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AN EXTRACT

FROM

PROF. MÜLLER

ON

THE REFLEX FUNCTION

OF

THE SPINAL MARROW.

For the Editors of the Edinb: Medical & Surgical Journal

On the Reflex Function of the Spinal Marrow; by Prof. Müller*. *Communicated by* MARSHALL HALL, *M.D., F.R.S., &c.*

[From the Lond. and Edinb. Phil. Mag. and Journal for December 1836.]

SINCE the publication of my Memoir on the Reflex Function of the Medulla Oblongata and Medulla Spinalis, published in the Transactions of the Royal Society for 1833, I have been greatly gratified to find that Prof. Müller, the justly celebrated physiologist of Berlin, had been led, entirely independently of me, into the same path of investigation,—to nearly similar results,—and even to the adoption of the same designation † for the special function of the spinal marrow which is the subject of my inquiries.

Prof. Müller states, as will appear from the paragraph of which, by the kindness of Mr. Paget, I am enabled to send a translation, that the first part of his "Handbuch," containing the principles of the reflex function, was published in the spring of 1833, the very year in which my paper was published in the Philosophical Transactions. I had, however, read a short account of the same principle of action in the spinal marrow, to the Zoological Society, the year previously, viz. 1832, which was published in the "Proceedings of the Committee," and referred to in this Journal, vol. ii. p. 477; so that the question of priority of publication is decidedly in my favour. At the same time, the almost perfect coincidence in our observations and experiments, and in our conclusions from them, is at once most remarkable and satisfactory. The name of Prof. Müller will not fail to give importance to the inquiry; and, for my part, I recall to mind, with pleasure, the

* *Handbuch der Physiologie.*

† Prof. Müller goes further. He says—"The spinal marrow has the property of reflecting sensorial impressions made upon the sentient nerves, to the motor nerves. *It is a reflector*," &c. (*Opus cit.*, p. 789.)

remark of Sir Humphrey Davy, that "we may generally discover how our labours will be appreciated eventually, from the opinion of contemporary foreigners, who being unbiassed by circumstances of personality, will reduce every object to its just proportions and value." See further, p. 23.

"*Of the Reflexion in the Motions after Perceptions.*

"The observations which are brought forward in this Chapter are new, and denote a remarkable progress in our science. They relate to phenomena of the so-named sympathetic motions after perceptions, which were formerly very liberally supposed to be exercised by the sympathetic nerve, though it may be clearly proved that they take place quite independently of it. As the phenomena belonging to this class are uncommonly numerous, and include a great part of the phenomena, which were formerly without any proof attributed to the sympathetic nerve, the use of the sympathetic nerve in the explanation of nervous sympathies seems constantly to diminish. How much this part of physiology has altered, is clearly seen, by comparing the explanation of a great part of the nervous sympathies which the admirable Tiedemann investigated in the year 1825*. The explanations of the sympathies by means of the sympathetic nerve, in fact, explain everything and yet nothing. Thus, as this work will fully show, the most evident and frequent sympathies between the uterus and mammæ, the parotid and testes, the larynx and testes, are quite inaccessible to these explanations. We will not positively say that the sympathetic nerve does not take a part in any of the sympathetic phenomena, but we do altogether deny that the sympathetic nerve participates in all the so-called sympathetic phenomena, which will be examined in this chapter, and we think it very probable that the sympathetic nerve is generally unconnected with the greatest part of those sympathies, in which motions take place after perceptions, or perceptions after other perceptions, or motions after motions. The explanation of sympathies by nervous connexions had been already made very ques-

* *Zeitschrift für Physiologie*, i.

tionable by the microscopic anatomy of their primitive filaments. For how could this explanation be received, when at present, though we know of connexions of the fasciculi of the nerves, we are acquainted with no union of their primitive filaments? A mere nervous connexion, therefore, without any ganglion on the part, cannot of itself in the present state of the science explain any sympathy.

"The phenomena now to be examined were observed at nearly the same time by Dr. Marshall Hall and myself. As the greatest part of the 'Nervenphysik,' as here given, was completely prepared several years since, so also this Chapter on the reflected motions after perceptions, was written down almost exactly as here given several years ago. That this explanation is correct, is shown by the first part of this manual, which appeared in the spring of 1833, and which in pages 333—335* already developed the fundamental principles

* "The system of the respiratory nerves may be thrown into morbid action, producing convulsive motions, by local stimuli in all parts which are provided with mucous membranes. Stimuli applied to the mucous membrane of the nose, produce sneezing; in the pharynx, œsophagus, stomach, or intestines they produce the concurrence of the respiratory motions, in vomiting; while powerful stimuli in the rectum, urinary bladder, or uterus, produce a concurrence of respiratory motions in the involuntary discharge of fæces or urine, or the expulsion of the fœtus. Stimuli of the mucous membrane of the larynx, trachea, and lungs, nay, even a stimulus exciting a tickling in the Eustachian tube, produce cough.

