

Additional experiments on the excitability of paralysed and healthy limbs by the galvanic current / by R. B. Todd, M.D., F.R.S. (Physician to King's College Hospital).

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Publication/Creation

1853

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ADDITIONAL EXPERIMENTS

Professor Bennett ON
with the Authors kind regards
THE EXCITABILITY OF

PARALYSED AND HEALTHY LIMBS

BY

THE GALVANIC CURRENT.

BY

R. B. TODD, M.D., F.R.S.,

PHYSICIAN TO KING'S COLLEGE HOSPITAL.

*[From Volume XXXVI of the 'Medico-Chirurgical Transactions,'
published by the Royal Medical and Chirurgical Society of
London.]*

LONDON:

PRINTED BY

C. AND J. ADLARD, BARTHOLOMEW CLOSE.

1853.

ADDITIONAL EXPERIMENTS

ON THE EFFECTS OF THE ELECTRIC CURRENT

ON THE VITALITY OF

CELLS AND BATTERIES

AND THE EFFECTS OF THE ELECTRIC CURRENT

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PARALYSED AND HEALTHY LIMBS
BY THE GALVANIC CURRENT.

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R. B. TODD, M.D., F.R.S.,
PHYSICIAN TO KING'S COLLEGE HOSPITAL.

Received June 28th.—Read June 28th, 1853.

IN the summer of 1847 I ventured to submit to this Society the results of some experiments made with the view of ascertaining whether limbs paralysed in consequence of the removal of the brain's influence upon them were more excitable by the galvanic stimulus than healthy limbs whose muscles still remained in connection with the centre of volition.

In pursuing this subject subsequently, as opportunities offered, I found that my observations justified my adhering to the general views expressed on that occasion as to the *modus operandi* of the galvanic current when transmitted through the limbs, and furnished me with some additional facts, which I am desirous of laying before the Society as a sequel to my paper already referred to.

I shall first give an account of the results of my observations on the transmission of the galvanic current through the limbs of healthy subjects, both in man and the lower animals.

A Cruickshank's battery of fifty pairs of plates, each plate being about two inches square, charged with dilute sulphuric

acid, was employed for these experiments. The current was transmitted through the arms by connecting the poles of the battery with basins of water, in which the hands were immersed.

Twelve students of King's College Hospital kindly submitted to these trials, all apparently in robust health, and I was myself the subject of the same experiments.

It is evident from the arrangement adopted, that the current as transmitted through the arms, was direct in one arm, and inverse in the other.¹

The following results were obtained from these experiments.

1. That the obvious physiological effect was produced only on completing or on interrupting the galvanic circuit through the limbs.

2. That a greater effect, *i. e.* more vigorous contractions, followed the completion of the circuit than its interruption.

3. That in every instance the completion or interruption of the direct current, produced more vigorous contractions than the completion or interruption of the inverse current.

The greater influence of the direct current in producing contractions was so marked, that it was easy, by observing the action of the arms, to tell the direction of the current, it being always direct in the limb in which the contractions were most active and vigorous. And each individual who submitted to the experiments readily perceived the difference in his own person, from being conscious of more lively contractions in one limb than the other.

These phenomena became still more striking, on our adopting an arrangement by which the direction of the current through the limbs could be instantaneously reversed, making it, at the same moment, inverse where it had previously been direct, and *vice versa*. The more active contractions of the direct current, in the most striking way, seemed, as it were, to change sides with the change of direction of the current,—this being equally obvious in

¹ The current is *direct* when it passes from centre to periphery, *inverse* when it passes from periphery to centre.

the change produced in one's own sensations as the current became reversed in each limb.

4. A smaller number of plates was capable of exciting contractions by the direct current than by the inverse, thus affording a further illustration of the greater energy of the former current than of the latter.

When, by various contrivances, the current was made to pass in the same direction in both limbs at the same moment, no difference was observable in the relative power of the contractions of each limb, but it was still obvious that the contractions excited by the direct current were more vigorous than those excited by the inverse. The simplest mode of subjecting both limbs to the action of a current, which shall have the same direction in each, is by immersing the feet in one basin and the hands in another; thus, the former will be connected with one pole of the battery, and the latter with the other, the direction of the current in each pair of limbs being indicated by the pole with which they are connected.

The foregoing experiments were made with the galvanic trough. It has been asserted that the physiological action of the coil machine and of the magneto-electric machine, was not only more intense than that of the galvanic trough, but that it was also so different, that the use of the former instruments would lead to results quite opposite to those obtained by the latter.

