giving a single sound, or in the production of the voice.

In like manner, the commissure between the nuclei of the vagus, Fig. 1, *e*, *d*, B, and the longitudinal columns for respiration, Fig. 2 A, *m*, *d*, appears invariably to convey the stimulation of one nucleus, and of one lateral column of the medulla to those of the other side. Thus, a bilateral action, which is so necessary in respiration, and in the production of abdominal pressure, is ensured. The decussation of these in the middle line is perhaps the cause why a central puncture or wound, whereby this connexion is broken, arrests respiration, and is immediately fatal (Flourens' Point vital), as then the connexion between the above two points is severed.

* Fig. 2, *d*, *m*, *l*, *a*, *k*.

CHAPTER VIII.

ON THE PARTS IN THE MEDULLA OBLONGATA WHICH CO-OPERATE IN DEGLUTITION.

As we have seen in the preceding chapter, how movements, more or less complex, are excited in different nerves of the medulla oblongata by means of auxiliary ganglia, a function remains to be examined, which, on account of its complexity, and of the various nerves co-operating in it, well deserves separate consideration. I allude to the process of deglutition. As the hypoglossus is the chief agent in swallowing, we might regard as the central organ the corpora olivaria inferiora, which, as we have found, are intimately connected with that nerve, and, in animals at least, cannot serve for the articulation of the voice. But in my opinion, this question is not so simple, and in order to obtain a clear insight into the subject, it is necessary first to ascertain what combinations must in this case be effected, after which, we can examine whether in the structure of the medulla oblongata arrangements are to be found, by which these several combinations may be harmonized.

Swallowing is certainly a very complicated process, requiring the co-operation, not only of a great number of very different muscles, but of several wholly different nerves, and this simultaneously, at the same moment.

I shall not here enter into a detailed consideration of the mechanism of deglutition, nor of the muscles which take a part in it, as I suppose this process to be understood; it will suffice, if we first examine what nerves engaged in swallowing are excited by a common and simultaneous impression.

That in the first place the action of the tongue is required in swallowing, in order to push the food against the palate backward into the throat, and at the moment of swallowing the root of the tongue is particularly active, is well known. All parts of the tongue are not, however, equally engaged in this operation, and thus, for example, a partial paralysis of that organ may exist, by which speech may be impaired, without deglutition being impeded.*

In like manner, cases are on record where, from a central cause, swallowing was obstructed without speech being impaired.†

Hence it appears, that in the articulation of words a different point of union serves for the combination of muscular movements, which may be destroyed, while other movements of the tongue, as those occurring in swallowing, continue unimpaired; consequently the central seat of these two actions must be different.

This will be sufficiently evident on an examination of the several nerves, which must coöperate in swallowing, most of which remain inactive in the articulation of words.

In the first place, we here again meet the hypoglossal nerve, both in its action on the posterior part of the tongue, and also principally on the muscles, which at the moment of swallowing raise the os hyoides, and with it the larynx; in which movements totally different nerve-fibres must act from those engaged in speech.

But this nerve, by its simultaneous action on the tongue, and on the muscles of the larynx, occupies a first place also among the nerves which must coöperate in deglutition.

Furthermore, we must add the accessory of Willis, which besides the muscles of the larynx closing the glottis, also moves the constrictors of the pharynx‡ with the soft palate, both of which act in swallowing.§

Lastly, it is even said, that some filaments of the glosso-pharyngeal

* Of this we have an example in the case of the girl, where the articulation of words was absent, while swallowing was unimpaired (p. 149). Difficulty of speech often occurs after apoplexy without lesion of swallowing. Thus in the case above quoted from Lallemand, Letter 1, Obs. 4, pp. 19 *et seq.*, in which speech was in the highest degree impaired, and the tongue when protruded inclined to one side, although all the other motions of the organ were very free, no mention is made of any difficulty in swallowing, which would not have been passed over in a report of the symptoms, which is in other respects accurate.

† See among others Olivier, *Traité des Maladies*, t. II., Obs. 112, p. 319, and Obs. 127, p. 400.

‡ Longet saw the most distinct movements in the muscles of the larynx, pharynx, and upper part of the œsophagus follow galvanic irritation of the accessory. *Anat. et Physiol. du Syst. Nerv.*, t. II., p. 265.

§ J. A. Heine saw motions of the palate on irritation of the vagus as well as of the accessory. See Müller, *Arch. f. Physiol.*, 1844, pp. 336 *et seq.*

may participate in this process; as it appears to possess motor-filaments, which coöperate in the movements of the palate.*

During swallowing, therefore, some filaments of the hypoglossus and accessory, and perhaps, also, of the glosso-pharyngeal, if its motor-root acts in deglutition, which, however, is not probable, must be excited on both sides to a simultaneous and uniform action almost in a moment; thus rendering necessary the supposition of a partial connexion of all these filaments in one or more coherent central points.

Now, it is well known, that swallowing is a reflex action, produced by a stimulus operating behind the tongue and against the palate. Even the will appears to accomplish swallowing only indirectly. Thus we can indeed swallow when we choose, but we cannot make the act of deglutition itself slower or more rapid. Swallowing, as is absolutely necessary on account of the impediment it offers to respiration, always takes place very quickly, and within a definite time, and herein this action differs from all other voluntary movements of the body, which we can perform at will more quickly or more slowly. Deglutition is therefore a reflex action *par excellence;* so that even our will in it appears not to act directly on different nervous centres, but as in involuntary swallowing, to operate by its impression or stimulus on that part whence the compound reflex action for deglutition proceeds.

If, however, a stimulus acts in the throat or on the palate, or on the posterior part of the tongue, we are compelled to swallow, and cannot restrain the act. Deglutition is therefore quite involuntary, and is produced by reflex action occurring on the application of a stimulus; a combined bilateral action ensuing of all the muscles which coöperate in swallowing.

* Volkman and Müller, *Archiv,* 1840, p. 489. Heine confirms the same. Müller, *Archiv,* 1844, p. 333, and lastly, this appears to be reduced to certainty by Biffi and Morganti. Müller, *Archiv,* 1847, p. 357. They assume a distinct root of motor fibres in the glosso-pharyngeal, which is said to serve for these movements of the palate, rendering this a mixed nerve, just like the spinal nerves.

It is, however, not very easy to trace such a distinct root, which must necessarily be very slender, in its course through the medulla oblongata; although it must in that case certainly have a separate origin, as ganglionic groups for sensation cannot at the same time serve for motion, as is indicated also by the different situations of the two classes of cells in the medulla oblongata

If we now arrange synoptically these complicated actions, we shall find that there must be present in the medulla oblongata filaments or nerve-fibres, whereby :—

1. The applied stimulus, whether directly, or indirectly by way of reflexion, is conveyed to some common centre or point of action, whence the simultaneous combinations of muscular action may be excited as from a single point.

2. There must exist fibres or routes, by which these excitements of the central organ of deglutition may be conveyed to the several nerve-nuclei which, in swallowing, enter into action in the various nerves.

3. Fibres, which, as conductors of the orders of our will, may act on these same central organs, and so, by this voluntary route, excite an involuntary reflex act, such as swallowing.*

4. Fibres, to connect these central organs bilaterally, rendering this reflex action during swallowing invariably bilateral, simultaneous and uniform.

I shall now proceed to inquire, whether it is possible, in the labyrinth of fibres, which are so diversely interwoven through the medulla oblongata, to discover these definite paths. In this I shall follow the course which I have endeavoured, by the careful examination of physiological phenomena, to borrow from nature.

1. An irritation applied behind the tongue or against the palate, is conveyed to the central points for the act of swallowing.

There are two ways whereby this might take place, namely, through filaments of the glosso-pharyngeal nerve, which, as is is well known, is

* It is evidently necessary that these routes for the transmission of the orders of our will, and of the irritation applied to the tongue, should be different; and that such is the case is proved by pathological observations.

Thus Romberg relates a very remarkable case, where, with complete paralysis of the tongue, swallowing still resulted, if the food was brought behind into the throat or pharynx, all the necessary motions of the tongue being accomplished at the moment of deglutition. On dissection, a cyst was found at the right side of the anterior lobe of the brain, with inflammation of the septum lucidum. Unfortunately, no attention seems to have been given to the medulla oblongata, as no mention is made of lesions in its tissue. See Romberg, *Lehrbuch der Nervenkrankheiten*, 1846, 1 B., 3 Abth., pp. 658 *et seq.* The impression of the will from the brain was therefore disturbed; that by reflex action had continued.

The case communicated by Dr. A. Stich is not less remarkable, in which the reverse seemed to obtain. Here perfect anæsthesia of the trigeminal distributed to the posterior part of the tongue, and which also gives some branches to the soft palate and the pharynx.

Or through filaments of the trigeminus, which, through the pterygo-palatine nerve, gives sensation to the soft palate, and through the lingual nerve to the tongue. Even the upper part of the pharynx appears to receive branches from the pterygo-palatine nerve.*

As concerns the first of these routes, through the glosso-pharyngeal, it would seem that, as this nerve distributes its gustatory branches chiefly on the posterior part of the tongue, it should contain also the reflex nerves for deglutition; the more so as, according to Longet, after cutting through the lingual branch of the fifth pair, a degree of sensation still remains at the base of the tongue; which he, however, is inclined to attribute to some accompanying cervical filaments of the hypoglossus.† This latter hypothesis appears to me to be very improbable.

Bowman observed, in insensibility of the trigeminus, that taste was completely lost in the anterior and middle parts of the tongue; but was unimpaired in the posterior part. He does not state whether,

and glosso-pharyngeal nerves existed, completely depriving the patient of all taste and sensation in the tongue; and nevertheless, swallowing was quite normally performed, although it was not possible by stimuli to excite reflex movements from the trigeminus or glosso-pharyngeal. The writer caused a piece of sponge, fastened to a thread, to be swallowed, but I think it is doubtful, whether in this experiment he made a sufficient distinction between sensitive and reflex filaments. As, however, a sponge, fastened to a piece of whalebone, and thrust into the throat, excited no vomiting, but contraction of the constrictors, it would seem necessary to suppose that the reflex filaments of the glosso-pharyngeal or vagus in the pharynx were destroyed, or at least inactive, and that thus only the route by which the action of the will was conveyed to the centres of deglutition remained. It is to be regretted that this important case and its phenomena have not been more distinctly and more definitely given. See *Annalen des Charité Krankenhauses*, 7 Jahrg., 1 Heft., 1856, pp. 168 *et seq.* In this instance, therefore, reflex action seemed to have been annihilated, while the impression of the will was preserved.

* A. C. Bock, *Nachtrag zu der Beschreibung der 5 Hirnnerven*, Pl. V., Fig. 4, N. 54.

† *Anat. et Phys. du Syst. Nerv.*, t. II., p. 174, *et la Physiol.*, p. 297. In a case of paralysis of the trigeminus, observed by Herbert Mayo, the base of the tongue was still sensitive, and a probang, passed into the throat, produced vomiting, even when the instrument touched only the insensible side. Magendie, *Journal de Physiol.*, t. III., p. 358.

in this case, insensibility existed also in mechanical irritants on the back part of the tongue.*

Bowman states, after Reid, that section of the glosso-pharyngeal nerve is not only painful, but also that if the trunk of the nerve was cut through a short way below its exit from the cranium, and the end was irritated, extensive movements were produced in the throat and the lower part of the face; whence he infers, that the irritation was conveyed by reflexion to the vagus and facial nerves. On the contrary, if, in an animal just killed, provided the filaments were sufficiently isolated from the pharyngeal branches of the vagus, the glosso-pharyngeal was centrifugally irritated, no movements were developed,—showing that the glosso-pharyngeal is a nerve capable of exciting movements by reflexion.†

Longet, on the contrary, saw movements take place in the pharynx, if he irritated centrifugally or peripherically the pharyngeal branches of the glosso-pharyngeal;‡ while he regards the pharyngeal branches of the vagus as reflex filaments.§ I shall not go further into this controversy, but only observe, that much as it may appear from the above, that the branches of the glosso-pharyngeal nerve to the tongue are the routes whereby the reflex irritation repairs to the centre for deglutition,—this view cannot be adopted, as it is shown by Panizza, and confirmed by others, as by Stannius,‖ that when the two glosso-pharyngeal nerves are cut through, swallowing is performed in a dog, in every respect, as perfectly as in the sound state.¶ Bowman likewise remarks this, and says that other fibres must be present, adapted to convey stimulation to the pharynx by reflexion, as, after cutting through both glosso-pharyngeal nerves, swallowing is not impeded.**

The glosso-pharyngeal nerve, accordingly, cannot be the route by

* *Physiol. Anatom.*, Part II., p. 444 *et seq.* Since, as we have above seen, the trunk of the glosso-pharyngeal nerve passes through the middle of the root of the trigeminus in the medulla oblongata, fibres of both may here perhaps commingle and form a nerve; so that the sensation of taste may belong to some branches of the fifth, and sensation proper to others of the glosso-pharyngeal, which is perhaps the simplest mode of reconciling or explaining this as yet undecided controversy.

† *l. c.*, Part III. p. 117. ‡ Longet, *Physiol.*, p. 392.

§ *l. c.*, *Physiol.*, p. 308. ‖ Müller, *Archiv*, 1848, p. 137.

¶ C. Schneeman, *Versuche ueber die Verrichtungen der Nerven*, Erlangen, 1836, p. 43, wherein the experiments of Panizza on taste are given.

** *Physiol. Anat.*, Part III., pp. 117 *et seq.*

which stimulation is conveyed by reflexion to the central point for swallowing.

This being once established, there remains only the nervus trigeminus, which we have already found to be, *par excellence,* a reflex nerve, as the route by which the reflex stimulation for deglutition shall be conveyed. The question is only, by what branches of the trigeminus is this accomplished? Involuntary deglutition ensues, when the food is passed into the back of the mouth, and comes in contact with the root of the tongue, the arches of the palate, and the palate itself.

We might, therefore, suppose, that in the lingual nerves, as sensitive nerves of the tongue, reflex nerves for swallowing were comprised; but in addition to the opinion previously expressed by Longet, that the lingual branch of the trigeminus gives absolutely no branches to the base of the tongue,* this hypothesis is completely refuted by the experiments of Panizza,† who shows that swallowing is not impeded by cutting through both lingual branches of the trigeminus.

There remain, however, other branches of the trigeminus, namely, the palatine ramifications of the second twig of the fifth pair, which also gives off the nasal nerves, whereby sensation in the nose, and consequently sneezing is excited; whence it appears, that this branch too is connected with the vagus and accessory nerves. It would seem, therefore, that in this nerve-branch are also to be sought the reflex filaments which occasion swallowing, and indeed, these appear to be situated less in the root of the tongue itself than in the palate and in its pillars, against which the food is pressed by the tongue, causing the stimulus to swallowing.

This is confirmed chiefly by an experiment of Magistel, on a dog, communicated by Schneeman, in which, although the two lingual nerves of the trigeminus were cut through, the animal still made the motions of swallowing, if a little alcohol was applied with a brush to his palate.‡ After cutting through the hypoglossi, however, swallowing was of course prevented by the paralysis of the tongue.§

* Longet, *Physiologie*, p. 298.

† Schneeman, *Versuche, &c.*, p. 44. Stannius, too, says expressly, that in his experiments, after cutting through both lingual nerves, no movement had ceased, and that the animals drank milk; consequently, still swallowed. Müller, *Archiv*, 1838, p. 136.

‡ Schneeman, *Versuche, l. c.*, p. 96.

§ Schneeman, *l. c.*, p. 33.

I have already remarked that the nervus trigeminus may, *par excellence*, be denominated a nerve of both sensation and reflexion. In accordance herewith the root of this nerve follows such an obliquely downward direction, through the medulla oblongata, that in its course it passes all the other nerve-roots from the medulla, with which it produces reflex phenomena, and terminates on a level with the inferior part of the corpora olivaria, or of the roots of the hypoglossus. Accordingly, therefore, as the stimulus is applied to one or other branch, a different reflex action, or none, is excited, sneezing being apparently produced through the nasal ramifications of the second branch of the fifth nerve, and swallowing through the palatine ramifications of the same branch.

Thus we can also explain, how in the above-described case by Stich,* with complete anæsthesia of the fifth pair, involuntary deglutition, that is by reflex action of the fifth, was impeded; although voluntary swallowing by direct influence on the will on this part of the corpora olivaria remained.

2. Can we exhibit fibres, passing from the fifth pair to a central organ for reflex action, whence the act of swallowing should be capable of extending bilaterally?

If we make transverse sections of the medulla oblongata from above the insertion of the glosso-pharyngeal nerve to the inferior roots of the hypoglossus, we see everywhere the roots of the fifth nerve, and hence, just as from the corpus restiforme, an exceedingly great number of fibræ arciformes radiating through the corpora olivaria, and further passing through the raphe to the other side.†

These transverse fibres are large, and most numerous on a level with the hypoglossal and accessory nerves; the greater number appear to perforate the corpora olivaria, others seem to be lost in the latter. This is particularly observable in the corpora olivaria inferiora in animals, which seem specially to comprise the centres for the reflex movement of swallowing.‡ Indeed, these corpora olivaria inferiora appear to be connected only with the hypoglossus, and partially with the accessory; since, as we have seen above, they are situated on a

* See above, p. 193, *note*.

† Fig. 1, D, *n*, *l*, *q q*, *r*. See also Stilling, *Medulla Oblongata*, Pl. V. and VI., the corpus restiforme *n*, and before it the trunk of the fifth nerve, whence arciforme fibres *e*, *i*, *u*, *q*, pass to the corpus ciliare.

‡ Fig. 12, *l*, *i*, K.

level with the roots of the hypoglossus, and are confined exactly within the bounds of this nerve.*

This is likewise the case even in birds, although in them the ganglionic groups, occurring in the situation of the corpora olivaria inferiora, but which are also interlaced by numerous transverse filaments from the root of the trigeminus, are simple. The less complexity of these ganglionic groups is also proportionate to the greater simplicity of the mode in which swallowing is accomplished in these animals, a much smaller number of muscles coöperating in the process, which in birds consists merely in the pushing forward and closing of the rima glottidis.

Now, as these corpora olivaria inferiora, from their situation at the inside of the hypoglossus, behind the corpora pyramidalia, exactly correspond to the additamentary nuclei or accessory corpora olivaria, occurring in man in the same place,† but are not, as has been incorrectly supposed, everywhere distinct from the corpus olivare, and as these accessory nuclei entirely agree in structure with the corpora olivaria inferiora in animals, being like them, perforated by numerous transverse fibres: we might suppose that in man these internal accessory nuclei should likewise be regarded as reflex centres for deglutition. The only difficulty in such a view is, that the corpora olivaria inferiora in animals consist of three groups situated close to, and more or less connected with one another,‡ while in man they are more simple, although in some places they occupy a considerable extent. The correspondence of situation, however, and similarity of the nerve-connexions, make this supposition not improbable.

We have further seen, that fibres must also arise from these centre organs of swallowing, connecting the latter with the nuclei of the nerves which act in deglutition.

* As the glosso-pharyngeal nerve in animals is situated much higher than the corpora olivaria inferiora (see Figs. 8 and 10 *b b*, *g*), it would appear that this nerve does not contribute to deglutition.

† Fig. 1, Stilling, *Medulla Oblongata*, Pl. V., VI., *r*. Lenhossek represents several so-called additamentary corpora olivaria or accessory nuclei, Pl. II., Fig. 1, *h*, *i*, *k k*; but he confounds with these several ganglionic groups, which, in my opinion, do not belong to them, as they consist of larger ganglionic cells; which from his mode of making the preparations transparent, he could not observe with sufficient accuracy. The most internal alone should I refer to the corpora olivaria.

‡ Fig. 12, *k*, *b*.

And such we find to be in fact the case; for, from these inner corpora olivaria, as well as from the large corpora olivaria in man, as also from the corpora olivaria inferiora in animals, a number of central or radiating fibres pass especially to the nuclei of the hypoglossal and accessory nerves,* which are closely connected with the first.

These radiating fibres between the hypoglossal nucleus and the corpora olivaria are, however, not equally distinct in all sections, in some places they occur in greater number, in others less distinctly, as Stilling,† without knowing the use of these fibres, so correctly represented. They, accordingly, appear to be connected only with some parts of the hypoglossal nucleus;—an arrangement which seems to correspond to the action of the nerve in swallowing, for in this process a great part, but not the whole nerve acts, the sternohyoid and thyroid muscles, for example, and also the genio-glossal, so far as relates to the protusion of the tongue, continuing inactive.

The mouth also, or rather the jaw, is closed during swallowing by the masticating muscles, in order to give a firm point of support. We might, hence, suppose that the motor root of the trigeminus should be simultaneously affected by reflexion from the corpora olivaria. As, however, this root is in animals situated much higher than the corpora olivaria inferiora, such a connexion appears to be doubtful. We can, however, imagine, that in this reflex irritation of the fifth nerve the stimulus may be conveyed immediately from the sensitive to the motor root, while the nuclei of the motor root of the trigeminus are situated so near one another at the raphe, and appear to be connected with one another by so many filaments,‡ that they may be capable of always acting bilaterally, independently of the coöperation of the corpora olivaria.

3. That, as the third requisite, the central organs for swallowing must also be accessible to the orders of our will needs no formal proof, because we have already seen that the medulla oblongata consists chiefly of longitudinal fibres, which, derived from the brain, betake themselves to the several nuclei of the medulla oblongata,

* Fig. 1, *i*, *p*. Stilling, *Medulla Oblongata*, Pl. V., *r*, *d*, *g*, of the internal corpora olivaria. My Fig. 12, *k*, *d*, from the corpora olivaria inferiora in a cat.

† Stilling, *Medulla Oblongata*, Pl. V., *r*, *d*, *g*, compared with Pl. VI., *r*, where they, as in my Fig. 1, appear to be almost wanting.

‡ Stilling, *Pons Varolii*, Pl. XV., *t t′*, *a*^x^ *a′*.

and, consequently, also to the corpora olivaria. These last may therefore be regarded as conductors of the orders of our will in voluntary deglutition, and if the trigeminus be destroyed, and reflex action consequently intercepted, voluntary swallowing is still possible.

Thus we can understand why voluntary deglutition is, nevertheless, always a reflex action; as it appears that in it our will does not act directly on the nuclei of the nerves themselves, but on the corpora olivaria; whence the action is then reflected to the nuclei, bringing into play simultaneously and uniformly, the muscular groups which conjointly perform the act of swallowing.

4. In like manner, the reason is self-evident why the act of swallowing is always bilateral, since, as I have already shown, these corpora olivaria are most intimately connected, by means of transverse fibres, at either side of the raphe. I therefore feel that what I have advanced is sufficient to leave very little doubt as to the whole mechanism of the bilateral reflex action of the nerves in deglutition.

I may sum up the principal points of the foregoing in the following propositions:—

A. *Of the Medulla Oblongata.*

1. In the medulla oblongata a perfectly unique organization commences. The nuclei or ganglionic groups whence the nerves arise are here more distinct from one another. The nuclei for motion, as those of the hypoglossus, the accessory, facial, and the small branch of the trigeminus, lie near the raphe or septum; the nucleus of the abducent is still uncertain; the nuclei for the nerves of sensation, which are first distinctly seen in the medulla oblongata, as the portio major trigemini, the vagus, glosso-pharyngeus and auditory, lie more to the outside, and further removed from the raphe. In addition, auxiliary ganglia or accessory nuclei, each of which has its own function, occur in the medulla oblongata.