"All these involuntary motions, cough, vomiting, spasmodic involuntary discharge of fæces, the forced passage of urine, are produced with the assistance of the respiratory motions. The local stimulus here acts from the inner membrane of the viscus, on the branches of the sympathetic ramifying therein, and in the stomach, pharynx, trachea, and lungs, on the branches of the vagus which they receive, or in the nose on the nasal branch of the trigeminus, and is reflected to the source of the respiratory motions in the medulla oblongata and to the spinal marrow, from which proceed the groups of respiratory motions that produce vomiting, cough, sneezing, &c. Stimuli of the nasal branches of the trigeminus produce sneezing, even when secondary; for instance, when the stimulus of the sun's light acts first on the optic nerves, the latter act on the brain, and the brain causes a secondary excitement of the nasal nerves and coincidently of the respiratory nerves. I, like many other persons, sneeze as soon as I see bright sunlight. Stimulus of the vagus alone in the larynx, trachea, and lungs excites cough, that of the pharyngeal branches of the vagus and glossopharyngeal in the

of the reflected motions after perceptions from observations, which will be here further detailed. It is remarkable that the same ideas, with the same instances and observations on narcotized animals, were propounded in the same year by Dr. Marshall Hall, in the Philosophical Transactions of 1833. Although these ideas were formed by us independently of each

pharynx, or of the vagus in the stomach, excites vomiting. We will now go through the several groups of these sympathetic respiratory motions.

" All the several respiratory motions may be produced in an isolated manner, and sometimes are united in groups, such as do not regularly occur in respiration.

" The contraction of the diaphragm, united with the motions of respiration, takes place, voluntarily or involuntarily, in the forcible expulsion of a body from parts of the abdominal cavity ; e. g. voluntarily in the expulsion of fæces and of urine, involuntarily in vomiting, parturition, involuntary expulsion of fæces after their too long retention, and in the involuntary discharge of urine long retained. The pharynx, stomach, rectum, urinary bladder, and uterus, all stand by means of their nerves in such connexion with the cerebral and spinal nerves, that a violent stimulus applied to any one of them, excites contraction not merely in it, but also in the abdominal muscles and diaphragm, to the expulsion of the irritating matter upwards or downwards. This effect takes place by reflexion to the brain of the stimulus of the branches of the vagus in the pharynx and stomach,—to the sympathetic system and to the brain and spinal marrow, from the sympathetic twigs of the stomach, —and by the reflexion to the spinal marrow of the stimulus of the partly sympathetic and partly sacral nerves in the rectum, uterus, and urinary bladder. In all these motions for the expulsion of a part upwards or downwards, the glottis is for a long time closed.

" For the explanation of the production of vomiting, an observation of mine is very instructive, viz. that if we open the cavity of the abdomen in a rabbit, and having exposed the splanchnic nerve on the left side (near the inner side of the renal capsule) tear it with a needle, contraction of the abdominal muscles often takes place. I have not seen this in the dog.

" In cough, the stimulus of the vagus, in the larynx, trachea, and lungs is propagated to the medulla oblongata. The medulla oblongata thereupon excites contraction of the glottis, with spasmodic expiratory motions of the thoracic and abdominal muscles, by which at each expiratory action, the previously closed glottis is somewhat opened and a loud tone produced. The diaphragm has nothing to do with the cough, except that sometimes a deep inspiration is made before coughing. According to Krimer[1] and Brachet, after division of the vagus on both sides of the neck of an animal, cough can no longer be excited by violent stimuli of the internal surface of

[1] *Untersuchungen über den Husten.*

other, yet the great correspondence in the observations and explanations is not difficult to account for, if one considers, that the physiology of the nerves has attained a condition, such that in pursuing the subject the most remote observers may at the same time be led to similar new observations and ex-

the trachea. It certainly, however, may, according to Krimer, after division of the sympathetic nerve in the neck.

"We have the power of closing the entrance into the larynx, not merely by the closure of the glottis, but even in the fauces from the nasal and oral canals. Dzondi discovered that this takes place by the approximation of the posterior arches of the palate, which lie almost like two curtains approaching each other from the sides, and by the apposition of the posterior part of the tongue against this inclined plane. This motion always precedes sneezing.

