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ON

LOCALIZED GALVANISM

APPLIED TO THE TREATMENT OF

Paralysis and Muscular Contractions.

By RICHARD MOORE LAWRANCE, M.D.,

Ophthalmic Surgeon to the Great Northern Hospital.

LONDON: HENRY RENSHAW, 356, STRAND.

1858.

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WORKS BY Dr. LAWRANCE.

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BY

RICHARD MOORE LAWRANCE, M.D.,
OPHTHALMIC SURGEON TO THE GREAT NORTHERN HOSPITAL.

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PREFACE.

SINCE the publication of my former works on the use of Galvanism as a therapeutic agent, it has assumed a new and a highly practical character. By a change in the mode of applying the remedy some important physiological and pathological discoveries have already been made, and facts accumulated in sufficient numbers to prove, that in Localized Galvanism we have at last discovered a remedy for the cure of some forms of nervous, articular and muscular diseases which have hitherto resisted all other remedial agents.

Already by means of Localized Galvanism has been created a new kind of anatomy, the surgical anatomy of the nerves: by its means the functions of many muscles, hitherto so obscure, can now be demonstrated in a way to admit of no dispute; pathological conditions of the muscles hitherto unknown and not even suspected to exist, have been discovered; whilst by the same means a flood of light has been thrown on those articular diseases which classed under the vague head of rheumatism of the joints and muscles, were in most instances, confessedly beyond the then known surgical remedies. Localized Galvanism is in fact not merely a remedial agent of great power, but a means of diagnosis by which, in many cases of deformities of the trunk, displacement of the shoulders and lateral curvature of the spine, the true cause of the disease may be shown to be of a nature wholly different from what modern pathology teaches and has taught.

To a brief history of animal electricity from its first employment as a therapeutic agent by the Romans, to the recent discoveries of Du Bois Reymond, I have added an equally brief outline of static electricity and of galvanism properly so called; but it is chiefly to the history of Localized Galvanism as a therapeutic agent that this little work is devoted. The basis of the whole inquiry is strictly experimental and demonstrative; unlike those of preceding inquirers, the experiments have been made on man himself, thus removing nearly every source of fallacy: time alone can show what the therapeutic results may amount to, but of this I feel assured, that if it be permitted to conjecture the future by the past, science may congratulate itself in having bestowed on the medical art, a new therapeutic agent with remedial powers superior to all hitherto discovered.

April 1858.

22, *Connaught Square*,
London.

CONTENTS.

PART I.

INTRODUCTION.

CHAPTER I.

CHAPTER II.

CHAPTER III.

CHAPTER IV.

PART II.

CHAPTER I.

CHAPTER II.

CHAPTER III.

CHAPTER IV.

CHAPTER V.

PART III.

CHAPTER I.

CHAPTER II.

CHAPTER III.

PART IV.

CHAPTER I.

CHAPTER II.

CHAPTER III.

CHAPTER IV.

PART V.

CHAPTER I.

CHAPTER II.

CHAPTER III.

CHAPTER IV.

CHAPTER V.

CHAPTER VI.

CHAPTER VII.

CHAPTER VIII.

CHAPTER IX.

PART VI.

CHAPTER I.

CHAPTER II.

CHAPTER III.

CHAPTER IV.

CHAPTER V.

CHAPTER VI.

ON LOCALIZED GALVANISM.

PART THE FIRST.

INTRODUCTION.

ELECTRICITY under its two most remarkable forms must have been known to mankind from the remotest ages. The thunderstorm and the lightning's flash are phenomena which at all times and under all circumstances, however much the human mind may have suffered debasement, must have acted strongly on the intelligence, exciting a terror and awe to which the uncontrollable and irresistible power of the unseen and mysterious agent materially and powerfully contributed. So with that other form of electricity which certain animals exhibit. The torpedo was and is an inhabitant of the Mediterranean; the silurus of the Nile was known to the inhabitants of Egypt, the oldest seemingly of civilized men. Thus the electric fishes, as they are called, were early known as such to the three great races of mankind, the most remarkable for their early civilisation—the Coptic, the Grecian, and the Roman. As usual, applicative art preceded science, and the torpedo was employed for centuries by the Romans* for the cure, or at least as a method of treatment, of palsies

* Scribonius Largus, De Compositione Medicamentorum Medicæ.

and rheumatic affections, before it ever entered into the head of man to discover by dissection, the nature of the mysterious organs which gave to their possessor the power of so singularly acting on man himself.

To me, it appears certain that the electricity we now call *static*, or that produced by friction, must have, in like manner, been early observed by the most illiterate of mankind. The Rev. Dr. Livingstone, for ever celebrated for his bold journey across the African continent, describes in his missionary travels, the electric condition of the hot winds of the Kalihari desert. 'This wind,' he says,* 'is in such an electric state, that a bunch of ostrich-feathers held a few seconds against it, becomes as strongly charged as if attached to a powerful electric machine, and clasps the advancing hand with a sharp crackling sound. When this hot wind is blowing, and even at other times, the peculiarly strong electric state of the atmosphere causes the movement of a native in his kaross (a mantle made of the skins of wild animals) to produce therein a stream of small sparks. The first time I noticed this appearance was while a chief was travelling with me in my waggon. Seeing part of the fur of his mantle, which was exposed to slight friction by the movement of the waggon, assume quite a luminous appearance, I rubbed it smartly with the hand and found it readily gave out sparks, accompanied with distinct cracks. "Don't you see this?" said I. "The white man did not show us this," he replied; "we had it long before white men came into the country, we and our forefathers of old." Unfortunately, I never inquired the name which they gave to this appearance, but I have no doubt there is one for it in the language.

* Missionary Travels in South Africa, p. 123.

Otto von Guerrike is said by Baron Humboldt to have been the first that ever observed this effect in Europe, but the phenomenon had been familiar to the Bechuanas for ages. Nothing came of that however, for they viewed the sight as with the eyes of an ox. The human mind has remained here as stagnant to the present day, in reference to the physical operations of the universe, as it once did in England. No science has been developed, and few questions are ever discussed, except those which have an intimate connexion with the wants of the stomach.'

Thus it would appear that electricity, as we see its results in the flash of lightning, electricity as it shows itself in the Gymnotus, the Torpedo, the Silurus, and the electricity artificially produced by friction, now called *static* electricity, have been at all times known to mankind. But it is only of late that science, turning its attention to phenomena, gazed at by the mass with stupid wonder, or as the African traveller has happily expressed it, 'with the eyes of an ox,' grouped the phenomena together, recorded and substantiated the facts which, isolated and unconnected by known laws, are but of little interest, even in a practical sense, and of no interest in a scientific point of view, and finally succeeded by the discovery of some of the laws regulating electricity in applying the forces still mysterious in their nature to important practical purposes. And now investigations, comparatively of late date, which have been carried through by distinguished observers, some of whom are still alive, have placed the whole problem to be solved under a new light, opened up new fields of inquiry, and fixed on scientific bases what heretofore was simply a matter of idle curiosity.

CHAPTER I.

On the Development of the Various Kinds of Electricity.

As applied to medicine, electricity has been employed under several forms :—

1st. By modern physicians under the form of *static* electricity, that is, the electricity of friction.

2nd. Under the form of *dynamic* electricity, a name applied to electricity in motion, or as a current, to the electricity of contact and to the electricity of induction.

Electricity disengaged or set free by the voltaic pile, or by the galvano-dynamic or magnetic machines, possesses physiological properties essentially distinct from those of static electricity ; and although cases unquestionably have occurred in which the curative powers of static electricity have proved equal to those we now derive from the dynamic, yet, as I shall endeavour to prove, it is to the employment of electricity under this latter form, that we must look for all future progress in the treatment of disease.

The identity of the electricity of the clouds and of the electricity of friction was the discovery of the immortal Franklin ; to the celebrated Galvani we owe, as I shall afterwards endeavour to show, the discovery, not only of metallic or chemico-thermal electricity, but also that more obscure form which is now known to pervade certain tissues of animals. This must not be confounded with the electricity developed by the Torpedo and Gymnotus, as has been often done by distinguished observers, nor even with the unknown nerve-force, which in some of its phenomena so closely resembles electricity. To prove its presence in animal bodies so as to admit no longer of any cavil was reserved for Du Bois Reymond,* one of the most distinguished observers of modern times. The first step towards the elucidation of that animal electricity which Galvani had suspected but did not prove, was made by the illustrious Oersted, who discovered the deflection of the magnetic needle by the galvanic current in 1819; and this led to the construction of the galvanometer, an instrument intended to detect the presence of electric currents in situations where heretofore they were either not suspected to exist, or could not be demonstrated. In the hands of Du Bois Reymond the discovery of Oersted assumed a new form and led to the most important results; it conducted, in fact, to the demonstration of an animal electricity constantly present in the nerves and muscles of living animals and of the laws regulating the electrical currents in nerves and muscles. Lastly appeared on the field of these singularly interesting inquiries, Duchenne, to whom we owe the discovery of localized galvanism and of its application to physiology, pathology, and therapeutics, in other words, to the science of life, and to the applied sciences or arts of medicine, surgery and midwifery. As an original observer, and one who had the prejudices resulting from the prestige of half a century of failure by others to overcome, it was not to be expected that he could at once place the discovery in all its bearings before the medical world. He was, as he admits, ignorant of anatomy; and of human physiology and pathology he had

* Untersuchungen ueber thierische Electricität.—Bd. i. & ii., 1848 and 1849.

made no special study. This deficiency I have endeavoured, to the best of my ability, to fill up, by placing the whole subject on a correct anatomical basis and connecting its results with existing pathology.

We have seen, that until the period of Franklin, the development of electricity was supposed to be limited to the natural electricity of the atmosphere as witnessed in the thunderstorm and to that produced by friction. The fact that certain fishes could develop electricity at will was either not attended to or overlooked. The dissections of the immortal Hunter* had no physiological results, though in the right direction, and extremely important in explaining to scientific men the character of the structures employed by nature in the performance of a function, which, in point of mystery, yields only to the human intelligence itself. But now other actors appear on the scene, natives of that land which had been the birthplace of Galileo and Torricelli, of Leonardo and Raphael—Italy. It fell to the lot of Galvani† and of Volta‡ to show the development of electricity under new forms: to the former, we, in reality, as it now appears, from works to which I shall presently refer, owe the discovery of animal electricity; not of the electricity set free by electric fishes, in which we find a special apparatus of organs obviously arranged by nature *ad hoc*, but of an electricity, or, at least, electrical currents constantly present in the nerves and muscles of animal bodies, seemingly dependent on or intimately united with the organisation of these organs. To Volta we owe perhaps the discovery of what we now call

* Philosophical Transactions, 1773.

† De Viribus Electricitatis in Motu Musculari Commentarius.

‡ Schriften über Electricität und Galvanismus, Herausgeg. Von Nasse, 1803.

Galvanism, although there are circumstances in the history of these great discoveries—for they truly deserve the appellation—which may lead posterity to ascribe to Galvani alone the real merit of both.

As it is by means of the instruments invented by Galvani and Volta, and perfected by a host of observers, amongst whom stand conspicuously Faraday, Du Bois Reymond, and Duchenne, that all these discoveries have been made, it may not be uninteresting to trace, rapidly and briefly, the progress of the scientific inquiry; that those who peruse these contributions, may be enabled to assign the merit of priority to him to whom it is justly due; and it will further enable them to follow with more interest the practical details, which, in point of fact, are based on, and, in some measure, flow from the views of the original observers.

Dr. Du Bois Reymond seems to have been the first to place clearly before the world of science the discoveries of Galvani and Volta, and to have established the degree of merit due to each; but he has done more,—by his researches in Animal Electricity he has discovered many new truths, and deduced definite laws from masses of seemingly incoherent and even discordant facts. I cannot therefore do better than give you in his own words his summing up of many of these interesting points, and the history of two such men as Galvani and Volta, names which will never disappear from the page of history. 'No one who has read Galvani's writings, can, without reverence, turn from the simple picture of that man whose restless, yet blind labours and naïve desire for knowledge were destined to bear such fruits. Every one will easily excuse his having wandered in that way which we shall soon see him take.

The problem presented to him was, an equation with two unknown quantities, one of which was the galvanism which Volta discovered, the other animal electricity, which latter after half a century, now again appears claiming its proper place.

'Galvani really discovered, not only the fundamental and physiological experiment of galvanism, properly so called (the contraction of the frog when touched with dissimilar metals), but also that of the electricity inherent in the nerves and muscles themselves. Both of these discoveries were however hidden in such a confusion of circumstances, that the result in both cases appeared equally to depend upon the limbs or tissues of the animals employed.

'Galvani was by profession, an anatomist and physiologist. He was possessed with the idea, which then was popular, of an animal electricity which he demonstrated to his class in the anatomical theatre. It is not therefore, to be wondered at, that he should endeavour to solve the problem in that manner which appeared to open the way to the explanation of a multitude of facts. Volta indeed, held the same opinion, though at first he was sceptical, in consequence of the many deceptions which had already occurred in this branch of knowledge. He passed as he himself tells us, from unbelief to fanaticism, as soon as he had handled the wonderful facts. Nevertheless he was ready to reject those bright projects which galvanic discoveries appeared to unfold for the physiology of the muscles and nerves, as soon as he considered that he had proved that they were not tenable in the existing state of science. No one who wishes to judge impartially of the scientific history of those times and of the leaders, will consider Galvani and Volta as equals, or deny the vast superiority of the latter over all his opponents or fellow-workers, more especially over those of the Bologna school. We shall scarcely again find in one man gifts so rich and so calculated for research as were combined in Volta. He possessed that incomprehensible talent, as Dove has called it, for separating the essential from the immaterial in complicated phenomena; that boldness of invention which must precede experiment, controlled by the most strict and cautious mode of manipulation; that unremitting attention which allows no circumstance to pass unnoticed; lastly, with so much acuteness, so much simplicity, so much grandeur of conception, combined with such depth of thought, he had a hand which was the hand of a workman. It is strange, indeed, that a German voice should call an Italian philosopher to order for depreciating the great Volta.'

CHAPTER II.

Discovery of Galvanism.

It was during the summer of 1786 that Galvani first observed the effects of static electricity on the nervous and muscular systems of a frog prepared for that purpose. The sparks employed were drawn from the electric machine; he soon after repeated the experiment with lightning. In the autumn of the same year he endeavoured to discover the action of atmospheric electricity on the prepared limbs of frogs during a stormless sky. On the 20th September 1786, he made his great discovery, which he at first misinterpreted and misunderstood, in other words, he discovered metallic electricity and the properties of the combinations of different metals; he compared the muscles of the frog, and, by inference, of all animals to a Leyden jar, their outer surface being charged with negative, their inner with positive electricity; the nerve he viewed as the conductor of this jar, and together with the blood-vessels as the means by which the muscles are supplied with electricity. In his view, the metals he employed merely completed the circle, and had nothing to do with the generation of the electric phenomena which ensued by their contact, nor with the power, which acting on the muscles, caused them to contract. Yet we now know that he early suspected the truth to be opposed to his theory, for, on the cover of a journal, containing his first experiments in September 1786, there is this inscription in Galvani's handwriting, 'Experimenti circa l'Elettriciti di metalli,' and he seems soon to have abandoned this direction and to have returned to his original ideas of animal electricity. Thus was the field of discovery in metallic electricity left open to Volta, who entered on the inquiry with all the advantages of an intimate knowledge of what Galvani was then doing and had already done.

Carried away by the novelty of the discovery and of the great results to which it seemed with certainty to lead, Volta came to the conclusion that most of the phenomena observed by Galvani had nothing to do with animal electricity, but that the contractions in the muscles of the frog were caused by very feeble currents of electricity produced by the application of heterogeneous metals to the limbs of animals. He went still further,* for he contended, that even when the metals were believed to be

* Animal Electricity. By Du Bois Reymond, M.D. Edited by H. B. Jones, M.D., p. 11.

homogeneous, some slight difference on their surfaces which had escaped observation had produced the electricity. To show what slight differences were sufficient, he made the experiment with a rod of really homogeneous metal, that is, one which produced no contraction in the limbs of a frog. He then dipped one end of this rod into boiling water for half a minute, and repeated the experiment before it had time to become cool; and the muscular contractions immediately occurred. The same result happened when one end was softened while the other remained hard: he therefore rejected altogether the existence of an animal electricity, and whenever contractions occurred, he alleged that they were caused by heterogeneous metallic combination.

Galvani became thus forced to enter on new inquiries, not merely with a view to support his theory, but even to prove the existence of an animal electricity, which Volta, followed by some of the most distinguished observers, had called in doubt. He succeeded so far as to produce contractions in the muscles of frogs and other animals without the intervention of any metal whatever; and had he and his followers remained content with the amount of this discovery and its true application to facts, admitting at the same time, the truth of Volta's discoveries, the controversy must have ceased, and animal electricity properly so called, together with that produced by heterogeneous metals, would have assumed their just position in science. Each on the contrary, together with his partisans, maintained exclusively his respective views; and it was reserved, as we have already seen, for another age and other inquirers finally to adjust their differences, and to reduce to laws the discordant results of numerous experimenters. In the mean time, it must never be forgotten, that nothing is yet in reality known of the true nature of the electric or the magnetic fluids or forces, or of what is called nerve-force, and that, in this respect, as on many other points in their history, an ample field for observation and discovery remains open to future observers.

CHAPTER III.

Animal Electricity—Researches of Humboldt.

Whilst the discussion between Galvani and Volta was at its height, the illustrious Humboldt* came to the aid of animal electricity, almost defeated and expunged from the list of realities. He established a circuit, merely and simply of nerve and muscle, and excited vivid muscular contractions. I may here remark that such an experiment does not in any way prove the existence of an animal electricity constantly present in the nerves and muscles. What are, in fact, the elements of such a phenomenon? The bringing a nerve in anomalous contact with a muscle in an equally anomalous condition might develop electricity which previously had no existence there, or cause by an influence, unknown as yet to us, the contraction of the muscle so touched. Neither did it follow, nor even is this point now clear, that it must of necessity be due to the development of electricity. Still we know not as yet any other force but electricity equal to the production of the phenomenon, for the terms 'vital force' and 'nerve

* Versuche über die gereitze Muskel und Nervenfaser, &c. Berlin, 1797.

influence,' are terms too vague to be accepted in strict physics. Further, he drew the nice distinction between metals which being homogeneous, do not convulse an animal when applied to its tissues but which do so when rendered heterogeneous by the slightest alteration in mixture, polish, hardness, form, or temperature, a fact discovered by Volta, but interpreted by him in a way to suit his own hypothesis. Thus did Humboldt clearly perceive the source of the discrepancy and the cause of the dispute; but he did, in my opinion, more than this; he established one of two things, either that electricity is a force most widely extended and apt to be developed like heat, by changes so slight as to be scarcely perceptible; or that muscular contractions are excitable in certain animals by an electricity of the very feeblest character. As to the existence of animal electricity itself, he had so far set the question at rest by the following experiments: 1st. By bending the thigh of an animal upon its ischiatic nerve when these parts were in organic connection. 2ndly. By touching simultaneously the crural nerve and the muscles of the thigh with a portion of the crural nerve which had been cut off. 3rdly. By establishing a circuit between one point of the nerve and some other point of the same nerve by means of some animal tissue.

In the first case, contact was made between parts organically connected; in the two last, it was made by separated parts, which shortly before had belonged to the stimulated organ, and were homogeneous with the sensitive or irritable fibres.

These experiments it is true, do not prove the identity of the power passing from the nerve to the muscle, or *vice versâ* with metallic or with any other form of electricity; they merely show that after the circle is completed, the muscle acts, proving by its contraction, that a stimulus has been applied to it analogous to electricity, that its contractility finds an excitant in the nerve; but this even takes place under the action of the will and of a great many other stimulants, mechanical, chemical, &c. Matteucci had long since obtained currents from the dissected muscles of frogs whilst they were still in connection with the living body of the animal; but such experiments did not prove, even in his own opinion, that the currents existed in the animal previous to any dissection or experimental arrangement. To prove this fact was reserved for Du Bois Reymond.

The experiments of Humboldt, though admirable and fruitful, do not therefore, prove absolutely the identity of the exciting power of a nerve with electricity, or rather the presence of electricity in the nerves and muscles; to prove this, it became necessary to invent an electrometer so delicate as to detect the absolute presence of electricity in the muscles and nerves, independent of all physiological phenomena.

CHAPTER IV.

The Galvanometer or Electrometer.