The latter part of this statement is so much at variance with the results of my own experiments with the coil machine, and the magneto-electric apparatus, and also so inconsistent with the most reasonable theory of the mode of generation of the galvanic force by them, that I determined to try their influence upon a number of healthy persons, in the same way as I had tried the influence of the galvanic trough.

The results of these trials were exactly the same as those obtained from the experiments with the galvanic trough, *i. e.*, the contractions were distinctly greater in the limb in which the current was direct. And by changing the direction of the current in each limb, making it direct

where it had been inverse, and *vice versâ*, the contractions always became more intense when the current was made to take the direct course.

In short, these experiments showed that the physiological effects of the coil machine and of the magneto-electric machine were precisely the same as those of the galvanic trough. Both these instruments are capable of producing contractions of the utmost intensity, but they are also extremely manageable. The coil machine readily permits its intensity to be regulated, for by varying the quantity of the inductive material its power may be made to range from almost zero up to such a degree as to excite violent tetanic convulsions and the most horrible pain.

I must leave it to others to explain how, under similar circumstances and in the same individual, *opposite* physiological effects may be produced with the galvanic trough and with the coil machine. Perhaps in the experiments which yielded these opposite results, the importance of attending to the direction of the current was overlooked.

The facts above detailed have a very important significance. They denote, not only that in comparing the excitability of one limb under the influence of the galvanic current with that of its fellow, due care must be taken to compare them under similar states of galvanic influence,—*i. e.*, with the current taking the same direction in each,—but likewise that in exciting contractions the galvanic current acts primarily upon the nerves, and through them upon the muscles.

This latter conclusion, to which I had already been led by the facts and reasonings contained in my former paper on this subject, receives strong confirmation from other circumstances.

1. The galvanic current, when applied directly to a muscle, excites it to contract with just the same intensity, whatever direction it may take.

2. If the nerves be carefully removed from the limbs of an animal just killed, the galvanic current will excite contractions on both sides, nor can any difference be observed

between the contractions of the limb in which the current is inverse and those of the limb in which the current is direct.

3. After the nerves have been removed, the limbs no longer exhibit those differences in the influence of the inverse and direct current first noticed by the Italian *physiciens*, such as the excitation of contractions on *completing* the direct current, or *interrupting* the inverse.

4. After the nerves have been removed, the excitability of the limbs by the current ceases in each at the same moment.

5. The removal of the nerves prevents the development of that remarkable phenomenon,—the sudden assumption, on breaking the circuit, of the tetanoid state by the muscles of a limb through which the inverse current has passed for some time without interruption.

I shall now proceed to narrate a few experiments made upon paralytic patients, in which greater precautions were taken than in my former experiments, both with reference to the direction of the current and to other points, which will appear in the account of each experiment.

CASE I.—*April* 14, 1848. My friend Dr. Walshe, of University College Hospital, kindly permitted me to compare the excitability to galvanism of the healthy and paralysed limbs in a patient who was suffering from hemiplegia, and he also lent me his valuable assistance in the experiments.

The patient was an old woman, who had suddenly become completely paralysed on the right side; the muscles of that side were perfectly relaxed, and presented not the slightest rigidity: they were softer than those of the sound side, and appeared to have experienced a slight degree of wasting. The seizure was not preceded by any premonitory symptoms.

The first trials were made with a Cruickshank's battery. The current was passed only through the upper extremities, as it was found inconvenient to include the lower extremities.

I shall give the results in the following tabular form,

just as the notes were taken by Dr. Walshe, at the bedside of the patient :

1. With thirty pairs of plates.

a. Current direct in paralytic limb—moderate contractions of the biceps ; *none*, of the muscles of the fore-arm.

Current inverse in the sound limb—strong sharp contractions of the biceps ; strong contractions of the muscles of the fore-arm ; slight jerking of the limb ; contractions of the fingers.

b. The current was now reversed, retaining the same number of plates.

Current inverse in paralytic limb—very faint contractions of the biceps ; *none* in the fore-arm.

Current direct in sound limb—*powerful contractions* of all the muscles.

2. With twenty pairs of plates.

a. Current direct in paralytic limb ; very slight contraction of the biceps only.

Current inverse in sound limb ; as much (if not more) contractions of the biceps, and also distinct action of the muscles of the fore-arm.

b. Current inverse in paralytic limb. *No action.*

Current direct in sound limb ; strong action.