"Sneezing is a violent sudden contraction of the expiratory muscles, after the air-passages anteriorly have been previously closed. This closure changes at the moment of the violent expiration into a sudden opening of the oral and nasal canals together, or of the latter alone. Sneezing has nothing whatever to do with the diaphragm, which so many ancient and modern authors have supposed to take a part in it. The widely spreading nervous sympathies appear quite unnecessary in the explanation of sneezing. In the false supposition that sneezing is effected by the diaphragm, it was thought that the stimulus of the nasal nerves was propagated to the deep twig of the Vidian and to the sympathetic, and from thence to the cervical and the phrenic nerves. Even Arnold still speaks of this. Now as the expiratory muscles (with previous closure of the mouth and nose) produce the act of sneezing, and not the diaphragm, the simplest view is to regard the medulla oblongata itself as the medium between the nasal branches of the trigeminus, the expiratory muscles, and the muscles of the velum palati, after the analogy of the sympathetic motion of the iris by the stimulus of light. For in this case, as may be clearly shown, the stimulus of light acts neither immediately on the ciliary nerves, nor from the retina to the ciliary nerves. The arteria centralis is indeed, according to Tiedemann's discovery, accompanied by a fine twig from the ciliary ganglion. But this twig is distributed on the arteria centralis retinæ, and is in no proved connexion with the retina. In complete paralysis of the retina, light in general no longer produces contraction of the iris, though still through the healthy eye it does produce a contraction of the iris of the diseased one. (There are however exceptions to this rule, which Tiedemann has collected in his *Zeitschrift fur Physiologie.*) The motion of the iris therefore probably results from a reflexion of the stimulus of the retina to the brain, from the brain back to the oculo-motor nerve, and the ciliary ganglion. The sympathies of a great part of the nerves with a local stimulus through the medium of the brain and spinal marrow, are very well shown in the phenomena following the narcotization of an animal, in which a slight touch on the skin produces general tetanic spasms."—pp. 333—335.

planations. I shall in the following pages first communicate my own observations, as they were originally formed, and shall then compare them with the results of the English physician and physiologist.

"When perceptions, which are produced by external stimuli on sensitive nerves, produce motions in other parts, this never takes place by a reciprocal action of the sensitive and motor filaments of the nerves, but by the sensorial excitement acting on the brain and spinal marrow, and from these back to the motor filaments. This extremely important principle in physiology and pathology requires a strong proof, which may be very clearly attained empirically, and then explains a number of physiological and pathological phenomena.

"I shall first prove that the motor and sensitive filaments of a nerve, after the connexion of their two roots, do not enter into any connexion with one another, but run separately to their respective parts, and that therefore, even in cases where the nervous sympathy is not in play, the sensitive and motor filaments of a nerve have no reciprocal action whatever.

"The proof of this position may be shown clearly in the following manner: If a compound nerve be stimulated (after being divided,) at its central portion, severe pain is produced, and the animal may express this pain by motions of flight, crying, &c.; but the muscular nerves connected with the stimulated portion are not excited to action. No twitchings take place in the muscles which receive nerves from the divided trunk.

"It may also be proved in the following way: As the three nerves destined for the posterior extremity of the frog form a plexus, which again gives off two nerves, so, if one of the latter nerves be divided and isolated from all its connexions with the muscles, and then the central portion be mechanically stimulated, the injury produces a centripetal excitement of the sensitive fibres of this nerve; but the other nerves, proceeding from the same plexus, do not, when the isolated nerve is injured, excite any twitchings in their muscles. That moreover, the general twitchings that ensue on any touch, in narcotized frogs and other animals, are only pro-

duced through the medium of the spinal marrow and brain, may be decisively proved; for if a limb be cut off from a narcotized frog, touching it (the limb) will not produce twitchings in it. These experiments are still more instructive in the lizard.

"The spotted lizard retains for a long time after division of the spinal marrow, the so-named sensitive power in all parts below the section; or, if this cannot be called sensitive power, the capability of propagating sensitive impressions to the spinal marrow, and of re-acting by twitchings. Even the end of the tail has still perception; nay, this power is as much elevated by the division of the spinal marrow, as in frogs which have been previously narcotized: if a portion of its trunk after being cut off be only very lightly touched, it always contracts, and this continues for hours. But this interesting phenomenon is only shown when the spinal marrow is still contained in the separated piece, and not in whole limbs separated from the trunk and not containing any spinal marrow. These interesting facts I observed several years ago, 1830, when with Herr Jordan I was investigating the poison of the cutaneous glands in the spotted lizard. It results from this that the general twitchings which take place in animals on touching particular parts, do not result from communication of sensorial and motor nervous filaments, but that the spinal marrow is the connecting medium between the sensorial-centripetal and the motor-centrifugal excitement.

"The phenomenon of general twitchings after local perceptions is therefore also independent of the sympathetic nerve, and is induced by an irritation of the spinal marrow, by which every purely local sensorial-centripetal excitement propagates itself to the whole spinal marrow and brain, and from thence of necessity excites all motor fibres. But this irritable condition is excited by the following causes:

"1. In many animals by the mere division and injury of the spinal marrow. Thus tortoises move after the head is cut off, whenever they are touched; and young birds move on being touched immediately after decapitation, as do also all parts of the cut-off trunk in the lizard.

"2. Further, the spinal marrow is irritated to this degree in the first stage of narcotic poisoning in frogs, as well as in mammalia, which move after poisoning with nux vomica, whenever they are touched. This stage of excitable debility in narcotization almost always precedes the stage of paralytic debility.

"3. Other causes also, which debilitate the brain and spinal marrow by stimulation, produce the same phenomenon. In men with excitable debility of the nervous system any unforeseen sensation, sound, touch, or mechanical shock produces a general start. So also in men who, by stimulation of the genitals, and thereby of the spinal marrow, or by other causes, have acquired an excitable debility of the spinal marrow. We may here cast a glance at the nature of nervous irritation. All nervous stimuli may induce in succession three conditions. First, excitement, in which the powers appear still uninjured. Second, in proportion as the excitement is repeated, excitable debility. Third, atonic debility.