This new phasis in animal electricity and in electro-physiology may be said to date from the discovery of an electrometer in the magnetic needle; the deflection of the needle by the galvanic current was the discovery of Oersted. Ampère's double astatic needle followed, and by its means Nobili was enabled to give to the galvanometer, which in fact means electrometer, a delicacy beyond expectation. On its discovery, Nobili* immediately sought for electric currents in nerves. As his first experiments, as we have already seen, were not successful, I need not describe them. In his second, he proved by the deflections of the needle that a positive current was passing from the muscle to the nerve, or from the feet to the head in the frog. He proved the current to be not only present at the moment of closing the circuit (of nerves and muscle) but permanent, that is, constant and never ceasing; and that it is not caused by any external element. Now this was, in point of fact, the great matter in dispute, and is a matter wholly independent of any metallic or thermo-electric theory. Yet Nobili did not seem to have fully comprehended the value of his own discoveries; this was reserved for Matteucci, and more especially for Becquerel, who falling back in 1831 on the obvious anatomical facts connected with the subject of electric fishes, proposed what some have called a theory of animal electricity. This hypothesis was that, at the moment of the shock, the electricity was developed in the brain, and was thence conveyed to the electric organs to charge the little cylinders of which they are composed. Matteucci seized on this idea, one indeed which must have occurred to every one who had ever dissected the electric organs of the gymnotus or torpedo, and published it in various journals; he is accused of not having mentioned the name of its author, but was this necessary in respect of an hypothesis of such simple and easy invention? Further reflection naturally induced him to abandon it,

* Bibliothèque Universelle. Nov. 1827.

and to recommence the study of the electric current in the frog, the object being to remove from the frog-current all suspicion of a simple chemico- or thermo-electrical origin. Its supposed metallic origin had been already refuted by Humboldt, and perhaps by Galvani himself. The history of this scientific investigation into a series of phenomena of a singular and mysterious character merits the greatest attention, even admitting that the results of the inquiry do not as yet elucidate in any remarkable manner the nature of life.

Nobili applying skilfully Ampère's astatic needle, gave suddenly to the galvanometer a delicacy beyond expectation: this was not wanted, it is true, in a practical sense, but it is a feature of modern times that the sciences pure and applied mutually aid and react on each other, whilst the ingenious mechanic lends his aid towards the perfecting of those instruments which genius alone could invent. Accordingly, we find that the first use Nobili made of the discovery of Oersted's needle, improved by Ampère and himself, was to search for electric currents in the nerves. He knew perfectly well that by means of electricity applied from without, sensation and motion, pain and muscular contraction can be excited in living animals; he must also have known perfectly well that certain fishes have the power of discharging electric shocks at will, from the surface of their bodies; but all this has nothing to do with what is properly called animal electricity, in other words, the existence or non-existence of electric currents in animal bodies, constantly present and requiring for their development no special organs — such as we find in the gymnotus and torpedo.

I have said that the first use Nobili made of his discovery was to search for the electric currents in nerves: he failed to observe them. He then compared the sensitiveness of the frog's limb with that of his galvanometer. He repeated Galvani's well-known experiment, which was this: 'When the spinal column and the feet of a frog are dipped in two vessels containing water or brine, the limbs contract as soon as the vessels are connected by some conductor, such as a strip of moist asbestos or of cotton. The galvanometer being included in the same circuit, the needle remained motionless whilst the frog was convulsed. The current, strong enough, though weak, to act on the frog had no effect on the galvanometer.'

But Nobili soon invented a new and more perfect instrument, and he obtained one which, with a solution of salt in the conducting vessels, acted on the needle, causing a deflection of 10° to 20°, and even of 30°. The deflection of the needle when present always indicated a positive current passing from the muscle to the nerve, or from the feet to the head, in the frog. Galvani knew of this current: to it Nobili gave the name of *la corrente proprii della rana*. It may be called the frog-current.

To some it may appear unnecessary to record thus minutely the history of the galvanometer, inasmuch as the existence of animal electricity in the sense I use the term had been demonstrated by Galvani; but we shall find presently that the scientific world generally had not accepted of his demonstration; nor was it until, by the labours of Oersted, Nobili, Ampère, Matteucci, and, lastly, of Du Bois Reymond, that this important fact was finally made out.

Before I proceed to consider the important investigations of this, the ablest and most successful after Galvani and Volta of all these experimenters, I shall offer a few remarks on the labours of some who may almost be considered their junior contemporaries.

Du Bois Reymond has proved the frog-current to be not only present at the moment of closing the circuit—it is permanent. The frog-current itself is quite independent of the property which the leg of the frog possesses of contracting by the action of that current; in other words, the muscular contractility of the muscles of the frog is a property of the muscle itself, which, although probably derived from the nerve-influence, is not derived from the electric current of the nerve, but merely brought into play by that current in the same manner as if it were excited by any other form of electricity. It does not even seem to be the same as the contractility which obeys the will of the animal. These curious facts came out but recently, and are the results of experiments made not on frogs or rabbits but on man himself. Moreover, the frog-current continues for several hours after death, whilst the leg, that is its muscles, when subjected to the action of its own current, are no longer excitable after a quarter of an hour.* It might be objected, however, to this experiment, that, when the current which still continues in the nerves of the dead frog fails to produce contractions in the muscles of the limbs of the animal, this result may arise from the weakened current, or from the rapidly exhausting electro-contractility of the muscle.

The ingenious Nobili believed the origin of these currents in the nerves and muscles to be thermo-electric

* Vorläufiger Abriss einer Untersuchung über den Froschstrom, u. s. w.—Pogg. Ann. 1843, Januar.

and not animal, and ascribed the phenomenon to the more rapid cooling of the smaller masses of nerves in comparison with the slower cooling of the larger masses of muscles.

Nor was it until after Matteucci* (1839) had again recalled the attention of the scientific world to the character of these interesting phenomena that the existence of these currents was finally admitted by all. The object of his experiments was to remove from the frog-current all suspicion of a simple chemico or thermo-electrical origin. With this he coupled a theory or hypothesis concerning the origin of the electrical currents in the brain—a theory he was soon forced to abandon. The results of his valuable but confused papers have been summed up by an able and candid writer.

Matteucci showed that the electro-motive action in the frog upon which the frog-current depends is independent of the contact of the muscle and nerve, external to the limb, so that by connecting any two parts of the frog, the back and the leg for instance, a current is obtained. Nevertheless, the conclusion was still open to certain objections, which the reader will readily perceive: these seem to me to have been finally removed by the researches of Du Bois Reymond.

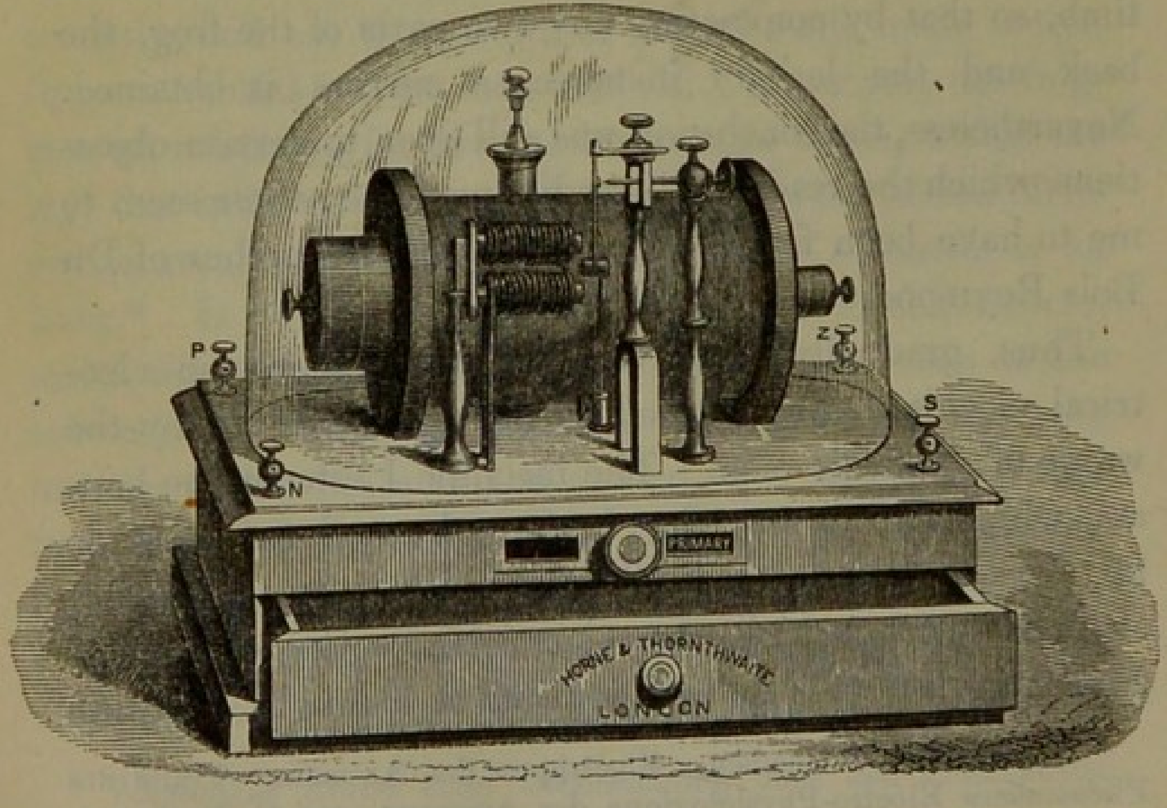
Thus, gradually arose various improvements in electrical machines, necessitated or at least called for by the wants of scientific men. The machine I esteem the best, and which I always employ, is the galvano-dynamic, made by Messrs. Horne and Thornthwaite. It is the instrument with which the electrician works with most advantage, whether he be a medical or a purely scientific

* Essai sur les Phénomènes Électriques des Animaux; Traité des Phénomènes Électro-Physiologique des Animaux, par C. Matteucci suivi d'Études Anatomique, par Paul Savi. Paris, 1844.

man, labouring to discover scientific truths for the sake of truth alone.

The last great improvement in what may be called the mechanics of electricity was the discovery by Faraday, in 1831, that when an electric current traverses a wire it induces or excites another current in any conductor held parallel to it, a second being excited the moment the first current ceases to traverse the wire. These currents are respectively named primary and secondary, and are always opposed in direction to the battery or exciting current. He called these currents, on account of the manner by which they are produced, induced currents.

As an appropriate conclusion to this brief history of the origin of the various forms of electricity, I shall here describe the construction of the electrical apparatus I always employ.



The galvano-dynamic apparatus represented in the annexed cut consists of a coil of insulated copper-wire, about $\frac{1}{20}$ inch, surrounding an interior core of soft iron-wire, and itself surrounded by a helix of very fine insulated copper-wire. The coil of thick wire is connected by means of the binding screws Z and S with the galvanic battery, and forms what is called the primary current arrangement. The outer coil of fine wire produces the secondary or induced current. The binding screws marked P and N are connected with the conductors by flexible metallic cord, and when not in use are contained in the drawer in the pedestal of the instrument. The P and N denotes the direction of the current, or the positive and negative poles of the instrument; and these screws are brought in contact with the primary or induced arrangement, as desired, by turning the button in front of the pedestal, the connection being indicated by the words "Primary" or "Induced" appearing at one or other of the two longitudinal openings. The primary current is regulated by the smaller sliding graduated metal tube at the right of the instrument, and the secondary current is regulated in a similar way by sliding the larger metal tube at the left. Either of these currents can further be adjusted by the water-regulator at the back of the coil, by sliding up or down the platinum wire attached to the ivory top. The adjustment of the contact-breaker in front, so as to produce either the effect of a continuous current or a number of distinct currents or shocks, is accomplished either by unscrewing entirely the wire and adjusting weight from the lower portion of the vibrating iron-keeper, or fixing the weight at any portion of the wire from its end to contact with the keeper. In the former case the utmost rapidity of vibration is produced, and in the latter any number of shocks in a second that may be required, commencing at the lowest point of two.

PART THE SECOND.

CHAPTER I.

I SHALL pass over the early efforts of Du Bois Reymond to form a galvanometer sufficiently powerful to prove the existence of electric currents in animals, and to detect, under all circumstances, the presence of an electric current in the muscles and nerves; this Matteucci had failed to do. Du B. Reymond constructed two galvanometers; with the smaller he detected the nervous current as well as the muscular; the wire of this instrument is 3,280 feet in length, and is coiled 4,650 times around the frame. With a new and more powerful instrument he was enabled to detect delicate variations of the nervous current which he had anticipated, but been unable to detect with the smaller galvanometer. It forms no part of the plan of this Work to describe the instruments by which this distinguished observer arrived at his conclusions; it is with these, and their bearing on electro-physiology, that we are chiefly concerned here. In the larger instrument the wire wound upon the frame is a copper wire 5,584 yards or 3·17 English miles in length; it forms round the frame 24,160 coils.

The conclusions to be drawn from the ingenious and most conscientious researches of Du Bois Reymond,* have been thus summed up with great care by a gentleman who has devoted much attention to the progress of the inquiry I now consider:—

1. The muscles and nerves, including the brain and spinal cord, are endowed, during life, with an electro-motive power.

2. This electro-motive power acts according to a definite law, which is the same in the nerves and muscles, and may be briefly stated as the law of the antagonism of the longitudinal and transverse section; the longitudinal surface being positive, and the transverse section negative.

3. As the nerves have no natural transverse section, their electro-motive power, when they are in a state of rest, cannot be made apparent unless they have previously been divided.

4. The muscles having two natural transverse sections may show their electro-motive power without being divided. However, the electro-motive power of the undissected muscles is often more or less concealed by the contrary action of a layer situated on the natural transverse section called the parelectronomic layer. The contrary electro-motive power of the parelectronomic layer may be increased by cooling the animal.

5. Every minute particle of the nerves and muscles acts according to the same law as the whole nerve or muscle.

6. The currents which the nerves and muscles produce in circuits, of which they form part, must be considered only as derived portions of incomparably more intense

* Animal Electricity, p. 210.

currents circulating in the interior of the nerves and muscles around their ultimate particles.

7. The electro-motive power lasts after death, or in dissected nerves and muscles after separation from the body of the animal, as long as the excitability of the nervous and muscular fibres; whether these fibres are permitted to die gradually from the cessation of the conditions necessary to the support of life, or whether they are suddenly deprived of their vital properties by heat, chemical means, &c.

8. In the different contractile tissues the electro-motive power is always proportioned to the mechanical power of the tissue.

9. Other animal tissues may, indeed, produce electro-motive action; but it is neither so strong as the action of the nerves and muscles nor so regular; nor does it vanish with the vital properties of the tissues; nor does it lastly undergo those sudden variations of intensity and direction which may be thus briefly stated.

10. The current in muscles when in the act of contraction, and in nerves when conveying motion or sensation, undergoes a sudden and great negative variation of its intensity.

11. Muscles inactive from the contrary action of the parelectronomic layer, when contracting become active in the opposite direction to that which muscles in a state of rest exhibit. Hence, it must be concluded, that the electro-motive force of the parelectronomic layer remains constant in the act of contraction.

12. The negative variation of the muscular current is not a permanent one during permanent contractions; it consists rather of a rapidly following succession of simple and sudden variations of the intensity.

13. It has not yet been ascertained, whether in the act of contraction the muscular current is only diminished, or wholly vanishes, or whether it changes its direction.

14. After the contraction has ceased, the current does not suddenly recover its original intensity, but the tetanus has a slight subsequent influence on the intensity of the current.

15. The negative variation of the muscular current in the act of contraction fully explains Matteucci's so called induced contractions.

16. If any part of a nerve is submitted to the action of a permanent current, the nerve, in its whole extent, suddenly undergoes a material change in its internal constitution which disappears on breaking the circuit as suddenly as it came on. This change, which is called the electro-tonic state, is evidenced by a new electro-motive power, which every point of the whole length of the nerve acquires during the passage of the current, so as to produce, in addition to the usual current, a current in the direction of the extrinsic current. As regards this new mode of action, the nerve may be compared to a voltaic pile, and the transverse section loses its essential import. Hence the electrical effects of the nerve, when in the electro-tonic state, may also be observed in nerves without previously dividing them.

17. The electro-tonic state of a nerve is the commencement of its electrolysis. The contraction on making the circuit is caused by the nerve passing into the electro-tonic state, and that on breaking the circuit by the nerve passing out of this state.

18. In the muscles the electro-tonic state does not manifest itself as it does in the nerves.

19. Approaching death, and severe injuries of the muscular and nervous tissue cause other modifications of the electro-motive power of the nerves and muscles of which some are permanent, and connected with the total extinction of that power; others are only transitory.

20. The electric phenomena of motor and sensitive nerves are identical. Both classes of nerves transmit irritation in both directions.

CHAPTER II.

Discovery of Localized Galvanism.

Whilst scientific men, properly so called, were thus slowly and cautiously establishing the facts, firstly, that animal electricity exists, and, secondly, what were its laws in various animal bodies, others were turning their attention to the application of the newly-discovered forms of electricity to the alleviation of human disease. Amongst these foremost stands Duchenne, the discoverer of the application of localized galvanism to living organs. In the present state of this important inquiry, it would be rash to venture a prediction as to the extent to which man may ultimately be benefited by the discovery, but without being too sanguine, it may with all safety be assumed, that galvanisation will henceforth assume an important position amongst the remedial agents at the command of the physician and surgeon. Before entering on the details inseparably connected with the subject, and which, indeed, in the present state of electro-physiology, form its most important feature, it may be advantageous to the reader, and is indeed incumbent on me for many reasons, to present him with a brief summary or outline of the labours of that inquirer to whom the profession owes the discovery of localized galvanism.

We learn from the inventor of localized galvanism that, for ten years, the endeavour to direct or limit the electric power in the organs formed the constant subject of his thoughts. By it he hoped, and it was a reasonable expectation, to study certain physiological properties in the organs themselves, as well as to learn by this method something of their pathological conditions. Persuaded of the close analogy which obviously subsists between electricity and the nervous influence or power (nerve-force), he soon discovered that the will does not possess to the same extent as localized galvanism the power to limit the nervous influence over or in each organ. Consequently, if we succeed in localizing the action of electricity, we ought to expect to see developed new phenomena more or less different from those of the will. Now, this expectation has been realised. For a long time in fact, following the method of Duchenne, we can now at will confine the electric power to the surface of the body or causing it to traverse the integuments without exciting them, concentrate its action on a nervous trunk or filament in a muscle, or in a muscular fasciculus. Applied to physiology, to pathology, and to therapeutics, it has already fulfilled, and even surpassed, the expectation of its inventor.

Of the various kinds or forms of electricity Duchenne gives the preference to the electricity of induction, and this is the method I have myself almost uniformly adopted. The method being determined on, it became necessary to create as it were a new kind of anatomy, or rather to determine rigorously the position of the nerves and organs to be acted on, and their coincident points on the surface of the body—points now so well determined as to enable us at all times to apply the force without hesitation; to do, in fact, for the nerves what surgical anatomists had long since done for the arteries, namely, determine their exact position and their corresponding points on the surface of the body. It was, in fact, the surgical anatomy of the nerves to be determined, not by dissection but by physiological experiments made on man himself.

In this inquiry it was constantly to be kept in view that muscular contractions are never isolated absolutely: the actions of the muscles are, in fact, synergic. In the course of the inquiry a new fact also appeared, namely, that the electro-muscular contractility is not necessary for the performance of voluntary movements. From this fact, which Duchenne believes to be wholly new to science, flows, as he thinks, the conclusion that the nervous fluid and electricity are not identical. Another conclusion which he drew from his experiments, for such in reality they were, was that voluntary movements take place from the exercise of a property as yet unknown or not understood. To this property he proposes to give the name of muscular consciousness, and this property is lost in certain pathological conditions. I shall not stop here to inquire either into the novelty of these views or the propriety of the name given to the power of the will over the muscles of voluntary motion. The muscular sense, or sense of resistance, derived no doubt in part, if not wholly, from the exercise of the will, was carefully analysed with other views by the celebrated ideologist, Detust de Tracy, who claims, in fact, to be the discoverer of a muscular sense—the sense of resistance, a sense in which some metaphysicians place the consciousness of our existence.