Thus it appeared that with twenty pairs of plates the *direct* current produced strong action in the healthy limb ; and caused slight contractions of the biceps muscle only in the paralytic limb.

3. With ten pairs of plates. No action in either limb.

4. With the entire battery (50 pairs of plates).

a. Current direct in paralytic limb—free and strong contraction of the biceps—but *no contractions* of the muscles of the fore-arm.

- b. Current inverse in sound limb—free action of the biceps—the contractions being quite as strong, but not stronger, than those of the paralysed limb; *intense contractions* of the muscles of the fore-arm.

Thus, with the whole force of a battery of fifty pairs of plates, and the advantage of a direct current, the muscles of the paralysed fore-arm could not be excited to action; while even with the inverse current *intense* action was excited in the healthy limb.

We next used the coil machine: the result of the influence of this instrument was, that with the current direct in the paralysed limb there was moderate action of the biceps of the paralytic arm, but none of the muscles of the fore-arm, whilst the muscles of the sound limb contracted freely. On reversing the current, the muscles of the healthy limb became much more active in their contractions, and the biceps of the paralysed limb contracted only very feebly.

The influence of the coil-machine, therefore, produced results in exact correspondence with those obtained from the galvanic battery.

The patient who was the subject of these experiments died of pneumonia very shortly afterwards. On post-mortem examination, there was found softening of the left corpus striatum, with spots of yellowish discoloration, probably from small hæmorrhage. No trace of pus or other inflammatory product could be discovered.

CASE II.—June 19, 1848. Jane Williams, æt. 36, a patient in Guy's Hospital, under Dr. Addison, who with Dr. Gull witnessed the experiments. There was hemiplegia of the left side; the paralysis was complete, and the muscles quite flaccid.

The experiments were made with the Wollaston's trough, and on the upper extremities only. When thirteen pairs of plates were employed, no contractions were excited on either side, whatever the direction of the current.

With seventeen plates, no contractions were excited in the paralysed limb with either the direct or the inverse current, while slight ones were produced in the healthy one, chiefly in the fore-arm. These were much more distinct when the current was direct than when it was inverse.

With twenty-five pairs of plates distinct and strong contractions were produced in the sound limb, slight ones in the paralysed, which were confined to the fore-arm. The difference in the intensity of the contractions was very great, whatever the direction of the current.

With thirty-three pairs of plates, and afterwards with fifty, the same contractions became general in both limbs, but with a marked difference of intensity in favour of the healthy limb, whatever was the direction of the current. This difference was more manifest when the current was direct in the healthy limb, less so when direct in the paralysed limb.

The lesion in this case, as I learned afterwards from Dr. Gull, consisted in very extensive colourless softening of the white substance of the right hemisphere.

CASE III.—Catherine Williams, *æt.* 50, admitted into King's College Hospital. Two days before her admission, while sitting at breakfast, she suddenly lost the use of the left arm and side of the face, and in the evening of the same day the left leg became paralysed. The attack was not accompanied by any loss or impairment of consciousness. On admission, she was found completely hemiplegic on the left side, the facial palsy being complete, and the tongue, when protruded, deviating to the left side. The paralysed muscles were very much relaxed; there was not the slightest appearance of rigidity nor the least resistance, when extension or flexion of either limb was effected.

The trials of galvanism were made with the trough and with the coil machine, both of which yielded similar results. Whatever the direction of the current, very faint contractions were excited on the paralysed side—whilst those on the sound side were distinct, although not very strong; they were more distinct under the influence of the direct current.

This woman was in a state of great debility, and did not long survive her admission into the hospital. After death, the lesion was found to be extensive softening, with loss of substance of the right corpus striatum, but without any sign of an attempt at cicatrisation.

CASE IV.—Thomas Hardwick, æt. 49, a smith, admitted into King's College Hospital, August, 1848. In this patient the hemiplegia was on the right side, the power of motion was not completely lost; more so in the arm than in the leg; there was some loss of sensation in the arm. The muscles of the paralysed limbs were firm and rigid, especially those of the arm. This rigidity was sufficient to give a condition of semi-flexion to both arm and leg, especially the former, which was most conspicuous at the elbow and in the fingers.

This patient was galvanised in the usual way, with more effect on the *paralysed* than on the *sound limbs*, which was very obvious in the early part of his stay in the hospital. After some time, the muscles of the palsied limb became less rigid, and in proportion as the rigidity became less the influence of the galvanism diminished likewise.