"4. A local violent excitation of a sensitive nerve, may by the violence of the centripetal excitation of the brain and spinal marrow, induce twitchings and tremblings, as after a severe local burn, in tooth-drawing, &c.

"5. Local stimulations of the nerves by inflammation or tumours, often also produce general spasms, or even epilepsy.

"6. The irritation of the spinal marrow, originating from local sensorial excitement, may in violent injuries be so great, that the movements are constant, and continue even without touching. This irritation of the spinal marrow resulting from severe local nervous injuries, is the tetanus traumaticus. Every severe irritation of the spinal marrow generally is tetanus, whether produced by narcotic poisoning or locally and indirectly. I have here shown how the production of tetanus traumaticus is to be explained by simple empirically determined facts.

"7. The severe irritation of the sympathetic nerves of the intestinal canal also excites by acting back on the central parts general spasms; and thus the cramps in sporadic cholera,

as well as the convulsions in the diseases of the viscera in children, are to be explained.

"The previous considerations however lead us only to the determination of the fact, that, wherever general twitchings originate from local sensation, this takes place by no other connexion of sensorial and motor fibres than through the spinal chord. In very many cases, however, after local excitation of the nerves, there ensue not general, but local twitchings, which, however, must also be constantly explained by the spinal marrow being considered as the connecting link between the sensorial and motor fibres. The cases which may be arranged here, are the following:

"1. The simplest is the case, in which the local sensorial stimulation, propagated to the spinal marrow or brain, excites merely local movements, and these in the parts lying in the neighbourhood, whose motor fibres proceed from the spinal marrow near the sensorial. To these belong the spasms and tremblings of the limbs which are severely burnt, &c. Certain very excitable parts of the organism, as the iris, contract extremely easily, when only slight stimuli excite other sensorial nerves, and the excitement of the latter is propagated to the brain, and from it through the oculo-motor nerve to the short root of the ciliary ganglion, the ciliary nerves, and the iris. It has long been known that the iris is not excitable by light, and that light acts on it only through the medium of the optic nerve and the brain; this results from the experiments of Lambert, Fontana, and Caldani. Rays of light passing through a small cone of paper, or through a small hole in a piece of paper, and thus transmitted through the pupil, and falling on the retina, immediately induce motion in the iris, but have no power when they fall on the iris itself. The iris of an amaurotic eye moreover is immoveable, as long as the sound eye is closed, but contracts when the light excites the optic nerve of the latter. The exceptions in which the optic nerve of the amaurotic eye still retains mobility*, may easily depend on an incomplete amaurosis, or if only one eye was

* See Tiedemann in his *Zeitschrift*, i. p. 252.

amaurotic, the cause of the motion of the iris in the amaurotic eye was the open state of the sound eye. The mobility or immobility of the iris of an amaurotic eye can and is only to be investigated when the healthy one is closed. Every observation in which this precaution has not been taken is valueless; Van Deen has therefore deceived himself in his otherwise very valuable work*, when having in a rabbit cut away one hemisphere of the brain, and the optic nerve of the same side, he saw the iris contract on the application of a light, and therefore concluded, that the optic nerve had no influence on the iris. For as Van Deen brought the light before both eyes (ante oculos), the same result would follow as when the iris of an amaurotic eye is moved by the influence of light on the sound one. Tiedemann's interesting discovery that the arteria centralis retinæ is accompanied by a fine twig from the ciliary ganglion, cannot in this case explain anything. For all vessels are accompanied by nerves; but this twig is distributed with the arteria centralis, and is in no proved connexion with the retina. This reflex action from the brain to the iris takes place through the oculo-motor nerve, which according to Mayo's experiments at every stimulus excites a contraction of the iris†. We know from the same author that the cerebral end of the divided optic nerve, when stimulated, still induces contraction. Thus, in the contraction of the iris there is presented a kind of "Statik" of the excitement between centripetal-sensorial and centrifugal-motor action through the medium of the brain. Other nerves also may alter this *equilibrium*, as the sensorial branches of the trigeminus, for cold water thrown into the nose produces contraction of the iris. To these more simple instances of reflected excitement belongs also the winking of the eyelids from long impression of light, or from a loud sound (what has the optic nerve to do with the auditory?), or from a threatening impression on the sight.