With all the enthusiasm of an inventor, of a discoverer in fact, Duchenne sees in his discoveries a means to elucidate many obscure affections and deformities which have long baffled all surgical appliances, physiological explanations, and pathological discussions. The *paralysis* and the *contraction* of the diaphragm are discoveries which he thinks would not have been made but by the aid of localized galvanism; he makes the same remark in respect of the *fatty* and *progressive muscular atrophy*—a disease attacking indiscriminately all classes of society, and to this very disease of muscular atrophy he owes the discovery and demonstration of the truths of electro-physiology from the point of view in which he considers it. But it is in paralysis mainly that the method has been productive of the largest results.

At first purely scientific, his researches gradually assumed the form of electro-therapeutics; in other words, they became applicative and practical: thus his views were gradually extended. The results have been summed up by the author in his Treatise* on Localized Galvanism, and its application to Physiology, Pathology, and Therapeutics. As the results of the method will fall to be considered in detail in the following chapters, I shall here confine myself to a very brief outline of the views of Duchenne, and of the success, as reported by himself, which hitherto has accompanied his practice. None will be disposed to question the ingenuity and singular in-

* De l'Électrisation localisée, et de son application à la Physiologie, à la Pathologie et à la Thérapeutique. Paris, 1855.

dustry with which the author has carried out his first idea: it is for the profession, and for those who follow us, to decide on the value of the therapeutic agent by the rigid test of trustworthy statistics. Its application to disease has been my constant labour for many years.

CHAPTER III.

Of the Various Forms of Electricity in Use, and of their Mode of Action on Living Bodies.

In medical practice we employ the electricity of friction, the electricity of contact, and the electricity of induction: the first is called static electricity; the two last are confounded under the name of dynamic electricity; the last is more especially called galvanization. It has been proved experimentally that simple galvanism and the galvanism of induction differ materially in their effects on the surface of the body and on certain organs situated at various depths. The latter best suits muscular galvanisation, especially when the remedy must be frequently applied and for a great length of time. In fact, by the electricity of induction we may excite the most vigorous muscular contractions without at the same time exciting the cutaneous sensibility, without producing any commotion or disturbance, without throwing the organs into a sort of stupor, without tearing the capillary vessels; in a word, without occasioning, as static electricity does, all those accidents which produce in different individuals different reactions. It is known also that, if simple galvanism and the galvanism of induction possess equally the property of recomposition, or of re-collecting their force profoundly under the integuments, or, in other terms, of concentrating their action in the muscles and nerves without exciting the skin, it is nevertheless known that the chemical and physical properties of inductive galvanism are infinitely less developed comparatively with those of simple galvanism, and that they are too feeble to be appreciable during the muscular galvanization. It is known also that the galvanism of induction acts but feebly on the retina, and does not complicate in any troublesome manner the galvanisation of the muscles of the face. Hence arises the importance and the necessity of employing localized galvanism, and the electricity of induction, which, by altering in no way the tissues, is essentially medical galvanisation.

The difficult problem being now solved as to the possibility of throwing the whole influence of the electric power on a particular muscle, nerve, or organ without injury to and without even affecting the neighbouring organs, the next step, and that, in reality, the most important, was, to ascertain the curative powers of the new therapeutic agent, its influence over paralysis, contractions, and other disorders of the muscles, lesions of the organs of sense, vitiated, interrupted, or disordered secretions, in fact over all those diseases which might be supposed to be dependent on or connected with the nervous system. For whatever view might be taken of the nature of the electric power, and however employed, one thing was manifest, the close resemblance of some, at least, of its effects to the equally unknown, equally mysterious nerve-force or nervous influence. On theoretical grounds it might be objected, that in many nervous ailments there exists no proof that such arose from any deficiency of the natural electricity of the body, and that the discoverer himself admitted that irritability is not necessary to mobility, or, in other terms, that the integrity of the electro-muscular contractility is not necessary for the exhibition of the voluntary movements; the excitability of the muscles by electricity may be lost, and the power of the will over these may be retained. When the celebrated John Hunter recommended one of his patients who had become paralytic in one arm, to make an effort of the *will*, and try, were it only in thought, to move the arm, it is clear, that the illustrious surgeon and physiologist viewed the power of the will over the muscles, merely as one of many excitants and not as the actual contractile power itself. To this curious subject Duchenne devotes a chapter; and many other points equally difficult and equally obscure, will, no doubt, have already suggested themselves to my readers, most of which I shall have occasion to consider in the ensuing sections of this Work, whilst discussing the practical applications of the method; for in our art the appeal must ever be made to practice, to observation, and to oft-repeated experience; from these flow the laws or rules of practice, which are, in fact, but the result of the accumulated experience of ages.

Some ingenious observations occur in the work I here allude to on the existence of a new muscular property to which the author gives the name of muscular consciousness; to this property I have already alluded. It may or may not be the same property described by Detust de Tracy in his Ideology. Tracy was no physiologist but a profound metaphysician. His ingenious views have been plundered without acknowledgment by many modern writers. But however this may be, the facts are certain, viz., that there are persons deprived of all sensibility of the skin, muscles, bones, nerves, in whom, in fact, it is impossible to excite any sensation, and who yet feel the pressure or pinching of their muscles; who perceive any blows struck on the limbs; who have the consciousness of the movements these may be made to perform mechanically, and of the extent of the movements they themselves perform; and who finally have a perfect consciousness of weight and of resistance; in whom, in fact, voluntary contractility, with a consciousness of its use, has undergone no alteration—has suffered no diminution of power.

Another singularity in this form of anæsthesia, which may be complete, that is, extend over the whole body, or be limited to a single limb, is this; if the loss of sensibility of the skin be superadded to that of the underlying organs, (muscles, bones, nerves,) not only the phenomena above mentioned, but others also are observed: the most violent blows inflicted on the muscular masses of the insensible limb are not felt by the patient when he is in the dark, or if so arranged that he does not see the blow struck or the mechanical movements impressed by another on the limb: under such circumstances when unaided by the sight, he remains wholly unconscious of any change. So also with the direct electric excitement, which, under such circumstances, produces no results however intense the inductive current may be, however violent the muscular contractions excited by it; the patient unaided by sight remains wholly unconscious of them.

To this sense Monsieur Gerdy, gave the name of sensation of muscular *activity;* Charles Bell called it the muscular *sense;* it is no doubt the sense of muscular resistance, originally discovered by Tracy; its presence depends on the exercise of one faculty, the will, or the resulting muscular contraction following the exercise of the will. The resistance offered to the exercise of the will, may be, and always is of one character, although at first sight it may seem double; but this idea arises from forgetting that every muscle in contracting meets with resistance to that contraction. Accustomed to refer all resistance, weight, &c., to objects placed external to us, we forget for a moment that the mind is quite as conscious of the weight we raise in extending a finger or the resistance we feel in flexing a limb as if a weight were attached to the finger or limb. Duchenne draws a nice distinction between muscular consciousness and the sensation which follows the muscular act; he thinks that the sense of sight is auxiliary to this sense, and may supply its place. Some curious facts are related as to the loss of power over the voluntary muscles during the absence of the light and the recovery of this power so soon as the light was restored to the apartment. The whole subject is one of great difficulty, physiologically, but it is satisfactory to know in the meantime that persons so afflicted may be cured by the application of the electricity of induction, localized.

Another objection which the theorist might offer to the success of the therapeutic agent I now proceed to examine is the great variety of affections in which it has been recommended. Such affections obviously differ widely from each other; they cannot flow from the same cause; they cannot be remediable by the same means. To this it might be replied, that the affections chiefly treated have clearly a reference to the nervous system and to the system of organs, the muscles, intimately connected therewith; that the analogy between common electricity and the nervous power was obvious, even to the most careless observer, before it was finally proved by the able researches of Du Bois Reymond that an electrical current pervades all nerves and muscles; that the existence of an animal electricity can no longer be denied. But the best answer to all these theoretical objections is undoubtedly an exposition of facts; to this I next proceed, concluding this part of my work with a few practical observations on the method of using electrical machines, in order to obtain from them results similar to those, and equally successful as rewarded the discoverer of localized galvanism.

CHAPTER IV.

On the Mode of Applying the Various Forms of Electricity.

THE field of inquiry opened up by the valuable researches of Du Bois Reymond suggested to practical men, the application, or attempted application of some of the laws discovered by him to medicine and surgery. The most successful of those who took up this line of inquiry and experiment was unquestionably, as I have already observed, Duchenne. Leaving to the strictly scientific man the higher questions of electro-physiology, he made living man in a healthy and diseased condition the object of his especial study. The existence of a muscular and a nervous current, and the laws regulating these having been demonstrated by Du Bois Reymond by means of his improved galvanometer or electrometer, it remained for the medical man to apply some of the laws so discovered to practical ends. This was the work of Duchenne. When I first became acquainted with his method I felt convinced that had the distinguished observer availed himself of what was already known in anatomy, physiology, and pathology, his progress would have been much more rapid, and his labours would long since have assumed a systematic form instead of a collection of detached essays. On this view I have acted from the commencement, my great object being to give to localized galvanism a basis in science.

It being admitted that electricity is a stimulus equal to the production of sensation in the nerves, contraction of the muscles, and vascular and nervous excitement of other organs, as well as chemical and thermal effects on the tissues, its employment for therapeutical purposes became warranted by theory; the empirical practice of the ancient Romans had already, to a certain extent, tested, however imperfectly, the value of the therapeutical agent under another form. By it heretofore electrical stimulation was general, and extended over numerous organs: now it can be localized and confined to a single organ, a single muscle, or even to a fasciculus of a muscle; to the root of a nerve; to the skin; to a branch of a nerve, be it sentient or muscular; to the deepest structures, even to the bones themselves. The strength of the current may also be modified and adapted to the pathological exigency, and unlike most other therapeutical agents, the pain caused ceases instantaneously with the removal of the exciting cause; experience further shows that its employment is not accompanied with this further disadvantage, so common with remedial agents, a loss of power by repetition.

I have already alluded to the three forms under which electricity has been employed—the frictional, galvanic, and induced; the first also called static, and the two latter dynamic; the method by induction was the discovery of Dr. Faraday, to whose name it has given immortality. Prior to this discovery, Fabrè Palaprat taught that frictional electricity (static) was best adapted to the treatment of paralysis of the nerves of sensation, and of the muscles of volition; and galvanism (the electricity excited by chemical action) to the irritation and excitement of organic muscles and delicate organs. These assertions have proved incorrect. The researches of Duchenne show that the different kinds of electricity possess peculiar physiological and therapeutical properties, each of them answering to particular indications.

It must long ere this have been evident to the readers of these contributions to medical electricity, that I attach but little value to the use of any form of electricity, excepting that by localized galvanism. I shall therefore be very brief in my remarks respecting other modes of electrization. In static electricity the usual mode of application was by the electric bath, the electric spark, and the Leyden jar.

1. The electric *bath* (either electro-positive or electro-negative) was formerly held in high estimation; but later experiments have proved it of no value. The electric *spark* from an electric machine combines with the electricity of the body, on its surface. Pointed conductors allow the fluid to pass off more readily than round ones, but both discharge only one spark at a time, whilst a conductor with a flat surface discharges several at once: a

brush of fine brass wire also allows several sparks to pass at the same time.

It is only the most irritable of the superficial muscles which are covered with a thin layer of cellular tissue, as for example, the anterior border of the sterno-cleido-mastoideus and some facial muscles, which contract under the influence of the electric spark; therefore frictional electricity is only applicable to cases in which it is requisite to excite a slight irritation of the skin.

2. The *Leyden jar.*—The electric tension obtained by the discharges of the Leyden jar overcomes powerful resistance, and effects energetic contractions of the muscles, accompanied by violent shocks affecting the whole nervous system. If a conductor be applied to the skin over a nerve, the sensation produced is as if the nerve were violently compressed, and this is succeeded by a tingling sensation spreading to the extreme termination of the nerves. When the jar is discharged, the portion of skin acted upon turns pale in a few seconds, the papillæ are raised above the surface, and the temperature of the part is slightly diminished. After an interval of from twenty to forty minutes the pallid hue gives place to an erysipelatous red, and the temperature perceptibly increases, thus indicating reaction, which appears to set in after the temporary suppression of the capillary circulation. Duchenne discharged a Leyden jar upon an exposed muscle, and the result proved that the effects are precisely the same on the muscular tissue beneath the skin.

This enables us to estimate the therapeutic value of the discharge from the Leyden jar, and it is evident that should too strong and frequent shocks be applied to an organ whose vitality is already depressed, there would be danger of its remaining in the benumbed condition without reaction setting in.

However favourable the conditions under which the Leyden jar is employed, it is never advisable to apply too many shocks to a patient, or, in the case of a paralysed limb, to electrify each individual muscle. The discharge always produces pain, as the unavoidable irritation of the skin increases with the increase of electric tension required to reach a deep-seated muscle.

Static electricity was formerly much employed, and effected some remarkable cures; but this goes no further than to prove that some forms of paralysis yield to the influence of the electric current in whatever way it is applied.

I shall proceed to the consideration of the far superior mode of exciting muscular contraction which we now possess in dynamic electricity. Electricity excited by *contact* and *induction* is essentially different in its effects from *static* electricity: the strength of the current may be increased or diminished at pleasure; it may be conducted and confined to single organs without exciting the surrounding parts; its influence may be restricted to the skin, or we may cause it to pass to parts beneath the surface and the most powerful contractions may be produced by it in a muscle or nerve without those severe shocks which, in many cases, would contra-indicate the application of *static* electricity. These peculiar properties render *dynamic* electricity of great value as a therapeutic agent.

The electricity which is excited by contact, and that which is excited by induction, are combined under the name of Dynamic Electricity; but as these kinds essentially differ from each other it is necessary to consider them separately.

3. *Galvanic Electricity.* Whatever may be the means employed for obtaining the electric fluid, it always produces the same effect upon the human body, provided the current is of equal quantity and intensity. The quantity of electricity obtained depends upon the size of the plates which are used and the intensity upon the number employed, so that, according as we connect the cells of a battery, we have either quantity or intensity of the electric fluid. Galvanic electricity can be applied either as a continuous or as an intermittent current. The *continuous* current is scarcely felt, except at the moment of making or breaking contact, yet it produces erythema and cuticular disorganisation, the rapidity with which the latter proceeds depending upon the strength of the current. Its effect upon the muscles is to cause them to contract but slightly, even when the current is of high intensity: a feeling of great warmth is at the same time diffused throughout the part.

The *intermitting* current has three distinct effects: the *first* on making contact, the *second* whilst the circuit is closed, and the *third* on breaking contact. The muscle acted upon contracts strongly on establishing contact; it remains motionless whilst the circuit is complete, and again contracts, though much more feebly, on breaking contact, whilst the feeling of warmth increases in intensity with the duration of the current. The intermitting current causes a painful sensation in the skin, but does not, like the continuous current, produce decomposition, except between its entrance and exit, when, as it is impossible to prevent decomposition taking place in a greater or less degree, it cannot be employed for the excitation of the skin.

The effect of galvanic currents upon nerves of special sense is to bring into play the special actions appertaining to each of these nerves. If an intermitting current is applied over the fifth pair of nerves, the eyes being closed, flashes of light will be seen, and unless especial caution is observed, paralysis of the retina may ensue.

The light seen, whether the current be continuous or intermittent, is coloured; if the positive pole is placed on the closed eyelid an intense blue light is perceived; if the negative, a yellowish red light. Galvanism should therefore be applied with great care to the eyes, as the light may be so dazzling as to injure the sight if the application be continued too long, the intermissions too rapid, or the current too strong. At the same time, a skilfully-conducted application has great therapeutical advantages in nervous diseases of the eye. It is not advisable, for many reasons, to employ intermitting galvanic currents for the excitement of muscular currents in the treatment of paralysis. In these cases nutrition and sensation are diminished, and, consequently, powerful batteries are required to produce sufficient power to cause them to contract; but then we have to contend with the dangers which arise from the heating power of the batteries. The cumbersome apparatus required, the acids which are necessary, and the gases which are generated, render the employment of galvanic batteries difficult in practice.

The thermal effects of the continuous galvanic current have been of late much used in surgery for the extirpation of tumours,* solution of calculi,† the coagulation of the

* Die Galvano-caustik. A. T. Middeldorpf, Breslau, 1854.

† Prévost et Dumas, Annales de Chimie, &c. 1823. Melicher, Die Effekte des Galvanismus auf Harnsteine, 1848. Froriep's Notizen, 1848.

blood in aneurisms,* in fractures, ulcers,† and for the extraction of various minerals from the body.

4. *Induced Electricity.* This is obtained by sending a battery current through a circular coil of insulated copper wire with a hollow axis, in which a bundle of iron wires is placed, and over this is wound another coil of thin copper wire also insulated. The current traversing the thicker coil is called the primary or inducing current, and by it is excited in the thinner coil the secondary or induced current.

Dr. Duchenne was the first to demonstrate that each of these currents possesses peculiar physiological properties. The *primary* current exerts a specific influence on the contractibility of the muscles, and the *secondary* on the sensibility of the skin and nerves; the latter also excites the retina more powerfully than the primary when applied by means of wet conductors to the face or eyeball.

Induced electricity is the only therapeutical agent which is capable, without destroying the skin, of producing immediate and intense irritation of that enveloping membrane, which ceases with the breaking of contact, leaving no trace behind. Its value therefore is obvious in cases of loss of sensation, neuralgia, rheumatic pains, whilst the chemical action is so slight as not to be worth a consideration.

Induced electricity is particularly indicated in cases in which it is necessary to excite contraction of the muscles as in paralysis, and this effect can be produced without causing pain when the application is properly conducted.

* Ciniselli, Gaz. Med. di Milano, 1846.

† Spencer Wells, Bemerkungen über Heilwirkungen des Galvanismus, &c. Oppenheim's Zeitschrift, 1849, and Medical Times, July, 1853.

Very strong currents are required in the treatment of many muscular affections, and these can be obtained by no other means.

The conductor must be a straight, unyielding metallic substance of different sizes; the ends covered with sponge or leather, and before being used, moistened with hot water. The conductors must be applied with a firm pressure; this decreases the sensation in the skin, and allows the current to pass to the deeper-seated structures. The limb should be kept fixed in one position to prevent the skin being moved when the conductor is applied; this in thin persons is very apt to occur, in which case the motor nerve escapes and no effect is produced. The positive pole should be applied to the motor nerve and the negative conductor, which should present a larger surface to some other part to complete the circuit.

CHAPTER V.

Electro-Magnetic Machines.

In the employment of local galvanization the choice of a good machine is of the greatest importance. It should be so constructed that the primary and secondary current may be applied at pleasure according as it is requisite to act upon the muscles or nerves, and that the intermissions may be regulated with a view to the different physiological effects which are produced by their being quick or slow.

Effect of rapid Intermissions on Muscular Contractibility.

A muscle excited by a single intermission of an induced current contracts and relaxes again immediately. If these intermissions follow in rapid succession, corresponding muscular contractions take place, and the quicker the intermissions succeed each other, the less the muscle relaxes in the interval.

We must not conclude that a rapidly intermitting current causes more powerful contraction of a muscle than a slower one.

If we cause a paralysed muscle (whose irritability is normal), for instance, the M. flexor communis digitorum to contract alternately with quick and slow intermissions, hanging weights at the same time to the fingers acted on by this muscle, we shall find that a rapidly intermittent current does not enable the muscle to raise a heavy weight so readily as one which intermits slowly. The vibrations produced by the intermissions of the current diminish in proportion to the rapidity with which these intermissions succeed each other; when they follow very quickly the contractions are continuous as if they were produced voluntarily, and this peculiarity furnishes us with a means of studying the actions of individual muscles. When the shocks are less frequent the motions are more tremulous.

In addition to these laws the following corollaries may also be laid down and accepted in the present state of our knowledge.

1. The *muscular sensibility* is more strongly influenced by rapid intermissions than by slow ones; and it may be excited to a degree which is acutely painful.

2. The *tonicity of the muscles* is increased by rapid intermissions, whether they are in a normal condition or not; a muscle in a pathological condition may be developed more rapidly by quickly succeeding shocks than by slower ones, as is seen in cases of atrophy.

3. The *electro-cutaneous sensibility* is much more painfully excited by rapid intermissions than by slow ones.

4. By reason of the recent improvements in electrical machines we can act more or less energetically upon the muscular contractibility or sensibility; for although every electrical excitement of a muscle produces both sensation and contraction, the current may be so regulated as to diminish the contraction or increase the sensation, or *vice versâ* at pleasure.

5. In the galvanization of delicate organs in sensitive patients it is advisable to operate with slow intermissions.

6. The treatment of hysterical anaesthesia generally requires very powerful currents.

PART THE THIRD.