In examining the brain of this patient after death, it appeared that the lesion consisted of inflammatory disease of the pia mater, compressing and irritating the optic thalamus of the left side. An irritating lesion of this kind explained the rigid or spastic condition of the muscles of the paralysed limb. This was due to an exalted polarity of the nerves, which kept the muscles in this firmly contracted or spasmodic state, and to the same state of nerve was to be attributed the increased excitability of the muscles of that side to the galvanic stimulus.

CASE V.—Elizabeth Clarke, æt. 63. (Case Book, vol. xxiii, p. 163.) This woman was a housekeeper at one of the west-end clubs. She was admitted on the 1st of May, 1848, semi-conscious, having just had a paralytic stroke, which induced complete hemiplegia of the right side. The muscles of the arm and leg were perfectly lax.

The first trial with galvanism was made on the 3d of May, two days after her admission, with the Cruickshank's battery. With twenty-five plates, and a direct current in the right or paralysed arm, very feeble contractions were excited in that side; distinct ones in the left, or sound side, although in it the current was inverse. On reversing the current, the contractions became very vigorous in the sound arm, and were scarcely perceptible in the paralysed.

With fifty plates, very distinct contractions were excited in both arms; those of the sound side, whether with the inverse or the direct current, being always obviously the stronger.

A second trial with the galvanic current was made on the 15th. Her mental functions had much recovered, but the palsy remained in *statu quo*. The results of this trial were precisely the same as regards the *comparative* effects of the galvanic current on the two sides; the only change being that a little more power of contraction was exhibited on both sides, which was probably due to an improved state of the patient's general health. On the 17th, these experiments were repeated with the same results.

On this occasion, an arrangement was adopted, by which the current was divided, and made to pass down each arm as a direct current. Thus each arm was, at the same time, similarly affected by the galvanism. The contractions were invariably stronger in the sound than in the paralysed limb. When the current was inverse, the contractions on both sides were very feeble, but more pain was excited, and greatest muscular action in the sound limb.

The palsy in this case was caused, in all probability, by white softening of the left side of the brain, due to defective nutrition, and possibly there might have been slight hæmorrhage into the substance of the brain. The patient remained two months in the hospital, and partially recovered the power of the limbs.

CASE VI.—John Shea, æt. 44, admitted April 4, 1849, a bricklayer, and of intemperate habits. Going down by

railway to Sydenham, on the 2d of April, he had a fit in the carriage, and was found lying on the floor in a state of insensibility. On recovery, he was found completely paralysed on the right side. There was complete relaxation of the muscles, except the biceps. The right side of the face was paralysed in a very marked manner, and the tongue, on being protruded, deviated to the right; speech was impaired. The lethargy consequent upon the attack did not go off for some days. The first trial with galvanism took place on the 5th of April. The Cruickshank's trough was used as in the other experiments.

With five plates, no contractions were excited in either arm.

With twelve plates, there were slight contractions in the left fore-arm (the sound side), none in the right (the paralysed).

With fifteen plates, contractions in both fore-arms, but decidedly weaker in the right.

With twenty plates, manifest contractions in both, but distinctly weaker in the right. When the arms were loosely suspended in a basin, the right or palsied arm was most jerked, evidently in consequence of the lax state of the muscles and the absence of due antagonism.

With twenty-five plates, vigorous contractions, but the superiority of the left over the right was still very manifest.

In these experiments the current was always direct in both arms. The patient's hands were immersed in one basin, and his feet in the other, and the positive wire was connected with that in which the legs were placed.

A second trial with the galvanism took place on the 26th. No improvement had taken place in the motor power of the paralysed side; but the sentient power, which, after he had rallied from the shock of the palsy-stroke, we found had been very much impaired, had now nearly recovered itself. The condition of the muscles was the same.

On this occasion the results of the experiments were precisely the same as before.

In this case I have no doubt the lesion was a clot, which involved a considerable portion of the left corpus stri-

tum. The patient frequently visits the hospital, and I have seen him within the last few days (May, 1853). He has not recovered the palsy, excepting, in a slight degree, that of the leg. The muscles of the fore-arm have become wasted and contracted, causing permanent flexion of the fingers, and of the fore-arm upon the arm, a condition which, in my opinion, is apt to follow the absorption of a clot, and the contraction and cicatrisation of the torn brain-substance.