"Further, to these belong the contraction of all the muscles

* *De Differentia et Nexu inter Nervos Vitæ animalis et organicæ.*

† Magendie's *Journal de Physiologie*, iii. 348.

of the perinæum, the sphincter ani, levator ani, bulbo-cavernosus, and ischio-cavernosus in the emission of semen, in consequence of the irritation of the sensitive nerves of the penis; in these cases the spinal marrow is the connecting link between the sensations and motions. Exposed muscles, whose motor nerves are themselves coincidently stimulated in the stimulation of the muscles, do not require these centripetal and centrifugal actions to excite contractions. But the muscles which are covered by sensitive membranes, and do not themselves lie exposed to stimuli, must receive the stimulus to motion through the sensorial excitement of their sensitive covering, the centripetal action of these sensorial nerves, and the centrifugal motor excitement from the brain. Thus the contractions of the glottis and air-passages induced by irrespirable acid gases, cannot result immediately from the excitement of these passages, but from the centripetal-sensorial and centrifugal-motor excitement. Brachet has very fully proved this. For if the nervus vagus on both sides of an animal be divided, an exciting chemical substance introduced into the trachea ceases to act as a stimulus to cough. The cough from stimulus in the air-passages is induced only by sensorial centripetal, and centrifugal motor excitement. It is the same with the contraction of the sphincter ani and sphincter vesicæ urinariæ. These muscles cannot themselves be excited to contract by the stimulus of the excrement and urine, but these substances act on the sensitive nerves of the mucous membrane, and excite the spinal marrow, which, constantly charged with motor nervous power, acts back on these muscles; therefore after injury of the spinal marrow the contraction of these muscles ceases.

"2. The second case is, where the sensorial excitement being quite local, the reflex acting excitement from the brain is more diffused, as shown already in the phenomena which accompany cough, in which not only the nervi vagi, but the spinal nerves supplying the thoracic and abdominal muscles, act in coincidence. It is the same with a number of spasmodic respiratory motions, sneezing, hiccup, vomiting, &c., all of which are produced by stimuli of the sensitive nerves of the

system of mucous membranes of the respiratory organs and intestinal canal, which stimuli are reflected to the brain, and thence put in action the source of the respiratory motions in the medulla oblongata. I have already in p. 333* mentioned the remarkable peculiarity, that the system of respiratory nerves may be put in action by local stimuli applied to all mucous membranes. For all the motions, cough, sneezing, vomiting, spasmodic involuntary discharge of fæces, involuntary forcible passage of urine, arise from violent irritation of the mucous membranes of the fauces, œsophagus, stomach, intestines, and respiratory apparatus. Sneezing has been explained as a spasmodic affection of the diaphragm; Tiedemann† and Arnold‡ still speak thus of it: however, it has probably nothing to do with the diaphragm, for it is a violent expiration, and the diaphragm is no expiratory muscle, but the contrary. Under the incorrect supposition that sneezing resulted from the diaphragm, the stimulus of the nasal nerves was considered to be propagated to the spheno-palatine ganglion, the Vidian nerve, the sympathetic, the cervical nerves, the phrenic, the accessorius Willisii, and the facial§. The highly talented Tiedemann endeavours also to prove that sneezing does not result from a reflected stimulus from the brain, and supports himself on the fact, that a man has still sneezed from snuff, without any sense of smell. Why should he not, seeing that when the nerves of smell are deficient, the nerves of common sensation in the nose, the nasal nerves, have still as in healthy men the perception of tickling? But by minute anatomy the explanation of a sympathy can still only be attained through the sympathetic nerve. Yet how can sneezing be explained by a connexion of nerves, by which everything and yet indeed nothing can be explained? We may explain anything by it, because the sympathetic is connected with almost all nerves; and yet nothing can be explained by it, because there is not the most remote reason why a stimulus of this nerve of the nose should produce sneezing

* See note p. 5.

† *Zeitschrift*, i. 278.

‡ *Der Kopftheil des Vegetat. Nervensystem*, p. 181.

§ Tiedemann, *l. c.*, p. 278.

and not many other motions, as, for instance, an increased motion of the intestinal canal. Nothing can be explained by it, because in no connexion of the sympathetic with another nerve is there an actual union of their filaments. In sneezing, for instance, there is a violent contraction of all the muscles of respiration; all the primitive filaments of the intercostal nerves therefore, which produce contraction of the thoracic and abdominal muscles, must therein be irritated. But how could all these filaments be irritated from the sympathetic nerve, which adds to each of these nerves a fasciculus of filaments, that, far from uniting its primitive filaments with all the primitive filaments of a spinal nerve, only receives them with the latter from the spinal marrow? Now since primitive filaments cannot impart anything to others lying near them, especially in a motor root without a ganglion, so in this case the sympathetic affection of all the primitive filaments of an intercostal nerve by the sympathetic nerve is a perfect impossibility. All these sympathies of sneezing, coughing, vomiting, are done away with, as soon as we know of the reflex function of the spinal marrow and brain, which we have before proved; and no further difficulty lies in the way of the explanation, as soon as one proceeds from the fact, that all respiratory nerves, the facial, vagus, accessorius, phrenic, and the other spinal respiratory nerves of the trunk, by their origin from the medulla oblongata, or their dependence on it, may be easily excited to convulsive motions in muscles, by all stimuli, which are conducted from the sensitive nerves of the mucous membranes to the spinal marrow or the medulla oblongata.