CHAPTER I.

We have been thus as it were insensibly led (such is the history of all human progress) from the dawn of electric science in the experiments of Franklin to the improved galvanometer of Du Bois Raymond, and from the employment of the first electric machine in medicine, the living torpedo, to the admirably finished workmanship of modern times. Let us now examine carefully the results of these improvements in the science, pure and applied, physiological and pathological, and test their value by an exposition of facts. One step further we shall find was required to be taken to render the new therapeutical agent of value in medicine. What that step was my readers may probably have already anticipated. The application of the method was to man himself, and it must be evident that its application to be successful must be made in accordance with the known facts of human anatomy and physiology. If it proved antagonistic of these one of two things followed, either the received anatomy and physiology were false and incorrect, or the agent acted agreeably to laws not yet ascertained, and therefore empirically, as looked on from a scientific point of view. The truth, I believe lies between these two points. The descriptive anatomy was not at fault, but some of the physiological and pathological views were; the full powers of the agent are not even now brought out nor all its laws established. It is a curious fact, and one which must have had its weight with Duchenne, sustaining him throughout his elaborate inquiries, that nearly all the persons who first employed electricity for medical purposes were unacquainted with anatomy; the remark, to a certain extent, applied to himself. On the other hand, the inventor of the method of localized galvanism was so convinced that nothing remained to be discovered in the physiology of the muscles as regarded their mechanical uses, that he was seized with the utmost surprise and pleasure on discovering, at the very outset of his inquiries, that the action of the muscles of the fore-arm and hand were not understood by modern physiologists. This fact he mentions with all the naïveté and sincerity of his character. I have now to view the question practically, and the first consideration which presents itself is, the position of the art itself. For sixteen years it has been my favourite pursuit, and its improvement and application ever present to my mind. Whoever has, I think, as I have done, followed with attention the progress of medical electricity for the period I allude to, will come to the conclusion that this therapeutic agent occupies a position wholly distinct from what it did but a few years ago. At that time there were in fact no fixed principles, and the practice was not only in the hands of empirics, but was in reality entirely empirical. It is right to notice here, that Duchenne's researches were first and last, wholly, if not entirely, physiological and therapeutical; he admits that he has never himself made any anatomical* investigations to verify any of the facts he brings forward; and as the labours of anatomists have very generally been directed to other views, so that the precise anatomical relations of the motor nerves to the muscles they supply have either been overlooked or included in the description of branches obviously of a mixed character, it seemed to me that a careful analysis of these was a deficiency which ought to be supplied. The local stimulation of the muscles by localized galvanism being the most important feature in the modern application of the art, I shall commence with this set of organs.

1. *Localized Galvanism.*

Local or localized galvanism, whether derived from a metallic or magnetic source, consists in restricting the electric current so obtained, as much as possible to the external integuments or skin, to the individual nerves or their branches, to a single muscle or to a single fasciculus of a muscle, or to an internal organ, without any lesion of the skin, and without any of those shocks or effects, which in so many cases of disease rendered the forms of electrization formerly in use wholly unavailing in the treatment of disease, or at the least highly objectionable. By its means the conductor being applied over a motor nerve, all the muscles which that nerve supplies are made to contract, provided the electric contractility be present in the muscle; if to a branch supplying a single muscle, that muscle will act alone independent of the group with which it is naturally associated. The successful application of localized galvanism is an art not to be readily

* J'avoue n'avoir fait aucune recherche anatomique sur le cadavre pour vérifier ces faits, p. 46.

acquired, and indeed can only be so by an extended experience and much practice; the motor branches of the nerves, on a knowledge of whose distribution and locality depends much of the art, are not so readily to be found as the main trunks, nor do anatomical works furnish the requisite information on this point. By experiments on the living body we find them out, and thus create a kind of surgical anatomy of the nerves, a regional anatomy, as some may call it, similar to that which surgical anatomists have performed for the arteries.

This is not the place to discuss the difficult questions as to the nature of the electrical currents which pervade the muscles and nerves of living animals; or in what these currents resemble or differ from the electricity developed by certain living animals, as the torpedo, the gymnotus, and the silurus; nor what these currents have to do with the phenomena of life, of muscular contractility, sensibility, and nutrition. We know, at least, that such currents exist; Nobili discovered the frog-current, as I have remarked in a preceding chapter, in 1827, but he ascribed it to a thermo-electric origin. Matteucci showed, but especially Du Bois Reymond that this, as well as the theory of its electro-chemical origin, was erroneous. We know not, indeed, what it is nor what are its functions, but we have seen the existence of such currents now fully proved by Du Bois Reymond.

But the experiments to which I now direct your attention are, in a sense, much more important than any of these; they relate to the influence which electricity, however developed, exercises over the nerves and muscles of man when applied to them from without, and chiefly to the power which the electricity of induction has in developing sensation and muscular contractility when present, or of proving their absence as a negative result.

By means of the localized galvanic current we are enabled to irritate the smallest nerve, and to excite its specific action without affecting the cutaneous nerves; that is, without causing reflex action or acute pain. Duchenne thinks it possible to produce muscular contraction independent of nervous influence; but I feel disposed to agree with Remak,* that, in the direct muscular galvanization it is only a question of irritating the motor nervous fibres, and thus I consider the terms he employs of intra-muscular and extra-muscular irritation of the motor nerves as being more correct than those employed by Duchenne. According to this author, muscular galvanization is either direct or indirect: the first causes contraction of the muscle by exciting the contractibility of any nervous influence; the second causes muscular contraction by exciting the larger motor nerves. I prefer the views of Remak. To him also belongs the merit of pointing out certain obscurities in Duchenne's work, and of basing extra-muscular irritation on scientific principles. He believed that extra-muscular contraction can be induced in all the superficial muscles; but, as some are supplied with nerves from the under or deeper surface, we can, in most cases, rely only on intra-muscular irritation.

2. *General Distribution of the Nervous System.*

It is through the agency of the nervous system, and chiefly through the nerves themselves, that electricity

* Ueber methodische Electrisirung gelähmter Muskeln. Berlin, 1855.

under all its forms is supposed to act on the body. That nervous system may, for practical purposes, be divided into, 1st, a cerebro-spinal axis; 2ndly, nerves of sensation and of motion, whose peripheral terminations are in the organs of the body, and whose central terminations, or origins as they are usually called, may be traced to the cerebro-spinal axis itself; lastly, a system of nerves and ganglions of obscure functions, called the sympathetic system of nerves. Of the nerves which may be traced to or from the cerebro-spinal axis some appear as single, others compound, or double, or mixed; of the single, some are obviously nerves of pure sensation, as the olfactory and optic; others purely motor, or esteemed so, as the third or motores oculorum; the fourth, or patheticus; the ninth pair of Willis, or twelfth pair of Soemmering, called also the lingual or great hypoglossal. On the other hand, by far the greater number of nerves assume the form of mixed or compound nerves, that is, having double roots, of which one may be called the motor and the other the sentient. If we examine, for example, the spinal nerves, commencing with the last and tracing them to the highest or first, the sub-occipital pair of nerves of descriptive anatomists, we shall find one uniform system or mode prevailing as to the origin and termination of these nerves. They commence by double roots, an anterior proved by physiological experiments to be the nerve of motion, and a posterior determined in a similar manner to be the nerve or nerves of sensation: after a short course a ganglion is found on the posterior or sentient root, through which the nervous filaments pass to resume their course immediately and uninterruptedly; the anterior or motor roots in the mean time pass over this ganglion, but soon join the nervous filaments of the posterior roots, to form with them a mixed nerve, in which the respective functions of the filaments can no longer be recognised by mere inspection. And now, if the filaments composing this mixed nerve be traced towards their peripheral termination, that is to the organs or tissues of the body, it will be found that the great distribution of such nerves is to the common integuments of the body and to the masses of muscles usually called voluntary, that is, muscles which we can call into action through the will, and of whose action, when so excited, we are conscious. Amongst these, however, must be included many other muscles, continually acting, without our consciousness, and over which our will has but a limited power; such as the diaphragm, the intercostales, and the abdominales muscles. These act night and day without our consciousness, and have a rhythm or order of succession almost as regular as the heart itself.

If we now pass from the spinal column to the head, or, as anatomists would say, from the cervical vertebræ to the cephalic, we shall, in addition to the single nerves already alluded to, find others which are clearly mixed nerves, that is, pairs of nerves composed of sentient and motor roots. The first we meet with, proceeding from behind forwards, is the so-called eighth pair of Willis, the ninth, tenth, and eleventh of the arrangement of Soemmering: of this pair it may be said that the portion called vagus with the spinal accessory constitute a pair of mixed nerves, the vagus representing the sentient portion, the spinal accessory the motor; 2nd, the glosso-pharyngeal nerve is more doubtful—it clearly has a ganglion on it, and its peripheral terminating filaments are no doubt mostly sentient, but motor filaments seem to be wrapt up with them.

Still proceeding forwards we find the seventh pair, of which the auditory represents the sentient, and the portio-dura or facial the motor portion. Lastly, the fifth, than which there can be no more complete specimen of a double or mixed pair of nerves. Palletta,* who first described its true anatomy, remained contented with describing, as an anatomist merely, the course of the motor and sentient filaments; had he but stated their functions, which actually lay before him, he would have anticipated and cut short all the unpleasant disputes and discussions on the functions of the roots of the nerves, which cannot, even now, be said to have altogether terminated.

From the time that the motor and sentient filaments have become mixed the anatomist is no longer equal to determine by mere inspection which is sentient, which motor; there remains, in fact, to the anatomist but one mode of doing so, that is, the tracing the nerve or filament to its peripheral termination; and even this does not absolutely determine the function of the filament so traced. The physiologist, armed with inductive electricity, seems to me to proceed on much surer grounds: he projects through the doubtful nervous filament an electric current, and observes the results. Sensation or motion determine then the character of the filament whose functions are in question.

Let us proceed then by this method in the first place, to determine the functions of most of the motor nerves in direct connection with the cerebro-spinal axis. The localization of electricity enables us at last to place this great question in a new point of view.

* De Nervis, &c., Lipsiae, 1791.

CHAPTER II.

Results of Physiological Experiments made by means of the Inductive localized electricity chiefly on living man.

THE basis of the experiments is this:—

1. Place two dry conductors on the dry skin, and the electric currents will be neutralized on the surface of the common integument, whilst sparks, attended by a peculiar crackling noise, are produced without any physiological result.

2. Place a wet and a dry conductor on the skin, and it will be found that a superficial irritation of the skin takes place beneath the dry conductor. The positive and negative currents neutralize each other at the dry point, after having passed through the skin by means of the wet conductor.

3. Place on a thick part of the skin, which has been previously moistened, a dry metallic conductor—a stronger superficial irritation will be produced, but unaccompanied by sparks or crackling. The currents in this case are neutralized in the substance of the skin.

4. Place on the moistened skin two wet conductors; we shall then have neither sparks, crackling, nor sensation of heat, but only contraction and sensation, which vary according as we act upon muscle, nerve, or bone. In the last case very severe pain is felt.

These experiments prove that electric currents can be arbitrarily directed to the skin, or parts beneath. It only remains to be demonstrated that the sparks, crackling, and the burning sensation which attend the use of dry conductors are alone consequent on the irritation of the skin, and that the contraction and sensation caused by the use of very wet conductors are to be attributed to the direct excitement of the nerves and muscles. This Duchenne has proved by the following experiments:—

A part of the crureus muscle in a man happened to be laid bare; Duchenne applied to this exposed part a dry metallic conductor, upon which it contracted, and a dull peculiar sensation was experienced. He then placed the same conductors on the skin over this muscle, a burning sensation was felt, but there was no muscular contraction; in the next place he attached wet sponges to the conductors, and on applying them to the skin contraction of the muscle beneath took place, attended by the same dull peculiar feeling which was produced by their application to the naked muscle. In another individual the radial nerve at the lower half of the fore-arm was destroyed, as also the power of electric contraction and the sensibility of the muscles at the back of the fore-arm, whilst the sensibility of the skin remained, as the cutaneous nerves were uninjured. Dry metallic conductors placed on the skin at the back and front of the fore-arm produced a burning sensation throughout the limb; the wetted conductor applied to the back of the arm had no effect whatever, but when placed on the fore part where the nerve was uninjured, muscular contraction, with the usual accompanying sensations, was produced. Duchenne is further of opinion that the electric irritation of a muscle produces only its individual contraction without affecting other muscles, and that, consequently, no reflex action of the spinal marrow takes places. In proof of this he instituted the following experiments:—

1. The facial nerve of one side of a rabbit was divided, so that the muscles supplied by it were no longer in connection with the spinal cord. The muscles of both sides of the face were then alternately subjected to the electric stimulus, and contracted equally on both sides.

2. The brain of the same animal was destroyed, to put the spinal marrow in the most favourable condition for the production of reflex movements. The separate muscles were again excited, and contracted equally on both sides. The same experiment was tried on the muscles of the lower extremities after division of the ischiatic nerve and with the same result.

3. Duchenne showed that there was no perceptible difference in the way in which the muscles of a healthy limb or of one which had lost its sensibility, would answer to the local irritation of galvanism; each would contract individually, and that, in cases of cerebral hemiplegia, the same influence would produce isolated contractions equally on both sides. We shall now consider the proper method to be observed in the local application of electricity.

2. *Cutaneous Galvanism.*

As the skin of different parts of the body possesses different degrees of electrical sensibility,* it is indispensable that cutaneous galvanization should be adapted to these conditions by various modes of application; we therefore use the hand, the conductor, and the wire brush.

The method of applying the current by the hand is as follows: A wet conductor is placed on some least sensitive part of the body of the patient, and another is held by the

* Ed. Weber, Quaestiones Physiologicae de Phaenomenis Galvano-magneticis in corpore Humano observatis. Lipsiae, 1836.

operator, who, with the back of the free hand, gently rubs the affected part. The only feeling produced is a slight pricking in the most sensitive part, which is attended by a crackling noise.

In using the conductor we moisten such parts of the skin as are thick and dry, and rapidly pass it over the affected parts. When the conductor is slowly moved, a severe burning pain is induced. If it is required to act as a strong counter-irritant, the conductor must be held to the spot, the wire brush is either kept pressed firmly on the skin, and kept there a short time, or we lightly strike with it the affected part. When it has been applied for a few minutes, the skin around becomes erythematous, and a vesicular eruption is produced. This is a most powerful application, producing the effect of the actual cautery, without injuring the tissues beneath, and the pain subsides as soon as the brush is removed.

It is important to discriminate which portions of the skin are most sensible to the electric influence.

In the normal state, the skin of the face, especially in the mesial line, possesses the greatest sensibility; the eye-lids, nose, and chin, are more sensitive than the cheeks; the forehead and head the most sensitive. The skin of the neck and trunk is more readily irritated than that of the extremities, and that of the inner and anterior surface of the limbs than the outer and posterior part. The skin of the hand is not very sensitive, nor yet the sole of the foot, except at its middle and inner side. The cutaneous nerves are not very sensitive when a wet conductor is applied to them, except when their terminal branches are affected; for example, the external saphenous nerve is only sensitive behind the malleolus, and when touched by the conductor at that point, a creeping, pricking sensation is felt on the upper part of the foot.

3. *Muscular Galvanization.*

It has been already shown, that if wet conductors are placed on the skin, the electric current passes through and excites the parts beneath, producing contraction of the muscle. We may cause a muscle to contract either by irritating the nerves which supply it, or by acting directly upon the muscle itself. The first method is called extra-muscular galvanization, and produces movements in whole groups of muscles; the second, intra-muscular galvanization, causes only single muscles to contract. A correct knowledge of anatomy is indispensable, for the successful application of either method, especially when acting on the deeper-seated muscles.

To the muscles of the trunk which have a broad surface, we apply large wet conductors, and smaller ones to those which present a small surface as the interossei, for which as well as for exciting the nerves, we also use conductors of a conical form covered with wet wash-leather; the conductor must be placed on the belly of a muscle not on the tendon, as the irritation of the latter produces no muscular contraction.

The thicker the muscle the more powerful is the current required; as it is only the superficial fibres which contract under the influence of a weak current, whilst a powerful one deeply penetrates its structure. In saturnine paralysis, for example, certain superficial muscles at the back of the fore-arm are atrophied and do not contract on being galvanized; a powerful current is therefore necessary to pass through these palsied muscles, in order to produce contraction in those which lie beneath. Strong currents are also necessary to reach the muscles in very stout persons. Galvanization of the muscles of the face is difficult on account of the numerous nervous ramifications, to avoid interfering with which it is necessary to use very small conductors.

CHAPTER III.

1. *Excitement by localized Galvanism of the Nerves and Muscles. General Remarks.*

THE galvanization of a muscle or nerve produces, in its normal state, contraction and sensation. Fleurens called the power—which a nerve artificially excited, possesses of producing muscular contraction—the motricity* of the nerves. The power in the muscles themselves of contracting under the direct influence of electrical excitement, is called by Duchenne, the *electro-muscular* contractibility, and he has given the name of *electro-muscular* sensibility to the recognition of that peculiar sensation which we have described as attending contraction.

Every organ, muscle, and nerve, has a fixed amount of electrical contractibility and sensibility. The motricity of the branches of the external thoracic or external respiratory nerve, is so great, that the slightest electrical irritation produces contraction in the muscles supplied by them.

The electro-muscular sensibility of the face is very considerable, dependent, no doubt, on the ramifications of

* Motricité.

the fifth pair of nerves, and it is necessary in galvanizing the facial muscles carefully to avoid the infra-orbital and mental nerves, as otherwise intense pain in the teeth and orbits would be produced. The frontal muscle is very sensitive; then follow in order, according to their relative amount of sensibility, the levator anguli oris, levator labii superioris alaeque nasi, depressor labii inferioris, levator labii inferioris, orbicularis oris, depressor anguli oris. The zygomaticus major and minor, masseter, and buccinator are not so sensitive.

In the neck, the platysma myoides, the clavicular portion of the sterno-cleido-mastoideus, the upper part of the dorsal portion of the trapezius muscles are very sensitive.

The pectoralis major and the infra spinatus muscles are more sensitive than the muscles of the back and abdomen which are not very readily excited.

The deltoid and muscles of the fore-arm are moderately sensitive, those at the front of the fore-arm, more so than those at the back.

The glutei and the tensor vaginae femoris are very sensitive in comparison with the other muscles of the thigh, and those on the inner side of the thigh are more sensitive than those on the outer.

The electro-muscular sensibility of the leg is greater at the back than on the front and outer side.

The brief analysis just made of some of the leading phenomena and of the practical suggestions arising from the extended experience of Duchenne and of myself, might suffice to place before practical men the rules to be observed and the caution requisite for the successful practice of electricity; but I feel assured that a further extension of the analysis, so as to embrace a larger amount of practical details, will be acceptable to those who may not have made the application of electricity their peculiar study. In proof of the correctness of this view, I may mention, that whilst pursuing his inquiries into the nature of galvanization, and indeed at the very commencement of the inquiry, Duchenne discovered the singular fact that the functions of certain muscles, and especially those of the hand, were not well understood. This led to a series of electro-physiological experiments on living man, the results of which I propose giving in the remaining portion of this part of my work. They are interesting in the highest degree, and the facts discovered by Duchenne and others* are found to react on the pathology of these organs and to give rise to valuable suggestions in the cure of many diseases. It was natural for Duchenne to describe the facts and experiments in the order in which they occurred to him. His first discoveries were made on the functions of the muscles of the hand; then followed those which move the arm or the shoulder; his third inquiry relates to the functions of the diaphragm; the fourth to the functions of the muscles of the face; the fifth to the influence of the electro-muscular contractility and the muscular sensibility over voluntary movements; the last to the uses of the corda tympani. With the utmost candour he admits that he has not yet studied the functions of the intercostal muscles, of the sacro-spinal, of the muscles of the abdomen, and of those of the lower extremities; that he might indeed publish a history of their electro-physiology, but proceeding on the idea that

* M. Meyer, Die Electricität in ihrer Anwendung auf practische Medicin. Berlin, 1854.

electro-physiology alone teaches us nothing of the true history of the muscular system, he has purposely delayed to a future time the publication of the results he has already obtained. The arrangement I shall follow in this inquiry will simply be an anatomical one, commencing with the nerves of the head and trunk, and terminating with those proceeding to the extremities; the inquiry into the functions of the muscles will necessarily follow the same order.