2. Of the spinal cord, only the anterior columns pass, in the corpora pyramidalia, as conductors of the orders of our will for the movement of the extremities, upwards towards the brain. The lateral columns of the cord terminate on a level with the vagus, which is intimately connected with, and exercises a reflex action on them. Consequently, in hemiplegia we never have paralysis of the

half of the trunk, but only of the face, the tongue and the extremities.

3. At the inferior boundary of the medulla oblongata, and above the termination of the lateral columns just mentioned, a new system of fibres begins in the medulla oblongata, descending from the brain (the thalami, and especially the corpora striata), and here dividing into an infinite number of fine longitudinal bundles, separated by transverse fibres. These longitudinal bundles, at least for the most part, curve, to penetrate into the raphe, to decussate there, and so to pass over into the nuclei of the nerves of the opposite side, as conductors of the orders of our will, or for the communication of the impression of sensation to the brain. The accessory ganglia also receive the conducting filaments by which they communicate with the brain, from the same fasciculi.

4. The nerves of the medulla oblongata do not participate in the decussation of the corpora pyramidalia, as they are situated higher up. They themselves do not decussate; but in the manner described in the preceding paragraph, the conductors of the orders of our will decussate here also, as in the corpora pyramidalia for the movement of the extremities. In the medulla oblongata the decussation is in the situation of the nucleus; for the nerves of the extremities it is situated above the nuclei, in the known decussation of the corpora pyramidalia; in both parts there is, therefore, perfect correspondence. In like manner, filaments arise from the nuclei of the sensitive nerves, which decussate, and convey the received impression to parts situated higher up. Now, as sensation appears to decussate, and the nuclei of the sensitive nerves lie on the same side as their termination, these nuclei cannot be the seat of the perception of sensation.

5. Besides this, there exists in the medulla oblongata a system of transverse fibres (*fibræ arcuatæ*), some of which arise externally, surround the medulla, and pass into the raphe, while others, in part, arise internally from the corpora restiformia and the root of the trigeminus, in part from the nuclei of the nerves, and from the corpora olivaria. These transverse fibres serve to unite the two halves most intimately, and to produce a bilateral action so eminently characteristic of most nerves of the medulla oblongata, and such as occurs in no other part of the body, being seen in the bilateral action of the face, the tongue, the voice, and respiration.

B. *Of the Nerves of the Medulla Oblongata.*

6. In addition to the above-mentioned bilateral connexion, the nuclei, particularly of the facial, accessory and hypoglossal nerves, are in part connected from behind near the fourth ventricle, by a transverse commissure, which appears to increase the bilateral action of these nerves.

7. Of all the nerves, the auditory has in its central nucleus the largest ganglionic cells, and in it the connexion of the latter with the nerve-filaments, and with one another, is very easily seen. From this central nucleus fibres radiate in the direction of the nucleus of the facial nerve, probably for reflex action of the stapedius muscle and of the tensor tympani, and for the partly involuntary reflex movements in the erection of the ears in animals.

This nucleus of the auditory nerve is also closely connected with the sensory root of the trigeminus, and the two nuclei of the auditory are intimately united by many fibræ arciformes, radiating from this point.

The so-called roots of the auditory nerve in the fourth ventricle do not serve for hearing: but appear to be reflex filaments, which are connected by means of ganglionic cells with the auditory nerve, and in terror caused by an unexpected sound, reflect upon the whole muscular system, and place the body in an attitude of defence.

8. The glosso-pharyngeal nerve has this peculiarity, that it passes through the middle of the great root of the trigeminus, thereby perhaps creating a closer connexion between nerves of taste and sensation.

9. The abducent nerve differs from all other nerves of the medulla oblongata in this, that its root, instead of curving inwards to the raphe, bends outwards. In this way it perforates, in an outward direction, the fibres of the facial nerve and a portion of the facial nucleus. It does, not, as Stilling thinks, arise from the latter, but merely perforates it, to pass posteriorly and superiorly to the facial nerve, apparently into a nucleus.

This nucleus does not appear to be in close connexion with the raphe; that is, no filaments seem to run from the nucleus to the decussation. Perhaps it is more or less intimately united with the higher situated cerebral fibres, passing to the opposite nucleus of the oculo-motor—an arrangement which would afford a simple explanation of the antagonism between the oculo-motor of the one side, and the internus of the opposite side.

10. The nervus trigeminus is one of the most remarkable nerves of the medulla oblongata.

While its minor portion, as a muscular nerve, finds its nucleus very near the raphe, the major portion perforates, in an obliquely descending direction, the whole medulla oblongata, to the inferior border of the corpora olivaria. In this course it passes all the other nerves of the medulla oblongata and their nuclei, and gives off fibres to every nerve, except the abducent; consequently, it is connected with, and can act on all the other nerves and their nuclei, as the facial and glosso-pharyngeal, and it is particularly intimately connected with the vagus and accessory, and also with the hypoglossal nerves. In the same manner it is closely connected with the corpora olivaria.

Hence the nervus trigeminus is a reflex nerve, *par excellence*, whose reflex filaments convey the impression they have received either directly to these different nerve-nuclei, or indirectly give it up again to the auxiliary ganglia.

11. In every situation, where reflex filaments proceed from the root of the trigeminus to the nerve-nuclei, fresh groups of ganglionic cells arise in this root. It is even probable, that in general, where a nerve-filament determines a special action, the latter is communicated to it through ganglionic cells.

c. *On the Auxiliary Ganglia.*

12. Several nerves of the medulla oblongata have their auxiliary or accessory ganglia, which endow them with peculiar and most complicated functions.

The principal of these auxiliary ganglia are the corpora olivaria.

13. Almost all these auxiliary ganglia act bilaterally, and are at the same time connected by special radiating fibres with the nuclei of the nerves on which they act.

14. The corpora olivaria, as the largest and most important of the accessory ganglia, are distinguished from other ganglionic groups by their peculiar structure and very small multipolar ganglionic cells, whence fibres pass outwards and inwards, to unite as marginal fibres, into fasciculi of different degrees of strength. Of these fasciculi, some run to the central nuclei of the nerves, and others to the raphe, to unite with the corpus olivare of the opposite side. Besides these,

there are appendages, or accessory corpora olivaria, which appear to agree with the former in structure and function.

15. The corpora olivaria are more intimately and closely connected with the nuclei of the hypoglossus, than with the nucleus of any other nerve. This connexion is accomplished by a special tract passing out from the hilus of the corpus olivare, and terminating in the nucleus of the hypoglossus. The corpora olivaria are also united by other fibres with the nuclei of the accessory nerve. Besides these connexions, the upper part of the corpus olivare is further united with the nucleus of the facial nerve.

16. Through these connexions, the corpus olivare seems to serve as an auxiliary ganglion for the hypoglossal and accessory nerves, for the purpose of regulating the innumerable combinations of movements of the tongue, which, as appears from pathological observations, take place in the articulation of the voice during speech, and in deglutition. All these movements require a bilateral action, which appears to be effected through the corpora olivaria.

17. In animals, the corpora olivaria are smaller; in apes, although smaller, they correspond to those in man.

In the lower orders, where the medulla oblongata is prolonged, the corpora olivaria are separated into two divisions on each side, of which the superior, situated somewhat more outwardly, are on a level, and intimately connected with the nucleus of the facial nerve; whilst the inferior standing on a level, and united with the nucleus of the hypoglossus, approach nearer to the raphe.

18. The superior corpora olivaria are more strongly developed in the carnivora; they are somewhat smaller in the rodentia, still smaller in the herbivora, and particularly small in the ass.

They therefore stand in a direct relation to the reflex action of the facial nerve, which, as expressive of the passions, acts much more strongly in the carnivora than in the herbivora, and particularly slightly in the ass.

They consequently appear to be organs for the involuntary or reflex expressions of the passions.

19. The inferior corpora olivaria are of the same size and extent in all animals which I have examined, and do not exhibit the variety in convolutions and circumference presented by the superior; they are strictly limited within the roots of the hypoglossus, and therefore serve as auxiliary ganglia in deglutition, which is performed in the same manner in all these animals.

20. In man, these divisions are united, and it would appear that different parts of the corpora olivaria exercise different functions, according to the nerves with whose nuclei they are connected by radiating fibres, for these several functions, as expression, articulation of the voice, and swallowing, may be separately lost in disease.

21. In birds, too, the corpora olivaria are very small, both the superior, which are connected with the facial nerve, and the inferior, which are connected with the hypoglossal nerve.

They have likewise a simple structure, and consist of ganglionic cells of a larger kind, which are, however, situated in the same places as in the lower mammalia.

The transition of corpora olivaria with minute ganglionic cells into portions which exhibit larger cells, is very well seen in the horse.

In birds, also, the superior corpora olivaria seem to serve for the movement of the feathers of the head and neck in passion; the inferior, for swallowing.

22. Besides these corpora olivaria, another group of larger ganglionic cells occurs also in man and animals as auxilary ganglia, on a level with the facial nerve, being very closely connected on the one side with the nucleus of the facial nerve, and on the other with the root of the trigeminus. This group appears to serve for the reflex action of the trigeminus, in winking of the eyelids, which, as is well known, depends especially on irritation of the fifth pair.

It is remarkable, that this group of ganglionic cells is equally extensive in birds, which seems to be connected with the strong movement of the membrana nictitans.

This group does not appear to act always bilaterally.

23. The connexion of the nervus vagus and its nucleus with a bundle of longitudinal fibres, which is situated on its outside, and appears to constitute the upper part or summit of the lateral columns of the spinal cord, is of great importance. From the nervous vagus fibres pass into the longitudinal fasciculus, where again ganglionic cells are situated at the seat of transition.

This connexion appears to be subservient to respiration.

Hence it follows, that a very strong centripetally acting stimulus to the vagus brings all the muscles of the chest and abdomen into a state of tension. One not so strong seems to act, in the first place, by means of these longitudinal fasciculi on the phrenic nerve and the muscles of inspiration, causing the descent of the diaphragm and the enlargement of the chest.

As the lateral columns act on the muscles of the trunk, these irritations of the vagus are not followed by convulsions in the extremities, nor have we, in hemiplegia, paralysis of one half of the trunk.

In birds this combination appears likewise to be present.

24. Both longitudinal columns are connected with one another, as well posteriorly at the fourth ventricle, as anteriorly by transverse fibres or commissures and fibræ arciformes through the raphe, rendering respiration bilateral.

A puncture or wound in the middle line or raphe, destroys this connexion in action, respiration ceases, and death is instantaneous.

25. Besides these, there are also proper marginal fibres, which run parallel with the conductors of the orders of our will round the hypoglossal and accessory nuclei, and in the same manner decussate, and then curve upwards; they terminate in the lateral longitudinal columns, with which they appear to be connected by multipolar ganglionic cells. Through these fibres, our will acts on the lateral columns of the spinal cord, and so on the respiratory organs.

26. With these longitudinal columns, and especially with the nucleus of the vagus, the great root of the trigeminus enters into very intimate connexion, so that in some places they seem to be coherent. This state of things is apparently closely related to the known reflex action of the trigeminus on respiration, exemplified in sneezing, &c.

27. Swallowing, when voluntarily excited, is also a reflex action, which is always accomplished with rapidity, but is very complicated.

The exciting stimulus appears to proceed chiefly from the second branch of the trigeminus, namely, the palatine nerve; for division of the lingual or glosso-pharyngeal nerve does not prevent swallowing. But the irritation seems to be conveyed to the corpora olivaria inferiora in animals, and to the corresponding parts in man, whence it is reflected on the hypoglossal and accessory nerves, with which these corpora olivaria are closely connected, and through which the act of deglutition is occasioned by the simultaneous excitation of many muscles into bilateral action.

Perhaps, also, the small root of the trigeminus, by closing the mouth, participates in the act.

28. The nuclei of the glosso-pharyngeal also appear to be united with an auxiliary ganglion similar to that of the facial nerve, which auxiliary ganglion is also closely connected with the trigeminus. With its action I am unacquainted.

SECOND PART.

CHAPTER I.

PATHOLOGICAL INVESTIGATION OF THE MEDULLA OBLONGATA IN GENERAL, AND ESPECIALLY OF THE PROXIMATE CAUSE AND RATIONAL TREATMENT OF EPILEPSY.

It is now many years since my investigations led me to the notion, that the proximate cause, and as it were the starting-point of epilepsy and of convulsions, was to be sought in the medulla oblongata. In accordance with this view, I conclude my essay on the spinal cord, publish in 1854, in the following words:—

"The medulla oblongata is the principal centre, whence the more general reflex movements and convulsions derive their origin. I have for years been accustomed to seek in it the starting-point of epileptic attacks, and consider that to it the physician should direct his special attention. Even though the primary irritation may be remote, for example, in the intestines, a morbidly elevated sensibility and irritation in the medulla oblongata always form the foundation of such attacks, and render the organ in question more capable of, as it were, discharging itself in involuntary reflex movements.

"An accurate examination of the minute structure of the medulla oblongata, and especially of the pathological changes produced in it by epilepsy of long standing, which I have often observed under the form of hardening, yet in reference to which no microscopic investigations have been made, may still throw much light upon the subject. I have not yet had opportunity to put in execution these investigations, to which I was anxious to direct the attention of physicians.

"In this way alone will it be possible to escape from the unhappily rude and empirical treatment, which is still so commonly prevalent in reference to epilepsy, and of which I have witnessed so many sad examples. A rational system of treatment of this obstinate disease can be based only upon a better acquaintance with the functions of the medulla spinalis, and especially of the medulla oblongata, whence we must endeavour to trace more accurately the nature and essence of the disease."*

Impelled by the wish to contribute my share in the solution of this difficult question, for the advantage of so many unhappy beings, I felt it my duty to apply myself diligently to the work. I have now examined microscopically the medulla oblongata in not less than fourteen epileptic patients; and in this essay I have endeavoured, as far as possible, to explain the structure and physiological action of this part. Lastly, I have endeavoured to apply the increased knowledge thus obtained, in the more accurate investigation of the nature of epilepsy, and have communicated the results of my microscopic investigations on the subject, in order, if possible, to establish our knowledge of this miserable disease on a more solid and rational basis.

If we briefly review what has been said with respect to the medulla oblongata, I think it will clearly appear from my remarks and investigations, that this important part is characterized by a great peculiarity of structure and function which remarkably distinguish it, both from the brain and from the spinal cord.

In the first place, the medulla oblongata differs from the brain and spinal cord principally in this, that its halves are so closely connected by an exceedingly great number of transverse fibres (*fibræ arciformes*) and commissures, that a bilateral action must be recognized as more specially peculiar to it; which action manifests itself also in the functions of most of its nerves, as I have above stated in detail of the facial, accessory, and hypoglossal nerves.

In the second place, the medulla oblongata is uncommonly rich in different ganglionic groups or nuclei, both for sensitive and motor nerves, to which several auxiliary ganglia are superadded, possessing the special property of immediately exciting in the healthy condition, on the application of any stimulus, numerous reflex phenomena in different definite groups of muscles. In no other part of the body do such phenomena occur in the same degree, and they manifest themselves especially in the muscular movements of the face, the tongue, and the organs of respiration. Hence, the medulla

* Essay on the Spinal Cord, p. 80.

oblongata is distinguished as if *par excellence* by a peculiar capability of exciting bilateral reflex phenomena.

If we now compare with it the brain, it is well known, that an effusion of blood in cerebral apoplexy produces only an unilateral effect, giving rise to so-called unilateral paralysis or hemiplegia. The same is true of the spinal cord. There also unilateral lesions or irritations, if they are not so violent as to give rise to general excitement, exercise only an unilateral effect upon the power of motion.*

We cannot, therefore, by any means be surprised that morbid affections and irritations of the medulla oblongata should ordinarily be characterized by bilateral reflex phenomena, indicating precisely the medulla oblongata as the starting-point of these phenomena.

Hence we understand how in the sensitive child any irritation—such, for example, as teething, whereby the nervus trigeminus, the reflex nerve, *par excellence*, is irritated—so easily gives rise to con-

* Some months after I had handed in this Essay to the Royal Academy of Sciences, I received, at the meeting of Natural Philosophers, at Bonn, through the kindness of Prof. A. Kussmaul, the Treatise published by him in conjunction with A. Tenner, *Untersuchungen ueber Ursprung und Wesen der fallsuchtigen Zuckungen bei der Verblutung so wie der Fallsucht ueberhaupt*, Frankfurt, 1857, reprinted from the *Untersuchungen zur Naturlehre des Menschen von* Moleschott.

These writers excited epileptic attacks in rabbits by cutting off the current of blood to the brain, by tying or compressing the four cerebral arteries. They thus came nearly to the same conclusion, that the cause of such attacks was situated principally in the medulla oblongata; as these convulsive spasms were still excited by keeping back the blood, after the cerebrum, the thalami, even to the corpora quadrigemina, and to the pons Varolii, were cut away, as well as after the removal of a great part of the cerebellum (*l. c.*, pp. 78, 88). The cause of these convulsive movements cannot, therefore, be situated in these parts, but must, of course, be sought in the medulla oblongata (*l. c.*, pp. 92 *et seq.*); while, if the spinal cord near the medulla oblongata was deprived of blood by tying the aorta, convulsive spasms of this kind never arose (*l. c.*, p. 63).

It is well known that Marshall Hall at an earlier period ascribed the convulsive spasms in apoplexy and epilepsy to obstructed return of venous blood (*On the Threatening of Apoplexy and Paralysis, &c.*, by Marshall Hall. London, 1851, p. 30, § 122). This impeded return of venous blood is said to be the result of the spasmodic contractions of the muscles of the larynx and of the neck, viz., the platysma myoides, sterno-cleido-mastoid, omohyoid, trapezius, scaleni, and even of the subclavii, which certainly do not act injuriously, *l. c.*, p. 37, § 151 *et seq.* He forgets, however, to state what is the cause of these previous muscular contractions, which take place in the course, and not at the first commencement af the attack.

vulsions, that is, to involuntary reflex movements, in the first place of the face and respiratory organs, and in a more advanced stage, of the trunk and extremities.

The first action manifests itself, as has just been observed, almost always in the face and the respiratory organs. If we now remember what we have above remarked, with respect to the oblique course of the root of the trigeminus in the medulla oblongata, and to its reflecting powers on the facial nerve, on respiration, swallowing &c., we shall not be surprised at the occurrence of these involuntary reflex movements and convulsions on increased irritation of these parts.

If we further compare the phenomena which occur in epilepsy, we shall be led to the same results.

It is well known that the attacks of epilepsy are distinguished by severer or slighter fits; that is, that all the phenomena do not occur with equal constancy in every seizure, but that some are often wanting, while others exhibit themselves more constantly, even in slight attacks.

Although in my opinion, Herpin's well known work on Epilepsy,* in the great majority of points, does not deserve the high consideration which has fallen to its lot, yet the accurate description of the phenomena of epilepsy, and especially the division which the author makes into the more and less constant of these phenomena, appears to me to be one of the most elaborate parts of the work; of the correctness of which description and division ample experience has convinced me.

One of the principal of the more constant, in addition to the loss of consciousness, is a spasmodic affection of the pharynx and larynx, with more or less of spasms of some of the muscles of the face, so that even in slighter cases these are scarcely ever absent.† With these symptoms is usually combined greater or less disturbance of respiration, which, if the attack becomes more severe, increases in degree; on which strong convulsive movements of the face, trunk, and extremities rapidly follow, although in slighter attacks they do not appear frequently.‡

In some cases, of which I have observed several examples, no loss

* Herpin, *Du pronostic et du traitement curatif de l'Epilepsie*, Paris, 1852.

† Herpin, *l. c.*, pp. 433 *et seq.*

‡ I freely admit with Marshall Hall that the muscles of the neck and larynx at the same time, by their spasmodic contractions, compress the veins, and so promote venous congestion, and increase the severity of the attack.

of consciousness takes place; but a few contractions set in suddenly in the face, and spasms along the back, with more or less change in respiration, while the spasms may extend even to the extremities. In these cases it is only occasionally that perfect attacks of epilepsy with loss of consciousness occur.

In other instances, in slight attacks, loss of consciousness alone takes place, without any convulsive movement. In one case which occurred under my own notice, a lady continued to walk about and follow her occupation, even to eat and drink; so that nothing unusual could be observed in her. But she did not answer questions put to her, and awoke after some moments as out of a dream, without knowing what had happened in the interval. Only occasionally did more complete epileptic symptoms manifest themselves. Similar loss of consciousness without convulsive movements, and even with maintenance of position, I have often observed, and have seen it alternate with true epilepsy.

The loss of consciousness is, therefore, not a cause of epilepsy, but probably, as I shall show hereafter, a result of the altered circulation in the brain, which arises in the beginning of the attack from the effects of spasm upon the cerebral vessels.

Sometimes the epileptic attack begins with a shriek, on which the sufferer falls suddenly down. Several varieties, however, occur, the special description of which would lead us too far.

It will be sufficient, in summing up this brief enumeration of the phenomena, to state, that the convulsive spasms in epilepsy affect by preference and in the first place those muscles whose nerves arise in the medulla oblongata, as the facial, accessory, hypoglossal and the

It is chiefly the muscles moved by the accessory nerve, as the sterno-cleido-mastoid and trapezius, and by the hypoglossus (descending branch), as the platysma myoides and omohyoid, which act in this case. It is, however, very incorrect to suppose, with this writer, that the vertebral veins are more forcibly compressed in epilepsy, and the jugulars in cerebral apoplexy. Let it not be forgotten, that in the commencement of the fit this pressure and action have not yet taken place, and that the venous congestion is strongest towards the end of the attack, exactly when the most violent phenomena again begin to disappear. Nevertheless the venous congestion positively increases the violence of the attack, and towards the end the circulation is restored through the exhaustion of the spasmodic action of the medulla oblongata, and of the facial, hypoglossal, and accessory nerves. This congestion, however, is not the cause of the attack. We can easily perceive how much such actions of the muscles indicate an irritated condition of the medulla oblongata.

portio minor trigemini, the affection of these nerves being plainly manifested in the grinding motions of the jaw, or in the rigid closure of the mouth. The convulsive affections which occur in slighter cases, are limited within the sphere of these nerves. These spasms we may regard as constant, and as I have already observed, more or less violent disturbances of respiration attend them. If, however, the attack is more severe, the spasms are no longer confined to these nerves; the muscles of the chest and abdomen especially become violently contracted, and are sometimes so rigidly fixed as to produce suffocation, showing that in epilepsy the lateral columns of the spinal cord, which arise in the medulla oblongata and govern the movements of the chest and abdomen, participate with particular violence in the abnormal or excited action. If we now remember, that on central irritation of the nervi vagi, as we have above seen, a similar tetanic contraction of the muscles of inspiration and expiration is excited, this phenomenon, so common in epileptic attacks, will of itself indicate the medulla oblongata as the point whence the proximate irritation causing the convulsive movements proceeds. In this sort of attack the action also extends to the anterior columns, which as corpora pyramidalia pass through the medulla oblongata, and thus developes the well known spasms of the extremities.*

The swelling and protrusion of the tongue, the latter being usually more or less severely bitten by the patient during the attack (without his feeling it, as he is then perfectly insensible), deserve especial attention. In some epileptic patients, as I shall hereafter more fully show, this symptom of biting the tongue never occurs.