"On every violent stimulus in the intestines, the urinary bladder, and the uterus, contraction of the diaphragm and the abdominal muscles easily ensues, lessening the cavity of the abdomen; and its contents are forced upwards when contained in the stomach (vomiting), or downwards through the rectum or urinary apparatus, or through the genitals as in parturition. The forcible expulsion of fæces is the same phenomenon in the lower part of the intestinal canal as vomiting is in the upper. The forcible expulsion of urine presents the same motions in mental passions; parturition calls into action the same muscles as produce expulsion upwards in vo-

miting; the parturition too which takes place even after death, just like the firm application of the pharynx round a finger introduced into it in a beheaded young animal, shows us, of what important influence, and how intimately connected with life, this power of the spinal marrow is, of being excited to motorial discharges by local excitations of its sensitive (or perceptive) nerves. In many of the stimulations belonging to this class, in vomiting, &c., the sympathetic nerve may indeed take some part, but it is nothing more than that of reflecting, like all other sensitive nerves, the stimulation to the sensorium. But that it may have this action may be shown by an experiment on rabbits; for instance, by tearing the splanchnic nerve in the abdomen, I have observed frequent twitchings of the abdominal muscles, and have repeatedly seen the same phenomenon in other rabbits, though the same experiments did not succeed with me in dogs.

"3. In the cases mentioned under 2, the reflected motion is, the motion following on perception, and diffused through a large series of nerves, the respiratory nerves, and it arises most easily from stimulation of the mucous membranes; but in greater stimulation the diffusion of the reflected motions may be still greater, and affect nearly all the nerves of the trunk, when the irritable condition of the spinal marrow is extensive. Among these cases are to be reckoned those of sporadic cholera, (I do not mention Asiatic cholera because of the obscurity of that disease,) in which, when severe, spasms may take place even in the trunk.

"4. In the reflected motions which arise from violent perceptions of the cutaneous nerves, and not those of the mucous membranes, the group of respiratory motions is not brought into associated action, but there more usually occur spasms of the muscles of all the nerves of the trunk without spasmodic respiratory motions. The highest degree of this is the epileptic spasm from local nervous affections and the tetanus traumaticus from injury of a nerve.

"If the first demonstration of the phenomena of reflection in the first part of this manual * which appeared in the spring of

* See note, p. 5.

1833, and which I have here enlarged with reference to the observations of Van Deen, be compared with Dr. Marshall Hall's demonstration, a remarkable correspondence is found in the ideas and instances.

"Dr. Marshall Hall distinguishes four kinds of muscular contraction: 1st, The voluntary, which appears to depend on the brain; 2nd, The respiratory*, which appears to depend on the medulla oblongata; 3rd, The involuntary, which depends on the nerves and muscles, and requires the immediate application of stimuli to the muscles provided with nerves, or to their nerves; and 4th, The reflecting, which continues, in part, after the voluntary and respiratory have ceased, and is connected with the medulla spinalis. It ceases after removal of the spinal marrow, though irritability does not diminish. In this fourth the motor stimulus does not originate in a central part of the nervous system, but at some distance from the centre; it is neither voluntary nor direct in its course, but rather excited by peculiar stimuli, which act, not immediately on the muscular fibres and motor nerves, but on membranous expansions, from which the stimulus is conducted to the medulla spinalis. Dr. Marshall Hall illustrates the importance of this reflecting function of the medulla oblongata and spinal marrow by some instances. The prehension of food is a voluntary act, and cannot be performed after removal of the brain; the passage of the morsels of food over the glottis and through the pharynx depends on the reflex function, and still continues after the brain is removed. Although, for instance, the muscles which are active in this case, may also act voluntarily, yet the presence of the morsel in the pharynx produces a series of violent motions, which have been described above (p. 479.), and which arise from the stimulus of the morsel acting on the sensitive mucous membrane, and this perception exciting the medulla oblongata to discharge in the motor nerves. Dr. Marshall Hall regards the further act of deglutition in the œsophagus as the effect of the stimulus

* I am now of opinion that respiration itself is a part of the reflex or excito-motory function, and dependent upon appropriate excitor nerves.—M. H.

acting immediately on the muscular fibres of the œsophagus, and the result of the irritability of the latter, which may appear very doubtful*. Even in beheaded young animals we may, however, as already shown, observe the reflected motorial excitement still following mechanical stimulation of the pharynx. Dr. Marshall Hall next shows the permanent influence of this function in the sphincters. The sphincter ani remains closed in a tortoise after decapitation, so long as the lower part of the spinal marrow is uninjured, but instantly becomes flaccid and opens, when the spinal marrow is removed.

"Dr. Marshall Hall divided the spinal marrow in a live *Coluber natrix* between the 2nd and 3rd vertebræ. The motions ceased at once, and when the animal was not stimulated it remained quiet. But if it were stimulated, it continued moving for a long time; for at every altering position new parts of its surface came in contact with the ground: gradually it again became quiet, but the slightest touch again renewed the motion.