2. *Nerves of Motion.*

I have now to call your attention to the action of electricity over the nerves of motion and of muscular sensibility; the nerves, in fact, which obey the commands of the will; which further, when acted on by electricity, excite contractions in the muscles, and which, moreover, in a manner unknown to us at present, are intimately associated with the nutrition of the organs they supply with that mysterious influence called nerve-force.

1. The *facial* nerve, called also the portio-dura of the seventh pair, is easiest reached by the operator at the point of its emergence from the foramen stylo-mastoideum or aquæductus Fallopii, between the mastoid process of the temporal bone and the condyle of the lower jaw-bone, in the hollow, immediately below the external ear. The trunk cannot be reached whilst deeply buried in the parotid gland through which it passes, but many of its branches may be excited by electricity. Of these, I may mention the posterior auricular, (which, when excited causes great pain), and a branch to the stylo-hyoid, and posterior belly of the digastric. The motor points by

which to act on these may be determined on any anatomical engraving, and the experimenter would do well to note the points on an anatomical figure or drawing kept always before him; by keeping before him such a reference, many minute anatomical details may here be dispensed with. By this means I shall also avoid numerous tedious details, and thus be enabled to place before the reader more prominently most of the important conclusions which have hitherto flowed from the modern practice of localized galvanism.

The general distribution of the facial nerves to the muscles of the face, or as they are sometimes called, the muscles of expression, must be well known to all anatomists. They supply, in fact, branches to nearly all these muscles, commencing with the occipito-frontalis and extending quite to the base of the lower jaw. Certain of these muscles may be excited to contraction independent of others, but difficulties occur here owing to the complication of these muscles, their mutual connexions, and sometimes the minuteness of the nervous twigs themselves. Many of these muscles overlap each other and also conceal the nerves, and when this happens isolated contraction cannot well be effected. The great sensibility of the integuments is also to be taken into account, and it is scarcely necessary to remind the surgeon, that the points where the three great terminal divisions of the fifth pair appear on the surface ought generally to be carefully avoided if possible. These points are readily determined, for a probe placed so as to descend perpendicularly from the supra-orbital notch of the frontal bone to the base of the jaw will be found to intersect the three.

The *buccal* nerves will be found at the inner border of the masseter muscle and the nerve supplying the depressor anguli oris, near the outer margin of the muscle it supplies. The facial sends twigs to the platysma myoides from its lower division, called cervico-maxillary, but it also receives branches from the nervus communicans faciei, and generally from the anterior branches of the cervical plexus, so that we are compelled to call the negative pole to our assistance to obtain a perfect contraction of this muscle.

Excitation of these anterior cervical branches, at a point corresponding to the middle of the sterno-mastoid muscle, is sufficient to show the action of the platysma—a muscle whose functions have not as yet been fully determined.

To excite the orbicularis oris, several conductors must be applied.

The temporal and masseter muscles can only be excited feebly by intra-muscular irritation, in consequence of the point of entrance of the motor nerves to these muscles being deep and inaccessible. The branches supplying them belong to the motor portion of the fifth pair of nerves, the branch or portion so carefully described by Palletta. These motor branches lie very deep; they supply the temporal, masseter, pterygoid, and buccinator muscles, and are no doubt intimately united by sympathies with the sentient nerves of the third division of the fifth pair, of which it forms a portion. It is from the sentient part of this division that the gustatory nerve proceeds; nevertheless, the temporal may be acted on by applying the positive conductor to the posterior, the negative to the anterior border of the muscle, thus corresponding to a certain extent to the course of the deep temporal nerves supplied by the third division of the fifth. To excite the masseter muscle, the conductors may be applied over the incisura separating the coronoid from the condyloid process, at which point the nerve enters the muscle.

Intra-muscular excitation is shown by a powerful closing or snapping of the lower jaw, when the mouth has been previously opened—a result perfectly identical with that experiment on living animals wherein the brain, being exposed, the motor root of the fifth pair is touched with the point of a needle. Thus does electro-physiology already prove a substitute for the cruel experiments by vivisection, which commenced with Galen, but did not terminate with Majendie.

The *spinal accessory* of Willis may be readily reached in the latter part of its course. Press the conductor a little beneath the margin of the sterno-mastoid muscle, and the excitement will act on that muscle and on the trapezius. Its action on the trapezius will be rendered more perfect by placing the negative conductor on the cervical branch, which enters the muscle.

The *great hypoglossal*, or lingual nerve, may be reached at a point a very little above the great horn of the hyoid bones, in front of the hyo-glossus muscle.

The branch from the fourth cervical to the levator anguli scapulæ will be found immediately under the spinal accessory, at the point indicated above: a very fine conductor must be used.

Near to this point, also, the dorsalis scapulæ nerve may be reached; and, through it, the rhomboidei and serratus posticus muscle may be powerfully acted on.

The *phrenic* nerves, whose position on the scalenus anticus muscle is so well known to surgical anatomists in consequence of their dangerous proximity to the subclavian artery, on which they may be preparing to place a ligature, may readily be reached by a conductor placed on the outer border of the sterno-mastoid muscle.

PART THE FOURTH.

CHAPTER I.

The Electro-Physiology of the Nerves and Muscles— Continued.

1. Close to the anterior border of the trapezius muscle, immediately above the clavicle, and soon after their emergence from the scalenus medius (called by some posticus) muscle, the *long thoracic nerves* may readily be reached by the electrician, and on the spot just indicated being touched by the conductor, the muscles they supply will be brought immediately into action. When the *short thoracic* nerves are at the same time acted on, the serratus major anticus is energetically contracted. All anatomists are aware, no doubt, of the course of the *supra-scapular* nerve and its relation to the ligament, which, extending from the base of the coracoid process to the cervical margin of the scapula, converts the incisura or notch into a foramen or hole by which the nerve reaches the fossa supraspinata scapulæ, and the muscle which fills the fossa. After supplying this muscle the nerve proceeds to furnish branches to the infra-spinatus muscle as well. Now these muscles contribute powerfully in rotating the shoulder (head of the humerus) outwards;

they are, in fact, rotators of the shoulder, in the strict sense of the term, and we should expect, that when the branch of the nerve supplying them is excited by localized galvanism, its influence would be exercised on these muscles, and that rotation of the arm outwards must follow. This accordingly happens so soon as a conductor is placed over the point of integument corresponding to the supra-scapular nerve, a point easily made out, even in fleshy persons, by attending to the position of the superior angle of the scapula. On the other hand, the *sub-scapular* nerves, supplying the sub-scapular muscle, the sole antagonistic rotator inwards to the aforesaid rotators outwards, are too deeply placed to be readily reached by this form of galvanism. Nevertheless, this difficulty has been overcome, more especially in the emaciated. There cannot be a doubt that these rotator muscles play an important part in the deformation of the shoulder-joint in those cases where a pathological condition has been induced by rheumatism, by falls or blows on the shoulder, by dislocations, and other causes; antagonists of the deltoid in some measure, paralysis of this powerful muscle leaves them without a sufficient opposing force, and a permanent contracted condition is the necessary result. These muscles and their nerves are, moreover, often injured in severe cases of dislocation, and they do not readily recover.

On the upper border of the pectoralis major muscle and between its margin and the clavicle from the point where it ceases to arise from it, the electrical conductor may readily be placed on the point of integument corresponding to the course of the *short thoracic nerves*. On these being excited, the action of the muscle follows, and by this the arm is forcibly drawn towards the front of the body, raising the elbow at the same time to a level with the breast. In this action we recognise in fact the usual action of the pectoralis major muscle when obeying the will.

The *circumflex nerve* lies deep near the upper and posterior wall of the axilla; its importance may be judged of by the fact, that it alone supplies the deltoid muscle with that power by which the arm is useful to man. The nerve, it is true, sends branches to the teres minor, (a rotator outwards of the head of the humerus) and to the sub-scapular, but these sink into insignificance when compared with its supply to the great elevator muscle of the humerus. The circumflex nerve, as is well known to surgeons, is in a peculiar manner exposed to numerous serious accidents in dislocations of the head of the humerus from its scapular socket; such as violent stretching, accompanied with lacerations, implicating a large portion, or even the whole of the nerve. The mischievous results of these on the contractions of the deltoid and the utility of the arm may readily be understood. By placing a conductor over the course of the circumflex, notwithstanding its depth, the deltoid may be immediately acted on by electricity, and the effects of the localized process may be still further increased, by placing the negative conductor over the branch of the short thoracic nerve, which also supplies the deltoid and enters the muscle by its anterior border.

2. The *external cutaneous nerve* may be excited in the groove between the coraco-brachialis and biceps, and by this excitation the fore-arm becomes powerfully flexed, and a pain is felt on the radial side of the fore-arm. The

conductor must be firmly held in its place. By placing the conductor somewhat below the biceps at its lower third, the brachialis flexor muscle may be brought into play; at the point indicated, the second branch of the external cutaneous nerve enters the muscle. But the median nerve being more readily reached, requires to be pushed aside that its excitation may not interfere with the action required. If a negative conductor be placed over the branch which the brachialis anticus muscle receives at its outerside from the radial nerve, the fore-arm may be flexed, independent of the biceps flexor cubiti, this latter remaining soft and relaxed. By such ingenious experiments we learn at least that the new method exercises functions beyond those of the will, for we naturally have no such power as flexing the fore-arm by the action of the brachialis alone.

3. The sulcus bicipitalis throughout its whole length, marks the course of the *median nerve*, and consequently of the various points on which an electric conductor may be placed: but the preferable point is towards the lower third of the arm, near to which the nerve has crossed to the inner side of the humeral artery, and where it can be pressed against the humerus. It is almost unnecessary to add that exciting the nerve at the point indicated causes painful sensations throughout all its sensitive branches; and besides calls into action the pronator teres and quadratus, the flexor carpi radialis, palmaris longus, flexor sublimis and flexor profundus digitorum, the muscles of the thenar eminence or ball of the thumb, and the first, second, and third lumbricales muscles. Thus the motions produced by exciting the median nerve are, powerful pronation of the fore-arm, flexion of the fingers and of

the thumb, which thus becomes opposed to the others. If excited above the wrist and before it plunges beneath the annular ligament of the carpus (anterior retinaculum) and where it is placed between the tendons of the flexor carpi radialis and palmaris longus, it powerfully contracts and opposes the thumb to the other fingers, at the same time abducting it; there occurs also a slight bending of the first (proximal) phalanges of the index and middle finger.

I may here remark that the galvanization of the muscles on the inner side of the fore-arm, and especially of the pronator teres, is exceedingly painful, in consequence of the number of sensitive nerves supplied to the integuments over the whole region. True; the excitement of one of the branches supplying the pronator is sufficient to pronate the arm, but the application will be rendered more efficacious if we place the negative conductor on the muscle whilst we excite the nerve with the positive.

On the other hand, the branch which the median nerve supplies to the flexor sublimis digitorum communis cannot be isolated, as it enters the muscle on its deep aspect; and the same remark applies to the flexor profundus digitorum communis. The branches which the same nerve transmits to the flexor carpi radialis and palmaris longus muscles are readily found, on the under side of these muscles.

The experience of every-day life proves to us, that some parts at least of the *ulnar* nerve may very readily be reached by a mechanical injury done to the nerve, and surgeons in resections of the elbow-joint, on finding that they have accidentally partially injured the nerve, have not hesitated recommending its complete division with the bistoury, rather than leave it in a semi-divided condition. The nerve I now consider may be acted on by the electric conductor nearly throughout its whole course from the axilla to the elbow. But the best and surest point is that already alluded to, where it is often excited, or rather paralyzed, by a blow, the space between the olecranon process of the ulnar and the inner condyle of the humerus: here the nerve is much exposed to external injuries and all exciting causes, and when acted on by electricity at this point, pain is caused in the hand, together with contraction of the flexor carpi ulnaris, flexor digitorum profundus, of the muscles of the hypothenar eminence, and of the interrossei, the abductor pollicis, and of the third and fourth lumbricales muscles.

Above the wrist the ulnar nerve may be said to be superficial, and is placed on the radial side of the tendon of the flexor carpi ulnaris. Close to the pisiform bone lies the branch to the ulnar side of the hand, whilst in front of the unciform process of the unciform bone will be found the branch supplying the flexor brevis minimi digiti. On the other hand, the interossei muscles from the deep position of their nervous branches must be excited by the intra muscular application of galvanism to the back of the hand, and this gives rise to the abduction of the index, middle, and ring finger, from the mesial line.

4. Near the posterior wall of the axilla, lies, with several other nerves, the *musculo spiral* nerve, one of the most remarkable and important of the nerves of the upper extremity. It is most easily reached when passing around the humerus, it occupies together with the musculo-spiral artery, a groove in the humerus. At this point it may also be readily compressed against the bone, or at least

partially fixed in its position. Whilst winding around the humerus, the branches it supplies to the triceps muscle are given off and are easily found; on the other hand, the branches to the supinator longus are deeply situated, and cannot be reached in an isolated manner. Irritation of the musculo-spiral nerve causes contraction also in the supinator brevis, the extensor ulnaris, extensor radialis externus or longus, extensor communis digitorum, extensor indicis proprius, extensor minimi digiti proprius, extensor pollicis longus and brevis, abductor pollicis, in a word, such irritation causes supination of the fore-arm with complete extension of the hand and thumb, extension of the first (proximal) phalanges of the fingers, whilst the middle and distal phalanges remain slightly flexed.

No difficulty exists in exciting the branches to the extensor carpi ulnaris nor those proceeding to the anconeus. When these are acted on, the contraction of the muscle causes slight extension of the fore-arm, thus proving, that in point of fact, the muscle is but an appendage of the triceps. If the conductor be placed at the radial side of the extensor communis digitorum, the extensor ossis metacarpi pollicis and indicator may be made to contract.

5. To those acquainted with the course of the great nerves supplying the muscles of the lower extremities I need make but few remarks. Generally speaking, their course may be understood by a reference to a good anatomical drawing; but considerable dexterity, patience, and practice are requisite to enable the electrician to excite even these nerves with advantage to his patient. The old methods of throwing the electric current through a large nerve and observing the results are no longer admissible.

The crural arch or ligament of Poupart is the key to the position of the *crural* and *obturator* nerves; the *sciatic* can only be reached below the gluteal depression where the hip joins the thigh. Even here it lies covered by the flexor muscles. The crural nerve supplies chiefly the extensors of the thigh; the obturator the adductors; the *sciatic*, the muscles of the leg, and of the foot. For painful affections of the integuments of the leg and foot, subcutaneous sections of the nerves supplying the pained parts, have often been recommended and practised. I venture to urge a trial of localized galvanism in such cases, on the improved principles now put in practice.

The nerves which supply the great erector muscles of the spine are not easily reached, and hence the superficial muscles only, can be excited to contraction; but in time, no doubt, means will be discovered to enable the electrician to act on those more deeply placed. A moment's reflection on the distribution of the posterior branches of the spinal nerves will explain to the anatomist that they present but few points for the direct application of localized galvanism; and this remark applies with more or less force to all these nerves, whether cervical, dorsal, lumbar, or sacral; nevertheless, as it is from certain of these nerves that the broad abdominal muscles derive their motor branches, perhaps also their sentient, it will be readily understood, that their further investigation merits the attention of all interested in the progress of the new therapeutical agent we now consider.

CHAPTER II.

The Electro-physiology of the Muscles—Continued.

1. Localized galvanization by enabling us to act on single muscles, or to bring into action whole groups of these organs, imitates not merely the voluntary power, but in some instances, mainly pathological, it even goes beyond this power, especially in respect of the isolated contraction of portions of muscles. It may be useful, therefore, in this chapter, to view the subject from this point of view, although it be true, that electricity acts on the muscles solely through the nerves. By an analysis of this kind we arrive at many important and curious physiological facts, and at a rational explanation of many pathological phenomena heretofore misunderstood or overlooked. They explain the necessity for great caution on the part of the electrician, lest in strongly exciting one muscle he gives rise to deformities by neglecting to call into play the synergic action of the group with which the individual muscle electrized is naturally associated. It may, indeed, be remarked that the natural carriage and position of the limbs is, in a great measure, dependent on the tonicity of the muscles; and thus, if the tonic power of one muscle be unnaturally increased or diminished, deformity is, or may be the result. Notwithstanding the crowded state of the muscles of the expression of the passions, (I allude to those of the face), and that they are known to be covered with numerous ramifications of sensitive nervous twigs derived from the sentient part of the

fifth pair, it is yet quite practicable to practise galvanization of the facial muscles, singly or in gróups. If it be desired to produce corresponding contractions on both sides of the face, two galvanic machines are required to be employed, otherwise the muscles acted on will contract unequally or give rise to contortions.

By the loss of the tonicity of the *occipito-frontalis* muscle the wrinkles of the forehead (if they exist) not only disappear, but cannot be reproduced at will: a drooping of the eyebrόws also occurs when the muscle has become paralysed. Thus the expression is lost, by the absence of that action, with which we associate the ideas of cheerfulness, of doubt, of surprise, and astonishment. The scalp can no longer be moved. On the other hand, a loss of power over the orbicularis palpebrarum and corrugator supercilii may be immediately observed, and electricity resorted to to restore the lost power of the will. The same remarks apply to the pyramidalis nasi, usually considered as a slip of the frontales muscles. The curious physiological experiments which have been made more especially in Germany, by means of localized galvanism upon this muscle, confirm generally what might be inferred from the known anatomical relations of the pyramidalis with the dorsum of the nose and the frontalis muscle; the pyramidalis is, in fact, the antagonist of the frontalis. Experiments by means of electricity have been made on the muscle called *compressor nasi;* they tend to show that this muscle expands, but without raising the nostrils. A loss of tonicity of this muscle is said to produce compression of the nares. Aware of the complexity of the muscular apparatus surrounding and acting on the cartilaginous skeleton of the nostrils, I merely give the results, which seem to have been made out in a satisfactory manner: but I do not attach much importance to experiments made on muscles whose anatomy has not as yet been clearly demonstrated; and whose complexity is great anatomically and physiologically. The nostrils seem to act in unison with the diaphragm and the *intrinsic* muscles of the larynx: these contractions seem to be the first step in the respiratory act; and although in man, many of the structures found here may be viewed as rudimentary when compared with the same structures in the horse and larger mammals, there is no reason for supposing that, small as they appear, they are without influence in the mechanism of respiration.

The *orbicularis oris* is a muscle which by receiving nerves from both sides (a consequence of its mesial position), requires the employment of several conductors. If acted on close to the mesial line, the lip is drawn inwards, and it becomes wrinkled; the electric power being transmitted through the lateral parts, the muscle in contraction draws the lip outwards. By means of the employment of localized galvanization we learn that the exterior fibres in contraction turn the lip outwards, whilst the inner direct it towards the teeth. The inner half of the eccentric fibres wrinkles the lips and brings them forward mesially, whilst the inner half of the concentric fibres wrinkles the lips and inverts them. From pathology we learn, that when the muscle is absent, as in fatty degeneration, the face assumes a strange expression. The lips project from the teeth, the mouth is open, the cheeks are flattened and furrowed with longitudinal wrinkles, and the speech is affected in so far as regards the pronunciation of the vowels o and w.

Localized galvanization presents no new facts in respect of the action of the *levator labii superioris alæque nasi;* it does not enlarge the nostril, but a loss of tonicity of the *zygomaticus major* muscle produces a sinking of the commissure of the lips, lowers the cheek, and inferior eye-lid, so that the eye-lids cannot be fully closed. The lower part of the sub-nasal furrow disappears. The action of the *zygomaticus minor* resembles that of the major; so also are the results of its loss of power.

By electric action we learn that the depressor labii superioris alæque nasi in reality forms two muscles with an independent or conjoined action as the case may be. The fasciculus in connection with the septum draws the posterior portion of the ala downwards and backwards, thus increasing the longitudinal diameter of the nostrils. When this muscle is strongly developed, and the contraction, however induced, powerful, a sort of dimple is formed at the commencement of the line which proceeds from the nose to the lip, and the septum follows the motion of the ala, and becomes flattened. The induced contraction is sufficient to give a nasal tone to the voice. By its contraction an expression of age is given to the face. If such experiments have little practical tendency, they yet affect and improve our diagnostic methods, and place the physiology of the muscles on a basis heretofore absent—the basis of direct experiment.