We may therefore regard the more or less violent congestion of blood in the head, which constantly manifests itself in ordinary epileptic attacks, as secondary, and as the result of impeded respiration. In consequence of the spasmodic contraction of the respiratory apparatus, the circulation through the lungs is obstructed; by the spasmodic contraction of the cervical muscles the veins are compressed (trachelismus of Marshall Hall) and the return of the blood from the

* It appears to me to be still uncertain whether we should regard these affections of the corpora pyramidalia, apparent in the convulsive movements of the extremities, as being communicated from the medulla oblongata to these columns, or whether they are the result of secondary, or sometimes, indeed, of primary congestion and irritation of the corpora striata in the brain. It is sufficient that in an epileptic attack the convulsive spasms in the extremities do not manifest themselves as the first phenomenon; they are almost always preceded by the affections of the face and respiratory organs, however brief this interval may be in violent attacks.

head is impeded. The reflux of venous blood to the chest is meanwhile promoted by the alternate spasms of the extremities, and the blood so accumuluted tends still more strongly to oppose the return of that from the brain.

Towards the end of the fit the impediment to respiration commences to pass off with a deep inspiration, followed by stertorous breathing, during which the congestion begins to diminish, and the swollen veins of the head to contract and unload themselves. The internal congestion of the brain and its consequences are subsequently manifested in the more or less profound sleep which follows every attack.

Although in the fits of epilepsy the convulsive spasms are usually bilateral, both sides are not equally affected, or, rather, the intermittent convulsive movements are often stronger on the one side than on the other. Thus, the angle of the mouth is often drawn obliquely, more strongly to one side than to the other—even the eyes are frequently turned obliquely with slight convulsive spasms, to the one side; the tongue is obliquely curved in the mouth, and very often the patient bites one side of the tongue in each attack. The head is also, with constant shocks, obliquely drawn more strongly to the one side, through the preponderating action of one sterno-cleido-mastoid muscle, which, as is well known, receives also motor filaments from the accessory, and thus participates in the general convulsive movements with which the muscles receiving their nerves from the medulla oblongata, are preferentially affected. The cause of this unequal action appears to me to lie especially in a primary affection of the brain, in reference to which I shall hereafter enter into several particulars.

As, however, it is by no means part of my plan to digress into a detailed description of epilepsy and its phenomena, the foregoing may suffice to show, from the generally received symptoms of this disease, that the starting-point of the various convulsive movements in epilepsy, must be sought in the medulla oblongata. So that even in slighter attacks of epilepsy, the spasmodic phenomena begin from this part, whence, in more violent seizures, the action excited extends to a greater distance over the nervous system.

The same is true of most other convulsive affections, as eclampsia, chorea, in which, commonly, the muscles of the neck, head, and tongue are affected.*

* Romberg, *Lehr. d. Nervenkr.*, 1 B., 2 Abth., p. 437.

Thus, a contraction and obstruction of the throat is known as globus hystericus, which, proceeding from the accessory or vagus, again implies an irritated condition of the medulla oblongata. Even tetanus and hydrophobia we cannot separate from this organ;* and it is thus evident, what an important part the exalted capability for reflex movements possessed by the medulla oblongata when irritated plays in most nervous affections.

Let it suffice for our object to show, that precisely in this exalted sensibility of the medulla oblongata lies the starting-point and source of spasm in epilepsy.

* Romberg makes the important observation, that in hydrophobia the corpora olivaria are very highly injected, *l. c.*, p. 528.

CHAPTER II.

ON THE NATURE AND PROXIMATE CAUSES OF CONVULSIVE MOVEMENTS.

WHEN we inquire what are the proximate causes of convulsive movements, we are at once referred to the ganglionic cells as the parts of the nervous system whence all action proceeds, which is conveyed through the nerve-filaments as conductors to the muscles. It is, therefore, to the ganglionic cells our attention must first be directed in entering on a more accurate investigation of the subject of the present chapter.

These ganglionic cells, which are almost always collected in groups, and are mutually connected, may be compared to galvanic or electric batteries, which must be charged to a certain extent before the electricity accumulated in the Leyden jar, has acquired sufficient tension to discharge the flask. The discharge is in this case effected, not by a constant stream of fire, but by a sudden spark. Or, perhaps, a comparison with the phenomena in electrical fishes is still better, where, likewise, a violent discharge takes place, which requires some time, especially where there is any exhaustion, before it can be repeated.

There is, however, in these ganglionic cells something peculiar, which is not yet fully explained. Thus they are connected, as I have formerly endeavoured to show at length,* on the one side with nerve-filaments, which, as conductors of the orders of our will, are derived from the brain. Through these the ganglionic cells can be immediately brought into action and the muscle contracts almost at the same moment in which the orders of our will are issued. Yet these ganglionic cells are also connected on the other side with nerve-filaments, accompanying the sensitive nerves, which I have described as reflex nerves,† and of which, in treating of the trigeminus, I have brought forward a sufficient number of examples.‡ Usually the action does not take place so quickly on stimulation through the

* Essay on the Spinal Cord, pp. 60, 66.

† *l. c.*, p. 66.

‡ See above, pp. 156 *et seq.*

reflex filaments, and, at least when the ganglionic cells are discharged, some time is necessary before the reflex action manifests itself anew. If, however, the action has once begun, the muscular contractions follow rapidly, as in sneezing, swallowing, coughing, &c. The more irritated the condition of the cell now is, the more quickly does the reflex action take place, and the slighter will be the stimulus to the reflex nerves required to produce a reflex action. If the cell is exhausted, some time is necessary, as it were, to charge it again, just like an electric jar, which, if it is discharged by a spark, must be charged afresh before it can again exhibit the same electrical phenomena.

Now, why the orders of our will act otherwise on these ganglionic cells, so that we can maintain a muscle for a long time in a state of strong or weak tension, while, in reflex action, the power of the cell is exhausted, as in a moment, and the action ceases for a shorter or longer period, we know not, and we can scarcely offer a satisfactory hypothesis in explanation of this point. It is enough that experience proves its truth, and we must, therefore, receive it as an unexplained fact, and infer that the action of the reflex nerves on the ganglionic cells differs from that of the orders of our will. Perhaps the cause exists in the peculiar nature and action of the reflex cells; since, if our will acts directly on these reflex cells, as in swallowing, the action, rapidly interrupted, is performed by way of discharge.

It has, however, been clearly ascertained that for the restoration of this activity, a certain quantity of arterial blood is required, on the effect of which on the ganglionic cells their capability of action depends. It is, indeed, true, that we see convulsive movements ensue also after loss of blood in hæmorrhage; but here so many causes coöperate to produce a change in the cell, that we are not in a state to follow with sufficient accuracy the whole course of active causes and effects in their several relations, and to watch nature everywhere in her hidden agencies. Quite in accordance with this, is the great number of blood-vessels which are present in the grey substance of the spinal cord and brain, in comparison with the so-called white or medullary matter, which is produced by the conducting filaments. Of this I have given several drawings in Ecker's dissertation,* all taken by myself, with the greatest fidelity, from preparations of my own.

* Ecker, *Cerebri et Med. Spin. System. Capill. Traj. ad Rhen.* 1853, also copied into the *Nederlandsch Lancet*, 1852—53, pp. 329 *et seq.* See for example,

Nowhere, however, have I found the quantity of capillary vessels so great and presenting such a densely interwoven tissue, as in the corpus ciliare of the corpora olivaria.* This body, in fact, affords one of the most beautiful capillary networks to be met with in the system; the vessels existing here in much greater number than in the grey cornua of the spinal cord itself.† Thus, also, I have observed that the other groups of ganglionic cells occurring in the medulla oblongata, as those for the hypoglossus, vagus, &c., with the accessory or auxiliary ganglia, are uncommonly rich in blood-vessels.

We must hence infer, that more arterial blood flows in the ganglionic groups of the medulla oblongata, and that thus also a more active metamorphosis of tissue takes place there than in the grey horns of the spinal cord. To the very vascular parts belong, however, in addition to the grey substance of the arbor vitæ in the cerebellum,‡ —with the use of which we are still unacquainted—the thalami,§ and especially the corpora striata,|| which are very rich in vessels, although none of these parts equal in vascularity the corpora olivaria.

It is evident that the vascularity of the ganglionic groups, and the quantity of arterial blood supplied to them, are directly related to the intensity of their action. We see this sufficiently exemplified in childhood, where the metamorphosis of tissue takes place more quickly, whilst the vascularity is also greatest, and the excitability or sensibility of the whole nervous system is so much more intense, that a relatively slight irritation, as that of cutting teeth, easily produces convulsions, which, at a later period of life in the most violent attacks of toothache or facial neuralgia, occur with extreme rarity.

The capacity for reflex movements is thus promoted by a strong arterial afflux of blood, which increases the vital actions of the ganglionic cells. As, however, the ganglionic groups in the medulla oblongata receive the most vessels, the reflex movements should also by preference take place here; and this again agrees with the function, for example, of the corpora olivaria, whereby such different reflex

Fig. 1, *a*, mat. corticalis cerebri; *d*, materies medullaris. Fig. 2, *a*, *b*, the grey substance of the cerebellum; *d d*, *e e*, the medullary matter between the laminæ of the arbor vitæ. Still stronger for example, in Fig. 3, *a a*, a portion of the corpus olivare from the corpora civaria; *e e*, *f*, the medullary substance in and without this body.

* Ecker, *l. c.*, Fig. 3 *a a*.

† *l. c.*, Fig. 9, *b b*.

‡ Ecker, *l. c.*, and *Lancet*, Fig. 2, *a*, *b*.

§ *l. c.*, Fig. 4.

|| *l. c.*, Fig. 5.

movements, as we observe in no other part of the nervous system, are produced, or with the constant reflex movements, which are incessantly developed from the vagus on the lateral columns of the medulla for regular breathing.

We may hence infer that, other things being equal, where there is general excitement of the vascular, and increased activity of the nervous system, involuntary reflex phenomena should, perhaps, after the application of a slight stimulus, first arise in the part in which vascularity is greatest, and where the natural capacity for reflex phenomena is strongest, namely in the medulla oblongata. This extremely probable conjecture has been converted into certainty by the important experiments of Brown-Sequard.*

Thus, this observer found that if he injured the spinal cord in mammalia, especially by cutting through one half of the cord, or the posterior columns and posterior horns of the grey substance (wherein I have, on a former occasion, shown that very fine longitudinal fibres exist, which appeared to me to serve to unite in an harmonious movement the reflex impressions on several distinctly situated ganglionic groups),† and if the animal survived this dangerous operation, after the lapse of three weeks convulsive movements were excited, quite agreeing in every respect with epileptic attacks. At the same time the very remarkable phenomenon was observed, that if the left side of the spinal cord was cut through at any spot between the seventh or eighth dorsal and the third lumbar vertebra, it almost invariably followed that stimuli applied to the left side of the face occasioned convulsive movements, while if applied to the right side, they by no means had this effect.

This capacity for reflex movements did not manifest itself until after the third week from the receipt of the injury. The convulsions extended over the whole body, with the exception of the part paralyzed by the transverse section, and were consequently not unilateral. After some time these convulsions again ceased, and were subsequently repeated.

The convulsions sometimes arose spontaneously without any external stimulation; but among all the parts of the body there is only one where slight irritation was sufficient to excite them, namely the side of the face, or as was subsequently more particularly shown

* *Comptes Rendus*, 1856, No. 3, Janvier, pp. 86 *et seq.*, and 11 Oct., 1856, No. 91, pp. 644 *et seq.;* and *Archives Générales de Médecine*, 1856, Fevrier.

† Essay on the Spinal Cord, p. 68.

by Brown-Sequard, of the cheek. The space in question was bounded above by a line drawn from the eye to the ear; anteriorly, by one drawn from the eye straight down to the under jaw; and inferiorly by one passing hence to the ear and the lateral parts of the neck, sometimes even to the shoulder; it consequently corresponded to the region supplied by the second and third branches of the trigeminus.* Singularly enough, irritation above the eyes, the ears, and the nose was not capable of exciting these convulsions, that is, irritation of the second and third branches of the trigeminus including the temporo-auricular branch, and, according to Brown-Sequard, also, perhaps of the second and third cervical nerves, to which in the cases where irritation of the shoulder was sufficient to produce the spasms, we should add the fourth cervical nerve. I believe, however, that these nerves are less engaged in producing this action, and that the latter is a result of irritation of the accessory, which extends through the sterno-cleido-mastoid to the trapezius above the shoulder. Indeed, if we irritated the middle line in the neck, whether anteriorly or posteriorly, to which the accessory nerve does not extend, no convulsions followed, as should have taken place, if the second and third cervical nerves were, in these instances, the conductors of the reflex movement.

No other part of the body, notwithstanding the greatest irritation, was capable of producing these convulsions; yet if respiration was obstructed for a couple of minutes, convulsions were likewise excited.

If now only one side of the spinal cord was cut through, only one cheek was capable of exciting these convulsive or epileptic movements, and the other cheek might be irritated with impunity, and pinched without any result. But if both posterior columns were cut through, the symptoms were occasioned by irritating either one or the other cheek. These experiments lead to most important conclusions.

In the first place, this capacity for convulsive movements did not take place until the third week after the infliction of the injury, and then originated in the medulla oblongata, which is very far from the injured part. We must hence infer, that the irritated condition developed by the injury of the inferior dorsal or lumbar portion of the spinal cord, extended slowly upwards to the whole cord, and particularly to the medulla oblongata. Indeed, these convulsions could

* *Comptes Rendus*, Oct. 1856, pp. 644 *et seq.*

be excited by irritation only from the medulla oblongata through the nervus trigeminus, and probably through the accessory.

This is still further confirmed by the course of the convulsions themselves. Thus the first convulsive movements which arose, were confined to spasms of the face and of the eyes; some days after this first attack, the muscles of the larynx, neck, and chest were affected with convulsions, and finally, the muscles of the trunk and extremities participated in the movements.* One of the first phenomena of a complete attack, consisted in a spasm of the glottis, or of the muscles of respiration.†

This is more fully explained in the second essay by the writer,‡ where he says, that if the skin be gently irritated in these animals in one of the places mentioned, a slight spasm of the muscles of the eyelids, face, and neck, of only short duration, ensues, but only on one side. The animal cries even less than if other parts are irritated; it is, therefore, not the pain, but the action on the reflex nerves, which produces the spasms. Thus also, a stimulus to the trunk of these nerves (the second and third branches of the trigeminus) produces no convulsions, but convulsions are developed so long as these nerves are connected with the skin, the latter being at the same time irritated; and the same is true of reflex nerves in general. Indeed, it is well known, that reflex phenomena are excited by a stimulus to the skin or mucous membrane, but not to the trunks of the nerves themselves, a fact, which is confirmed by my own experiments.

If, however, the irritation on the cheek or neck is severe, the head is drawn strongly by the convulsions to the one side by nearly all the muscles of the side (probably most strongly by the sterno-cleido-mastoid); the mouth is opened by the action of the depressors of the lower jaw (*n. mandibularis* and *hypoglossus*); oftentimes a loud hoarse cry is produced by the muscles of expiration and the convulsive vibrations of the chordæ vocales (or rather of the muscles in the larynx, which put these upon the stretch), and the animal quickly falls, sometimes on the irritated, sometimes on the other side. The convulsive spasms now manifest themselves over the whole body, except in the paralyzed limb. The head moves alternately from one side to the other (consequently the influences which produce the contractions are not

* *Comptes Rendus*, 1856, Janvier, section 7.

† *l. c.*

‡ *Comptes Rendus*, Oct., 1856.

confined to the one side, but have, in the medulla oblongata, been conveyed also to the other side, as from our anatomico-physiological theory of the organs might be expected); the muscles of the face and eyes successively contract (facial); the non-paralyzed parts are thrown into violent convulsive movements; the respiration becomes irregular and spasmodic; the fæces are expelled, and discharge of urine also often takes place (that is the contraction of the abdominal muscles is excited, or tetanus of all the respiratory organs, as in more violent attacks of epilepsy); sometimes there is even an erection of the penis with seminal emission. The fit does not last long, but is frequently repeated.*

We see in this description, as Brown-Sequard himself expressly states, the exact picture of a violent attack of epilepsy with all its symptoms, in the order in which they occur in an epileptic patient.

It is extremely important to observe in the foregoing that after such an injury of the dorsal or lumbar portion of the spinal cord,† the exalted reflex phenomena do not exhibit themselves in irritation of that part of the cord which is situated next the wound, and which we should expect to be first and most violently affected by the application of the stimulus. But the phenomena exhibit themselves first in the medulla oblongata, when the part commences to participate in the general morbid excitation of the spinal cord occasioned by the injury. And even then irritation of the inferior portion of the cord is not competent to excite these convulsions, but according to Brown-Sequard only irritants, directly applied to the medulla oblongata are capable of producing such effects. Even irritants applied to the paralyzed foot, which on unilateral section of the spinal cord changes into a condition of hyperæsthesia or increased sensibility, do not produce these convulsions.

* *Comptes Rendus*, Oct. 1856.

† There is no doubt that injuries of higher parts of the spinal cord would produce the same phenomena; but these affect the life of the animals so much, that they die before this change in the medulla oblongata has occurred. The animals do not under these circumstances live three weeks, or at least, if the injury was not so severe, they very seldom do so. But if the spinal cord is irritated, indirectly for example, through an injury of the finger or the neck, which produces constant nervous irritation, the medulla oblongata may by this nervous irritation be affected in the same manner, and spasms, epilepsy, and even tetanus are often the well-known results. See several such cases among others mentioned in Pflüger, *Die Sensorischen Functionen des Rückenmarks*, Berlin, 1853, pp. 87 *et seq.* *Beobacht* X., XII., XIII., *et seq.*

These important investigations quite agree with the results previously deduced by Pflüger, from a great number of observations, his conclusion being, that on irritation of a sensitive nerve of the brain (*trigeminus*) the progress of reflex movements is downwards, or towards the medulla oblongata, while on irritation of a spinal nerve the progress of reflexion is inverted, from below upwards, that is, likewise towards the medulla oblongata.* Hence, if the reflexion occurs in motor nerves, lying even very distant from the irritated sensitive nerve, the reflectorally-excited motors are always such as arise from the medulla oblongata;† and it is therefore not until the irritation has reached the medulla oblongata that the reflex movements can pass to the other side and extend over the whole body.‡ But if the irritation of the medulla is not too great, it may, when it has reached the medulla oblongata, extend over the body, but only on the same side.§ Consequently a higher degree of irritation is necessary for the transference of the spasms to the opposite side than for their extension on the affected side; therefore tetanus is a result of a greater irritation than that by which intermittent spasms and convulsions are excited. From all this we clearly see, both that the medulla oblongata is distinguished by a greater sensibility to irritation, and also that this is the situation where bilateral convulsions originate; that thus we must regard the medulla oblongata as the proximate starting-point in convulsions, such as those which occur in epilepsy and other nervous affections; and that in the majority of cases the most violent action takes place on the side whence the irritation of the spinal cord or from the brain has proceeded.

We have shown above, that the medulla oblongata is particularly rich in blood-vessels, because an abundant current of arterial blood is required during its increased activity. On the other hand, we have seen that in reflex movements its activity is commonly rapidly exhausted and the convulsive motions set at rest;—to begin again subsequently, or to be constantly repeated,—an important peculiarity which requires still further explanation.

From Brown-Sequard's experiments, it appears that if the one side of the spinal cord, or the two posterior cornua are cut through, and the animal has borne the consequences of this violent operation,

* *Die Sensorischen Functionen des Rückenmarks.* Berlin, 1853, p. 74.

† Pflüger, *l. c.*, p. 78, V. ‡ *l. c.*

§ Pflüger, *l. c.*, *Beobacht* II., III., V., VIII., XII., XIII., etc. See also the Index and an Appendix to the work.

the epileptic symptoms do not begin to manifest themselves until the third week after the operation. It was also found that for exciting these symptoms a slight irritation was at first usually required ; sometimes blowing on the part was sufficient; but that afterwards convulsive spasms began to manifest themselves spontaneously, in other words, the animal had become epileptic.

Hence we see, that after the infliction of a wound in the inferior part of the spinal cord, a certain morbid condition has been slowly developed; that is, inflammation has arisen as a necessary result at the seat of injury, and a state of exalted sensibility has gradually been communicated to the entire cord, and finally to the medulla oblongata. But we have already shown, that the medulla oblongata, above all other parts of the nervous system, possesses a special capacity for exciting reflex phenomena, even in the healthy state. It is, therefore, very natural, that, as a consequence of the augmented irritability, this capacity for reflexion should be greatly increased ; and we accordingly see it, as in epilepsy, rise so high that the reflex phenomena begin to manifest themselves spontaneously and without external irritation. Moreover, what is most important, these phenomena are not constant ; but, as Brown-Sequard expressly observes, the fit does not last long, but is often repeated.

Here, then, we observe the singular fact, that although the exciting cause, the irritating wound inflicted on the spinal cord, and the more excitable state of the medulla oblongata so produced, are constant, the phenomena are, nevertheless, intermittent.

The same very often takes place in the human subject. From a great number of examples which I might bring forward, I will select only one, borrowed by Pflüger from Dieffenbach's *Operative Chirurgie*.

" A young girl, who some years before had fallen with one hand on a wine-glass, suffered from violent neuralgic pains, emaciation, contraction, and complete uselessness of the hand. But the whole nervous system was affected in paroxysms with reflectorally-excited epileptic attacks. The fingers were in the highest degree contracted, partly by spasms, partly by dense cicatrices. On cutting the latter, a minute splinter of glass was found, of the shape of a fine fish-scale, which had wounded (*angeschnitten*) a nerve. The nerve was, in this situation, thickened and hardened. After the operation the neuralgia, the emaciation, the contraction, and the epilepsy disappeared. The patient again became perfectly healthy, and even regained the complete use of the hand." Pflüger adds : " This case teaches us, in the first place, the law of unilateral conduction and reflexion, as we observed in it a tonic reflex spasm (only in the one arm). With reference to the seat of the affection, we find it to be constant in the one brachial plexus, to which the irritated sensitive nerve-fibre belonged. From time to time, however, the irritations extended to other motor nerves, and appeared under the form of general reflex spasm, which still bears the trivial denomination of epilepsy."*

Thus we see in this case, also, a constant irritation; the inflamed nerve, and the spicula of glass, which producing persistent contraction of the muscles of the arm, excite in the medulla oblongata only temporary reflex phenomena, that is, epilepsy; all which phenomena again completely disappear after the removal of the permanent cause, namely, the fragment of glass from the inflamed nerve. Consequently, there cannot have been any great organic change or degeneration in the cervical plexus or spinal cord, or the medulla oblongata; for had such source of irritation existed, the phenomena would not so easily or quickly have given way after the removal of the foreign body.

To produce epilepsy, therefore, no disorganization is necessary, no great change in the tissue, but only increased excitability, and commonly, as we shall hereafter see, augmented determination of blood and chemical change are required.