CASE VII.—John Liftin, æt. 55, admitted April 11th, 1850. On Easter-day (April 9th), at half-past ten o'clock in the morning, whilst walking across the room, he dropped a candlestick which he was carrying in his hand, and his wife then found that he had lost the use of his right side; he soon became very lethargic, with stertorous breathing; in this state he continued for some days. On coming out of this lethargy, he was completely paralysed, with relaxed muscles on the right side, the face, tongue, arm, and leg being affected, and his powers of articulation were very much impaired. Sensibility was not injured; on the contrary, pinching the skin occasioned more pain in the paralysed than in the sound limb.

The galvanism was tried first on the 14th of April.

With nine plates, the palsied side having the advantage of the direct current, much the strongest contractions were excited on the sound side. On inverting the current, very strong contractions were excited in the sound limb; those in the paralysed were very slight.

With eighteen plates, the current being direct in both arms, the contractions were strong and distinct in the sound side, very feeble in the paralysed. They were also very feeble in the legs, in which the current was inverse.

This patient remained in the hospital many weeks. He recovered in the course of the first four weeks a certain amount of power in the leg, so as to enable him to walk with the characteristic hemiplegic jerk, but gained no power in the arm.

On the 10th of June, a second trial was made with gal-

vanism. The current was made to pass through both arms and legs, so that it was direct or inverse in both arms, or in both legs, at the same time.

When the current was direct in both arms, decided contractions were excited, varying in force with the number of plates used, but with a very marked difference in favour of the sound arm. Analogous phenomena were observed under the influence of the inverse current; but the contractions in both upper extremities were decidedly less, although those of the sound arm predominated distinctly over those of the paralysed.

This, like the preceding case, was, in all probability, one of apoplexy, leaving a clot in the left hemisphere of the brain; the patient had made very little advance towards recovery when he left the Hospital, and probably would never perfectly recover the use of the right side. He has not since been heard of.

In the next case the influence of the coil machine was first tried, and afterwards that of the battery.

CASE VIII.—William Ware, æt. 30, a ploughman, (Case Book, vol. xxvi, A;) fifteen weeks before his admission he became suddenly paralysed on the right side in the night, having for some days previously experienced a numbness in the arm and leg of that side. On awaking in the morning he found himself in this hemiplegic state, but speedily lapsed into a state of unconsciousness, which lasted, more or less, for three weeks. As his intelligence recovered, he seemed to gain a little power over the affected side. He yawned frequently, and crying was excited on the slightest emotion.

On admission there was hemiplegia of the right side, the face and tongue being affected as well as the arm and leg. Some power had been recovered, and he could flex the fingers so as to grasp feebly. The leg had recovered nearly completely. The muscles of the arm were quite flaccid, and were but slightly wasted. Those of the leg had not yet recovered their usual size.

The first trial of galvanism was made with the coil machine.

When the current was direct in the *paralysed* side, and inverse in the sound, the contractions were equal in both arms.

But when the current was inverse in the paralysed and direct in the sound, the contractions of the former were feeble—those of the sound limb being strong and even violent.

The direct current caused greater contractions in the sound limb, than the same current in the paralysed.

But the inverse current caused distinctly stronger contractions in the paralysed side than the same current in the sound.

Two days after the above experiments a second trial was made, and now the Cruickshank's battery was used.

The direct current produced the greatest contractions through whichever limb it was directed, and those of the sound limb were distinctly greater than those of the paralysed. But, on transmitting a divided inverse current through both arms, the muscles of the paralysed arm were decidedly more affected than those of the sound limb.

After the lapse of a fortnight the leg had nearly completely recovered, and additional power had been gained in the arm. A third trial with the Cruickshank's battery showed that whether with the direct or inverse current the contractions, as well in the arms as in the legs, were distinctly greater on the sound than on the paralysed side. On this occasion the greater contractions of the paralysed arm under the inverse current were not observed.

This phenomenon of the greater contraction of the paralysed than of the sound arm under the inverse current, seemed to me attributable to some altered conditions of the nerves of the former limb, due, perhaps, to the process of repair going on in the brain.

The patient caught erysipelas about three weeks after the last trial of galvanism, and quickly succumbed under it. We had thus an opportunity of ascertaining that the left

half of the left corpus striatum was broken down and excavated into a small cavity, filled by an opaque buff-coloured fluid. Several bands of fibres passed across its posterior half. All the rest of the corpus striatum was healthy. The portion immediately surrounding the cavity was a little soft, but not otherwise altered.