Galvanic experiments throw little new light on the functions of the depressor anguli oris (the triangularis of some anatomists), and levator labii inferioris; when the last muscle is paralysed as in the double paralysis produced by neuralgia, labial sounds are articulated with difficulty. Patients thus affected wrinkle the lips in articulating the labials, and they further support the chin with the hand to facilitate the enunciation. Neither do such experiments furnish any new facts regarding the history of the buccinator, the attollens, the attrahens, or retrahens auriculam. As regards the latissimus colli, such experiments serve to show, contrary to the opinion of Bichat, that this muscle is the most expressive of all the muscles. Its action expresses terror and fury. It were interesting, in a physiological point of view, to follow out these experiments, and to describe them at greater length; but I purposely refrain from doing so, such being foreign to the object of this work.

2. The larger muscles of the neck and trunk furnish a large field for useful observation on the application of this therapeutic agent, in consequence of their connexion with the movements of the upper extremities. Experiments too numerous to be more than alluded to in this brief analysis have shown me that the excitation of the clavicular portion of the *trapezius* muscle draws the head rapidly towards the side acted on, giving to it at the same time a movement of rotation, by which the chin is turned towards the opposite side: when this inclination of the head towards the side acted on has reached its maximum, the contracted muscle then raises the collar-bone and consequently the shoulder.

In order to enable this clavicular fasciculus to act simply and exclusively on the shoulder, it is necessary that the muscles which oppose the inclination and throwing back of the head and its rotation, should act energetically; and even then the head will still move backwards to a slight extent: it will incline a little to that side notwithstanding all efforts to the contrary.

By the contraction of the clavicular portions of both muscles, the head is reversed directly backwards; the main action then of these clavicular portions of the muscle is upon the head and not upon the shoulders. On the other hand, the fibres of the middle portion of the trapezius attached external to the acromion and to the external half of the spine of the scapula produce when excited a double movement: first, a movement of elevation of the acromion, by which the inferior angle of the scapula is removed from the median or mesial line; second, a movement of elevation *en totalité* of the scapula. The fibres of the middle portion of the trapezius muscle, which are attached to the inner half of the spine of the scapula, raise but little, when excited by galvanism, the external angle of the scapula, but they draw the whole bone forcibly towards the mesial line or vertebral column.

When the electric agent is transmitted through the fibres composing the inferior portion of the trapezius, the internal angle of the scapula is depressed and the spinal margin of the bone approaches the mesial line. By employing several machines of equal intensity or of several currents derived from a single machine, and placing conductors on all portions of the trapezius, the various movements of this essential bone in the composition of the shoulder may be successively demonstrated. No muscular fibres are more excitable than the clavicular portions of the trapezius, due no doubt to the supply of nerve force they receive from the spinal accessory nerve of Willis, the external branch of which is distributed to them. The sterno-cleido-mastoid muscle for the same reason, namely, the being supplied with nerves from the spinal accessory, is nearly as excitable as the clavicular portions of the trapezius. But this portion of the muscle receives branches also from the cervical plexus, and this has its influence on the physiology and pathology of the muscle, as well as on its treatment in paralysis. It would seem to result from several carefully made observations that the clavicular portion of the trapezius is the portion mainly active in inspiration, whilst the middle portion contributes most in simply raising the shoulder, and by its tonic contractibility in maintaining the shoulder in its normal position of elevation; it also assists in the vertical elevation of the arm, and the inferior fibres assist powerfully in carrying the scapula towards the mesial line of the trunk.

The pathological physiology, if we may so say, of this superficial and yet important muscle is peculiarly interesting, and would form of itself materials for an extended chapter. As space cannot be afforded for this, I shall here confine myself to a few remarks. In progressive atrophy of the muscle it is very generally the inferior portion which disappears first; the clavicular part seems to retain, even in extreme cases, a portion of its original character. Pathology proves what surgeons had not even suspected, that when the fibres of the trapezius which draw the base or spinal margin of the scapula towards the vertebral column are atrophied, the scapula removes itself more and more from the mesial line, despite the efforts of all the antagonistic muscles. Physiologists will, I think, admit with me, that a fact of this nature could be discovered by localized galvanism alone, at least during the life of the patient.

When the inferior portion of the trapezius has become atrophied, the inferior angle of the scapula is drawn towards the mesial line, whilst the superior angle recedes from it, and the shoulder is depressed.

Observation shows that when, as happens very rarely, the clavicular portion of the trapezius has been destroyed or atrophied, the shoulder is no longer raised during deep inspiration, proving the peculiar action of this portion of the muscle, and its intimate connection with the inspiratory act.

The levator of the angle of the scapula under the influence of the electric excitation, slightly rotates the scapula upon its articular extremity, which remains fixed, so that the two other angles (the superior and inferior) are somewhat raised, the inferior, in the mean time, approaching the mesial line, and causing a slight prominence under the integuments. After this movement, the whole shoulder is elevated in a mass, and the head inclined somewhat towards the excited side. There is no depressor of the shoulder at any time, as Winslow conjectured, nor any rotation of the scapula upon a fictitious axis. The articular angle of the scapula is always fixed. The muscle is simply then an elevator of the shoulder, nor does its name of elevator of the angle (superior or posterior) exclude the idea. It often remains sound when the trapezius has become atrophied, and it is seldom itself affected with complete atrophy. It is an extremely excitable muscle; it acts in inspiration, and resists, for a long time, the progressive muscular atrophy, a pathological condition I shall consider in Part VI. of this work. The *rhomboideus* muscle is superficial only at a small triangular space, whose margins are formed by a part of the spinal border of the scapula, the upper edge of the latissimus dorsi muscle, and the outer border of the lower third of the trapezius muscle. At this spot we only meet with the lower *fibres* of the rhomboideus, and from the excitation of these, derive but an imperfect idea of its action. It frequently happens that when the trapezius is atrophied the rhomboideus muscle remains unaffected, and is accessible to the galvanic excitation. If the conductors are placed over the upper fibres of the rhomboideus muscle the shoulder-blade is moved obliquely from below upwards and from without inwards.

If the conductors are placed over the lower fibres, the shoulder-blade turns upon its outer angle, raising the lower angle and drawing it towards the mesial line.

If all the fibres of the rhomboideus are made to contract simultaneously, the scapula is raised and turns upon its outer angle. When this muscle is made to contract powerfully, the shoulder-blade and acromion are both raised, and its base moves obliquely from above downwards and from without inwards, so that its upper angle is removed from, and its lower angle made to approach the mesial line. If the arm is raised perpendicularly on the commencement of the contraction of the rhomboideus muscle, it is lowered in proportion as the lower angle of the shoulder-blade is raised.

We cannot form any idea of the action of the normal rhomboideus muscle by the mere application of galvanism. When its fibres are elongated by the sinking of the shoulder-blade, and the base projects in consequence of the loss of the trapezius muscle, then are we especially enabled to observe its powerful effect upon the scapula.

In patients thus afflicted the shoulder-blades turn upon their outer angle during the powerful contraction of the rhomboidei, and the lower angle is raised to the level of the outer.

Only a few of the upper fibres of the rhomboideus slightly draw the shoulder-blade towards the mesial line.

The slight raising of the shoulder (as in shrugging the shoulders) is performed by the contraction of the middle bundle of fibres of the trapezius muscle, for we can feel that the rhomboideus muscle is perfectly relaxed. On lifting the shoulder and on carrying a load the rhomboideus acts also powerfully.

Deformity of the shoulder.—The rhomboideus contributes but little in retaining the base of the scapula at a normal distance from the mesial line, but it holds the base firmly to the thorax. Indeed when this muscle is atrophied, we observe that the shoulder-blade stands off from the thorax. If the lower fibres of the trapezius are also atrophied, the depression between the base and the spinal column is particularly observable, but it disappears directly if the patient extends his arms outwards and forwards. This is effected by the action of the serratus.

The loss of tonicity of the rhomboideus muscle causes a pushing of the inner angle of the scapula outwards and forwards, because the serratus muscle turns the scapula on its inner angle.

The contraction of the rhomboideus muscle gives rise to the same positions as are caused by galvanic contraction.

Serratus magnus.—This muscle can be galvanized in the space between the pectoralis major and the latissimus dorsi muscles, where a part of its seven lower serrations are subcutaneous or superficial. The four last serrations present only a small portion of their anterior ends in front of the latissimus dorsi, so that galvanism affects them but slightly. The other serrations, especially the 4th, 5th, and 6th, produce in those in whom the muscles are well developed strikingly remarkable movements of the scapula. We must galvanize principally the large striped fibres which are inserted into the inferior angle of the scapula, and to which the serrations from the 5th to the 10th converge, in order to obtain the proper action of the lower portion of the serratus.

In the healthy condition these fibres are covered by the latissimus dorsi, and, consequently, inaccessible to direct galvanization. In many patients the atrophy of the latissimus dorsi will be found to coincide with a normal state of the serratus magnus; in young persons the fibres of the latissimus dorsi are often very thin and are sometimes wanting.

The slight galvanization of the lower fibres of this muscle causes the scapula to turn upon its inner angle, in consequence of which the acromion will be raised and the lower angle will be turned outwards and forwards. After this rotation the scapula is raised up, as on contraction of the lower fibres of the trapezius.

If we galvanize the middle and lower serrations simultaneously, the scapula will be moved forwards, outwards, and upwards, causing the base to recede from the mesial line, and be pressed against the thorax, giving rise to a deep furrow in the skin.

This rotation of the scapula on its inner angle and the lifting of the outer angles is effected in the same way as with the trapezius, rhomboideus, and levator anguli.

Some view this motion as a see-saw motion, but this is incorrect; for if we place a finger upon either of the angles we shall perceive that the scapula turns upon each of its angles as upon an axis, two angles always turning upon a third which remains stationary.

All the muscles which rotate the scapula raise it at the same time. This proceeds unquestionably from the fact, that these muscles have antagonists, which Winslow very properly called moderators, and which offer a tonic resistance, therefore the lower portion of the serratus magnus, like the middle fibres of the trapezius, raises the acromion powerfully, and moves the lower angle of the scapula outwards and forwards. This last motion is restricted by the lower half of the rhomboideus and the levator anguli scapulæ (their moderators), when these muscles have attained the maximum of their extension. If the contraction of the serratus or the trapezius continues, the scapula will place itself in a position in which it meets with no resistance, that is to say, upwards in the direction of the tangent of the united forces of these muscles.

The lower portion of the serratus magnus acts as a powerful elevator of the shoulder.

The serratus magnus is an important inspiratory muscle; in order that this muscle may elevate the ribs from which it arises, it is necessary that the scapula be fixed by the synergic contraction of the rhomboideus, otherwise the thorax would serve as a fixed point; the raising the shoulder by turning the scapula would only be the result of the contraction of the serratus alone; consequently, the serratus, as an inspiratory muscle, requires the synergic contraction of the rhomboideus.

To prove that the serratus can expand the thorax whilst it raises the ribs to which it is attached, and draws them outwards, Duchenne made the following experiment on a patient, whose serratus and rhomboideus muscles lay immediately beneath the skin, in consequence of the muscles over them (viz., the latissimus dorsi and trapezius muscles) being atrophied. Two electro-galvanic apparatuses were so adjusted that the current from one was four times the strength of the other. Duchenne placed the conductors connected with the weakest instrument over the striped fasciculus which belongs to the lower serrations of the serratus. The conductors, in connection with the stronger apparatus, were placed over the rhomboideus. (These different electrical powers are required for these two muscles, if we desire to equalise the power of their contractions, so that the lower angle of the scapula may remain motionless during their combined contraction.) When the current passed, there followed: 1st, a perpendicular raising of the whole scapula; 2nd, the convex parts of the ribs, whose convexity seemed increased were moved upwards and outwards.

The patient made during the experiment an involuntary noisy inspiration when the nose and mouth were closed.

The upward motion of the scapula, which results from the rhomboideus and serratus muscles contracting at the same time, favours the inspiratory action of the serratus, as it brings the upper and middle serrations of this muscle in a transverse direction from above downwards, and increases the obliquity of the lower serrations, which naturally tends to expand the thorax.

The weight of the arm would draw down the outer articular angle of the scapula but for the counteraction of the trapezius and striped fasciculus of the serratus muscle. If the serratus becomes atrophied the outer angle of the scapula drops, whilst the inferior angle is raised indeed nearly to the level of the outer one.

Pectoralis major muscle.—The upper portion of the pectoralis major muscle consists of the clavicular and upper sternal portion. If we galvanize this upper portion on one side whilst the arm hangs down, the shoulder will be directed obliquely upwards and forwards, and if on both sides simultaneously the elbows will also be directed forwards and inwards, and the arms be pressed against the chest. If the arm be raised vertically it will, when this portion of the pectoralis major is galvanized, drop gradually forwards to the horizontal level. The lower portion, which draws the shoulder downwards, consists of all the fibres excepting those which arise from the upper part of the sternum and from the cartilages of the true ribs. If the arm be placed perpendicularly to the axis of the body it will move obliquely from above downwards, and from behind forwards, as soon as this portion of the muscle begins to contract.

Each portion of the pectoralis major muscle has a distinct action, and contracts singly for different purposes. The upper portion raises and sinks the arm according to the position of the limb; the lower portion always depresses or draws it downwards. These movements are very important for many purposes.

Deltoid muscle.—When the arm hangs down by the side, on galvanizing the fibres of the deltoid which arise from the acromion process, the whole extremity may be at once extended or abducted directly outwards. The internal fibres of the deltoid also raise the arm, but direct it obliquely forwards and inwards, whilst the middle fibres direct it forwards and outwards: it is these last which are most frequently atrophied; but the only action affected thereby is the raising of the arm outwards, and that but slightly; the motion of the arm is much more affected by atrophy of the anterior fibres.

In a patient in whom the middle fibres were paralysed, the arm could be raised outwards and backwards to a considerable extent, but not forwards. If the patient desired to raise his hand to his head he lifted the arm outwards (by means of the middle fibres) and flexed the fore-arm, but he could not touch his head unless he bent the head forwards. Atrophy of the posterior portion of the deltoid muscle renders many movements almost impossible, such as putting the hands in the pockets, or raising the hand behind the back. In attempting the latter movement patients raise the arm straight outwards, bend the fore-arm, and pronate the whole arm, and even then cannot touch their backs. They are able to carry the humerus backwards by the action of the latissimus dorsi and teres major muscles, but then the arm droops and approaches the thorax, so that they get the hand behind them and cannot lift it. The lifting of the arm above the horizontal line is produced by the simultaneous action of the deltoid, serratus magnus, and middle fibres of the trapezius muscles.

Paralysis or atrophy of the serratus does not weaken the arm nearly so much as the loss of the deltoid muscle; and patients in whom atrophy of the serratus has taken place can perform many movements which would be impossible were the deltoid also atrophied.

CHAPTER III.

Electro-Physiological Experiments on the Muscles of the Hand; Peculiar functions of the Interossei and Lumbricales Muscles.

Extensor communis digitorum, Extensor minimi digiti, and Extensor indicis.—If when the hand and fingers are flexed we galvanize the extensor muscles of the fingers, we find that, first, the second and third row of phalanges, then the first, and lastly the carpus, are extended. The second and third rows of phalanges will remain extended until the metacarpus forms an angle with the fore-arm; the second and third rows then commence to bend, whilst the first row is more extended. To prove how weak the action of the extensors of the fingers is on the second and third row of the phalanges we have only to bend the metacarpus backwards towards the fore-arm, and cause the extensors of the fingers to contract, the conductors being placed close to their origin: the first row of phalanges now extends, whilst the two last remain flexed.

The action of the extensors upon the last phalanges is, consequently, very limited; and if these muscles were the only extensors of the fingers, they would assume a claw-like position when the wrist was bent back towards the fore-arm. The flexed position of the two last rows of phalanges, as may be seen in cases of such deformities, depends upon the tonic resistance of the flexor sublimis and profundus digitorum muscles, which the extensors cannot overcome.

The extensors of the fingers not only extend the first phalanges, but also spread them out if they were, when in the flexed position, close together.

With a little practice, and using small conductors, we can succeed in irritating single fibres of the extensor communis digitorum muscle; we then observe the following results: the fibres which go to the forefinger draw it towards the thumb; the fibres which go to the middle finger do not produce any lateral motion; the fibres which go to the fourth and to the little finger move them towards the ulna.

If we confine the electrical excitation to the extensor indicis, the forefinger will be moved towards the middle finger, and the little finger separated from the fourth finger, much more than happens by the contraction of the fibres of the extensor communis digitorum, which belong to it.

The isolated excitation of the extensor indicis muscle is rather difficult to effect, but there are persons in whom the fibres of the extensor communis digitorum do not extend far down, so that we can reach the deeply-situated extensor indicis without irritating the superficial muscles. We also often find in fatty degeneration of the muscles that the superficial ones are alone implicated. These experiments prove that the extensor communis digitorum and extensor indicis muscles not only extend the first phalanges, but also move laterally the fingers from the *fixed* middle finger. We may therefore, with Cruveilhier, consider the middle finger as the axis of the hand.

Flexor sublimis and Profundus digitorum.—The artificial contraction of the flexor sublimis and profundus digitorum muscles produces the flexing of the two last phalanges. The flexion of the first or proximal phalanges is but very slight and secondary, because this action generally takes place only when the muscles are already contracted.

If when the hand is strongly extended, as well as the two last phalanges, the flexors of the fingers are galvanized, the first phalanges will be powerfully contracted; if, on the contrary, the fingers are left alone, the two last phalanges will first contract, and then the first, though not very powerfully.

If we cause the extensors and flexors of the fingers to contract simultaneously by an equally powerful current, the first phalanges will be extended, whilst the two last are contracted. It follows that the flexors do not act upon the first phalanges with sufficient power to be antagonists to the extensors.

If the flexor profundus muscle at the commencement of a contraction is already shortened, its influence upon the last phalanx will be considerably diminished, for, if on bending the hand or finger powerfully, we cause this muscle to contract, the last phalanx will be bent but little, or perhaps not at all, and the second with difficulty and with a painful feeling. Doubtless, for this reason, the extensors of the first phalanges contract synergetically, when the phalanges contract voluntarily, and these apparently opposing actions are necessary for the use of the hand.

Of the Interossei and Lumbricales muscles.—The electric irritation of these muscles produces successively three actions: 1st, the passage of a moderate current adducts or abducts the finger (according to the particular position of the galvanized muscle). 2nd. A stronger current extends the second and third phalanx. And 3rd, the first phalanx is bent at the same time.

The two last movements are caused by the contraction of the four lumbricales muscles, the first only producing a weak abduction of the finger. The interossei muscles which move the fingers from the ulnar side of the hand, execute the abduction movement more completely than those which have to bring them towards it. But the adductors, although weaker, extend the two last phalanges more powerfully than the abductor.

We have already seen that the force of the extensors only extends to the first phalanges, and that it is too weak to overcome the tonic resistance which the flexors oppose to the extension of the two last phalanges. The interossei and lumbricales muscles alone are capable of overcoming this resistance. These small muscles execute so forcibly the extension of these phalanges, that they must be considered as their real extensors, and those extensors which come from the fore-arm pass for weak supporters only.

If we repeat the experiment which has been already described (wherein we saw that the first phalanx was extended by the electrical contraction of the extensors), and place small conductors connected with a second galvanic apparatus on the interrosseus muscle of the middle finger, the two last phalanges of this finger will be stretched out through the contraction of its interosseus muscle. In like manner we can extend the two last phalanges of the other fingers.

We can easily prove by galvanization, that the interossei and lumbricales muscles extend the first phalanges more powerfully than the flexor sublimis and profundus muscles.

The interossei and lumbricales muscles cannot extend the two last phalanges, without bending the first and *vice versâ.* We must assume an unknown anatomical condition, which permits these muscles to perform two opposite motions at the same time.

The benefit of these apparently opposing motions of the first and two last phalanges is very great, and they are very important in writing, drawing, &c. If we analyze for instance the motions of an individual drawing, when he holds his pencil between the thumb and the two first fingers, we perceive two movements, one which draws the stroke downwards and the other upwards.

1. Motion which draws the stroke downwards.—The two last phalanges which hold the pencil are at first contra-extended to the first phalanges, and these bent at a right angle towards their metacarpal bones. If we desire to draw the stroke downwards, the two last phalanges of the fore and middle fingers are bent, whilst their first phalanges are extended upon the metacarpus.

These movements are produced by the synergetical contraction of the flexor profundus digitorum and of the extensor muscles. If all these muscles acted with equal force on all three phalanges, these synergetical contractions could not take place, without having overcome a very powerful antagonism; the extensor digitorum muscle could not extend the first phalanx, without contending against the bending of the two last, and their bending would prevent the extension of the first phalanges. If this muscular antagonism really occurred, such powerful exertions would be required to overcome it, that the lightness and dexterity of the fingers would thereby be lost.