"Dr. Marshall Hall shows very beautifully the relation of the voluntary, respiratory, and reflected motions, when he endeavours to prove, that the reflected motions which take place after loss of the brain are not dependent on true *sensation*, but only on the centripetal nervous actions which take place in sensations. Sensation, will, motion, are the three links of the chain, when a motion is induced by pain; but if the middle link be destroyed, the connexion between the first and second with the consciousness ceases. We believe also that the reflected motions on stimuli of the skin, which take place after the removal of the brain, do not contain any proof that the stimulus excited true sensation in the spinal marrow; it is rather the centripetal conduction of the nervous principle which commonly takes place in sensations, but which

* There may certainly be considerable doubt respecting the action of the œsophagus—a doubt which nothing but careful experiment can solve. But I think I have proof that the *cardia* closes and opens upon the principle of the reflex function, as well as the pharynx, and that it is under the influence of the *internal excito-motory*, or pneumogastric nerve.—M. H.

here is no longer sensation, because it is no longer conducted to the brain, the organ of consciousness. During health also numerous reflected motions result from stimuli of the skin, which do not come as true sensations to the consciousness, but still may excite violent impressions on the spinal marrow; as, for instance, the permanent contraction of the sphincters from the stimulus of the excrement and of the urine. But Dr. Marshall Hall goes too far, when he supposes that in health every motion on true sensation is induced by the will, and that all excitations of sensitive parts in the reflected motions are without sensation. For the reflected motions of sneezing, coughing, and many others follow actual sensations*.

" The reflected motions, and the involuntary not reflected motions are not to be confounded with one another. If the rima glottidis of an animal be touched, says Dr. Marshall Hall, a contraction takes place; the same, when the heart is touched. By removal of the brain no alteration ensues; but if the medulla oblongata be removed, the contractions of the larynx on stimuli cease, while those of the heart continue. The action of stimuli on the heart is an immediate one dependent on its irritability; a stimulus applied to the larynx must, on the contrary, be propagated to the medulla oblongata, and the contraction results indirectly from it. In a snake after the removal of the head a motion of the larynx ensued; it was drawn downwards and closed, as soon as Dr. Marshall Hall touched a spot within the teeth of the lower jaw or the nasal apertures. After removal of the medulla oblongata this ceased. Lastly, he mentions as belonging to the reflex function, the winking of the eyelids when they are touched; the peculiar action on the respiration by tickling, or when cold water is thrown into the face; sneezing from stimuli of the nasal mucous membrane; cough; vomiting from stimuli of the larynx or pharynx; tenesmus from stimulation of the rectum; and strangury from that of the bladder. We see that the spasms in diseases may

* These and other acts of the excito-motory system are *attended by* sensation, but are not the less independent of it; some are entirely without it. —M. H.

have very different sources. There are, for instance, spasmodic affections which have their seat in the motor nerves themselves, and others which have their cause in the brain and spinal marrow; but there are also reflected spasms, whose cause lies in stimulation of sensitive nerves, as those which often take place after intestinal stimulation, in dentition, odontalgia, and painful nervous affections from organic and inorganic lesions generally.

"The phenomena which we have now described, first from our own observations and then from those of Dr. Marshall Hall, have all this in common with one another, that the spinal marrow is the connecting link between a sensorial and a motorial motion of the nervous principle, though still the course which the conduction in the reflected motions from the sensitive to the motor nerves in the spinal marrow takes may be more definitely pointed out. The most common kind of reflected motion is, that the muscles of a limb, in which violent sensations have been excited, may be moved, as in the burning of the skin twitchings take place in the burned limb; or as in the commencement of the narcotization of an animal, on the sensitive stimulus of the skin the muscles of the stimulated limb are most easily moved; or as the morsels of food produce the reflected motion of the apparatus for swallowing; or as the particle in the conjunctiva exciting merely sensation, produces the reflected closure of the eyelids; or as, lastly, the stimulus of the urine and excrement act indirectly on the motion of the sphincters. As soon therefore as the sensitive-motion has reached the spinal marrow, it does not pass over the whole spinal marrow, but most easily to those motor nerves which have their origin nearest to the stimulated sensitive nerves; or in other words, the easiest way for the current or vibration is from the posterior root of a nerve or some of its primitive filaments to its anterior root, or to the anterior roots of several adjacent nerves. We see, then, that the nervous principle in these currents or vibrations takes the shortest way, acting from sensitive fibres through the medulla spinalis on motor fibres; just as electricity takes the shortest way from one pole to the other. More correctly expressed, and translated into