CASE IX.—John Frost, æt. 50, admitted February 16, 1850. The attack was sudden, only a few days before admission; the patient was in a semi-comatose condition. There was complete paralysis of the right arm, with relaxation of all the muscles, except the biceps, which resisted extension of the forearm. The leg was only partially paralysed. The tongue was protruded to the left side, and the left cheek was paralysed.

The trial with galvanism was made in the usual way, giving the paralysed arm the advantage of the direct current; there was, nevertheless, a marked difference in the contractions in favour of the sound limb. The difference was much more manifest when the current was reversed, so that it became inverse in the palsied, and direct in the sound limb.

Subsequently the arrangement was adopted by which both arms became simultaneously excited by the direct or by the inverse current. The contractions in both arms were much stronger with the direct than with the inverse current, but with both, those of the sound limb were decidedly the strongest.

This patient died from the exhausting influence of diarrhœa eleven days after the attack. On examination, the lesion was found to be white softening of the left optic thalamus and the neighbouring fibres of the hemisphere, and a recent clot in the thalamus occupying its external two thirds.

CASE X.—S. Jago, æt. 40, a glass-cutter, of intemperate habits. Complete hemiplegia of the right side. The attack of palsy came on suddenly after previous head symptoms,

pains in the head, failure of memory, low spirits. These symptoms dated from a fall whilst intoxicated, twelve months before the attack of palsy.

He was admitted into hospital three weeks after the palsy-stroke, with complete paralysis of the right arm and leg, the muscles being relaxed.

The only trial with galvanism was made four days after his admission. The hands were placed in one basin and the feet in another; thus the current was direct or inverse at the same time, in both arms or in both legs. With both the inverse and the direct current, much more vigorous contractions were excited in the sound arm or leg than in the paralysed.

CASE XI.—J. Dowden, *æt.* 30, admitted June 8, 1850, for hemiplegia of the right side. The paralysis was perfect, and the muscles relaxed, but there was a tendency to flexion of the fingers, which resisted extension slightly. The attack occurred six weeks before admission; it was sudden, she fell, but retained her consciousness for a short time, but soon lapsed into a comatose state, out of which she came in three or four hours with palsy of the right side and loss of speech; she had had three attacks of rheumatic fever, and her heart was diseased, the mitral valve having been damaged.

On admission, this patient was recovering a slight amount of power in the leg and arm. There were strong reflex actions in the leg, and the arm was jerked up whenever she yawned.

The trial with galvanism was made in the usual way very soon after her admission. When the current was direct in either arm, the contractions of that arm were the more violent and the stronger. When it was direct in both arms, the contractions of the sound arm were the stronger; it was so likewise when the current was inverse in both. But, in both instances, whether with the inverse or the direct current, the difference between the contractions of the two limbs was not very great.

This woman remained in hospital about a month, and acquired some but not much additional power.

CASE XII.—For this case and the observations made upon it, I am indebted to my friend Dr. Brinton, in whose accuracy of observation the greatest reliance may be placed.

George Jenkins, *æt.* 30, on rising from his bed on the morning of February 23, 1852, found to his great surprise that he had entirely lost the use of his left side, so that he fell upon the floor. His speech was also impaired, but his intellect was not affected.

There was complete paralysis, with relaxed muscles of the left arm and leg, "these limbs lying like logs, incapable of the slightest obedience to the will." There was also nearly complete loss of sensation, and not the slightest appearance of reflex action could be produced.

After a few days' treatment with purgatives, and a blister to the back of the neck, galvanism was tried. The results of these trials I shall give in Dr. Brinton's words.

"The galvanic stimulus made use of was an electromagnetic apparatus, so graduated by the bundle of wires as to give a smart but quite bearable amount of stimulus to the sound arm. On applying this to the affected side, it was at first found impossible to excite any contraction of the paralysed muscles. In about half an hour movements were gradually produced.

"On the next day, I found that there was still a marked difference between the two sides. With all gradations of shock, short of the most violent, one could plainly see, that the effect on the sound side was vastly greater than that on the other. It appeared to make little difference whether the positive or negative pole corresponded to the central extremity of the nerve along which the current was led."

In the detailed account of the case with which he has favoured me, Dr. Brinton makes the following remark, "Two circumstances," he says, "ought, I think, to be noticed in a comparison of these contractions, both of them having a tendency to represent the effect in the healthy limb as less

than what it really is. The first is the evidently more co-ordinate and general character of the contractions on the sound side; which are sometimes contrasted by small, but comparatively isolated spasms on the diseased one, better seen among the torpid and relaxed parts which surround them. The second is, that the patient sometimes controls a tolerably powerful spasm in the sound limb by a vigorous exercise of the will. The former I suspect to be very difficult of proper correction, even though the eye be assisted by the touch."