But it is not necessary in order to excite this exalted capacity for reflex action in the medulla oblongata, that this stimulus should always be applied through a spinal nerve, the sympathetic and vagus effect the same. We know how, in children, convulsions arise from

* Pflüger, *Functionen des Rückenmarks*, pp. 80 *et seq.*, *Beobacht* XIII. In many cases of epilepsy the convulsive movements are usually more violent on one side than on the other, and the head, for example, is drawn constantly to the one side. How far we may hence infer, that the remote exciting cause is applied on the opposite side of the brain, or on the same side through one of the spinal nerves, I cannot say; but it appears to me very probable, that from stronger traction to one side in epilepsy, especially if this, as is usual, is constant, we must suppose the existence of an unilateral exciting stimulus, whether this be situated in the brain or in one of the spinal nerves. As it appears further from Callenfels' experiments (*Onderzoekingen over den invloed der vaatzenuwen op den bloedsomloop*, Utrecht, 1855, p. 67), that irritation of the one sympathetic influences the blood-vessels only on the one side of the brain, so perhaps a stronger action may even manifest itself on the side of the brain and thereby on the medulla oblongata, where there is intestinal irritation on the one side.

the irritation of teething, as well as from worms, when the dilated pupil sufficiently indicates the exalted activity of the sympathetic, under whose control the dilator of the pupil is placed. In like manner, we are sufficiently conversant with convulsions as results of acidity in children, or of exalted intestinal sensibility, and especially of inflammation of the intestines. Thus, a stimulus applied to the sympathetic or vagus from the stomach and intestines, acts as much in increasing the sensibility and activity of the medulla oblongata as inflammation in a spinal nerve.*

But these causes are not so limited. I have already more than once remarked, not only that the supply of healthy arterial blood to the medulla oblongata is very abundant, but that this abundant supply is an essential condition of the proper discharge of the functions of the part. Through this blood must the vital metamorphosis of tissue, and with it the organic activity in the medulla oblongata, as in all parts of the body, be kept up.

But if the blood itself be diseased, if it have deviated from its healthy composition, it no longer supplies the normal stimulus ; it no longer furnishes the nutritive matters in the state in which they are required for the maintenance of the vital functions. Thus we see all kinds of convulsions and nervous attacks, even epilepsy, arise from chlorosis, in which the iron or hæmatosin appears to be deficient, and the lymphatic white blood globules to predominate. And we find, that by restoring the constitution of the blood, by the administration of ferruginous preparations and by good feeding, all the nervous phenomena cease, and that even the epilepsy may be dissipated.

The same thing is seen in the administration of strychnia, when the blood is poisoned by the absorption of this powerful agent ; but although the strychnia which is taken up into the blood circulates in it, and therefore comes into constant contact and interchange with the medulla, the phenomena are not persistent, but manifest themselves in intermittent spasms. A dog, as I have on a former occasion stated in commmnicating a special investigation on this

* This influence of the sympathetic, in exciting convulsions by irritation of the medulla oblongata, is confirmed by a direct experiment of Kussmaul, who, after one carotid artery had been tied, saw galvanic irritation of the superior cut portion of the sympathetic produce convulsions in a rabbit, which terminated after the cessation of the stimulus, and could be again excited. See *Untersuchungen ueber Ursprung und Wesen der Fallsuchtzuchungen*, p. 114.

subject,* when poisoned with strychnia, suddenly falls into convulsions, and if the poison is strong enough, into very violent spasms and tetanus, in which, however he retains his consciousness, and absolutely gives no sign of pain. And even after the most violent convulsions, the dog in some time gets up again, walks about, and appears for the moment to ail nothing, he may be struck on the head or on the back, without causing any reflex phenomena. This free state I have seen to endure even for an hour-and-half, although at last the dog died with tetanic fixing of all the organs of the chest and of respiration. If subsequently to an attack the exalted sensibility was after some time restored, touching the animal, or even blowing on it was sufficient to reproduce the most violent epileptic and tetanic phenomena.

Hence it follows, that in these violent spasms and exalted capacity for action, which with strychnia is not confined to the medulla oblongata, the ganglionic cells are more or less rapidly exhausted; that is, a change takes place in the cell, which must be counteracted by fresh nutriment, and by the influence of a copious stream of arterial blood. It is, therefore, not until the exhausted irritability is restored by some rest that the capacity for reflex action or the radiation of power once more attains the height at which only a slight stimulus, or even no external irritant, is required to excite convulsions.

We see the same thing in epilepsy. It is a well-known fact, which I have observed hundreds of times, that if an epileptic patient has been attacked by a severe fit, he remains proportionably much longer free; but if he has had only a slight attack, this is repeated after a shorter time, often on the following day, in a more violent form, and now again the patient continues longer exempt. Even the exalted irritability in the nervous system, and especially in the medulla oblongata and in the brain, which are reciprocally so closely connected, manifests itself in the epileptic patient before the attack, very often by greater restlessness and increased tendency to passions, and sometimes in an unpleasant situation, from which the sufferers are again delivered for a time by the more or less rapid occurrence of the fit.

It is, as I have above remarked, difficult to explain in what this difference in the ganglionic cells consists, that their activity in a condition of exalted irritability, or even after normal reflex movements, as in swallowing, coughing, &c., lasts so short a time, and cannot be

* Essay on the Spinal Cord, p. 71.

prolonged by the influence of volition, while by our will we can produce a lasting impression on the muscles, and keep them in a state of long-continued tension. This may depend partly upon the peculiar nature of the accessory ganglia, which act on the nerve-nuclei in the medulla oblongata, and occur similarly constituted nowhere else, and partly in the difference in the routes by which the stimulus to action is conveyed to the ganglionic cells. Thus, the filaments of the white medulla and the anterior columns are, as conductors of our will, much thicker than the minute longitudinal filaments in the posterior horns, which, as we have seen, serve for reflex combinations, and appear to pass over into the same ganglia.* Now, whether this difference of action depends on the difference in the filaments with which the ganglionic cells are united, or on the different mode of action of special ganglionic cells for reflexion, we know not; but we see, that if the ganglionic cells are affected by a persistent irritant, for example, by poisoned blood, the same intermissions in the phenomena manifest themselves. It is sufficient, that this intermission of activity of discharge, as it were, is especially peculiar to the medulla oblongata; the more profound reasons are doubtless beyond the reach of our understanding.

The theory I have herein put forward of epilepsy and of its proximate cause, as consisting in an exalted action of the ganglionic cells, is more or less at variance with the explanation recently given by Kussmaul and Tenner, in their important Treatise on the subject.†

Led by their proofs—that keeping back the current of blood, especially from parts situated behind the thalami, that is in the medulla oblongata, excites epileptic convulsions—they think that epilepsy is not the result of sudden active determination of blood to these parts, but that it is produced rather by anæmia, or withholding of blood, which, in its turn, is caused by a spasmodic contraction of the capillary vessels.‡ Nutrition is thus suddenly impeded;§ or, rather, I should say, the metamorphosis of tissue is disturbed, causing these parts to be brought into an excited state, giving rise to convulsions. On every attack of perfect epilepsy the same material change is supposed to take place simultaneously in the brain and in a great portion of the parts situated behind the thalami.|| The whole brain is said thus to become suddenly anæmic.

* See Essay on the Spinal Cord, p. 52, Fig. 9 *b*, Fig. 10.

† [A translation of the Treatise alluded to in the text will shortly be issued to the members of the New Sydenham Society.]

‡ *l. c.*, pp. 112 and 117, No. 4. § *l. c.*, p. 77. || *l. c.*, p. 94.

I cannot in every respect assent to this explanation. On the contrary, I think that the writers have in a marked degree allowed themselves to be misled by these experiments, and that they have exhibited partiality in wholly excluding the casual influence of active arterial congestion.* For, although they admit other causes also, as chemical changes in the blood, foreign substances, &c., impeding nutrition,† they have, in my opinion, not sufficiently attended to the fact, that plethora and too strong congestion excite convulsions as well as anæmia.

They indeed admit that in subjects hanged convulsions arise likewise from increased determination of blood.‡ Even of two cases where they succeeded in compressing and tying the jugular and subclavian veins without effusion of blood, the one animal died with general convulsions forty-eight hours after the ligature was applied—as Cooper also had observed.§

Moreover, cases have been observed by Romberg, and still later by Reimer, where by compression of the carotids the fit was cut short. In the case observed by Reimer, this succeeded two-and-twenty times, the patient experiencing great relief and improvement in his memory and mental condition.||

If, further anæmia was so generally the cause, and if, as these writers have everywhere stated, after the return of the blood the convulsions ceased, the means for the rapid dissipation of the attacks must exist in epilepsy itself; since if we were to admit anæmia as a cause at all, congestion very quickly supervenes, during which precisely it is that the convulsions are most violent. The transition from anæmia to congestion, even before the blood has, through impeded respiration, become too venous, must certainly exercise influence on the attacks; and if we would explain this as the result of the venous condition of the blood, our explanation would be, as Foville justly remarks,¶ incorrect; since, when the fit is at its height, and the determination of blood is strongest, the attack oftentimes terminates suddenly and consciousness returns, which it would be difficult to reconcile with such a theory.

* *l. c.*, pp. 104 *et seq.*

† *l. c.*, pp. 100 *et seq.*

‡ *l. c.*, pp. 106 *et seq.*

§ *l. c.*, pp. 108 *et seq.*

|| Schmidt's *Jahrbücher*, 1857, No. 8, pp. 181 *et seq.*

¶ See *Dictionnaire de Médecine et de Chirurgie pratiques*, Paris, 1831, t. 7, Art. *Epilepsie*, p. 421.

Equally little does this view find support from the fact, that before the attack epileptic patients are usually more excited, more lively and more irritable, and their face and the increased heat of the head manifest a greater degree of congestion.

In one case I was able to ascertain this with precision. In a young man aged nineteen, who under the use of digitalis, had continued for a considerable time free from attacks, I found the heat of the head excessively great in comparison with that of the cheek, and a very small thermometer, which I had with me for the purpose of examining the difference of temperature, when applied alternately on the head and cheek indicated a degree of heat on the forehead and vertex greater by 13° Fahrenheit than that of the cheek. Before I could have cupping-glasses with scarification applied to the neck, he had fallen in a violent epileptic attack, scarcely fifteen minutes after I had examined the temperature; whence it appears, that in this case congestion rather than anæmia preceded the attack; and I doubt very much whether such anæmia as the writers caused by tying the four cervical arteries, ever precedes an epileptic attack. Such convulsions, it is well known, exhibit themselves in cases of violent hæmorrhage; but whatever the proximate cause may be, no practical man will confound them with epilepsy, neither do they return after recovery.

I will, indeed, admit, that in the very beginning of an attack more or less vascular spasm may exist, which may even produce a sudden momentary retardation or obstruction in the circulation through the capillaries rapidly passing into dilatation; but I should not consider this spasm to be the cause of the attack, but rather the result of the commencing discharge of the nerve-ganglia, which are certainly most closely connected with the vaso-motor nerves.

Schiff found that, after cutting through the medulla oblonglata on one side on a level with the point of the calamus scriptorius, an increase of heat took place in the head and ears on the side operated on,* whence it would appear, that the medulla oblongata must exercise a strong influence on the vascular nerves of the head. In like manner, the experiments of Callenfels have shown, that irritation of one sympathetic may produce constriction of the arteries of the pia mater

* M. Schiff, *Untersuchungen zur Physiologie des Nervensystems*, 1 Th., p. 202.

of the cerebrum, which is rapidly followed by considerable dilatation.*

It thus seems to be scarcely doubtful, that the excited action of the ganglionic cells in the medulla oblongata must extend its influence to the vaso-motor nerves of the brain, and this altered and more or less disturbed state of the circulation is, in my opinion, the cause of the loss of consciousness during an attack of epilepsy; while it is incorrect to suppose, that this loss of consciousness always precedes the attack. In one case, where an epileptic patient fell with a shriek, he assured me, in answer to my inquiry, that he had heard the shriek, but was unconscious of everything after it.

I therefore freely admit, with Kussmaul, that in an epileptic attack the whole brain participates more or less in the change; but the commencement of the fit, or of the discharge, must, I think, be referred to the medulla oblongata. In like manner, we must explain the loss of consciousness as the result of the action so produced on the walls of the vessels of the brain, while consciousness may, as I shall hereafter show, in some slight attacks, even be maintained, or else may be lost without convulsions being produced. That loss of consciousness readily follows on slight disturbances of the cerebral circulation, we see abundantly illustrated in the cases of so many girls or women, who become pale and fall in a faint, so that this is easily explained in epilepsy.

* J. van der Beke Callenfels, *Over den invloed der vaatzenuwen op den bloedsomloop*, Utrecht, 1855, pp. 67 *et seq.*

CHAPTER III.

PATHOLOGICAL ANATOMY OF EPILEPSY.

LITTLE progress has as yet been made in the study of the pathological anatomy of nervous affections in general. The lesions found after death are often unessential, the product and not the cause of the disease, or they consist in such slight and almost imperceptible changes, that we hesitate to refer to them the violent symptoms witnessed during life. Again, the insufficiency of our knowledge of the vital phenomena in the healthy body, renders us unable to explain the relation between the morbid alterations observed after death, and the disease itself; and there is unfortunately no affection to which these observations are more truly applicable than to epilepsy.*

Thus Foville, notwithstanding his great experience as a cerebral anatomist, who has shown by his excellent work on the brain,† that he has examined with greater accuracy than any one else the more profound connexion of the different parts of this organ, says, in

* It is still denied by many, that in the insane the phenomena found in the dead body throw any light on the nature and course of the disease. More than thirty years' experience has led me to a totally opposite opinion, and I do not remember to have performed, during the last twenty-five years, the dissection of an insane person, which did not afford a satisfactory explanation of the phenomena observed during life. On many occasions I was able accurately to foretell what we should find, of which my friend Liedholm, and formerly the celebrated Bends of Sweden, and van der Lith, Med. Doctr., of the Utrecht Institution, were frequently witnesses. Not long ago, in a remarkable case, in which I had anticipated degeneration, or rather inflammation of the cortical substance under the os frontis, Dr Albani of Lombardy, who just then visited me, had an opportunity of observing how completely the results, even in points of detail, corresponded to my diagnosis. The grounds of this I have already in various places communicated; I hope I shall yet be able, on some future occasion, to explain and demonstrate the subject more fully.

† *Traité complet de l'Anat. et de la Physiol. et de la Pathol. du Syst. cerebrospinal, avec Atlas*, Paris, 1844.

an admirable and judicious article, *Epilepsie,* in the *Dictionnaire de Médecine et de Chirurgie pratiques* :—*

" Si vous examinez le système nerveux d'un épileptique, chez lequel les attaques n'ont pas été suivies d'un trouble durable dans l'exercice des fonctions intellectuelles et locomotrices, vous ne trouverez aucune altération constante, si ce malade a succombé à une affection étrangère à l'épilepsie.

" 1. Vous ne trouverez rien, absolument rien, qui diffère de l'état normal dans le plus grand nombre des cas de ce genre. Dans quelques-uns, vous rencontrerez des altérations telles qu'un tubercule, un cancer, une production osteo-calcaire, qui peut bien être regardée comme cause occasionelle du désordre qui a excité les attaques ; mais ce désordre lui-même a disparu, comme les symptomes, le tubercule reste pourtant aucune phénomène ne trahit sa presence.

" 2. L'inspection des organes encéphaliques des épileptiques, sans complication de désordre permanent dans les fonctions intellectuelles et locomotrices, vous offrira une altération constante toutes les fois que ces malades seront morts dans leurs attaques. Cette altération sera une injection générale tres forte de la substance encéphalique ; la dure-mère, l'arachnoide, le cerveau, le cervelet, etc., seront gorgés d'un sang livide ; c'est aussi ce qu'on observe dans les mêmes organes des pendus, des asphyxiés. Ainsi cette altération, quoique constante chez les épileptiques morts dans l'accès, n'est pas caractéristique de l'épilepsie ; elle l'est plutôt de l'asphyxie à laquelle ont succombé les malades.

" 3. Chez les épileptiques offrant la complication d'un désordre intellectuel permanent, et aussi d'un affaiblissement dans les mouvemens, vous trouverez des altérations d'une autre espèce."

These he further describes as hardening, the medullary matter exhibiting a dull appearance ; sometimes in addition to the hardening a general vascular injection is present, and in a large number of cases there is extraordinary dilatation of the blood-vessels. Sometimes, we find softening in the general consistence of the cerebral substance, a sort of flaccidity, and at the same time great vascular dilatation.

These changes occur throughout the whole medullary substance of the brain, in the interior of the hemispheres, as well as in the corpus callosum, the cornu ammonis, the cerebellum, the protuberantia, the pedunculi cerebri and cerebelli. The alteration in the brain may, therefore, be very general. At the same time we find inequalities in the

* *Diction. Méd. et Chirurg. prat.*, t. 7, p. 419, Art. *Epilepsie.*

surface of the grey substance, as well as a marbled appearance, or rosy-colour of its interior; sometimes increased or diminished consistence; finally, adhesions to the cerebral membranes; in a word, traces of more or less chronic inflammation of the brain.

In this description, Foville does not rest solely upon his own experience, but quotes that of Bouchet, Casanvielli, Morgagni, and others.

I have, in place of bringing forward a number of various witnesses, quoted Foville more fully, as one of the most distinguished cerebral anatomists, who at the same time, from the abundant opportunity afforded him as Physician-in-chief of the Charenton Institution in Paris, was in a position to acquire an extensive experience in reference to epilepsy.

The result, however, has been such as to promise no information, and to deter the majority of investigators from venturing to seek any connexion between the post-mortem appearances of epilepsy and the phenomena observed during life. But this prospect becomes still more gloomy when we follow our sagacious author further.

Thus he infers from the foregoing data, that the negative results of pathological anatomy in epileptic patients, who have suffered from simple fits without mental complication, show, that there is absolutely no constant alteration in the brain to account for the phenomena. And, he asks, must it not be so? Since, when the phenomena of the attack have passed away, the epileptic patient is not ill, and in the exercise of his functions exhibits no remarkable difference from healthy individuals. To endeavour in these cases to discover the cause which has produced the previous convulsions appears to be as absurd as to attempt to find the traces of the changes in the brain which may have taken place in it in directing the voluntary movements.

He then asks, whether we may seek this cause in congestion. But, he says, how can we admit congestion as the cause, which must often have disappeared in less than a minute?

How can we explain the phenomena of epilepsy by congestion, which is incontestably less at the commencement of the attack than at the end, when the violence of the fit begins to diminish, while the latter entirely disappears, when the redness, the enormous tumefaction of all the external parts of the head, and the distension of the jugulars are still present, to show that the brain is in the highest degree of congestion?*

* *Dict. de Méd., l. c.*, pp. 420 *et seq.*

Such an opinion from a practitioner so experienced in nervous diseases, and from such a skilful cerebral anatomist, has indeed the tendency to deter any one from endeavouring to throw light on the subject, and to cause it to be considered venturesome to pretend to do so. But we cannot, especially as we are aided by the progress of science, and by the use of the microscope, with which Foville was not acquainted, as well as by our more accurate views of the minute structure, and of the functions of the nervous system, stand still, and we may at least make the attempt, though this may be regarded as only a first step.

My earlier experience as to post-mortem examinations in epilepsy quite agrees in main points with that of Foville; frequently I found hardening, and indeed contraction of the medulla oblongata, but not constantly. Sometimes there was degeneration of the brain, at one time appearing to be the cause, at another the effect of the disease. The spotted, and, as it were, marbled appearance of the medullary substance in the brain, in which I thought I discovered the results of chronic irritation, which might have given rise to the involuntary convulsions and epileptic attacks, long attracted my attention; until more numerous examinations showed me, that in epileptic patients who had died of other diseases, this did not occur, and that it, therefore, was the effect, at least in great part, of the congestion during the last fatal attack.

At length I thought it necessary to submit the medulla oblongata to careful and special microscopic examination. I had, however, in my investigations on the spinal cord often observed, that if the latter had lain too long in spirit it acquired a granular condition, and that by still longer action of the spirit the medulla presented more and more the appearance of firm fatty conglomerations in the tissue.

I was, therefore, much struck by perceiving that in the medulla oblongata of the first two epileptic patients whom I had occasion to examine, a minutely granular matter manifested itself in fine sections, even when the medulla has lain in spirits only a couple of days—I subsequently observed that this granular matter had again dissolved in a solution of chloride of calcium and water, and that therefore it was not fat, with which I had confounded it, but albumen coagulated by spirit, which had imparted the hardness to the medulla oblongata. I hence inferred, that in these cases the constant and repeated congestions had led to the exudation from the vessels of a more albuminous intercellular fluid than occurs in the healthy state, and that this fluid, causing the nerve-filaments to adhere to one another, and indurating the whole spinal cord, might also exercise an injurious influence on its functions. In the brain, too, I sometimes found the same phenomenon.

Subsequently, however, I found the opposite condition in other cases. The medulla oblongata was softened, swollen, and on microscopic examination, exhibited a most beautiful specimen of fatty degeneration, so that it was with great difficulty I could separate the fat sufficiently from the thin microscopic sections, to obtain the necessary degree of transparency. This I considered to be a more advanced stage of degeneration. I was obliged to leave the spinal cord longer than usual in tolerably strong spirit, in order to give it the hardness necessary to enable me to make fine sections of it; it was sometimes even very difficult to harden it sufficiently. There was in this case solution; the previously effused albuminous intercellular fluid was followed by one, perhaps more watery, or rather had passed into fatty degeneration. As in all instances of softening and solution, fatty degeneration had here begun, threatening more or less to destroy the whole structure. Here, too, I found the granular changes of the coagulated albumen, which subsequently again disappeared in chloride of calcium, proving that in this instance also, with softening and fatty degeneration, the intercellular fluid had not ceased to be highly albuminous.

This reminded me of the remarkable investigations of J. C. Bucknill, who found, that in dementia after insanity, the brain had become specifically lighter through an increase of fat, but that in patients demented after epilepsy such a change is of much rarer occurrence, the specific gravity of the brain being in the latter class of patients often increased, while the organ itself has become indurated.* For these changes the author felt himself unable to account, but it is probable that the increased gravity was due to the more albuminous condition of the intercellular fluid so frequently present in epileptic patients. It is, however, plain, that in this case we have not to do with a change of tissue, capable of causing epilepsy, but with one produced by the constant recurrence of violent congestions of blood, necessarily followed by increased effusion, which the high pressure, during these epileptic attacks, and especially the augmented irritation, must render more albuminous.

* *British and Foreign Medico-Chirurgical Review*, January, 1855, Vol. XV., pp. 207 *et seq.*

I therefore grant to Foville, that of the first efficient causes of epilepsy (increased sensibility of the medulla oblongata) no traces are apparent in the body of a patient who has died in an interval between the fits, in which we should be able to discover any change capable of giving rise to epilepsy; but, I deny, as I shall hereafter show, that this is always the case, even in epileptic patients, who have not yet become paralytic and imbecile.

Further, Foville compares the dementia after epilepsy with that after insanity, and thinks, that both exhibit exactly the same phenomena, the same caurse and morbid nature. He says:—

"Dans l'épilepsie compliquée d'aliénation, les attaques d'épilepsie précédent ordinairement tout désordre intellectuel; ce désordre, lorsqu'il arrive, offre le plus souvent le caractère de la démence, ou, si dans le principe c'est une excitation maniaque, la perte graduelle de la mémoire, de la faculté de coordoner, de lier des idées, même absurdes, en font bientôt une vraie démence. L'affaiblissement musculaire, caracterisé surtout par une sorte de bégaiement, se développe en même temps dans la même proportion. Dans l'aliénation, compliquée de paralysie générale et d'attaques épileptiques, les premiers désordres sont des troubles intellectuels, appartenant le plus souvent par leur forme à la démence, finissant toujours par y arriver lorsque dans le principe ils ont offert un autre caractère. L'affaiblissement des mouvemens se manifeste ensuite par degrés; il est sensible dans le principe par l'embarras des mouvemens de la langue; enfin les attaques epileptiformes caracterisées par une perte subite de connaisance, insensibilité générale, convulsions, rougeur livide de la face, écume de la bouche, etc., se manifestent.