2. Motion which makes the stroke upwards.—The

mechanism of this movement is naturally the opposite of the last, that is to say, the extended first phalanges bend and the flexed last phalanges extend.

The flexors and extensors take no part in this motion, but only the interossei and lumbricales muscles, as will appear from the following experiment.

The two last phalanges of the fingers and of the thumb, which hold the pencil, are bent as much as possible; if we now place the conductors alternately upon the interossei and lumbricales muscles of the fore or middle fingers, we shall see how the fingers irresistibly push the pencil forwards, while each phalanx performs the above-described motions. If we at the same time galvanize the muscles of the ball of the thumb, the thumb will exactly follow the movements of the fingers. If however the pencil is held as in the last experiment, and we excite the extensors alone or at the same time with the flexors, the first phalanges will be powerfully extended, whilst the last will be still more bent, and the pencil will drop out of the fingers.

CHAPTER IV.

Extensor ossis metacarpi pollicis; Extensor primi internodii pollicis; Extensor secundi internodii pollicis; Flexor longus pollicis.

THESE muscles are difficult to isolate in a normal condition, but in cases of partial paralysis it has been effected.

1. *Extensor ossis metacarpi pollicis.*—When the thumb

and the first metacarpal bone are advanced to the second, and this muscle is caused to contract, the first metacarpal bone will be directed obliquely outwards and forwards, and turned towards the carpus. The phalanges of the thumb are, during this motion, slightly bent, and are directed outwards from the fore-finger.

If we continue the galvanization, the hand will be bent towards the fore-arm and slightly abducted; supination never occurs.

Extensor primi internodii pollicis.—If this muscle be made to contract, the thumb being in the same position as before, the first metacarpal bone will be drawn straight outwards, whereby the first phalanx of the thumb will be extended, and the second bent. If the contraction is continued, the hand will be abducted, but neither bent nor supinated.

Extensor secundi internodii pollicis.—If the two phalanges of the thumb are bent, and the first metacarpal bone be directed obliquely outwards and forwards, we shall perceive, on the contraction of this muscle, two simultaneous movements, viz., an extension of both phalanges, and the movement of the thumb obliquely inwards and backwards. When the contraction is at its maximum it causes the thumb to form an acute angle with the wrist, and its last phalanx will be behind the level of the metacarpus. We never see supination take place through the contraction of this muscle.

Flexor longus pollicis.—The contraction of this muscle slightly flexes the first phalanx.

The abduction of the thumb belongs therefore to the extensor primi internodii pollicis, while the extensor ossis metacarpi pollicis draws the thumb forwards and outwards, and is really the extensor of the thumb; the extensor secundi internodii pollicis not only extends both phalanges, but adducts and also extends the first metacarpal bone, but does not produce any supination.

Abductor pollicis; Flexor brevis pollicis; Adductor pollicis; and Opponens pollicis.

The muscular fibres which constitute the *abductor pollicis*, *flexor brevis pollicis*, and *adductor pollicis*, have been arbitrarily divided into three muscles; in reality they form only two muscles, whose actions we will now consider.

1. Muscular fibres which go to the outer side of the first phalanx of the thumb and are formed by the *abductor pollicis*, and a portion of the *flexor brevis pollicis*. If we galvanize this fasciculus of muscle, the thumb being in its natural position, we obtain three distinct movements. The first metacarpal bone is moved forwards and inwards. The first phalanx is bent and inclined from within outwards, so that its front side is opposite to the volar surface of the finger. The second phalanx is extended if it was previously bent. If during this experiment the first metacarpal bone is in a position of abduction, the adduction movement will be greater and takes place by a kind of rotatory motion.

2. Muscular fibres which are inserted into the inner sesamoid bone at the metacarpo-phalangeal articulation of the thumb, and are formed by a portion of the *flexor brevis pollicis* and the *adductor pollicis*.

On the galvanization of these fibres, the first metacarpal bone is drawn towards the second, and places itself inwards and before it. The direction of the movement varies according to the position of the first metacarpal bone at the beginning of the contraction. If it was abducted it will be from without inwards; if it was bent, it will be extended; if it was adducted, it will be moved from the second metacarpal bone outwards.

From this we see that the so-called *adductor pollicis* is also an *extensor* and *abductor*.

The thumb follows passively the movements of the first metacarpal bone, but the first phalanx is bent at the same time that the second is extended.

3. *Opponens pollicis.*—This muscle both bends the first metacarpal bone and adducts it, but does not act upon the phalanges of the thumb. The first metacarpal bone is brought on a level with the second by a powerful contraction of this muscle; when the thumb is moved by no other muscle it will be directed outwards from the forefinger and its volar side inwards.

These experiments prove, that in some respects, a strong analogy exists between the action of these muscles on the thumb and the action of the interossei muscles on the phalanges of the fingers. All these muscles bend and adduct or abduct the first phalanges whilst they extend the last, which also receive a lateral motion from the first.

In order to exhibit distinctly the movements of abduction or adduction which the phalanges of the thumb execute by means of the muscular fibres which go to the inner or outer side of the first phalanx, it is necessary to hold the first metacarpal bone in the greatest abduction, the thumb will then be in its natural position. We then place the conductors alternately on the fibres which go to each side of the first phalanx of the thumb. At the same moment in which the fibres on the outer side contract, the first phalanx bends and the thumb inclines towards the little finger and describes a circle with its tip. If in this position of the thumb we galvanize the fibres which go to the inner sesamoid bone, the thumb will return to its natural position, and incline slightly towards its inner side. Hereby the last phalanx will be extended, and the first will make a lateral movement. If we irritate at the same time the fibres on both sides, the first phalanx will bend without lateral motion or rotation, whilst the second will be extended.

Three muscles of the ball of the thumb are therefore adductors and flexors of the first metacarpal bone; the opponens, the abductor pollicis and a fasciculus of the flexor brevis pollicis. Of the two fasciculi which incline the first phalanx laterally towards the little finger, the one belonging to the flexor brevis pollicis executes this movement more powerfully than that formed by the abductor pollicis. The abductor pollicis opposes the thumb only against the fore and middle fingers, but the flexor brevis pollicis against all four fingers.

The last phalanx of the thumb has three extensors acting in different ways. 1. The extensor secundi internodii pollicis extends the first metacarpal bone and the two phalanges of the thumb. 2. The adductor pollicis inclines the first metacarpal bone towards the second and bends it towards its inner side and extends the second phalanx. 3. The abductor pollicis and flexor brevis pollicis bend the metacarpal bone and the first phalanx and extend the last.

These three extensors are necessary in order that the first phalanx may be extended not only when the thumb is pressed against the fingers but also when the hand is open or when the thumb approaches the fore-finger. If the extensor primi internodii pollicis muscle alone extended the second phalanx, this would be very difficult to do when the important opposition of the thumb was required, because the extensor primi internodii pollicis moves the metacarpal bones in an opposite direction.

Winslow considered the first metacarpal bone the first phalanx of the thumb.

Indeed the first metacarpal bone is abducted in the chief movements of the hand, whilst the last phalanx is bent and *vice versâ*.

In drawing a line from above downwards, the last phalanx of the thumb is bent and the first extended, whilst the first metacarpal bone is abducted; when a line is drawn from below upwards the reverse takes place. The mechanism of these movements is exactly similar to what takes place in the fingers. In fact the abductor longus and extensor ossis metacarpi pollicis which cause the abduction of the first metacarpal bone and extension of the second phalanx, are not antagonistic to the flexor longus pollicis; on the other hand, the abductor longus and flexor brevis pollicis, like the interossei, effect at the same time flexion of the first phalanx, extension of the second and adduction of the first metacarpal bone. The extensor primi internodii pollicis might disturb this mechanism in consequence of its effect on both phalanges and the first metacarpal bone.

The abductor and flexor brevis minimi digiti bend, as in the thumb, the first phalanx and extend the last, but not very powerfully.

Pathological Physiology of the Muscles which move the Thumb and Fingers.

The importance and novelty of the facts furnished by pathology with the aid of localized galvanism must be my excuse for the introduction here of what may be deemed an episode in the history of electrical therapeutics. The importance of the hand to man cannot be overrated. The facts I am about briefly to sketch have been derived from various sources, and have been verified so frequently by myself as to leave no doubt in my mind of their accuracy.

In paralysis of the extensors, for example in saturnine palsy, the first phalanges will be flexed, and the extension of the last phalanges appears very limited, especially when the wrist is also flexed from paralysis of the extensors. But if the first phalanges and the wrist are kept extended as much as possible to compensate for the action of the palsied extensors, and the patient is made to flex and extend the two last phalanges, he will be able to do so as powerfully and perfectly as if the paralysis of the extensors did not exist.

The interossei and lumbricales muscles can, notwithstanding the palsy of the extensor muscles, extend the two last phalanges.

If we galvanize the palsied extensor muscles, as in lead palsy, they will not contract, and the phalanges remain motionless; but if we galvanize the interossei muscles the two last phalanges will be powerfully extended, and, indeed, in every position of the first phalanges and metacarpus.

The paralysis or atrophy of the extensor muscles impedes the bending of the two last phalanges.

In consequence of the paralysis of the extensors of the fingers, and especially when this is combined with paralysis of the extensors of the wrist, the bending of the last phalanges will become difficult, if not impossible. The wrist will then be bent towards the fore-arm, and the first phalanges bent towards the metacarpus. If the patient attempts to close the hand the second phalanges will be flexed, and the third will remain extended: he cannot exercise any strong pressure. The cause of this weakness is the shortening of the flexors; for if we hold the first phalanges and the wrist extended, the patient can close the hand by contracting the flexors as when in a normal condition. Hereby is explained, how the bending of the two last phalanges renders a synergic contraction of the extensors necessary.

Paralysis or atrophy of the flexor sublimis and profundus digitorum does not prevent the bending of the first phalanges, this being powerfully performed by the interossei and lumbricales muscles.

The action of the interossei muscles as extensors of the two last phalanges is modified by the tonic power of the flexor sublimis and profundus digitorum muscles; but if these are atrophied, then the two last phalanges will be extended by the interossei, and, indeed, the more so in consequence of the atrophy of the flexor muscles.

Paralysis or atrophy of the interossei or lumbricales makes it almost impossible either to extend the two last phalanges or to bend the first phalanges, even if the long flexor or extensor muscles are entire. In a patient in whom the spaces between the metacarpal bones of the hand were quite hollow, the galvanization of the interossei and lumbricales muscles scarcely produced a perceptible abduction or adduction of the fingers; the muscles of the fore-arm contracted on being galvanized. If the patient extended the fingers, the first phalanges only were powerfully extended, the two last phalanges being bent even when the wrist was flexed. If the patient wished to close the hand, the two last phalanges were powerfully contracted, whilst the first were but slightly inclined, so that he was only able to exert a slight pressure: this became more powerful on extending the wrist, because the flexors were lengthened at the commencement of the contraction and acted the more vigorously.

Paralysis and atrophy of the interossei and lumbricales muscles materially change and influence the natural position of the fingers, proving that these muscles are the only antagonists to the extensors of the first phalanges and to the flexors of the two last phalanges.

If the interossei and lumbricales muscles of the forefinger are palsied and atrophied, it still can be moved laterally by the extensor communis digitorum and extensor indicis muscles.

If the forefinger is moved laterally we can feel that the tendons of these muscles are on the stretch.

The fingers may be slightly separated notwithstanding the atrophy of the interossei by means of the extensors, which, as we have already seen, cause extension and a slight separation of the fingers. These motions will be feeble, as the separating and bringing the fingers together is chiefly effected by the interossei muscles.

The interossei muscles exert less force in separating than in bringing the fingers together: this fact is very important, as by it we can diagnose incipient weakness in them. Complete atrophy or palsy of these muscles is indicated by the extension of the first and the flexion of the two last phalanges in making this voluntary movement. If we desire to bring the phalanges on a level with the metacarpus the first phalanges are extended by means of the extensor muscles, and the two last by the lumbricales and interossei. The interossei are unable to do this without at the same time flexing the first phalanges: to overcome this antagonism, the extensors must contract with equal force, and in so doing they separate the fingers powerfully. In paralysis or atrophy of the extensor ossis metacarpi pollicis and extensor primi internodii pollicis, the first metacarpal bone is adducted, which materially interferes with the use of the hand, the thumb falling as it were into the hollow of the hand.

If the extensor secundi internodii pollicis is palsied, the first metacarpal bone will be more flexed than usual, as the extensor ossis metacarpi pollicis predominates; but this does not interfere with the motion in writing and drawing, as this muscle takes no part in these movements. The paralysis or atrophy of the abductor pollicis does not prevent the outer part of the flexor brevis pollicis from pressing the thumb against each finger; but if its metacarpal bone be not distant enough from the hollow of the hand, the tips of the thumb and fingers cannot be brought into contact without bending the last phalanges and extending the first. The paralysis or atrophy of the flexor brevis pollicis renders it impossible to bring the thumb in contact with the last two fingers; but if the abductor pollicis and opponens pollicis are unaffected the thumb can touch the two first fingers, and the hand be used in writing, &c. If, whilst the wrist and fingers are powerfully flexed, we excite contraction of the extensors, the two last, and then the first phalanges are extended.

Since these experiments were performed, Cruveilhier has repeated the same on the dead body; but, instead of employing galvanism, he pulled the muscles mechanically and obtained the same results. Bouvier* repeated Cruveilhier's experiments, confirming all these statements. On examining the works of the older anatomists we find that Columbus† of Padua, a pupil of Vesalius, suggested in 1559 that the lumbricales muscles were the flexors of the first phalanges and extensors of the two last. Thus early was the physiology of the muscles disputed by anatomists and physiologists, and *their functions admitted* to be obscure, if not wholly unknown. Localized galvanism, practised either on the healthy or the diseased, has furnished us at last with the means of deciding on all the disputed phenomena of the living organisation. The function of a muscle in the dead body, attached by one extremity to an immoveable part, and by the opposite extremity to a bone or lever obviously moveable, may be determined at once by pulling the moveable lever and drawing it towards the fixed point, thus imitating the contraction of the muscle during life, and exhibiting a function which it must at one time have performed. Thus no one can possibly doubt the action of the gluteus minimus, the pectoralis major, the adductors of the femur, or of the pectineus. Even should it happen that the muscle whose functions we propose determining after this rude mechanical fashion be attached by its two extremities to levers, both moveable,

* Electricité Médicale. Rapport lu à l'Académie Impériale de Médecine, Paris, 1856.

† De re Anatomica. Venet. 1559.

as the case may be, (as the muscle we call brachialis anticus flexor,) still there can exist no difficulty in the determination of its functions by experiments made on the dead and dissected muscle ; but, as we have just seen, the method does not apply with any security as to the correctness of a result, to the complicated and numerous muscles acting on the fingers and metacarpal bones. Some anatomists, it is true, had suggested that, to enable the hand to execute the finer works of mechanics—to perfect, in fact, the nice adjustment of the fingers in the performance of such works, and to place each joint thoroughly under the control of the artist or workman—the interossei and lumbricales had been especially superadded; but these suggestions, though ingenious, do not furnish us with the rigorous demonstrations of the special functions of these muscles, demonstrations unquestionably first given by the discoverer of localized galvanization. The biological fact, it is true, remains unaltered since its first *appercù* by Galen: he, the earliest of human physiologists, pronounced the human hand to be perfect; he had visited Egypt and lived in Imperial Rome, filled with the spoils of Greece: all that was great in art was before his eyes. On these monuments, the work of the human hand, the eyes of the million rested and were satisfied ; not so the anatomist, not so the scientific man: from the contemplation of these labours the mind of Galen reverted to the mechanism of the instrument by which these works had been fashioned—that instrument he declared to surpass all its works, and he pronounced it perfect.

Physiology and Pathology of the Diaphragm.

I should consider the view I have just offered of the action of localized galvanism on the nerves and on the muscles, directly and indirectly, as incomplete, were I to omit directing attention to certain facts made out by Duchenne respecting the most important of all the respiratory muscles—the diaphragm.

Prior to the time of Galen, it would appear that anatomists recognised only one inspiratory muscle, the diaphragm. Galen was the first who challenged this opinion and endeavoured by that method which he may be said to have perfected, (experiment on living animals,) to prove the existence of other muscles as muscles of inspiration, and thus to limit the action of the diaphragm to the inferior ribs which, in his view, it elevates upwards and outwards.

Vesalius was not more happy in his conjectures than Galen. Contradiction followed contradiction, until in the hands of Columbus and Riolan, although it must be admitted that Riolan approached most nearly the truth, in respect of the forms which the diaphragm assumes during the actions of inspiration and expiration. At last came Borelli, who, though not an anatomist, first proposed the doctrine accepted by Winslow, Haller, and all modern physiologists. Borelli denied absolutely that any inspiratory action could be performed by the diaphragm unassisted by the intercostals. Majendie endeavoured to revive the doctrine of Galen, who ascribed to the diaphragm a power of elevating the ribs. Thus doubts remained up to the moment when localized galvanism was discovered, as to the real action of the diaphragm as an elevator of the base of the thorax.

The experimental researches instituted on the movements of the diaphragm by Duchenne had a reference to 1st. The movements given to the ribs, by the diaphragm, so long as this muscle preserves its natural relations with the abdominal viscera. 2nd. The same movements when the natural relations of contiguity between the muscle and the abdominal viscera no longer exist. 3rd. The mechanism of these movements of the ribs in either case.

The first experiment was on man, made through the phrenic nerve. As the action of this nerve is confined to the diaphragm, and localized galvanism enables us to act exclusively on this nerve, whatever phenomena follow must be ascribed to the diaphragm. Now, whether acting on the living body, or on those just dead, but in whom there still remained some irritability, the results were constantly the same; as the diaphragm acted, the diaphragmatic ribs were instantly raised on the side galvanized, and on both sides when both phrenics were acted on. Now during this expansion of the thorax and elevation of the lower ribs, the intercostal and other muscles were completely relaxed, nevertheless the abdominal muscles were constantly contracted, a circumstance which cannot readily be explained.

When in the animals experimented on, the abdominal viscera having been removed, the phrenics were galvanized as in the preceding experiments, the ribs, elevated in the former case, were here drawn inwards or depressed. The diminution of the base of the thorax was chiefly in the transverse diameter.

Preceding his pathological inquiries by the electro-physiological experiments just alluded to, we next find Duchenne applying, with much ingenuity and great assiduity, the information thus acquired to the most important branch of our art; in other words, a series of observations followed on the atrophy and paralysis of the diaphragm, a subject most assuredly but little known, even to the most experienced. He found atrophy of this muscle to exist in a person affected with the *progressive muscular fatty atrophy* which I shall afterwards describe: this patient died. In a second, the disease was arrested by local galvanization. In a third, who had been poisoned by the action of lead, paralysis of the diaphragm occurred: this patient also recovered.

He found paralysis of the diaphragm to exist occasionally in hysterical persons; at other times to be caused by inflammation of the neighbouring organs, as of the peritoneum, similar to what Laennec had proved to happen to the intercostal muscles in inflammation of the pleura: finally, he detected contraction or spasm, momentary or continued, of the diaphragm, thus proving that a spasmodic condition of the diaphragm in man is not an hypothesis but a reality.

Thus has electro-physiology become in the hands of ingenious men, an instrument of research, superior, as it would seem, to all others. When Humboldt, in his minute dissections of some of the lower animals, used electricity as a test of the nervous or vascular character of the filament under his eye, he little thought that, in comparatively so short a time, he should witness its successful application, not merely to determine the functions of muscles, and the distinctive characters of nervous filaments, but to living man, in that direction which most interests mankind; for if there be an art which transcends all others, it must simply be that which restores to health and vigour the lame, the deformed, and the incapable.

Galvanization of the Internal Organs, and of the Organs of Special Sense.

Most of the internal organs admit of direct galvanization by means of properly constructed conductors; or of indirect, by directing the current to the nerves supplying them. Suppose it be required to galvanize the pharynx and gullet; a metallic conductor partially covered with caoutchouc is applied to the pharynx, and an ordinary conductor, wetted, to the back of the neck. Great care must be taken to avoid acting on the pharynx or gullet through the nerves they derive from the eighth pair of cranial nerves, lest dangerous irritation be excited. The gullet may be galvanized in a similar manner. It is obvious that galvanization in this form is quite indirect, but no other is applicable.