This patient gradually recovered the power of the left side, and as he advanced towards recovery, the difference in the excitability of the two sides to galvanism became less and less marked.

CASE XIII.—James Scott, æt. 53. Paralysis of the right arm, leg, and side of the face, with relaxed muscles. The paralytic seizure occurred on the 17th of November, and was not accompanied by any loss of consciousness. The trial with galvanism was not made until the 6th of December, when he had gained some power in both leg and arm. He could raise his hand to his mouth with difficulty, and bend the fingers feebly, and he could bend the knee somewhat, and raise the heel six inches from the bed, the whole limb being kept straight.

The galvanism was tried in the usual way, with Cruickshank's battery, and first with each hand in a basin with 19 plates, the current being direct in the right or paralysed arm. The right hand and arm moved more than the left, but the muscles of the left contracted with greater power, which was especially observed in the biceps, this muscle acting vigorously on the left side, while scarcely any action was observed on the paralysed or right side, notwithstanding that it had the advantage of the direct current.

When the current was inverse in the right or paralysed side, no contractions whatever could be distinguished in the right limb, either by the sight or by firmly grasping it in

different places. Vigorous contractions, however, were both seen and felt in the left limb.

The hands were now placed in one basin, and the feet in another, and forty-five plates were used.

Current direct in the arms.—The greatest motion was observable in the right arm, but the muscular contractions were firmer, and more vigorous in the left limb, both in the arm, and also in the fore-arm.

Current inverse in the arms.—The same phenomena were observed, but in a less degree.

CASE XIV.—Mary Reeves, æt. 49. In this patient the paralytic attack was preceded for a period of fifteen months by pains, which for a time were regarded as rheumatic, in the right arm and leg. Four months before her admission into the hospital, in November, 1852, she was seized, while out walking, with violent pain in her right foot, which caused her to limp, and she walked home with assistance, and not without considerable difficulty. The following day the pain subsided, but the leg and arm remained partially paralysed, and this paralytic condition gradually increased during the next fortnight. She now became subject to pain in the head, chiefly in the frontal region. Early in November (the 9th), she had a fit of loss of consciousness, and since that time she has had several attacks of a similar kind, in which she has fallen with loss of consciousness, but without convulsion. The memory had been failing for some time, and speech was much impaired.

She was admitted on the 24th, in a semi-conscious state, with nearly complete hemiplegia of the right side. The muscles of the arm and leg were rigid, those of the former especially. The arm was bent across the chest, the fore-arm being flexed on the arm, and the fingers in a state of flexion. There remained slight power of moving the fingers. The sensibility seemed rather exalted, as pinching, which was scarcely felt on the sound side, caused considerable pain in the paralysed arm. Reflex actions were exalted.

The direct current, with twenty-five pairs of plates, and

with thirty-two pairs, caused distinctly more powerful contractions in the sound arm than in the paralysed, whether the experiment was tried by placing a hand in each basin, and so passing the current through the arms; or whether the current was transmitted through both legs and arms, the feet being in one basin, the hands in another.

When the current was inverse in both arms, the difference of contraction was very slight, but it appeared to two observers to be in favour of the right or paralysed arm.

It should be stated that these observations were made a fortnight after the patient's admission into the Hospital, when the rigid state of the muscles of the paralysed limbs had nearly completely subsided under treatment.

This patient died on the 12th of December, and the lesion was found to be extensive softening of the left corpus striatum, extending backwards to the mesocephale, and downwards to the crus cerebri. The posterior portion of the upper surface of the mesocephale, and the posterior part of the left optic thalamus were in a very indurated condition.

In reviewing the preceding fourteen cases, I would direct the reader's attention to the following points:

1. That of all the cases, only three (Cases IV, VIII, and XIV) exhibited under the galvanic stimulus any approach to a greater excitability of the paralysed than of the sound limb, and that in two of these (VIII and XIV) it was manifested only under the influence of the inverse current.

2. That in three of the cases (I, III, and VIII), the galvanic stimulus was applied by both the coil machine and the Cruickshank's trough, and with results precisely the same. And in one of the cases (XII) the coil machine alone was used, with results corresponding with those obtained in similar cases by the galvanic trough.