"Ainsi, d'un coté, pour premiers symptomes, attaques d'épilepsie; de l'autre, attaques d'aliénation. Aux attaques d'épilepsie succède un affaiblissement intellectuel, à celles d'aliénation un affaiblissement musculaire; arrivent enfin, dans le premier cas une démence confirmée, dans le second un affaiblissement musculaire de plus en plus prononcé. Dans les deux cas, la marche des accidens semble s'arrêter dans l'intervalle des attaques; leur retour est le signal de l'augmentation des désordres, jusqu'à ce qu'enfin la mort termine cette déplorable existence, et c'est un dernier trait qui complète l'analogie, que l'incurabilité absolue de ces deux espèces de maladies compliquées de désordres analogues de l'intelligence et du système locomoteur."

He hence infers, that these changes consist entirely in the same kind of affections, and are results of epilepsy. I shall endeavour to show how Foville, and with him most writers, are vastly mistaken on this point, to the great prejudice of the epileptic patients, who, in case of commencing imbecility, are incorrectly considered to be wholly incurable.

Lastly, from the whole he draws the following conclusion :—

"Concluons que la cause matérielle de l'épilepsie simple est encore à fixer ; qu'elle est vraisemblablement aussi passagère que la durée des attaques, qu'elle consiste vraisemblablement dans une altération du mécanisme de l'innervation, que nous devons avoir bien de la peine à saisir, ignorans comme nous le sommes de ce mécanisme à l'état normal."*

I have already shown that this primary cause consists in an exalted sensibility and activity of the medulla oblongata, whereby this part more rapidly answers every stimulus in abnormal reflex movements, or transfers its accumulated nervous or electrical force to the nerves, and discharges itself in muscular contractions.

We must, therefore, as is the case in so many diseases, content ourselves with the investigation of the proximate results of the fits of epilepsy, and these appear to me to be not unimportant.

Besides the hardening or softening, which I have so often met with in epilepsy, and which is also noticed by Foville, the changes undergone by the blood-vessels in this disease are of especial importance, and it is to this point that I particularly wish to direct attention.

In the first place, I must observe, that in all dissections of the medulla oblongata in epilepsy, whether the patients died in or out of the fit, I met with great redness and vascular tension in the fourth ventricle penetrating into the medulla oblongata, sometimes to a considerable depth. Thus, in preparing transverse microscopic sections through the whole medulla oblongata, from beneath the pons Varolii to the inferior extremity of the corpora olivaria, I was particularly struck by finding the posterior part towards the fourth ventricle of a much darker colour, usually containing some more distended vessels, which then ran either in the course of the roots of the hypoglossus into the corpora olivaria, or in the course of the vagus and accessory, or in both. Where the degree of redness was slighter, it was commonly confined to the posterior half of the medulla ; in most cases, however, this hyperæmia extended into the

* *l. c.*, p. 424.

corpora olivaria, which were often furnished with large blood-vessels. Thus, also, in the raphe, dilated blood-vessels were almost always visible. After I had discovered the close connexion between the corpora olivaria and the hypoglossal nucleus in the subsequently described pedunculus olivæ of Lenhossek, I happened to find, exactly in this course, thick dilated blood-vessels, such as those above-mentioned, in the first epileptic patient, whose medulla oblongata I had the opportunity of examining microscopically. The part in question was sent to me from the Institution for the Insane at Meerenberg, through the kindness of the director and the principal physician Everts, and the third physician Opdorp, and was accompanied with a letter.*

It was an old case of epilepsy; the patient was also maniacal, and was often furious during the last five years that he was under treatment in Meerenberg. Latterly, he became more and more paralytic; swallowing was difficult. For the last twelve days he would use nothing but cold water. During his attacks, as I afterwards observed, he always bit his tongue. The following was the report I received of the dissection of the brain :—

"The skull was brittle and thin; the sinuses of the dura mater were wide, and partly filled with dark, half coagulated blood; the dura mater was not strongly connected to the skull; the arachnoid exhibited in different places a plastic exudation; this membrane was tough, and in many situations of a dull-white colour; the pia mater was thick and rather congested; it was, however, easily separated from the cerebral mass (atrophy of the cortical substance); the substance of the brain was somewhat congested, firm, and tough; the pituitary gland was very large and distended, and on section, discharged a white, slimy fluid."

It appeared to me important to ascertain the width of the vessels in the medulla oblongata under the microscope, and particularly of the widest vessels I could find. This amounted, in the course of the hypoglossus, to 0.230 mm.;† in the corpus olivare to 0.305; in the course of the vagus to 0.152. I connected the preponderance of the

* I gladly take this opportunity of publicly thanking Everts, Roëll of Dordrecht, and Ramaer of Zutphen, for the kindness with which, by sending me the medullæ oblongatæ of several epileptic patients, they have enabled me to accomplish these investigations.

† I have reduced all the following measurements to thousandths of a millimetre. I freely acknowledge that the measurements do not represent

diameter of the capillaries in the course of the hypoglossus over that of the vessels in the track of the vagus, with the fact that this epileptic patient had during his fits invariably bitten his tongue.

For, as this phenomenon, although very frequent in epilepsy, does not occur in all cases, it appeared to me, that if during the fit the vessels, which are so much wider, conducted more blood to the nucleus of the hypoglossus and the corpus olivare, which is in such close connexion with it,—it was not improbable that these parts would be still more irritated, which might cause convulsive movements of the tongue, and the protrusion of this organ between the teeth, and thus occasion it to be constantly bitten during the attacks of epilepsy.

Some time afterwards, in May, 1855, a patient died in the Asylum for the Insane, at Utrecht, who had been epileptic for fifteen years, and had for eight years been under my observation. I had in this case tried various remedies, but in vain. The patient's attacks were very variable; sometimes they were very severe,—at others, on the contrary, they were very slight; on the latter occasions he could continue sitting on his chair, was quite absent only for some moments, and was free from convulsions. He never bit his tongue; as to his state in other respects, he had quite lapsed into dementia.

I performed the post-mortem examination in the presence of my friend Liedholm of Sweden. Before the dissection, in order to test my hypothesis, I stated that I should, in this instance, find the medulla oblongata affected chiefly, not in the course of the hypoglossus, but in that of the vagus, as the respiration, too, was disturbed in slight attacks.

We found in the abdominal cavity the colon and sigmoid flexure very much dilated and lengthened, the latter ascending to the level of the transverse colon. Above and beneath the sigmoid flexure were many constrictions, which higher up again alternated with dilatations; the cæcum, too, was very much dilated. The patient suffered extremely from a torpid state of the bowels; and this tendency

the exact diameter of the vessels during life, as the latter had contracted both while they remained in spirit, and subsequently, still more while they were left in chloride of calcium; but this remark applies to all the vessels, and I was able to measure the cavity in which each had contracted. Besides, the question was not as to the absolute, but as to the relative width of the vessels; in reference to which, however, we must always bear in mind, that the wider vessels contracted proportionally more than the narrower and smaller ones.

to constipation and the changes in the colon had, probably, been the exciting causes of numerous cerebral congestions, which had been followed by epilepsy; just as in strictures and prolongations of the colon, the same conditions are so often productive of sympathetic mania.

The dura mater was very firmly adherent to the brain; the skull was however not thick, but soft, and free from the hardness which often accompanies such adhesions.

The pia mater was thin, there was no effusion on the surface; the veins of the membrane were very much distended; in some places there was effusion of blood under the pia mater. The convolutions were very much flattened on the surface, from distension of the brain; after the removal of the pia mater, they exhibited on the anterior lobes, under the os frontis, a more rosy-red colour. Here they were more firmly attached to the pia mater, so that the latter could with difficulty be drawn off from the convolutions without laceration (chronic inflammation of the cortical substance, and commencing adhesion to the pia mater). The earlier sympathetic affection of the brain had, therefore, become idiopathic, as is usually the case in old maniacal and demented patients. Particularly along the two fossæ Sylvii much blood was effused under the pia mater; the sinuses of the dura mater were very much distended and filled with blood; the pituitary gland was large; the basilar artery was very wide; the base of the brain was dry. The medulla oblongata appeared a little harder than the brain; although not thinner, it was not atrophied. The nerves in the pia mater, discovered by Bochdalek, were in this case very distinct on the cerebellum. In the postero-internal margin of the right inferior lobe, where this covers the crus cerebri from beneath, was a dark-grey, tough, viscid mass, here and there studded with black points of different sizes. Somewhat more anteriorly, and at some depth, in the so-called uncus gyri fornicati, and further towards the substantia reticularis Arnoldi,* these spots lay nearer to one another, and were interspersed with streaks of blood of a lighter red colour. Under the microscope, this part exhibited many brown cells, enclosing more or less altered blood-corpuscles. The crus fornicis, which here passes over into the inferior cornu, was degenerated, and near the entrance into this effused mass was furnished with black pigment, which could be traced into the inferior cornu to

* Arnold, *Tabulæ Cerebri*, Tab. VII., Fig. 3 *f*, *h h*.

the end, where an old sanguineous extravasation was present, which, probably, during the last long-continued and fatal attack of epilepsy had given rise to fresh effusion of blood. There was, further, a little fluid in the ventricles, probably effused in this situation in consequence of the generally œdematous state of the brain; in the choroid plextuses, as well as frequently in the posterior sinus, were large cells. In the semi-oval centre of Vieussens were extraordinarily dilated blood-vessels; the grey matter in the cortical substance was thin and pale, and had consequently already passed into a state of atrophy.*

The veins of the spinal canal were extremely distended with blood and dilated.

On making a section of the pons Varolii, I met, two lines above the entrance of the medulla oblongata, with a small sanguineous extravasation, from four to five mm. in breadth, whence a tolerably wide blood-vessel, of the thickness of half a mm., emerged. The vessel was filled with very stringy, firmly-coagulated fibrin.

The medulla oblongata exhibited, anteriorly, nothing particular except swollen capillaries; but, posteriorly, especially on the corpus restiforme, near the fourth ventricle, or, more exactly, on the so-called ligula or tænia plexus choroidei ventriculi quarti of Arnold, and the adjoining fasciculus cuneatus† on the right side, little tubercles appeared, perhaps twelve in number, each of which was surrounded by a capillary blood-vessel, situated as in a little depression between the tuberculous projections. On the left side, although in a much less degree, a trace of such a condition was, however, visible.

But on microscopic examination it appeared, that in this instance I had before me no tubercles of any foreign substance, but that this part had undergone very decided fatty degeneration, whereby it was enlarged; in which enlargement the blood-vessels had not so fully participated, causing the formation of little grooves, and giving rise to a tuberculous appearance. The fat exhibited itself in thin superficial sections in extraordinary quantity, more,

* We have, therefore, in this case an example, in which probably a sympathetic cause in the abdomen gave rise to the disease, and nevertheless, subsequently, unilateral change in the brain was the result; in this instance probably in consequence of violent congestion during the attacks of apoplexy.

† Arnoldi, *Tab. Cerebri*, Tab. VIII., Fig. 3 *h h*.

however, on the right side than on the left, which was also less affected, and was not so much swollen. On a transverse section, the greatest change appeared to be limited to the parts situated without the nervus vagus.*

On a level with the second cervical vertebra (the origin of the phrenic nerve) the grey substance was unusually red and highly coloured, more so than I had before found it. After the medulla oblongata had lain for three days in spirit, of specific gravity 0.895, it was still soft, so that it was with difficulty that sufficiently fine sections could be prepared. There was, however, a number of granules in the tissue between the ganglionic cells and the nerve-fibres, but which, from their less refractive power, and minuteness, evidently did not consist of fat; we likewise saw some crystals of hæmatosin. The following day, all these granules had disappeared in the sections which had been placed in a concentrated solution of chloride of calcium. I therefore concluded that these granules were formed by albumen, coagulated from the intercellular fluid in consequence of the action of the spirit, and that thus, notwithstanding the fatty softening, an excess of albumen was effused in the intercellular fluid, as a result of chronic inflammation.

In the transverse sections, the capillary vessels appeared very much dilated, especially in the paths of the hypoglossus and vagus. On the right, or more deeply-implicated side, the blood-vessels were wider in the course of the vagus; on the left they were somewhat wider in that of the hypoglossus, as here the vessels of the vagus were rather less swollen. On repeated measurement, it appeared that the widest capillaries in the path of the right vagus amounted to 0.268 mm.; in that of the hypoglossus of the left side, to 0.172; in the corpus olivare, to 0.178; in the septum, to 0.230.

It was evident that the sanguineous extravasations in the inferior cornu and the pons Varolii were results of effusions which occurred in the last period during violent attacks; as effused blood cannot be preserved in the brain for fifteen years, but would within that time have been absorbed.

We could, therefore, only suppose that the originally exalted irritation of the medulla oblongata, which had given rise to epilepsy, had finally passed into chronic fatty degeneration and inflammation, and that this had kept up the epilepsy and rendered it incurable. I

* My first figure, *e*, *f*, *v*, D, *t*, *n*, *m*, *s*.

thought that the results of the post-mortem examination especially justified this inference, as my diagnosis made previously to the dissections—that I should find the greatest amount of alteration without the course of the hypoglossus—was most remarkably confirmed; the lesion was, in fact, confined to the outside of the vagus. I hence inferred, that the original irritation of the medulla oblongata, and particularly of its outer side, had produced an increased afflux of blood, especially in the repeated attacks;—that the blood-vessels consequently became organically dilated, their walls being very much thickened and much stronger than in the normal state; and that through this increased afflux of blood the ganglionic cells became in turn irritated, and, as it were, overloaded, so that they were compelled from time to time to discharge themselves in epileptic fits. Hence it would follow, that the dilated state of the blood-vessels must be regarded not only as a result, but also, in fact, as a secondary cause of the attacks,—and that, as the congestion and the strong current of blood were kept up, both by the constant irritation in the attacks, as well as by the fact that the dilated vessels and their thickened walls could no longer be brought back to the normal state, and had now already produced a condition of fatty degeneration, they had caused the incurability of the epilepsy, against which I had in vain tried all kinds of remedies, both internally, and especially externally, as derivants.

It was thus of the greatest importance to continue these investigations, and I therefore requested my friends, Heeren Dr. Everts, Persyn and Opdorp, of the Meerenberg Asylum, where so many epileptic patients are under treatment, to be good enough to send me the recent medullæ oblongatæ of dead epileptic individuals. The gentlemen with the greatest readiness complied with my request; I had myself opportunities of adding some post-mortem examinations of epileptic patients who died in the Asylum for the Insane at Utrecht, and I also received the medulla oblongata of an epileptic from my friend de Ridder, a physician practising in this city; so that altogether I was enabled to examine the bodies of fourteen epileptic individuals.

In no other patient did I find so great a degree of fatty degeneration as that of which I have just now spoken. In some instances the medulla had however passed into incipient fatty degeneration with exudation of albuminous intercellular fluid; in several the medulla was hard and firm; in some it was rather slighter than is normally the case; in most I met the granular exudation of albuminous serum already described.*

I shall by no means weary the reader with the details of the histories of these epileptic patients: they were all old incurable cases. Of all I have in consecutive transverse sections micrometrically determined the width of the caplliary vessels in the medulla oblongata, and I have thrown the results into a tabular form.† For the sake of complete comparison I at the same time determined the width of the capillaries in the medulla oblongata of a maniacal patient with paralytic affections, though not epileptic; and of a woman dead of another disease, that is of a healthy medulla oblongata; and also the width of the largest blood-vessels in the medulla oblongata of a cow.

In the great majority of cases I succeeded in ascertaining whether the patients during the attack had bitten the tongue, which occurs in most instances, but to which attention is not always paid. In a couple of instances, however, this was uncertain; so that I have been obliged to separate two cases from the table, as from them no certain conclusions could be drawn.

In this point of view, I have divided the results into two tables: in the first, the cases are given of epileptic patients, who during the attack were in the habit of biting the tongue; in the second, I have placed those cases where this did not occur.

* Changes in the medulla oblongata often occur in epileptic patients, but are not always sufficiently attended to; I myself formerly often met with hardening and atrophy of this part. Even during the printing of this Treatise, I found in the annual statistical reports of the physicians of asylums for the insane, which will soon be published, a case of the presence of pus in one corpus olivare in an epileptic patient at Meerenberg, and of hardening and atrophy of the medulla oblongata in another instance at Franeker; unfortunately, no particulars of the previous illnesses are added.

† I had at first, for the last figure in the table, calculated the average of the several wider vessels in the paths of the vagus and hypoglossus, in the corpus olivare and the raphe, and although an evident difference was brought out in this way, I considered, that as I had admitted into this calculation a varying number of smaller blood-vessels, which would of course exercise a considerable influence on the determination of the greatest width, I could not in this mode obtain any certain result. As the question was merely as to the widest capillaries, I determined to bring into the table only the measurements of the largest blood-vessels which I could find in each medulla in the above-mentioned paths, and in this way the results are much more striking.

TABLE A.

EPILEPTIC PATIENTS, WHO BIT THE TONGUE DURING THE ATTACK.

Place whence the Epileptic came.	Width of the Capillaries.				Observations.
	In the path of the Hypoglossus.	In the Corp. Oliv.	In the Raphe.	In the path of the Vagus.	
	mm.	*mm.*	*mm.*	*mm.*	
Meerenberg, 6th Aug., 1854.	0.230	0.305		0.152	I did not determine the vessels in the raphe in this case. The patient did not die in a fit, but of phthisis pulmonalis. Man, aged 30.
Meerenberg, 18th Nov., 1855.	0.303	0.355	0.370	0.170	Died of phthisis pulmonalis. Man.
Utrecht B., 4th Nov., 1855.	0.393	0.350	0.305	0.292	Occasionally bit the tongue. Died of marasmus and exhaustion. Man.
Meerenberg, 5th Jan., 1856.	0.265	0.280	0.320	0.247	Great biter, violent epilepsy; died of marasmus and phthisis. Boy, aged 15.
Meerenberg, 4th June, 1856.	0.280	0.408	0.370	0.305	Died in violent excitement after an attack; occasionally bit the tongue. Man, aged 35.
Meerenberg, 17th June, 1856.	0.280	0.152	0.280	0.242	Died of marasmus and general paralysis. Man.
Meerenberg, 18th Nov., 1855.	0.390	0.355	0.485	0.253	Appeared to bite her tongue occasionally, but the case was not sufficiently observed. Woman. Emphysema of the lungs.
Average.	0.306	0.315	0.355	0.237	
Utrecht, de Ridder.	0.204	0.382		0.204	It was uncertain whether this patient bit her tongue; there were no particularly wide vessels in the raphe. Died of phthisis pulmonalis. Girl.
Dr. Roëll's case.	0.261	0.305	0.412	0.214	Uncertain; but probably bit the tongue. Died of inflammation of the brain, not in consequence of an attack. Girl.

TABLE B.

EPILEPTICS, WHO DID NOT BITE THE TONGUE.

Place whence the Epileptic came.	Width of the Capillaries.				Observations.
	In the path of the Hypoglossus.	In the Corp. Oliv.	In the Raphe.	In the path of the Vagus.	
Utrecht Kr., May, 1855.	*mm.* 0.172	*mm.* 0.178	*mm.* 0.268	*mm.* 0.268	Fatty degeneration on the outside of the vagus; died in a fit. Man, aged 50.
Meerenberg, 7th Feb., 1856. No. 1.	0.190	0.195	0.315	0.345	Deaf and dumb, died in a state of coma, after an attack. Woman, aged 40.
Meerenberg, 7th Feb., 1856. No. 2.	0.224	0.255	0.345	0.369	Died in an attack. Man.
Utrecht B., 18th March, 1856.	0.242	0.230	0.290	0.452	Died in an attack. Man, aged 50.
Meerenberg, 25th Feb., 1856.	0.223	0.229	0.318	0.305	Died in an attack; formerly bit his tongue, but subsequently ceased to do so. Man, aged 18.
Average.	0.210	0.217	0.300	0.348	
Mania paralytica.	0.140	0.160	0.160	0.173	In every part of the brain great dilatation of the vessels and adhesion between the pia mater and the convolutions on the upper surface.
Healthy Med. obl.	0.097	0.052	0.148	0.064	
Suburban Hospital (Buitengasthuis) at Amsterdam, 1st Feb., 1858.	0.360	0.360	0.430	0.255	Aneurismatic vascular dilatation in the right corp. pyramid., and extremely dilated vessels in the right corp. dentatum cerebelli; epileptic from childhood. Girl, died of pneumonia; did not bite the tongue.*

* While this work was passing through the press, I received this medulla oblongata from my friends, Prof. Schneevogt and Dr Moll, from the

If we compare these two tables, we shall find that they present a striking difference; namely, that in the first table, containing the epileptic patients who bite their tongues during the attack, the capillaries in the course of the hypoglossus and the corpus olivare are much wider than those in that of the vagus; while this state of things is reversed in the second table. For the sake of greater clearness, I shall here place the two averages from the tables in juxtaposition.

Different Epileptics.	Hypoglossus.	Corpus Olivare.	Raphe.	Vagus.
Table A. Tongue-biters	0.306	0.315	0.355	0.237
Table B. Not Biters - -	0.210	0.217	0.300	0.348
Difference - - - - - -	+ 0.096 A.	+ 0.098 A.	+ 0.055 A.	+0.111 B.

Suburban Hospital at Amsterdam. The specimen was accompanied with the statement that the girl, aged twenty, had been epileptic from her earliest youth. The attacks presented the characteristics of idiophatic epilepsy. Formerly they were very frequent, and had a blunting influence upon the exercise of the mental powers; but after menstruation set in, in her nineteenth year, they diminished to eight or ten in the month. She was latterly often attacked with fever, soon complicated with delirium, and finally passing into pneumonia of the right side, under which she sank. On opening the skull, much cerebro-spinal fluid flowed out; the vessels of the pia mater were very much distended.

I was particularly struck with the redness in the right corpus dentatum cerebelli, in which the vessels were dilated to nearly a mm. (0.920). Furthermore, a great aneurismatic dilatation of a blood-vessel in the right corpus pyramidale attained a width of 0.485, the diameter of the undilated portions of the vessel amounting to only 0.230. Lastly, this case affords an example of the vessels in the course and nucleus of the hypoglossus being wider than in those of the vagus, without the patient biting her tongue during the attacks, thus making an exception to Table A, while the table is confirmed in this, that the patient did not die during an attack, like all of Table B, where the vagus was more dilated.

What influence inflammation of the corpus dentatum cerebelli has had on the attacks, I cannot decide; I have in epileptic patients often found dilated vessels in it, but not such great dilatation as in this case. The aneurismatic dilatation, which in the right corpus pyramidale was confined to one side of the blood-vessel, is highly important, particularly as, according to the report, the tonic spasms and contortions were mostly on the right side.

Hence, it appears, that in epileptic patients, who were in the habit of biting their tongues during the fit, the vessels were wider than in those who did not bite the tongue on an average in the course of the hypoglossus by 0.096; in the corpus olivare, which certainly here plays an important part, by 0.098 mm.; and in the raphe by 0.055. In those who did not bite the tongue, on the contrary, the vessels in the path of the vagus were 0.111 wider than in those in the first Table A. This difference, so manifest in all, is too great to be considered merely accidental; and we must hence infer, that in epileptic patients who are accustomed to bite the tongue in every attack, the irritation and vascular dilatation are more decided in the track of the hypoglossus and the corpus olivare; in epileptics, on the other hand, who never bite the tongue, these changes are better marked in the course of the vagus. The vessels in the raphe appear too to be somewhat more dilated in the first class; yet as this is situated exactly in the middle, I have no remark to make on it.