physiological language, this means, that in violent excitation of the motor property of the spinal marrow through a sensitive nerve, that part only of the spinal marrow is first excited, and then excites movements, which gives origin to the sensitive nerve; and that the excitation of other parts of the spinal marrow, and the motor nerves arising therefrom, decreases in proportion as they are more removed from the spot excited by the sensitive nerve. The same holds also of the cerebral nerves, whose reflected phenomena appear to remain still almost quite unknown to Dr. Marshall Hall*. The great nerves of the senses are especially prone to cause reflected motions of the motor cerebral nerves, and especially the optic and auditory; they produce in vivid light and on loud sound a reflected excitation of the facial nerve, and thereby closure or winking of the eyelids. The optic nerve again easily produces the reflected excitation of the oculo-motor nerve in motion of the iris, and on looking at bright light it induces a reflected affection of the facial and other nerves in sneezing. But the great sensitive nerve of the anterior part of the head and the face, the great portion of the trigeminus, may excite the oculo-motor and facial through the medium of the brain; thus contraction of the iris takes place when cold water is thrown into the nose, and from tickling in the nose sneezing takes place, as well as the action of the facial nerve in the excitement of the facial muscles which is connected with it. In short, we see, that of the motor cerebral nerves, the part of the oculo-motor nerve which goes to the ciliary ganglion and thence to the iris, and the facial nerve, may most easily be excited by reflexion, and that the impressions either of sight, or touch, or hearing may be the exciting causes: therefore between the origins of the optic, trigeminus, and auditory nerves, and the points of origin of the motor nerves in the brain, there must be a facility of conduction pre-established by primitive formation. Those sensitive and motor nerves, whose mutual action is effected through the brain and spinal marrow, pre-

* I am still of opinion that the reflex function is confined to the medulla oblongata and spinalis, exclusively of the brain.—M. H.

sent a kind of balance with those central parts, one altering the other, as the ascent of one scale induces the descent of the other, or as the falling of a fluid in one leg of a bent tube produces the ascent in the other, till they are permanently at an equilibrium. If a sensitive nerve is not usually in a state to produce a reflected motion, yet on any violent impression on sensation it becomes so, and the brain and spinal marrow then reflect the currents or vibrations received from the sensitive nerves, into those motor nerves, to which the conduction from the sensitive fibres through the fibres of the brain and spinal marrow is most easy.

"Another very common path of conduction from the sensitive to the motor nerves through the medium of the spinal marrow and medulla oblongata, is that seen in the excitation of the mucous membranes and the secondary affection of the respiratory muscles in vomiting, evacuation of fæces, parturition, the coughing, sneezing, &c. Next to the above-mentioned law, that nerves of allied origins, or of not very remote origins, are peculiarly prone to the phenomena of reflexion, the most frequently acting law of the "Nervenstatik" is the reflexion now mentioned. Therefore, *in the medulla oblongata and spinal marrow*, between the sensitive nerves of the mucous membranes (the trigeminus in the nose; the vagus in the trachea, lungs, pharynx, œsophagus, stomach; the sympathetic in the intestinal canal and uterus; branches of the sacral plexus and sympathetic in the urinary bladder and rectum;) and the motor respiratory nerves (facial, accessory, and spinal nerves), there must be pre-formed easy means for a conduction; while, on the contrary, the spinal nerves going to the extremities are excluded from this harmony.

"But if a certain irritation of the spinal chord and brain be induced by narcotism or other causes, then every perception may produce a discharge of the spinal marrow to all the motor nerves, even to those which are affected with the greatest difficulty, viz. the motor nerves of the extremities." (pp. 688—701.)

Such is the account of this subject given by Prof. Müller. I may be allowed to repeat that I have perused this unprejudiced and independent testimony to the importance of my investigations with unmingled satisfaction.

Before I dismiss the subject, I must add that my views are somewhat different from those of Prof. Müller:

1. I view the reflex function as the *distinct* and *peculiar* or *proper* function of the medulla spinalis, equally independent of the brain, the sympathetic, and of the anastomoses and the mere origins of nerves;

2. I regard this function as residing in the medulla, as the *axis* of a *distinct* system of *excitor* and *motor*, and *excito-motory* nerves;

3. I consider this function and its system of nerves as presiding over the *orifices* and the *exits* or *sphincters* of the animal frame, and over *ingestion* and *egestion*;

4. The brain is the central organ of sensation and volition, the organ of *mental* relation with the external world; the spinal marrow, on the contrary, is the central organ of excito-motory phenomena, and of the *physical* appropriation of certain external objects;

5. Respiration even is a part of this peculiar function: it is *excited* on ordinary, and on extraordinary occasions, through appropriate excitor nerves, especially the pneumo-gastric, but also the fifth and spinal nerves;

6. *Volition* may *modify* the acts of the reflex function, and these acts may be attended by sensation; but this function is, otherwise, independent both of volition and sensation, of their organ the brain, and of the mind or soul;

7. The *passions*, in an especial manner, demonstrate themselves through the medium of the true spinal marrow; and thus *pain* may induce surprise or fear, and *appear* to occasion an excito-motory act;

8. The brain *sleeps*; but the spinal marrow *never sleeps*;

9. Finally, the excito-motory system of nerves are the peculiar seat of action of certain *diseases*, and of certain *causes* and *remedies* of disease.

These and other propositions I am about to illustrate in a

series of papers preparing for the Royal Society. That they involve a principle in physiology at once extensive and novel, will not, I think, be now denied.

I may add that in some of the *Invertebrata*, the necessity for the nerves being *intervertebral* not existing, the excito-motory system of nerves, with their axis, may be as *distinct* in their anatomy as they are in their functions. This question I am about to subject to the test of experiment.

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