3. That in each of the three cases, in which a greater excitability existed in the paralysed limbs, the paralyzing lesion in the brain was more or less of an irritative kind. In Case VIII, the irritation was probably connected with an incipient process of cicatrisation.

4. That in many of the experiments all degrees of galvanic power were used, and with no other difference than that of degree, the amount of physiological effect produced being exactly proportionate to the power of the galvanic stimulus.

The experiments which I have detailed have a two-fold bearing; first, on physiological doctrine; secondly, on practice.

As to physiological doctrine, the greater or less excitability of a muscle or set of muscles under the galvanic stimulus must depend on one of two causes, either on a *plus* or *minus* condition of the muscular force, or on a similar condition of the nervous force in the nerves which supply the muscles.

Those who maintain that the spinal cord is the source whence the muscles derive their peculiar power of contracting or their irritability, adopt the former view; and it follows, as a necessary consequence upon this, if the brain be the exhauster of this power, while the spinal cord is the magazine whence it is ever flowing to the muscles, that when the influence of the brain is removed, as in hemiplegia, the force would accumulate in the muscles, and ere long exist in them in a *plus* condition.

It was with a view to test the accuracy of such a doctrine as this, that the experiments which I formerly communicated to the Society were undertaken. It appeared to me, then, and I think so now, that if this doctrine were true, the augmented excitability of limbs paralysed by cerebral lesion ought to be so easily demonstrable, that "he who runs may read." And so, indeed, it seemed, from the experiments which were detailed on the first enunciation of this doctrine.

But the experiments, which I have instituted, show that an augmentation of the excitability of the paralysed limbs is the exception, while a diminution of it is the rule, and that every now and then we meet with instances in which the paralysed limb is wholly inexcitable, even by a powerful galvanic stimulus.

It is satisfactory to me that the results of my observations

have received ample confirmation from the similar experiments of two such competent observers as M. Brown-Sequard and M. Duchenne.

My first series of experiments was objected to, because it was affirmed (my own statement to the contrary notwithstanding, vide 'Med.-Chir. Trans.,' vol. XXX, p. 209), that I had used *only* the electro-dynamic, or the magneto-electric rotatory apparatus; and it was even asserted that *opposite* results were obtained and obtainable with either of these instruments and with the galvanic trough.

I have now shown that in healthy individuals these different instruments produce precisely the same physiological effects. And in four of the recorded cases of paralysis, the coil machine was used with results exactly corresponding with those obtained from the galvanic battery.

As regards the practical bearing of these experiments, I can only repeat that which I have stated in my former communication on this subject, namely, that the greater or less excitability of a paralysed limb to the galvanic stimulus is only an indication of the *plus* or *minus* condition of the nervous force in the nerves of that limb, and that it is sometimes of use in practise, as denoting that the paralyzing lesion is, or is not, irritant, or even inflammatory.

I must also adhere to the opinion before expressed, that we gain no assistance from testing the relative excitability of the paralysed and sound limbs in the diagnosis between cerebral and spinal palsy.

By cerebral palsy, I mean that caused by disease of the encephalon, or the nervous mass within the skull; by spinal palsy, I mean that originating in disease affecting the intraspinal nervous mass.

We will suppose a patient suffering from complete palsy of the right arm, and of that alone. The point to determine is, whether such paralysis be due to a simply local palsy, or to disease of the encephalon, or of the spinal cord. We cannot derive any assistance in the solution of this question from examining the relative excitability of the sound and of the paralysed limb: for not only may there

be, as I showed in my former paper, an augmented excitability of the muscles where the palsy is purely spinal, but in the majority of brain palsies, the excitability of the paralysed is less than of the sound limb. There is no fixed relation *as to place* between the paralyzing lesion and the state of the excitability of the affected limbs; there is, however, *as to the nature* of the lesion, whether that be irritating or depressing. And a lesion of the nervous centre will influence the excitability of the limb or limbs alike, according to its nature, whether it be *intra-cranial* or *intra-spinal*.

In the repetition of experiments on this subject, I would suggest to those who might be disposed to try them, that attention should especially be paid to the state of the muscles, whether they are quite flaccid and relaxed, or whether they are rigid; and, if the latter, whether the rigidity came on soon after or at the same time with the palsy-stroke, or at a remote period? These points, as well as the state of nutrition of the muscles, should be noted in the record of the experiments. Care should also be taken to compare the action of the limbs under the same state of galvanic excitement, that is, with the galvanic current, direct or inverse in each limb. The neglect of this precaution will certainly lead to fallacious conclusions.