In one vessel in the raphe, No. 1, in the second Table, B, I found the wall of the vessel increased in thickness to 0.064 mm., a thick-

To the observations on epileptics who do not bite the tongue, I am able to add three cases accurately described by Dr. Kroon, in his Dissertation on Epilepsy, and its treatment with valerianate of atropia and lactate of zinc *(over Epilepsie en hare behandeling met Valerianas Atropini en Lactas Zinci)*, published at Amsterdam in 1859. In these cases I examined the medullæ oblongatæ carefully with the microscope in the presence of the author.

None of the three patients had ever bitten the tongue, and each of them had died in an attack, which is extremely remarkable, and strongly confirmatory of my observations on this subject. No. 1, a woman aged 52, had had several apoplectic attacks, which had occasioned paraplegia; the two corpora striata were more or less degenerated, presenting softening and extravasations of blood, some of the latter being recent and some of long standing. Violent epileptic attacks, occurring in rapid succession, terminated her existence.

In No. 3, death was the result of a very remarkable and certainly very rare fissure or laceration, extending with red edges, in the right side of the medulla oblongata, above the glosso-pharyngeus and beneath the pons Varolii, in the direction marked in my Fig. 1, by the letters *n*, *l*, *i*, *k*. Perhaps this was the consequence of an apoplectic effusion. In addition, in all three cases, some ganglionic cells were more or less darkened and degenerated in the nuclei of the hypoglossi and vagi. The three medullæ were in a state of well-marked fatty degeneration.

In No. 1, moreover, the materies nigra in the crura cerebri, especially on the left side, was orange-yellow instead of black.

ness which exceeds the diameter of most capillaries in the medulla oblongata in the healthy state.

This result becomes still more striking, if we compare it with the diameter of the vessels in a case of mania paralytica without epilepsy, where, moreover, there was much vascular dilatation in the brain. In this instance, the diameter of the vessels in the medulla oblongata was, nevertheless, in general smaller than in any case of epilepsy.* Equally remarkable is the difference between the diameter of the capillaries in epilepsy, and that in the healthy condition where it attains to scarcely one-third of the diameter of the capillaries in epilepsy.

The difference in the diameter of the vessels of the corpora olivaria is very striking. The greatest diameter in the epileptics who bite the tongue, is to that in those who never do so, as 315 : 217, being a difference of nearly a third. Moreover, if we compare the diameters

The dilatation of the vessels is shown in the following table, in thousandths of millimetres.

Number of the Patient.	Course of the Hypoglossus.	Corpora Olivaria.	Raphe.	Course of the Vagus.	Observations.
1	0.317	0.355	0.190	0.470	The degeneration was strongly marked in the vagus; the dyspnœa was extreme.
2	0.380	0.330	0.355	0.470	On the left degeneration between the corpus olivare and corpus pyramidale.
3	0.265	0.330	0.344	0.355	The medulla oblongata was bent obliquely to the right.†

From the above table, therefore, it again appears that the greatest dilatation of the vessels existed in the course of the vagus, in epileptics who did not bite the tongue, and at the same time, that in consequence of the violent action in the centre for respiration, tetanus of the respiratory muscles occurred in the fit, producing death.

* See Table B.

† As I had no part in the correction of the proof-sheets of the Dissertation, a very unfortunate typographical error in the table was allowed to remain in the original, 10,000 parts of English inches having been taken as millimetres, and some figures moreover, having been wrongly placed. I have here corrected the numbers from the original notes, and have reduced them to thousandths of millimetres.

of the vessels in the paths of the hypoglossus and vagi nerves in A and B, the width of the capillaries in the hypoglossus is to that in the vagus in A, as 306 : 237 ; and *vice versâ* in B, as 210 : 348 ; or in A, the vessels in the hypoglossus are 0.069, in B, they are in the vagus 0.138 wider.

From all this, I think we have sufficient reason to conclude, that the first cause of epilepsy consists in an exalted sensibility and excitability of the medulla oblongata, rendering the latter liable to discharge itself on the application of several irritants which excite it, in involuntary reflex movements. This irritation may either be external (irritation of the trigeminus), an irritated condition of the brain, or, as is still more frequent, it may proceed from irritants in the intestines. In children, worms in the intestines, acidity, a torpid state of the bowels, &c., are among the most common causes; in adults, there may be irritation of the intestines, particularly of the mucous membrane, constipation, and prolongations of the colon connected therewith, but above all, onanism, which acts so very much on the medulla oblongata, and must be regarded as a very frequent cause of epilepsy. Amenorrhœa, chlorosis, plethora of the uterus, hysteria, &c., are also to be enumerated.

In the commencement there is still only exalted sensibility. If this can be removed or moderated, the epilepsy gives way of itself, especially if the sensibility is not renewed by remote causes.

But if the disease has already lasted long, organic vascular dilatation takes place in the medulla, the consequence being that too much blood is supplied, and the ganglionic groups are too strongly irritated, too quickly overcharged. Every attack then becomes a renewed cause of a subsequent attack, as the vascular dilatation is afresh promoted by every fit. Lastly, increased exudation of albumen ensues from the now constantly distended vessels, whose walls at the same time become thickened, producing increased hardness of the medulla, subsequently passing into fatty degeneration and softening, and rendering the patient incurable.

With these changes, vascular dilatation of the brain, and particularly in the cortical substance, goes hand in hand. The small ganglionic cells, which are here present in such great abundance, become compressed by the dilated vessels, and perhaps also in consequence of the more albuminous nature of the intercellular fluid. Dulness and loss of memory are the results; or if after a fit an unusual current of arterial blood is supplied, we have, following immediately upon the paroxysm, over-irritation, rage and acute mania, which is present in so many epileptics.

This dulness of the mental powers, which may represent apparent, until it finally passes into true dementia, differs very much from dementia after acute or chronic mania—a point which is not sufficiently kept in view. Dementia after epilepsy is for a long time the result of vascular dilatation, and as I shall show, if we succeed in conquering the epilepsy, the silliness, the blunting of the mental powers, and the shortness of memory give way, and the patient gradually regains his former powers of mind, although not always in a perfect degree, which depends on the amount of the affection. The dilatation of the vessels, kept up by no fresh attacks and congestions, begins by degrees to disappear, the vessels contract, regain their tone, the albuminous exudation becomes absorbed, and the patient recovers.

In cases, however, of dementia after acute mania the state of things is quite different. Here the affection begins with irritation of the cortical substance, especially of the anterior lobes under the os frontis; this passes under the form of chronic meningitis, which manifests itself only by increased excitability of the patient, into inflammation. The sufferers from mania have now great projects; they have become rich, play with millions, are generals, kings, and emperors, prophets, or ambassadors from heaven. There then ensues a formation of cells and granular cells, and the cortical substance becomes firmly adherent to the pia mater. The blood-vessels become atheromatous; with meningitis, effusion of much serum ensues; the vessels exude a more watery fluid and the cortical substance begins to atrophy. It becomes paler and thinner, and true dementia, which is absolutely incurable, follows the previous excitement.

Thus, although the phenomena may be the same, as in both cases there is compression of the cortical substance, the latter after mania and the coexisting inflammation passes rapidly into degeneration, and the disease becomes incurable; while in epilepsy, the vascular dilatation, which is only occasionally promoted by an attack, may last for a long time without producing active degeneration. I have, as I shall hereafter more fully state, seen cases of a high degree of silliness and dulness in consequence of epilepsy, from which the patients have completely recovered. Although this may rarely be the case, the instances I allude to are sufficiently numerous to establish the proposition I have advanced.

It is important to remark, in close connexion with this subject, that in patients epileptic in a very slight degree, where absence of mind took place almost alone, without convulsions, where, therefore, the brain was more directly affected than the medulla oblongata, I observed stupidity, diminution of memory, incapability of continued thought, or of comprehending anything, to arise much more rapidly, —than in cases where spasms were constantly repeated without loss of consciousness. In a case of constant spasms, with occasionally, for example once a fortnight, an epileptic attack, which now at length appears likely to recover, and where this state has already lasted several years, the patient's condition has had absolutely no injurious influence on his mental powers, but has allowed him to pursue his studies with much success; while in two other cases, where young girls of about the same time of life as the first patient, about twenty years, had suffered for scarcely a year from similar absence of mind, alternating with some singular fits, the patients, even at the end of six months, began to complain of loss of memory and dulness of mind. Accordingly, the longer the sleep lasts after each attack, and with it the severe congestion of the cerebral vessels continues, so much the more injuriously does epilepsy act on the mental powers, so much the more rapidly does dulness ensue.

After I had prepared these tables, and had drawn from them the conclusions just now communicated, it occurred to me that it was of especial importance to know whether the patients had all died in a fit or not, as this must of course exercise a great influence on the dilatation of the vessels. On adding the mode of death in the observations, the surprising result struck me, that all the five epileptic patients mentioned in the second Table B, in whom the degeneration predominated in the region of the vagus, and in whom the vessels in the path of the latter were more dilated, and who did not bite the tongue, had died in a fit, probably because the mechanism of respiration was in them more severely implicated, whereby they were suffocated. Of the nine epileptic patients in Table A, who bit the tongue in an attack, and where the affection appeared to be confined more to the corpora olivaria and to the hypoglossus, only one died of the results of a paroxysm, and that precisely the patient, in whom the blood-vessels in the course of the vagus were much more dilated than in any other in the first table; while all the remaining patients in this Table A, where the vessels in the path of the vagus were narrower than in that of the hypoglossus, died of consumption, exhaustion, or diarrhœa, among whom one was affected with difficulty of swallowing. This remarkable result shows still more forcibly the importance of the different degrees of dilatation of the vessels.

Hence it also appears, that Foville did not express himself correctly when he so strongly and decidedly asserted that nothing characteristic of epilepsy can be found in the body of an epileptic patient who has died during an interval, of another disease.* The dilated vessels in the track of the hypoglossus and the corpus olivare prove the contrary; in No. 3 of the first table, the vascular dilatation was even uncommonly great, although this patient died of diarrhœa and exhaustion.

* See above, pp. 232 *et seq.* From the case last observed, communicated in the note to p. 246, it appears that increased vascular dilatation may be present in the path of the hypoglossus and in the corpora olivaria, without biting of the tongue; however, here, too, the fact stated in the text is confirmed, as this epileptic patient, in whom there was little vascular dilatation in the course of the vagus, did not die in a fit. As we have here entered on an entirely new field, subsequent observations will no doubt disclose further peculiarities.

In the case of an epileptic woman, the report of which, with the medulla oblongata of the deceased, I received after my Treatise was printed, the vessels adjoining the corpus olivare were 0.410 mm. in diameter; in the course of the hypoglossus, they were 0.230; and in that of the vagus, they were 0.127. The patient bit her tongue from time to time, and did not die in a fit, but collapsed and sank from exhaustion. This case may, therefore, be adduced as additional evidence in favour of the views put forward in the text.

CHAPTER IV.

ON THE MEDICAL TREATMENT OF EPILEPSY.

Imperfect as is the present state of our knowledge of the pathological anatomy and proximate causes of epilepsy, and of our acquaintance with the connexion of the several influences which are capable of exciting and maintaining the disease, the condition of the medical treatment of this miserable malady is equally, if not still more defective.

In no department of medicine does a more rude empiricism prevail. All kinds of secret and open remedies are tried without distinction, and a proper rational treatment, of which there is such great need, can scarcely be said to exist; a state of things dependent on total ignorance of the nature and essence of the disease, as well as of the causes which excite it, and of the peculiar morbid changes which keep it up. Everything rests upon loose conjectures, upon the temporary fame—now of this, now of another remedy; in fact, it has often appeared to me that many physicians, when called on to treat epilepsy, take refuge in a great box full of all kinds of medicines, among which those whereof they know not even the ingredients, occupy no small place. Now, they close their eyes, grope blindly in the box, take out a remedy, and compel the unfortunate patient to venture the slight chance that, among the hundreds of remedies contained in it, this is exactly the one suited to his state and the nature of his illness. Meanwhile the first period in which this disease, like insanity and other affections of the nervous system, may be cured, passes by unhappily and unused.

If a physician has had the rare good fortune, by means of any remedy, for example, flowers of zinc, nitrate of silver, ammoniated sulphate of copper, or indigo, to cure an epileptic patient, and if he be asked, what he has accomplished with his remedy, how it has worked in the system, and what change it has produced, to which the patient's recovery should be attributed, he shrugs his shoulders and thinks it is enough that the patient is restored, and that he is thereby justified in treating all subsequent epileptic cases with the same remedy, from which he once thought he saw so much advantage derived.

I need not say that such a mode of treatment and such views differ widely from rational practice and theory, nor are they in harmony with the present position of our knowledge of the functions and connexion of the nervous system.

Far as I am from being able to undertake to cure every subject of epilepsy—as unhappily the majority, after having in vain employed all kinds of remedies, at last seek assistance when the period of recovery is already past—I am convinced from five-and-thirty years' experience in the examination and treatment of very many epileptic patients, that in the commencement, as I have just now stated, epilepsy is a disease which, at least in the great majority of cases, is very capable of rational treatment.

In order briefly and clearly to explain the principles of such treatment, as it is not now my object to write a manual on epilepsy, I may refer to the leading points brought forward in detail in this work, in which the essential nature of epilepsy consists.

We have seen that this is to be found in an exalted sensibility of the medulla oblongata, rendering the latter liable to discharge itself through the operation of any irritant, whether cerebral, from inflammation or tubercle, which may have developed itself in the brain; or through psychical influence. We have also seen, that irritations in the intestines, or of the organs of generation have a powerful reflex action on the medulla oblongata, and by their exciting influence may produce epilepsy.

It is therefore of the greatest importance to remove, or to diminish this exalted sensibility, this greater or less congestion in the medulla oblongata, and at the same time to get rid of the remote cause, which we must endeavour to discover.

An example may explain this. A child, for instance, is attacked with epileptic fits or convulsions, and the physician discovers that the little patient is tormented with worms, which, as is well known, often give rise to such diseases in children, though they are not so likely to produce them in adults as many suppose. The practitioner gives one or other anthelmintic remedy, and the remote cause is taken away; many worms are voided, and the child recovers.

Now the physician has indeed fortunately attained his object in the recovery of the child; but can we, therefore call this treatment perfectly rational? Hundreds of children are tormented with worms, but are not therefore necessarily epileptic; there must consequently be still a nearer, a disposing cause, which has given rise to epilepsy. The exalted sensibility of the medulla oblongata must be moderated, without which the child would not have been attacked with epilepsy. Now, if the physician had at the same time employed suitable external derivative means to moderate this exalted sensibility in the medulla oblongata, he might have been said to have treated the patient quite rationally, and to have combated both elements of the disease. In this manner recovery would probably have been more speedily and more certainly attained; for it is not always sufficient to expel the remote cause, in this case the worms, to obtain a cure. And, nevertheless, this proximate cause of epilepsy, this affection of the medulla oblongata is exactly the point to which medical men in general pay the least attention.

On account of the importance of the subject, I will endeavour somewhat more distinctly to explain in what manner, in my opinion, we can best attain this object, namely, the moderating of the exalted sensibility of the medulla.

CHAPTER V.

ON THE MEANS OF COMBATING THE PROXIMATE CAUSE OF EPILEPSY.

We have above seen that the source of epileptic convulsions must be sought in the exalted sensibility of the medulla oblongata, with the vascular dilatation and further results to which it gives rise. Consequently, in a rational mode of treatment, the first question which occurs is, in what manner we can moderate and wholly overcome this abnormal sensibility?

I have tried many remedies, with a view of directly obviating this exalted sensibility and tendency to involuntary reflex movements. Ordinary narcotic medicines, opium, morphia, belladonna, hyoscyamus, &c., did not fulfil this object: indeed, more or less congestion of the head attends the use of these remedies; which must rather aggravate the tendency of the vessels in epilepsy to dilatation or congestion, in consequence of which these agents do not act advantageously in that disease. But there is still another and greater difficulty. The question is not to remove exalted sensation, or pain, for these do not occur in epileptic patients; but to moderate the exalted capacity for reflex action, and so to counteract the convulsive movements. Now sensation is, indeed, blunted by these narcotic remedies, but on the contrary, the capacity for reflex action is exalted by them, so that they tend to a greater evil, the production of convulsions. We must clearly distinguish between these two conditions. Thus, for example, chloroform removes the perception of sensation, but the capacity for reflex action is usually increased by it, just as in a frog whose head has been cut off, where no perception exists, but the reflex movements have become so much the more active. Thus, too, epileptic attacks are usually so much promoted by chloroform, that this agent has been recommended as a means of distinguishing true from feigned epilepsy; and in the few cases in which I have tried chloroform, I found severe epileptic attacks to ensue, which deterred me from its further use. I now flattered myself that I should attain my object by another medicine.

We are aware that strychnia exalts the capacity for reflex action in an extraordinary degree, and gives rise to spasms, and finally to violent convulsions and tetanus. Now it is well known, that if we give strychnia to animals, so as to produce convulsions, and then administer conia, these convulsions cease, and the animal becomes immediately paralyzed. Conia, like some other medicines, does not excite convulsions, but appears to destroy the activity of the spinal cord, the animal sinks down paralytic and dies. I flattered myself that a small dose of conia should therefore diminish the reflex capacity for epilepsy, and that I should thus have found a means of directly removing the proximate cause of the disease.

I now gave this remedy to three epileptics of long-standing (among whom was an unmarried woman aged thirty), who were all attacked every eight or eleven days, sometimes at longer, sometimes at shorter intervals, with violent epileptic fits, and with whom I had already in vain tried several remedies. I prescribed a thirtieth of a grain of conia three times a-day. So early, however, as on the second and third days I was obliged to give up this medicine; as in all three patients the attacks were increased so very much in severity and number, that several violent fits occurred in one day. I saw that the reflex action was not diminished but exalted by the drug, and that I had tried a most injurious medicine in epilepsy. This restrained me from any further experiments with such remedies.

Many years before I had endeavoured in another manner to act directly upon epilepsy. For, as a sufficient afflux of arterial blood is required for every exercise of the nervous system, I imagined that by moderating the vascular action, I should diminish the determination of arterial blood, and so be able indirectly to counteract the exalted sensibility of the spinal cord. With this object I prescribed digitalis for several epileptic patients; and in fact perceived, that the attacks were in some remarkably abated, when the pulse had become slower. I found that for this purpose an infusion of digitalis acted better than the powder. In one case, where no diminution of the attacks nor of the pulse followed the administration of powdered digitalis, the fits ceased for six months, under the cautiously continued use of an infusion of the herb. Subsequently, however, they returned, in consequence of onanism, to which the patient had anew addicted himself, and which appeared, moreover, to be the cause of his epilepsy, and now the digitalis had no longer any effect, perhaps on account of changes of vascular dilatation in the medulla oblongata, resulting from the last attack. The patient afterwards fell into a state of complete dementia, with incurable epilepsy. This postponement of attacks I have observed in several epileptic patients under the use of an infusion of digitalis; but I have not succeeded in curing a single case of epilepsy with digitalis alone. The remedy may, therefore, promote the cure, but is not powerful enough to accomplish it alone.

There remained now but one mode of attaining my object, namely, the use of external derivatives. And in fact, these are the remedies with which I have succeeded in curing several epileptic patients, among whom were even some old and desperate cases. So long as more than thirty years ago I had made use of them, when I was resident physician in the Suburban Hospital at Amsterdam, and I had occasionally seen benefit from their employment. Subsequently, however, after I had gradually recognised epilepsy as a disease of the medulla oblongata, the success of the more suitable application of these derivative remedies was more decided.

Formerly, I applied the derivatives to the crown of the head, and I have in fact in this mode obtained some surprising results in cases of very long standing, where the brain itself was already affected, as I shall hereafter point out.

But the derivative applications answered better still, especially in more recent cases, in the neck, whether as an issue or as a seton, placed as high as possible. Sometimes, nevertheless, I observed that in very sensitive patients the application of a seton caused too great irritation, so that at first an increase of the attacks ensued, which, however, after the application of cupping-glasses with scarification, or of leeches, and, under the use of an infusion of digitalis, or of a solution of tartar emetic, in a little time disappeared. For these reasons, I commonly commence the treatment in sensitive patients with an issue, which I afterwards change for a seton.

If the patients are at all plethoric, the repeated use of cupping with scarification is very necessary, and is to be preferred to the application of leeches. By this alone I have often seen the attacks remarkably diminished. If the employment of cupping-glasses is difficult in children or sensitive women, I apply in two or three places, high in the neck, two leeches, near one another, and after they fall off, I exhaust the blood by placing elastic cups over the bites, which, particularly in children, on account of the slightness of the neck, must be provided with a rather narrow opening. In this mode

I have obtained the more strongly derivative action of cupping-glasses, while I have avoided the soaking, and the increased congestion of blood occasioned by warm poultices.

In proof of the efficacy of this mode of treatment, I will communicate a couple out of several cases.

On the 26th of December in last year, 1856, I received from W., of Koevorden, a letter, in which he requested my assistance and advice for the recovery of his son, of whom he gave me the following detailed report :—

"His son was strongly built, eighteen years of age. Up to the age of four years, he was healthy, although full about the head. At this period, he was seized with a severe convulsive attack, which left behind it a comparative amount of dulness. At the age of six or seven, he had again recovered; he was, however, always bronchitic, and was often tormented with a convulsive cough, which was of such a nature that coming from school he was entirely or almost out of breath. This shortness of breathing and cough could be relieved only by rubbing or slapping him rather smartly on the back.

"Although frequently coughing, and very much troubled with mucus in the nose, at the age of twelve or thirteen he improved; on which account he was sent to school, whence, after a continued stay of two years, he returned home in good health and spirits on a visit to his parents. On subsequently going back to school, he was very much affected and dejected, and was again much annoyed with mucus. (To the impression made by his separation from his family the father ascribed the following changes for the worse in his state, which had, however, probably previously commenced, and had altered his sensibility.)

"After the lapse of a short time, he began to complain of vertigo, which increased so much that he often fell down in a state of unconsciousness, while his bronchitic tendency remained unaltered. He now abstained from schoolwork ; but, in spite of the rest, the vertigo increased, his falls became more frequent, and the master was obliged to send him home.

"On his arrival at home his state was as follows :—very often he was silent and reserved, stood up on a sudden from his chair, knocked about with his legs and arms, ran hastily some steps up and down, in the room, sat down again on the chair, resumed his work anew tolerably calmly, and if this happened at meal-time, he recommenced eating, as it appeared, with appetite.

"On being asked what was the cause of this behaviour, he answered, 'It seems as if some one called to me, William! come quickly, quickly!' This was all he could say about it; he did not speak of pain. (There were, therefore, hallucinations of hearing, probably from congestion in the medulla oblongata and the nucleus of the auditory nerve.) He was, however, not conscious when this attack came on; but he quickly came to himself again. At present, this is unfortunately not the case.

"The attacks here described, about three and a half years ago, had much of the character of St. Vitus' dance, now they have become of a worse description. The medical treatment has as yet led to no favourable result. The father now wished to leave the case to nature, closely watching whether the use of the last pills (nitrate of silver), should subsequently have any beneficial effect; but he was persuaded at first to consult me.

"These attacks on one occasion ceased for a longer time, as in 1855, when the patient continued free from them from the 1st of January to the middle of June, and during that time went to school and church. But he was then terrified, by a fire in a mill, on which the attacks were renewed in a more violent form, and have now continued for a year and a half with some intermission. During the past summer (of 1856), he was once more for some weeks free, when on a hot day, after he had again become bronchitic, and was coughing, running hastily towards one of his relatives, with his head congested, he was seized with a most violent fit.

"The attacks, as they latterly took place, are thus described by the father:—

"In the attack the patient becomes first a little abstracted, begins to move his arms and legs, usually catches violently at his head and abdomen; the whole body is in a state of convulsive movement; in addition, rigidity of the arms and legs comes on, so that if not watched he would fall down. He often foams at the mouth, the forehead is hot, a rather violent pulsation comes on in the pit of the stomach, the whole position in which the patient lies presents much of a bad convulsive character. There is also turning of the head and arms; the mouth is awry and usually open; the eyes going up and down, mostly wide open; the face is purplish. Generally after one or two minutes he begins to cough, and then the great urgency is mostly over. Dulness, deafness, and drowsiness now ensue, lasting at most a quarter or half an hour; the patient then sighs or yawns violently; the pulse is unsteady; the want of consciousness produced by such an attack continues, and the articulation has been for fourteen days more difficult, slow, and sometimes stammering. His intellect is still occasionally clear; but the fatigue which follows the attacks often obscures it for a time. He eats slowly, and it would appear that swallowing is difficult. (Evident congestion in the corpora olivaria.)

"After the end of the attack, the patient turns his head usually to the right, and appears to fix his eyes on some particular object; he rectifies this, however, when his attention is called to it. The stiffness of the arms and legs is always present in the attacks.

"On the very least exertion, even on the most trifling question being put to him, or on the slightest reflection, an attack generally ensues, sometimes violent, sometimes less severe. The patient's mouth is frequently in motion; he seems to chew or grind his teeth; this is not a good sign. (Commencing affection of the medulla oblongata). If this happens late in the evening, it often forebodes a restless night, together with attacks. He has little sleep, as little by day as by night. (Irritatio cerebri.) The attacks by day come on from ten to sixteen times, by night three or four times. It deserves to be noticed, that at stool he almost always has an attack (from straining and congestion). When the attack has passed off, he makes the motion of swallowing, as if there were some irritation in the throat, and this precedes the cough; afterwards he groans, and the mucus is audible in the chest."

I have thought it right to give this history *in extenso* as it is reported by the father, though not a medical man, with more than ordinary fulness and fidelity. Some days later I received, at my own request, a letter from the attendant physician, in which I found the foregoing confirmed, and observed that he had fruitlessly used different remedies, among which were anthelmintics, and latterly, nitrate of silver, so usually given to epileptic patients. No indication of onanism, in reference to which I made inquiry, was discoverable; but all the members of the family were of a very nervous temperament.

I advised the physician to apply cupping-glasses, with scarification to the neck, every four or five days; and when there was great congestion, to apply leeches to the nostrils, and perhaps also to the anus, as well as to establish an issue in the neck, with a view to change it subsequently for a seton, as I was afraid of too great irritation from the latter remedy at first. Internally, I prescribed an infusion of one scruple of digitalis in eight ounces of water, two spoonfuls four times a-day, with small doses of tartar emetic if the patient could bear them without nausea, in order still further to moderate the excited vascular action. In addition, I recommended that a cold douche to the head should be used at intervals during the day.

On the 20th of January, I received a report that the cupping-glasses had been applied three times to the neck, and, as I had suggested, in a couple of days after the first application the issue was established. The result was, that, from the 8th of January the attacks, instead of fifteen times, had appeared but once or twice a-day.

On the 11th of February I was informed that, under the continued use of the means employed (the issue with digitalis and tartar emetic, which he bore very well), the patient had, on the 22nd of January, an attack, on the 25th one, on the 29th one, on the 1st of February one, and that no attack had since manifested itself.

In accordance with my former letter, the physician in attendance had been anxious to change the issue for a seton; but the parents could not be induced to allow it. However, on the 1st of February a carbuncle or anthrax had begun to form in the neck, into which a crucial incision had been made, and which now suppurated very well; so that nature herself had established a stronger derivant than the seton, to which the rapid and total cessation of the attacks is, in my opinion, partly attributable. The report added, that since that time the patient had become clearer in his mind, that all the functions were regularly performed, except that for a couple of days there were cramps in the lower extremities. I advised that the suppuration of the carbuncle should be kept up, and that an issue should be afterwards substituted for it; insisted upon a moderate diet, especially in the evening, as well as on exercise in the open air, and advised that the medicines should be continued.

On the 16th of March I had a report that the attack had not returned, the carbuncle in the neck was nearly well and an issue had been again established. The douche was still persevered in; but the internal medicines had been given up. The patient was well; no mention was made of cough or mucous expectoration.

In the end of the following month of April, I was informed of his complete recovery.*

* According to a report received at the end of last December, the patient continued well through the whole summer, without any further

Although the time the recovery has lasted may be considered short, I have thought this case very important as an example of idiopathic epilepsy, for which at least I could discover no remote cause; and at the same time on account of the undoubted and rapid result of the rational treatment, after the disease had already attained to such a height, accompanied, as it was, with many threatening symptoms. I should therefore hope that if my advice as to moderate living, exercise, keeping the issue open, and employing a douche to the head, be followed, the patient will completely recover, the more so as his mental powers are much improved.

If we now follow carefully the whole course of this case, we shall find a complete explanation of the phenomena, according to the principles above laid down, as arising from an affection of the medulla oblongata.

medicine, but in the end of November, having become corpulent and more plethoric, he was unexpectedly seized with a tolerably severe fit, which was subsequently followed by repeated attacks of spasmodic cough, and by returns of his former symptoms. Tartar emetic had been again employed, but no cupping-glasses, nor any derivative applications, on which I have laid great stress, were used. It is now two months since I have heard of him.

From accounts received since the publication of this Treatise, it appears that the patient's condition became worse and worse, so that he again had several fits in the day, and fell into a state of complete dotage. The issue had been closed in the month of May of the preceding year. The use of digitalis, tartar emetic, and leeches to the anus was of no avail, and his parents obstinately opposed the insertion of a seton. On the 23rd of Apıil, I prescribed for him four grains of flowers of zinc five times a day, with a view of increasing the dose. The attacks persisted. On the 30th of April, the seton was at last inserted.

There now followed on the 1st May six attacks.
„ 2nd „ one.
„ 3rd „ one.
„ 4th „ two.
„ 5th „ one very severe attack.
„ 17th „ one.
„ 26th „ one.

After this the fits did not return; so lately as the day before yesterday, the 8th July 1858, I received a confirmation of this result. The patient's mental powers are again improved, his former irritability of temper has settled down; he is once more at work; takes long walks, and thus appears a second time likely to recover; the seton produces abundant suppuration. A stronger proof of the advantage of the early employment of active derivatives could scarcely be desired.

The foundation of the disease must be sought, in addition to the hereditary tendency of a very nervous family, in the violent convulsions, in the fourth year of the patient's life, which, whatever may have been the exciting cause, proceeded from the medulla oblongata, indicating a high degree of irritation of that part, with great determination to the head. The abundant secretion of mucus and the cough are, however, remarkable.

I have elsewhere shown, that very often diseases of the chest, even phthisis, are results of an affection of the medulla oblongata, and of the vagus, which in this case acts eccentrically.* Hence it is, that in the same family phthisis so often occurs in some children, while others are affected with insanity, and that many cerebral lesions, especially softening, in which the medulla oblongata at last commonly participates, terminate in thoracic diseases and pneumonia. In the present instance this connexion is very evident; experience taught the parents at a very early period, that rubbing and even slapping the back, were the best means of relieving the cough, and thoracic spasm. We observe further, that the increased secretion of mucus and cough always preceded the attacks, and when the medulla oblongata had again discharged itself, diminished and disappeared. Subsequently, some cough followed every attack.

The incipient affection of the medulla oblongata was also evidenced by the grinding of the teeth preceding each attack. The progressive implication of the same part, probably the result of the considerable vascular dilatation in the corpora olivaria, manifested itself latterly in difficulty of speech and swallowing, while the affection of the extremities seemed to be rather secondary. The importance of the medulla oblongata in epilepsy is therefore clearly shown in this case, and is further illustrated by the powerful effect of treatment directed towards this part.

I could communicate several cases of six or seven years standing, where, under a similar treatment, recovery has so far been permanent; of still earlier cases I may suppose that the cure was also lasting, as I have heard nothing of any subsequent relapses. On account of the importance of the subject, I will, however, add another example.

During the latter half of December, 1851, my assistance was requested by a young man of about seventeen, whose brother had been

* Case of atrophy of the left hemisphere of the brain, in the *Verhandelingen der Eerste Klasse van het Kon. Ned. Instit.* 3e Reeks V. D., 1852, p. 67.

for some years under treatment in an Asylum for the Insane on account of violent epilepsy, arising from onanism, and who was considered to be wholly incurable, and in the highest state of dementia. My patient acknowledged that he too was formerly addicted to this vice, but added, that for the last year he had abstained from it, but was often tormented with nocturnal pollutions. He had been for the first time unexpectedly seized with an epileptic attack on the 16th of November, 1850; from which date he remained free until the 1st of March, 1851; the subsequent attacks took place on the 26th of July, the 7th of September, the 19th of September, and the 7th of December.

Formerly healthy, and of an active disposition, he had during the last half-year gradually become dull and silent; mental exertion was a labour to him, his memory was impaired, rendering him unable for the proper discharge of his duties in a counting-house, and particularly unfitted for calculation. In other respects, all his functions were normally performed.

I advised the repeated application of cupping-glasses with scarification to the neck, and the subsequent introduction of a seton. Internally he used, to moderate the action of the vascular system, tartar emetic in powders, which he bore very well. Subsequently, cold effusions on the neck and a douche to the head, with a moderate diet, were prescribed.

On the 31st of January following, I was informed that the cupping had been repeated once a week, and that in the intervals dry cupping-glasses had been several times applied to the neck; nevertheless, on the 8th of Jauuary the patient was again seized with an attack, as violent as those which had formerly occurred. Although he now lived very regularly, and was no longer addicted to masturbation, he had latterly again been much annoyed with nocturnal pollutions, even on one occasion recurring on four consecutive nights, without any discoverable external influence; suspecting that great congestion of the vesiculæ seminales promoted these emissions, I advised the application of six leeches to the perineum, and internally an infusion of digitalis with dilute sulphuric acid—subsequently to place a seton in the neck.

On the 5th of February it was reported, that notwithstanding that cupping-glasses with scarification had been applied to the neck two days previously, he had on the 2nd of that month had a fresh attack of epilepsy, which was, however, diminished both in violence and duration; the leeches had not been applied to the perineum. At the same time the physician in attendance informed me, that although the patient was habitually healthy, in some weeks after a preceding epileptic attack various unpleasant affections began to manifest themselves, as headach, mental depression, spermatorrhœa, &c., &c., ending in an epileptic fit, after which his state again became normal. This had also been the case on the present occasion.

Subsequently, on the 11th of April, I received a fresh report. On account of some tenderness in the neck, the insertion of the seton was still deferred, but was at last performed on the 27th of February. The results were very favourable; not only did the attacks not return, but the nocturnal pollutions were remarkably diminished, recurring only once or twice in the week. On a single occasion they took place on the alternate nights.

Three weeks before, the patient's state had caused apprehension of an approaching fit. He was dejected, his breathing was oppressed, he was melancholy, weary in his limbs, and very uncomfortable. There were no objective phenomena of any disease; the physician had therefore satisfied himself with watching the above symptoms, and on the following day they had all disappeared. Furthermore, he had observed that the dilatation of the pupil, which had always been very considerable, was now much diminished. He still continued, with an interruption of some days, the infusion of digitalis with sulphuric acid.

In the following month I received a visit from this patient, when he thanked me for my advice, as he had still continued free from the attacks. His face appeared much clearer, his spirits were more lively, his business, in which I still recommended him to be very cautious, was easier to him.

In August in the same year, he came to pay me another visit, feeling extremely happy at his recovery. He had for a considerable time been again daily occupied at his office, without suffering any inconvenience from his attendance. The nocturnal pollutions had become very infrequent, and did not occur oftener than is usual at his time of life. He still kept the seton always open, he had already two months before discontinued the digitalis and sulphuric acid. He now went for change of air to a country place belonging to his aunt. Ten days after he returned to me completely depressed and melancholy; he was quite disappointed, had lost all hope of recovery; for he had again had a severe attack, early in the morning, after a disturbed uneasy sleep interrupted by dreams.

On making inquiry as to the exciting causes, I found that the evening before he had been regaled with rice and boiled milk, to which he was not accustomed, and although he had already eaten enough, had allowed himself to be persuaded by the hospitality of his hostess to take a second portion. I set him at ease, by explaining that he was indebted for this attack solely to the immoderate use of this not very digestible food; impressed upon him the necessity of moderation for the future, especially in the evening, when he ought to eat scarcely anything, particularly as the fit usually came on towards morning, as is the case with many epileptics. He was to continue the use of the seton. I subsequently learned, that at the end of six months he had another attack from an accidental cause, since which time to the present he has continued perfectly well; the seton has been kept up for about a year and a half.

This case, too, is in many respects important. The close connexion between nocturnal pollutions and epilepsy is in itself very remarkable. Onanism is commonly considered, and often correctly, to be a cause of epilepsy; but onanism and excitement of the sexual organs are to a greater degree than is usually supposed, the result of irritation and congestion of the medulla oblongata.

The opinion formerly advanced by Gall, as to the localization of the sexual impulse in the cerebellum, has been sufficiently refuted, and the close relation between the medulla oblongata and the action of the genital organs is generally received by physiologists.* Let it suffice to call to mind the occurrence of erection and emission in persons hanged, how the sexual action is exalted in idiopathic mania with irritation of the brain and medulla oblongata, how, frequently after injuries of this part, erection and emission, or perhaps impotence, is observed. Kilian succeeded, particularly in pregnant Guinea-pigs (*Cavia cobaya*), in exciting movements in the uterus or tubes, by irritating the medulla oblongata.† In the case of epilepsy I have just recorded, this influence was very evident; the emissions disappeared for a time, when the sensibility and over-irritation of the medulla oblongata had again discharged themselves in a fit. By cupping alone the fit was moderated, but this means was not sufficient completely to overcome it; after the introduction of a seton,

* See among others Longet, *Traité de Physiologie*, t. II., p. 201.

† Henle, *Zeitschrift für rationelle Medicin*. 1851, 1 Heft.

only premonitory signs manifested themselves; but the epilepsy and excessive pollutions had ceased. It is but a short time since a similar case occurred to me, of a young man who was unable to continue his studies regularly on account of epilepsy, apparently originating in onanism. A few day ago I received a report, that for the last three months, after an issue had been, by my advice, established in the neck, neither the involuntary pollutions, which in this case also were frequent, nor the epileptic attacks, which commonly returned every two or three weeks, had again appeared, while the patient's head had become much clearer, and he was able to continue his studies.*

This return of clearness of head I have always observed, when I succeeded in checking the epileptic attacks. Not long since, I received an account of a girl, now about five-and-twenty years of age, for whom I was consulted seven years ago, for violent epileptic fits, which commonly returned two or three times a week, and had produced deafness and apparent idiocy, so that she could not appear in society. With her, too, I succeeded in overcoming this apparently highly unfavourable state by means of a seton in the neck, and within the year she was completely cured of the epilepsy. She has now been for a couple of years engaged with much success in the education of children in her capacity of governess in a wealthy family in England.

Rare as is recovery from epilepsy of long standing with idiocy, a physician should not be too ready to despair, especially if the patient is still young. In such cases, I have twice observed a wonderful effect from derivants to the head, which, on account of the importance of the subject, I will briefly state.

In the year 1823, having acted for a couple of years as physician to the Suburban Hospital at Amsterdam, I was very much struck with the number of old epileptic patients there, and as I had seen only occasional and very transient advantage from any internal remedy,

* While this work was passing through the press, I received the report of the case of a powerful plethoric young epileptic patient, in Meerenberg, in whom the disease had lasted a year and a half, and who had, in 1854, recovered after repeated leeching and cupping of the neck, with the internal use of digitalis and cathartics, and had since continued well. I also received the history of a second case, in which numerous fits recurred in a single day, in a strong young man, cured in the Asylum at Rotterdam, by the application of cupping-glasses with scarification, and subsequently, of a large blister to the neck. The latter case was under the care of G. Vrolik, the zealous physician to the Asylum.

I wished to try what effect a powerfully derivative application to the head might have. I therefore determined to apply to the head, in six epileptic patients, all cases of long standing, the actual cautery, which, if it is applied quickly and with a steady hand, seems to cause scarcely any pain. In all the patients operated on, this was followed by temporary improvement, which in some lasted from two to three months. Among them was a lad of seventeen, who had for several years been epileptic in consequence of fright, and was now nearly idiotic; he had usually two attacks in the night, and seldom remained free during the day. After I had tried different other means, I applied, on the 2nd of February, 1823, the red-hot iron to the head, a little above the occiput, without his seeming to have any perception of it; in fact, he believed what I had told him, that I was applying a warm plaster to his head.

On this, the attacks immediately ceased, and after ten days some fever set in, probably in consequence of the irritation of incipient suppuration under the burn; the patient's countenance was brighter, and his spirits were better. He continued free until the 22nd of February, when he was seized with two fits, which in three days after were followed by another. As his bowels had become torpid, I gave him a laxative. The fits did not now return; his dulness had quite given way, and he had begun, with much success, to learn to write in the Hospital. On the 3rd of June in that year, however, a very severe storm came on, with the extraordinary heat of 94° F., in which, after a loud clap of thunder, he was anew attacked with a violent fit. The sore on the head had meanwhile been closed for the last two months, as the patient appeared to be quite recovered. On the 7th, three attacks ensued; on the 10th two; on the 11th three. The disease so increased, that on the 20th he had no fewer that seven violent epileptic fits. Leeches, and even a small bleeding from the arm, which I employed in the fear that encephalitis might set in, were of no avail; the blood was not inflammatory.

I therefore determined to repeat the application of the hot-iron, which was done during a free interval on the 20th. The same evening a fit came on, but was much less severe. The 22nd, seven ensued, but were much less violent and were shorter. From this time the attacks were always lighter; on the 28th, the patient had three attacks. While, during the more violent fits, a week earlier, he had become quite dull and deaf, his countenance now regained its former vivacity, his dulness had disappeared, and he began once more to speak very well.

From this, the attacks began again regularly to diminish in severity and number, until, on the 20th of July, he was for the last time affected with a very slight fit.

Since this time, his health was quite restored, his mind was clear, and he seemed to possess considerable ability for business. I kept him under my care until November, when I could no longer oppose his wish to advance himself in life. Two years later, I found that he had made very good progress in his trade, and had not again been seized with an epileptic fit.

On account of its remarkable character, the reader will excuse the insertion of one case more.

Towards the close of the year 1845, my assistance was requested by a gentleman from Amsterdam, on account of the unhappy state of his son, aged about seventeen, who, after suffering for some years from epilepsy, had now become quite dull. His intellectual powers were very slight, and he was incapable of doing anything; the attacks, which varied in degree, were of almost daily occurrence. Even at an early period of life he had often been attacked with violent convulsions, which seem to have laid the foundation for epilepsy; I was not informed of any other causes of the attacks.

After I had treated him for some months with digitalis, flowers of zinc, and at the urgent request of his parents with a so-called secret remedy, consisting of zedoary root and dictamnus albus, without any advantage, and had, moreover, once applied leeches, and inserted a seton in the neck, without any important change having been effected, I at last explained to his father, that only from one single plan did any slender hope remain, but that the chance was very slight, and this consisted in making a transverse section through the skin, on the crown of the head, and keeping the wound in a state of suppuration by the insertion of peas.

After some time the father consented; the operation, which is very easy, and has this advantage over the hot-iron, that it is less terrifying, and by the hæmorrhage which immediately ensues evidently acts as a derivative, was successfully performed. Some days later, the father left town with his son, in June, 1846, and hearing nothing from him, I looked upon the latter as a lost patient.

At last, after the lapse of a year, I received a letter, dated the 6th of July, 1847, in which the father excused himself for having sent me no report, and stated that he had wished first to watch the result. The wound in the head was kept open all this time. During the first three months, July, August, and September, 1846, the patient had between sixty and seventy attacks; in the then prevailing epidemics, he had also been affected with fever, though slightly, and for a short time. Later in the autumn, the fits began perceptibly to diminish both in violence and number, which improvement continued regularly, though slowly, so that in May and June, 1847, he had only three or four attacks of but very slight severity. Sometimes he continued sixteen or seventeen days free, without any drawback.

His mental powers, although not greatly developed, were remarkably improved: writing, arithmetic, &c., progressed satisfactorily, while he had a situation in a factory. The only peculiarity he manifested was tolerably constant irritability of temper. It was, however, extremely important that from time to time, instead of an attack, hæmorrhage took place from the wound with the effect of greatly clearing his head. The appetite was good, but moderate, without the greediness which had existed at an earlier period, when he suffered from the violent attacks.

In the middle of summer, the fits at last wholly ceased, and his clearness of mind progressed. But in the summer of the following year, 1848, the lad caught cold, which produced catarrh, and left a persistent cough, becoming more and more obstinate, and about which I was at last, in November, called in consultation. I was then grieved to find him in the last stage of phthisis pulmonalis, of which he died in the beginning of December of that year. The epileptic attacks had not returned.

From this case it is particularly clear, that idiocy, or apparent dementia after epilepsy, is quite a different disease from dementia after idiopathic mania, which always depends upon degeneration and atrophy of the cortical substance, which is incapable of cure.

With respect to the employment of transverse incision on the head, I should observe, that this operation is not to be indiscriminately adopted. In some plethoric and excitable constitutions I have seen congestion, and with it even epilepsy increased by the continued inflammation, at least during the first period; but in indolent systems it may be tried as an extreme measure. The incision must be made transversely down to the pericranium through a length of three or four centimetres (above an inch and a half). In this case the edges of the wound are separated from one another by the action of the frontal and occipital muscles; if the incision be made longitudinally the hæmorrhage is less, and it is almost impossible to keep the wound open.

CHAPTER VI.

ON THE MEANS OF COMBATING THE REMOTE CAUSES OF EPILEPSY.

Important as it may be so far as possible to counteract the proximate cause in the medulla oblongata, and thus more directly to control epilepsy, this mode of treatment would, however, be very incomplete if we rested satisfied with it, and thought we had nothing else to do than to apply in all epileptics cupping-glasses, with scarification, to the neck, and to insert a seton. This would be to return to the irrational, rude, empirical system of medicine formerly pursued. It is unnecessary here to produce any further proof of the effects of irritants, even in remote parts of the body, in keeping up the sensibility of the medulla oblongata.

Among all the regions of the body there is none, the brain excepted, which reflects more strongly on the spinal cord and the brain than the intestines and sexual organs.

That in children epilepsy arises from worms, is well known; but it is not true that this statement is equally applicable to adults. I scarcely remember to have seen an example of epilepsy in adults proceeding from this cause alone, or cured solely by anthelmintics; and, nevertheless, because this is the case with children, who are so much more sensitive, it is argued that an anthelmintic treatment must be applicable to nearly all epileptic patients, whether there be signs of worms or not. For the sake of brevity, I shall in this part touch only upon the principal points.

The cause in the intestines may consist of some irritation or inflammation of the mucous membrane, whether connected with gastric symptoms or dependent on other sources. But it may also be situated in a peculiarly exalted sensibility of the sympathetic and vagus nerves, which are the routes whereby the reflex action is conveyed to the medulla oblongata. The two causes require different remedies. As to the first, it is of much importance. If the irritation of the medulla oblongata is great, epileptic as well as manical patients will be very greedy; they will overload the stomach, causing increased congestion and redness of the face; a state to be especially avoided at supper-time. In sleep, in consequence of the slumbering state of the brain, the tendency to reflex action is exalted, a condition which occurs also during the use of chloroform, whence it is that epileptic patients are so usually seized with fits towards morning, to which the promotion of congestion by the lower situation of the head, may contribute its share. It is for these reasons of the greatest importance to keep epileptic patients on a strict diet, as without this precaution most remedies directed against the source of epilepsy will be unavailing. This I have illustrated in the second case, where an attack was excited by a copious meal.

In some epileptic patients this sensibility of the intestines is excessively great. In a case of epilepsy, in which there was, however, a tendency to constipation, the administration of a neutral salt as a laxative, which irritated the bowels, was sufficient to bring on the epileptic fit. After I had kept this patient for a long time free from all attacks, the latter returned after he had partaken of shrimps, which were too heavy for his digestion. A very prudent diet and daily attention to the bowels are, therefore, primary requisites for the success of treatment, and the withholding of all stimulants, as wine, spirits, &c., is very necessary. The details of the treatment of an irritated state of the intestines can be deduced from the general rules of therapeutics.*

As to the second point, moderating the exalted sensibility of the sympathetic nerve, belladonna seems to me to be, of all remedies, the

* Probably it is by its action on the mucous membrane of the intestines, that in some cases the artemisia vulgaris may be useful in epilepsy. With it I have sometimes succeeded in greatly retarding the attack.

I cannot, however, pass over in silence a case communicated to me by a physician who had become afraid of this remedy in consequence of having, in some instances, found that the attacks remained away for a long time, but that a violent fit at last ensued, in which the patient died. It hence appears, as might indeed have been expected, that this medicine does not remove the sensibility of the medulla oblongata. If this part has once attained such a degree of increased activity as to discharge itself from time to time, we have already seen, that the longer the attacks intermit, in an ordinary epileptic patient, so much the more violent is the fit which next ensues, so much the stronger is the discharge. If the physician had not acted empirically, but if he had at the same time employed derivative applications to the neck, to moderate the exalted activity of the medulla oblongata, he would most probably have avoided this unfortunate result, and have saved the patient.

most satisfactory. The medicine acts specifically on the intestines. Thus laxatives, for example watery extract of aloes, with the addition of belladonna, are exceedingly useful in heartburn, spasms, and especially in constipation, which long experience and a great number of post-mortem examinations, have satisfactorily proved to me to be almost always dependent on constrictions in the descending colon. This state, moreover, exercises a powerful reflex action on the brain and medulla oblongata, as is shown by the melancholy with which it is so often connected. In these cases, the stricture is removed and the laxatives act infinitely better, in consequence of the addition of belladonna. I suspect that it is in this the principal use of the remedy lies, which is recommended by so many in epilepsy, though they do not state the indication for its employment in that disease. I have myself seen advantage from it, but I have never succeeded in permanently curing an epileptic patient with this drug alone. Among narcotics, belladonna appears by no means to produce so great congestion as many others; yet we must avoid too great doses. Opium, on the contrary, very much increases the capacity for reflex action and promotes congestion.*

The same is true of the sexual organs. Although we have seen that onanism is often the result of congestion and irritation of the medulla oblongata, this does not prevent its reacting most injuriously on epilepsy, and so long as it continues, rendering the disease wholly incurable. Of this I have above given an example (page 258).

What I have stated holds good with respect to both sexes; for even among females, this vice is not so rare as is supposed.

That amenorrhœa will at the same time have an important influence, as the upward current of blood must, under such circum-

* In a remarkable case of a young man, who in a fit of despair had swallowed a number of lucifer matches, and fortunately recovered by vomiting, great sensibility of the stomach remained, and after some time epilepsy ensued, alternating with frequent spasmodic cries, in which, with distortion of the face and turning his head, the patient uttered involuntary sounds or words. By the cautious use of acetate of morphia, I succeeded in curing the epilepsy, but the spasmodic cry has long resisted all remedies. In this case the morphia moderated the sensibility of the stomach, and thereby prevented the recurrence of the epilepsy as a reflex action on the medulla oblongata. I have also seen the intensity of the attacks in epilepsy very much diminished by hydrocyanic acid; in other cases the latter did not succeed. The variability in the effects of the medicine depends on the exciting cause of the epilepsy and not on the remedy.

stances, be greater, is sufficiently illustrated by hysteria and other examples. It is especially important that the physician should attend to fluor albus, which, when long continued, exercises a very injurious influence on the nervous system, and frequently leads to melancholy, mostly of a religious character, but may also very much promote epilepsy. Thus it is likewise remarkable, how uterine congestion, hypertrophy, and prolapsus may act injuriously. Two instances occurred to me of obstinate melancholy with prolapsus, where the melancholy gave way at the very moment when the uterus was replaced. In epilepsy also this deserves attention.

I need scarcely add, how important a healthy state of the blood is for the due performance of the functions of the nervous system, and that in chlorotic constitutions, for this reason, preparations of steel are capable of rendering excellent service in epilepsy.

True epilepsy, indeed, rarely occurs from deficiency of blood; although various hysterical symptoms and convulsions are connected with, and excited by this condition. The experiments of Sir Astley Cooper are well known, who by tying the carotids, and compressing the vertebral arteries in rabbits, produced unconsciousness and convulsions.* These causes are, however, so apparent, that no physician can easily be mistaken in them.

Not less important is the opposite evil, which more frequently occurs, the too violent action of the vascular system, characterized by a full and bounding pulse. It is admitted that general bleeding, especially if copious, is almost always injurious in epilepsy, as well as in mania. Under the general abstraction of blood, the sensibility of the nervous system is exalted, and the fits increase.

I have almost always found the employment of cupping-glasses with scarification, the application of leeches to the nose, and sometimes to the head, in the last case keeping up the bleeding by means of elastic cups (a very excellent method), to be satisfactory, and I have never seen any injurious results from this plan. I have, also, often seen this mode useful when employed in remote parts, for example, the application of leeches to the anus in hæmorrhoidal congestion, amenorrhœa, &c. Experience has convinced me that in

* Astley Cooper, *Some Experiments and Observations on tying the Carotid and Vertebral Arteries, etc.*, in *Guy's Hospital Reports*, Vol. I., London 1836, p. 465. Also in Romberg, *Lehrbuch der Nervenkrankheiten*, I. B., 2 Abth. p. 567. See also above, pp. 227 *et seq.*

convulsions in young children, even where there is a tendency to hydrocephalus, it is much more advantageous to place one or two leeches on the calf of the leg, than on the neck, or to the head : they have in the former situation a much more powerfully derivative effect, and give less trouble with the after-bleeding.

In further moderating this excessive vascular action, I found the greatest benefit from tartar emetic alone, in powders or pills, in which forms, on account of its slower absorption, it is less likely to produce nausea and vomiting (in these cases to be avoided) than in solution. I have also seen digitalis often render efficient service as an auxiliary in the treatment.

It is superfluous to say that attention to the state of the skin, cold bathing, very cautiously employed at first, much exercise, and the regulation of the whole mode of life, will be of great importance. I have frequently seen the daily use of a cold douche to the head advantageous, controlling the congestion.

Lastly, what must we think of the numerous far-famed specifics in epilepsy? I have already remarked how sadly we are in the dark upon this subject, and how indiscriminately these medicines are administered. If, however, we examine into the mode of action of some, I believe that we shall be able to form a few rules in reference to their use.

For example, as to the nitrate of silver, with which an epileptic patient has now and then been cured (although often as I have tried it, I have never been successful), it is certain that the remedy does not act on the medulla oblongata. With large doses we may excite irritation and inflammation in the stomach and intestines, but not convulsions or symptoms of direct action on the spinal cord. It is, however, well known, that nitrate of silver is an excellent remedy in irritation, or chronic inflammation of the mucous membrane of the intestines, and as the irritation which exalts the sensibility of the medulla oblongata so often starts from this point, it is not surprising that this medicine should occasionally be given where such a cause exists. It is also known, that by its continued use, under which the patients become blue, the latter sometimes, though not always, continue free from epilepsy. I have seen cases in which great blueness had occurred, but where the epilepsy continued. Perhaps the above favourable result is to be explained by the fact, that in these instances the nitrate of silver is deposited not only in the skin, but, as the kindness of my esteemed friend, Professor J.

van Geuns, has shown me, also in the internal parts, the peritonæum especially the kidneys, perhaps also in the nervous system, and that it may here produce an alteration in the sensibility.* This theory is, however, too doubtful to justify us in running the risk of discolouring a patient for his whole life, for the sake of so uncertain a result.

Sulphate of copper, too, of which I have made more use than of the ammoniacal sulphate, as the latter appeared to me to be more irritating to the bowels, is, as many observations on maniacal patients have convinced me, an excellent tonic in weakness of the bowels, exciting the appetite, promoting digestion, and counteracting the tendency to liquid motions. In epilepsy I have seen no advantage from it, and I have but seldom employed it in this disease.

The action of oxide of zinc appears to be somewhat different. In small doses I have never derived any advantage from it; in large doses, given after Herpin's method, I have, however, in several cases seen great benefit from its use, and have even witnessed recovery from epilepsy, when the patient had, for example, reached a dose of one drachm daily. My experience on this subject does not agree with that of J. Moreau, who in his very excellent prize essay on epilepsy, states that in nine cases, which he reports at full length, he saw absolutely no benefit derived from the employment of this medicine.†

That flowers of zinc exercise some sedative and calming influence on the nervous system, has long been known. They possess this property in common with many other remedies, which in large doses excite vomiting, especially with tartar emetic; the latter, however, irritates the mucous membrane more, but also, has a more strongly depressing action, while the flowers of zinc do not appear to irritate the mucous membrane of the intestines, but to moderate their sensibility. In large doses they promote the regular action of the bowels, the pulse usually becomes softer. It appears to me, that in this sedative

* The pia mater and arachnoid were indeed coloured blue, but the substance of the brain and the spinal cord differed but little from the ordinary colour; only some parts had assumed a light-grey colour. See *Verslagen en Mededeelingen der Koninkl. Akad.*, 3e Dl., 2e St., p. 176.

[I have, on another occasion, translated the observations of Professor van Geuns in reference to this subject, which may be found in the *Dublin Quarterly Journal of Medical Science*, Vol. XXVI., p. 244. W. D. M.]

† J. Moreau. *De l'étiologie de l'Epilepsie, Memoire couronné*, in the *Memoires de l'Académie Impériale de Médecine.* Paris, 1854, t. 18, p. 143.

power of the flowers of zinc upon the intestines its occasionally useful action in some cases of epilepsy resides. I have observed most effect from it precisely in those instances where the intestines were most sensitive, where irritation in the bowels, whether from slight indigestion, or from the use of a laxative, easily occasioned an epileptic fit. It appears to me to be probable, that the flowers of zinc also, although in a peculiar mode, act on the sympathetic nerve; while the gently laxative action, whereby under its use in these large doses the bowels become regulated, may promote the beneficial effect of the remedy.*

Of indigo and many other so-called specifics, I have never made use. As their physiological action was unknown to me, I had no definite indication for their employment, and without this, such an empirical proceeding always appeared to me to be equivalent to dealing in a lottery, to which I would not subject my patients. But I may add, that in a remarkable case, in which, after an attack of local inflammation of the dura mater, the inflammation began to be developed also in the brain, but was successfully combated by very active interference, epileptic fits commenced to manifest themselves in the course of the treatment. On the accession of such a fit, the patient's wife gave by mistake, in place of some spirit she had at hand, a bottle with liquid ammonia, which she held under his nose, with the fortunate result of cutting short the fit. Subsequently, the patient

* That the flowers of zinc do not exercise a direct influence on the medulla oblongata, I had, however, evidence, after I had sent in this Essay to the Royal Academy of Sciences. A highly esteemed physician to one of our institutions for the insane, to whom I had recommended the use of large doses of this preparation in epilepsy, experienced excellent effects from it in several patients. In three or four, to whom he had given the remedy to the amount of eighty grains daily, the attacks were remarkably diminished in number and intensity, and the patients were improved. One patient, however, whom my friend had shown me as apparently recovered, had had no more attacks, but, according to a later report received from the physician, had got such violent convulsions, that he despaired of her life. Under the use of cold applications to the head, cupping to the neck, and subsequently of arnica, she fortunately recovered.

He further communicated to me, that one of his extern patients at the institution, whose epilepsy had already lasted five years, had, under the daily use of eighty grains of flowers of zinc, continued for two months free from any attack; so that he already flattered himself with the prospect of success, when his patient unexpectedly got such a violent fit, accompanied with expectoration of blood, as had never before occurred completely recovered from both affections, and still continues, after a lapse of twenty years, quite well. But certainly caution would be necessary with this remedy.

Should these observations and hints tend to cause physicians, by adopting clearer views of the true nature and origin of epilepsy and

This attack passed into sopor and paralysis of the lungs, and terminated after some hours in death.

In this case, therefore, what I had before observed with the flores artemisiæ, took place. For want of discharging itself, the nervous power seemed to have accumulated so much in the ganglionic cells of the medulla oblongata, that at last a fatal explosion ensued, which would not have been the case if the flowers of zinc had been able directly to moderate the exalted action of the medulla oblongata. I wrote back to the physician, that if he had in these cases placed a strong derivant in the neck, most probably this fatal result would not have occurred.

In none of the patients had this large dose of eighty grains any injurious effect upon the bowels.

I therefore think we may assume that the flowers of zinc in these cases of epilepsy, moderate or destroy the sympathetic or remote action on the medulla oblongata, and so diminish or stop the attacks; but that, if in cases of longer standing the tendency to increased action in the ganglionic cells of the medulla oblongata has become habitual, this remedy cannot prevent its explosion, and it is, therefore, always of the greatest importance at the same time to place a powerful derivant in the neck.

The investigations of Dr Kroon, of Amsterdam, in reference to the use and action of lactate of zinc and valerianate of atropia, are important. See his Dissertation on Epilepsy (*Over Epilepsie, &c.*) 1859; the following is a summary of his results:—

Of twenty epileptic patients, three recovered under the use of lactate of zinc; eleven were improved; in six it was inactive. The three who recovered were under the age of sixteen, and in them the disease was of recent occurrence; the fits commenced with an aura; all three bit their tongues during the attack; they were all very excitable, and the epilepsy was sympathetic, in two, the aura started from the digestive, and in one from the sexual organs. Of the eleven who were improved, eight were women, all unmarried; three were men. Of the eleven, ten bit the tongue. The treatment was continued during five months. Of these eleven, six continue so much better as to afford hope of recovery.

The six patients (five women and one man), in whom the remedy was unavailing, were all cases of long standing, and what is remarkable, five of them did not bite the tongue; in four, the epilepsy had originally been hysterical, but had subsequently become idiopathic, with extremely violent fits.

The author hence infers:—1. That lactate of zinc acts most favourably in young patients, in whom the disease is of recent origin. 2. The remedy deserves to be recommended in many cases of sympathetic epilepsy, par-of the more rational mode of treatment based thereon, to forsake the rude and empirical system hitherto in vogue, and at the same time, by investigating the peculiar mode of action of remedies, to increase the stock of rational means, and so to lead to a more successful

ticularly where disturbances in the digestive or sexual organs have given rise to the attacks; it is particularly useful in hysterical epilepsy. In cases of long standing it is inefficacious. *Dissertatie*, pp. 92 *et seq.*

The results of Dr Kroon's investigations on valerianate of atropia, a very powerful remedy, are not less important; the formula for the administration of this medicine is, Valerianatis atropiæ, gr. 1; extracti glycerrhizæ, q. s.: misce, fiant pilulæ No. CXX.

He begins, according to Dr Michea's plan, with the one hundred and twentieth part of a grain *per diem*, and even in such doses, in very sensitive patients, symptoms of poisoning manifest themselves; he gradually increases the dose, even to one-fifth of a grain in the day. Such toxical phenomena as mydriasis, photopsy, photophobia, double vision, headach, vertigo, syncope, diarrhœa, pain in the abdomen and vomiting, dyspepsia, pain in the throat, and impeded deglutition often render it necessary to suspend the medicine for a time, to resume it again. The treatment is often rendered troublesome by the complaints of the patients in reference to the symptoms just described.

Of thirty-four epileptics treated with this remedy, who were almost all cases of long standing, fifteen were improved, eighteen were no better, and one was cured.

Of the fifteen improved, nine were women and six were men. They were all cases of long standing. Of the nine women, four bit the tongue, five did not; among the men were only two tongue-biters. In all the epilepsy was idiopathic, the patients had no distinct aura, and the fits came on suddenly. The case which recovered was the only one of short duration.

It is remarkable that this medicine seemed to be most useful in idiopathic epilepsy, even when of long standing. The eighteen patients in whom it had no beneficial effect, were distinguished from the fifteen, where the reverse obtained: 1. By the fact that in the former, the disease was of an hysterical character, and that the attacks were in part of a slighter nature; by these patients the remedy was in general not borne, and in consequence of their excessive sensibility, it rapidly excited toxical phenomena, while in them the lactate of zinc proved useful. 2. Most of these bit their tongue, and all had aura epileptica, which was not the case in those improved by the valerianate of atropia. 3. In many of them the attacks were of recent origin.

Those, on the contrary, who improved under the valerianate of atropia, exhibited in a much slighter degree only trifling toxical symptoms, so that the remedy could be given to them in much larger doses. From all his observations, the writer infers that:—

1. Valerianate of atropia causes improvement chiefly in cases of long standing, where the prognosis is in other respects unfavourable.

treatment of this disease,—I shall esteem myself extremely happy in having, as a conclusion to my five-and-thirty years' experience, scattered some seeds, which I trust a more youthful and vigorous generation may bring to greater growth and maturity.

2. This remedy is always contra-indicated in hysterical epileptics on account of the violent toxical symptoms it produces.

3. It is in general borne better by men than by women, *l. c.*, p. 75.

From the author's further investigations, which at my suggestion were extended to animals, as well as from the toxical phenomena to which the valerianate of atropia gives rise (dilatation of the pupil, impeded deglutition, &c.), it would appear that this medicine acts directly on the medulla oblongata, and as this part is irritated in hysterical epilepsy, the valerianate seems in such cases to act too violently, and therefore to be injurious; while in cases of long standing it is better borne, and then seems to lessen the tendency to reflex action and to fits.

The lactate of zinc, on the contrary, seems, as we have seen of the oxide of zinc, to act rather on the sympathetic nerve than directly on the medulla oblongata, and thus to be useful in hysterical and sympathetic epilepsy.

CONCLUSIONS

FROM THE PATHOLOGICAL PART OF THIS TREATISE.

1. As the two sides of the medulla oblongata are more intimately united by a much greater number of transverse fibres and commissures than any other part of the cerebro-spinal system, and as the multitudinous groups of ganglionic cells there situated appear to be destined for bilateral reflex action, as is evidenced in the acts of swallowing, respiration, &c.—so the morbid excitations and affections of this part are likewise distinguished by bilateral reflex phenomena, in the form of spasms, and epileptic convulsions.

2. Unilateral lesions of the spinal cord or of the brain, do not excite local bilateral actions; it is not until such irritation has communicated itself to the medulla oblongata that bilateral convulsions arise, the influence producing which proceeds from this part and affects first the nerves of the medulla oblongata, but may subsequently extend to other nerves.

3. Accordingly, convulsions and epilepsy first commence with convulsive movements in the face, the tongue, and the muscles of respiration; it is not until the disease has made further progress that the extremities take part in these movements.

4. The special seat and starting-point of these convulsive movements is situated in the ganglionic cells of the medulla oblongata, which, as reflex ganglia, possess the peculiar property, that when once brought into an excited condition, they may more or less suddenly discharge themselves and communicate their influence to different nervous filaments. After their discharge, a certain time is again required to bring them to their former degree of excitability, and to render them capable of fresh discharges, just as we see to be the case with electric batteries, or in the phenomena of an electrical fish.

Hence, a slight attack of epilepsy, whereby these cells are not completely discharged, is usually followed more quickly by a second attack, while a longer free interval generally succeeds to a severe fit.

5. For the restoration of activity in the ganglionic cells, a sufficient afflux of arterial blood is requisite, and accordingly we find that the ganglionic groups of the medulla oblongata in general possess more blood-vessels than the grey substance in the spinal cord and in the brain.

6. The exalted irritability and capacity for convulsive movements in the medulla oblongata is commonly excited by a remote irritant, whether this proceed from the brain, from one of the nerves of the spinal cord, from the influence of the sympathetic on the spinal cord, from the intestines, or the sexual organs. To the influence of such a remote irritant, epilepsy is very frequently due.

7. In the commencement of epilepsy, therefore, it would seem that no apparent organic change exists. Rapidly, however, probably in consequence of the repeated congestion, the presence of a more albuminous intercellular fluid between the nervous filaments is manifested, which may first cause more or less hardening, and may subsequently give rise to fatty degeneration and softening. In addition, dilatation of the arterial capillaries, and thickening of their walls ensue.

8. These blood-vessels in the medulla oblongata run chiefly in the region of the roots of the hypoglossus and vagus, as well as in the septum and in the corpora olivaria.

The posterior half of the medulla oblongata, from the fourth ventricle, in epileptic subjects, appears on a transverse section redder and more hyperemic, than in the normal state, whether the sufferers died during an attack or not.

9. Epileptics may be divided into two classes; those who bite their tongues during the fit; and those, in whom this never or extremely rarely occurs. In the former, the capillary vessels are usually wider in the course of the hypoglossus and corpora olivaria; in the latter, in the course of the vagus. In these last, the disease is, on account of the greater tension in the organs of respiration, more dangerous, and the patients die during a fit, most frequently in consequence of arrest of respiration, which appears to occur less frequently in patients of the first class.

10. This increased vascular dilatation, with thickening of the walls, whereby the afflux of arterial blood is augmented, and the ganglionic cells are more rapidly charged, and the altered exudation of intercellular fluid, appear to constitute the proximate causes of the incurability of many long-standing cases of epilepsy.

11. Dulness and apparent dementia, in consequence of epilepsy, afford no sufficient proofs of incurability, and must not be confounded with dementia after acute mania. Dementia after epilepsy appears to be the result of pressure on the grey substance of the brain, in consequence of the distention of the blood-vessels, and disappears again after the cessation of the attacks. Dementia after acute mania depends upon degeneration of the cortical substance and is incurable.

12. Attacks of unconsciousness, with little or no spasms, depress the mental powers much more rapidly than spasms without loss of consciousness.

13. For the rational treatment of epilepsy, it is requisite that we should fulfil the two following indications:—

I. To diminish the excessive sensibility of the medulla oblongata, and to moderate, if necessary, the superabundant determination of blood to these parts.

II. So far as possible to expel or remove the remote cause, which by its action on the medulla oblongata keeps up the increased capacity for morbid reflex movement and discharge of the ganglionic cells.

14. A very frequent remote cause of the disease is an exalted nervous action of the bowels or sexual organs, whence a reflex action on the medulla oblongata arises, producing epilepsy; but the remote causes occur also in the brain.

15. Most so-called specific remedies, as flowers of zinc, nitrate of silver, artemisia, and other drugs, appear to act by moderating the great sensibility of the irritated intestines; but have no direct influence on the medulla oblongata.

If by this mode we succeed, especially in a chronic case, in abating or postponing the attack, a more violent fit may ensue after a longer interval, and may occasion a fatal result. On this account we must simultaneously act on the medulla oblongata, and endeavour to diminish its exalted sensibility.

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THE END.

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