The muscles of the larynx, with the exception of the thyro-arytenoideus and crico-arytenoideus may be directly galvanized. The above-mentioned conductor is applied to the back of the larynx, whilst another wet conductor is placed externally over the region of the crico-arytenoideus posticus. And now the current being set in motion, the external conductor is moved up and down, by which means the crico-arytenoideus posticus, arytenoideus, and crico-thyroid muscles are directly acted on.

Indirect galvanization of the larynx is a more simple operation. The conductor is applied to the sides of the inferior constrictor muscle of the pharynx, and thus the inferior laryngeal or recurrent nerve may be immediately acted on. This nerve supplies all the intrinsic muscles of the larynx, and is, in fact, their motor nerve. It may also be reached through the gullet.

The depth at which the stomach, liver, lungs, and heart are placed, prevents their being acted on through the walls of the abdomen and thorax: but they may be indirectly galvanized by transmitting the current to the nervus vagus, or pneumo-gastric division of the eighth pair of cranial nerves, which may be reached through the pharynx or gullet, by a conductor placed therein. The extent of excitement depends on the position of the conductor; that is, whether it be placed higher or lower in the pharynx or gullet: in other words, nearer to or further from the central termination of the nerve. The circuit is rendered complete by placing one conductor in the pharynx or gullet, as the case may be, and another over the organ to be acted on. If the object be to act on the stomach or liver, a conductor should be placed as near as possible to the cardiac orifice of the stomach, whilst another is placed over the epigastric region. Symptoms of suffocation are easily induced, and thus the utmost caution is requisite in all these operations.

A few remarks will suffice in respect of the application of galvanism to the organs of special sense. The elastic cushion of the distal phalanx forming the organ of the sense of touch, may be galvanized by applying wet conductors in the course of the collateral nerves of the fingers. By wet conductors placed on the eye-lids and the circumference of the orbit, the eyes may be galvanized. The instrument of hearing is excited in this way; the meatus externus is, in the first place, filled with water, and a small conductor placed in it; another conductor is applied to the nape of the neck. The membrane of the tympanum is extremely sensitive, which must be borne in mind by the operator. If a wet conductor be placed on the mucous membrane of the nostrils and another on the nape of the neck, and an electric current be kept up uninterruptedly, the sense of smell will be galvanized. Intermitting currents fail in exciting this organ.

A conductor applied to the side of the tongue and another to the palate will be found equal to the galvanic excitation of the organ of taste.

No general rules can well be given for the treatment of cases requiring the use of galvanism. The intensity of the current which suits one patient may not be applicable to another; like every other therapeutic agent, localized galvanization requires for its successful exhibition, an experience to be derived from practice alone. These contributions, embracing an outline of the electro-physiological observations hitherto made on the nervous and muscular systems of living man, together with hints and cautions as to the employment of electricity in the healthy and diseased, will suffice, I trust, to explain to my readers the purely physiological part of my subject. A more interesting one remains; the examination of the results of localized galvanization applied to disease. To this I propose devoting the concluding chapters of this work.

PART THE FIFTH.

INTRODUCTION.

We have already seen how science came on the field of inquiry, enabling the observer to distinguish from each other, not only the various forms under which electricity may be developed, but also to acquire a distinct conception of other phenomena more or less remotely connected with it. We have also traced the progress of galvanic discovery down to the present time, and how from the mere contemplation of the phenomena of electricity however produced as something inexplicable and mysterious, science at last gave to practical men the mastery over nature's most powerful agent. The useful arts first benefited by the discovery, and the electric telegraph, threatens to alter the relations of the civilized world. Last, as was to be expected, came its scientific use in a therapeutic sense.

And now, notwithstanding the avowed difficulty of all biological inquiries, the curative powers of this agent have been proved by an amount of experience which must remove from the mind of even the most sceptical, all doubts as to the efficacy of a therapeutic agent over which, for the first time, the physician has now acquired a complete control.

To the practical results of the application of electricity in the treatment of the diseases of the nervous and muscular systems of man, I now propose directing the attention of my readers; reminding them that what we treat of here is no longer the chance shock from a live torpedo, a Leyden jar, or from a dynamic arrangement sent rudely through the system, but the transmission of an agent, whose identity with the nerve-force may one day be proved, to parts and structures over which heretofore the most skilled physician admitted he had no control.

CHAPTER I.

Diagnosis of Paralysis.

It has been often disputed whether a paralysed muscle can contract when acted on by an exciting agent. By the electricity of induction such questions are decided experimentally, and in a way admitting of no discussion or doubt. Dr. Marshall Hall,* to whom the medical art is greatly indebted for many useful practical suggestions, endeavoured to solve this question by the formula or thesis, viz., that in cerebral paralysis depending, of course, on lesion of the brain, or at least of the encephalon, the irritability of the muscles is increased, whilst in paralysis dependent on disease of the medulla spinalis or spinal marrow, it is diminished. The truth or correctness of this proposition was assailed by Drs. Todd, Pereira,† and

* Medico-Chir. Transactions, Series II. vol. iv.

† Elements of Mat. Med. and Therapeutics, vol. ii.

others, who disproved the general applicability of the thesis; Duchenne, and, after him, Dr. Meyer* re-examined the whole subject with great care; they came to conclusions hostile to Dr. Hall's theory, as we must now call it, and in the course of their inquiries, arrived at some important results, the chief of which I shall notice in this portion of my work.

Electricity directed to a muscle in its normal state, excites, as we have seen, its contractility and sensibility; these faculties must then depend on the same nerves proceeding to the muscle, or at least on fibrils wrapt up in the same nervous fasciculus. On the integrity of these nerves, it is evident that the healthy contraction of the muscle also depends, and this fact has been repeatedly proved in traumatic paralysis: for a wasting or atrophy of the muscle is not invariably the result of a loss of voluntary power. Thus complex, even in the first step, do we find these biological questions which the physiologists of the last century thought to solve by hypothesis.

The electro-muscular contractility, that is, the power or faculty possessed by the muscle of being excited to contraction by electricity, and the electro-muscular sensibility, that is, the sensibility proved to be present in the muscle by the application of the electric current, are always united in a normal or healthy condition of the muscle. But in certain pathological conditions they may exist either isolated or be lost together, sometimes partially, sometimes entirely. Let us now consider the influence of electricity in the various forms of paralysis usually recognised by medical men.

* Loc. cit. p. 81.

CHAPTER II.

Saturnine Paralysis.

This form of paralysis arises, as is well known, from the poisoning of the nervous system by lead. The affected muscles suffer in their electro-muscular contractility and sensibility, but it often happens that the first of these faculties may be greatly diminished, or even altogether lost, whilst the latter has been relatively but little weakened. It has also been noticed, that the degree or amount of injury sustained by single paralysed muscles varies exceedingly, whilst the order of succession in which they are attacked never varies. The first to suffer is the common extensor of the fingers (M. extensor communis digitorum), the indicator (M. extensor proprius indicis), the extensor of the little finger (M. extensor minimi digiti), and the long extensor of the thumb (M. extensor secundi internodii pollicis), the long abductor of the thumb (M. extensor ossis metacarpi pollicis), the radial and ulnar extensors (M. extensores carpi radialis et ulnaris), lastly, the triceps extensor brachii and deltoid: but there are a few cases in which the deltoid muscle suffers the first and the most. Thus, the mischief falls heavily on the muscles supplied by the musculo-spiral or radial nerve; in attacking the deltoid muscle it shows that the circumflex or axillary nerve is then involved.

When the common extensor of the fingers is paralysed, the proximate or first phalanx of the third and fourth fingers can no longer be extended: but the fore and little finger may, these having separate extensors.

The supinators as well as the anconeus preserve, in general, their electrical contractility, as well as the muscles in the interior region of the fore-arm and in the palm of the hand; in the left arm especially.

As regards the upper arm, the deltoid is more frequently attacked than the biceps; the pectoral muscles, the trapezius, and the muscles called supra and infra spinati, preserve almost always their electrical contractility.

The muscles which lose their electrical contractility become soonest atrophied, and offer the most resistance to the influence of the therapeutical agent recommended.

Case.—M. S. had tried a variety of remedies without deriving any benefit; he now consulted Duchenne, who found, on examining the patient, that both arms were immoveably fixed to the side; that the fore-arm could only be flexed with considerable difficulty, and that the use of both hands was lost, the deltoid muscles atrophied, as well as the muscles on the posterior aspect of the fore-arm—and to such an extent that the skin appeared merely stretched over the bones. This patient, after being galvanized daily for three weeks, was able to raise his arms, and to flex and extend the fore-arm without difficulty. The flexors of the fingers and the interossei gradually gained power and development, and after six months' treatment he had completely recovered.

There is a curious fact in the history of saturnine palsy, which merits attention. A case of paralysis consequent on poisoning by lead presented itself, but the source whence the poison was derived could not at first be detected. At last, Dr. Meyer had the snuff used by his patient analysed, and it was found to contain the poisonous ingredient. Duchenne had a similar case, and Dr. Baierlacher* makes mention of another: in consequence of such accidents, the packing of snuff in lead has been prohibited in France.

* Versammlung der Naturforscher und Aerzte. 1856 in Wien.

CHAPTER III.

On Palsies resulting from Lesions of the Medulla Spinalis or of the Spinal Nerves themselves; Traumatic Paralysis.

Traumatic lesions of nerves have, as an immediate result, paralysis as regards the power of the will over the muscles they supply. The muscular sensibility is also more or less weakened, and even the electro-muscular contractility begins about the fourth day after the accident to undergo a diminution, and, after two or three weeks, when the injury has been severe, entirely disappears.

The paralysis, at first confined to the muscles immediately supplied by the injured nerves, gradually extends to the other muscles of the limb; nevertheless, these always retain their contractility and their electric sensibility. Finally, the skin loses its sensibility at those points supplied by cutaneous filaments from the injured nerves.

The phenomena just enumerated may be taken as the more usual accidents following a lesion of the nerves; but they naturally vary according to the importance of the nerves injured, and the degree or extent of the injury.

It is exceedingly interesting to follow, in a well-marked case, the injury to a nerve, and the subsequent changes which take place in a limb. Thus, a man was wounded in the first days of June, in the revolutionary crisis which then disturbed Paris and France. A musket-ball passed through the left fore-arm, about the union of the lower third with the middle third of the fore-arm. In its passage it broke the radius and injured what Duchenne calls the radial nerve.

As the case is simple, and has been related with much brevity, I give it here in his own words ;* an analysis of it seems to me calculated to lead to conclusions somewhat at variance with the more generally received ideas on these points. "At No. 12 of the ward St. Charles (la Charité) lay a patient who was wounded as described above. The ball traversed the arm from without inwards, penetrated the left side of the body, and sliding over the ribs, passed out also on the left side. In its passage it fractured the radius and injured at this point the radial nerve. Four months afterwards, I first saw the patient and ascertained the presence of the following phenomena: considerable diminution of the size of the left arm, and especially of the fore-arm; atrophy and paralysis of the muscles of the posterior region of the fore-arm and of the hand: loss of sensibility of the skin over the mesial line of the posterior aspect of the fore-arm and over a part of the back of the hand."

It is difficult to conceive, as Duchenne remarks, how it happened that the muscles of the anterior region of the fore-arm, which in this case received their nervous supplies from nerves uninjured, should have been struck with paralysis so complete. But if we admit the fact that an injury to any branch of a nerve, however low in its course, tends to draw in by sympathy the other branches of the nerve, although uninjured, we have, I think, in the distribution of the radial nerve itself, a sufficient explanation of all the phenomena. For, not to allude to its connexion with the brachial plexus and the roots it derives from the sixth, seventh, and eighth cervical pairs of nerves, together with the first dorsal, this remarkable nerve,

* Duchenne de Boulogne.

before dividing into its terminating anterior and posterior branches, gives off many twigs in its course; some proceed to the triceps extensor brachii, one to the brachialis internus or flexor brachii: another remarkable branch to the anconeus muscle: still lower down a large branch proceeds to the integuments of the fore-arm; sometimes this branch is double. It perforates the brachialis flexor (internus), emerges between it and the supinator longus, passes behind the outside of the elbow and descends along the back part of the fore-arm and hand, as far as the thumb. Lastly, from the main branch of the nerve a branch is sent off to the supinator longus and long radio-carpal extensor.

Of the two branches into which the nerve divides, the anterior branch, the one, no doubt, spoken of by Duchenne as the radial nerve, is mostly a cutaneous nerve, supplying with sensibility the radial side of the fore-arm and hand; but it also furnishes twigs to the interossei muscles. The posterior branch of the radial, sends twigs to the supinator longus and extensores carpi radiales muscles, to the anconeus, the supinator brevis, extensor carpi ulnaris, and extensor muscles of the fingers: to the deep layer of muscles of the posterior region of the fore-arm, and to the integuments of the back of the fore-arm and hand.

Need we be surprised then at the consecutive phenomena to the injury of a nerve supplying so many parts; they are indeed exactly what we should have expected admitting the theory to be a correct one, that an injury to a nerve however low down in its course, is apt to draw into the circle of morbid sympathies, all or most of the branches belonging to the trunk from which it has sprung.

Even the mere contusion of a nerve may give rise to a considerable diminution of contractility and electric sensibility in the muscles it supplies; but as the consideration of this question would involve me in the entire subject of paralysis of the muscles from many other causes, I shall reserve this question, with others of great interest, to the chapter devoted exclusively to paralysis of the muscles. Then will be the most opportune moment to enter on certain difficult questions regarding muscular action and nutrition, questions which have at all times exercised the ingenuity of the most profound physiologists.

CHAPTER IV.

Cerebral Paralysis.

We have already seen that Dr. Marshall Hall imagined that in cerebral paralysis the irritability, meaning, I presume, the contractility called into play by electricity, was increased; but Duchenne and Meyer have proved by numerous observations, that the electro-muscular contractility and sensibility in such limbs remain perfectly normal: in cases of paralysis of long standing the cellular tissue has often disappeared, on which account the muscles of the affected will contract more powerfully than those of the healthy side. Similar results were arrived at in England, as may be learnt from the following notice in the 'Medical Times:'—

'In the summer of 1847, Dr. Todd submitted to a Society* the results of experiments tried with the view of testing the accuracy of Dr. M. Hall's dogma, that limbs

* The Medico-Chirurgical of London.

paralysed by lesion of the brain became more excitable than the healthy ones by the galvanic current, in consequence of an increased irritability of the paralysed muscles. The present communication comprises the results of experiments to determine the difference on the influence of the current according to its direction, and also to ascertain whether any real difference of physiological effect exists when the galvanic trough, or the magneto-electric or electro-dynamic machine, is used. Thirteen healthy individuals were subjected to experiment, and with the following results:—

'1st. That the obvious physiological effect was produced only on completing, or on interrupting, the galvanic circuit.

'2nd. That more vigorous contractions were excited on the completion than on the interruption of the circuit.

'3rd. That the completion or the interruption of the direct current produced more vigorous contractions than the completion or interruption of the inverse current.

'These experiments were made with a Cruickshank's battery, charged with very dilute sulphuric acid. The magneto-electric rotation instrument and the coil machine (electro-dynamic) were afterwards used, and it was found that the same effects precisely were produced, and the same variation in the intensity of the contractions, according as the current was direct or inverse. Fifteen cases of hemiplegic paralysis, caused by lesion of the brain, are afterwards detailed. The results of the galvanic experiments on these cases were as follow:—

'1st. That of the fifteen cases, in only three was there any approach to a greater excitability of the paralysed than of the sound limb, and that in two of these it was manifested only under the influence of the inverse current.

'2nd. That in three of the cases both the coil machine and the battery were used, and with precisely the same results; and that, in one of the cases, the coil machine alone was used, and with a result which corresponded with those obtained in similar cases by the galvanic battery.

'3rd. That in each of the three cases in which a greater excitability existed in the paralytic limbs, the paralysing lesion in the brain was more or less of an irritative kind. In one case, the irritation was probably connected with an incipient process of cicatrisation.

'4th. 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 being exactly proportionate to the power of the galvanic stimulus.'

When in apoplexies of long standing the cellular tissue of the paralysed limb has disappeared, offering thus less resistance to the electric current in its progress from the surface to the nerves and muscles, the muscles of the paralysed limb will be found to contract more powerfully than those of the unaffected limb, and even the sensibility or sensation connected with the contraction of the muscle will not unfrequently be more distinct. On the other hand, a thick hard skin as I have already mentioned, contributes greatly in increasing the resistance to the inducting currents. Meyer* found an increase in the thickness of the epidermis greatly to retard the cure of such cases. Thus it appears from a variety of circum-

* Loc. cit. p. 87.

stances, that each individual case has its peculiarities, and requires the most careful diagnosis and adaptation of the therapeutic agent. It even happens sometimes that an erroneous view may be taken of the actual condition of the limbs in the paralytic, whether normal or affected in consequence of the involuntary resistance offered by the patient to the electric current, and thus the affected limb being less able to offer such a resistance may seem to be in a worse condition than it in reality is.

The evidence produced by Dr. Meyer in respect of the actual condition of the limbs in cerebral paralysis, seems to me complete. I might add my own testimony if necessary, to the results obtained by him from direct observation. In fifteen cases of cerebral paralysis, the electro-muscular contractility and sensibility of the paralysed muscles were precisely as in the normal state.

CHAPTER V.

Rheumatic Paralysis.

RHEUMATIC paralysis* originates in neuralgic and muscular rheumatism, or from other rheumatic causes. In such cases, the electro-muscular contractility and sensibility are at times increased, and at other times diminished. The duration of the disease seems to exercise an influence in this matter, for in recent cases the electro-muscular contractility is normal, and the sensibility is evidently increased so soon as the electrical currents begin to act on the nerves and muscles of the affected part; but in cases

* Lawrance, Rheumatic and Paralytic Affections, p. 71.

of long standing, the contractility and sensibility are diminished. It is a fact known to medical men who practised formerly, when the only means of applying electricity to the body were sparks drawn from the surface, and shocks transmitted through the Leyden jar, that in cases of long standing electricity seemed for weeks to have no effect on the patient; but so soon as the sensibility and contractility became excited and acutely acted on by electric currents, patients could no longer bear the same strength of electricity, and were occasionally cured in no great length of time.

Duchenne notices a peculiar form of paralysis of the fore-arm,* which he considers as rheumatic, and which has its seat in the radial or musculo-spiral nerve. It seems to originate in a cold, and is seldom accompanied with pain. The electric contractility in such cases was always normal, but the sensibility was increased.

In general, rheumatic paralysis is preceded by obstinate pains in several muscles; and when the pains subside, the muscles may still remain paralysed. Now for the rheumatic pains, as well as for the paralysis and weakness which follow, there is no more powerful remedy than localized galvanism; and these remarks apply not merely to recent cases, but to those in which all other remedial means have been used for months in vain. Rheumatic affections are often relieved and cured after a few applications, and nearly one hundred cases might be brought forward in proof of this assertion. By the cutaneous galvanization, the pain is relieved at once, and soon the patient is enabled to use the muscles, for in point of fact the voluntary contractility has not been absolutely lost.

* Lawrance, loc. cit. p. 144.

When paralysis is present likewise, the currents must also be sent through the muscles affected; but the pains which harass such patients must in the first place be removed, and the treatment of the paralysed muscles by the same agent may then commence.

Rheumatic contractions* of the muscles occasionally give way so soon as the pains have been removed; thus Torticollis originating in a rheumatic cause, may be effectually cured by localized galvanism. So also may those cases of scoliosis, or lateral curvature of the spine, which have for their cause a rheumatic condition of the muscles. Duchenne mentions a case in which this morbid condition seized the diaphragm, and asphyxia was the result.

To overcome the contraction, or chronic spasmodic state of the muscles, their antagonists must be brought into play; thus an artificially-contracted muscle or muscles is opposed to a morbid one, and the deformity disappears. Duchenne made his first essay on these diseased conditions in a girl who had a contracted state of the rhomboideus and levator anguli scapulæ. His object was to bring the inferior angle of the scapula to the same level with the normally placed one, and he galvanized the antagonist of these muscles, namely, the serratus magnus. After several sittings, he succeeded in his object, namely, the restoration of the shoulder-blade to its natural position.

In another case he also cured a wry neck, depending on a permanently contracted state of the clavicular portion of the trapezius, by exciting strongly the corresponding clavicular portion of the healthy trapezius. In such a case a surgeon would have divided, by a subcutaneous section, the morbidly-contracted muscle, but the treatment by gal-

* Lawrance, loc. cit. p. 107.

vanism, if equally successful, is greatly to be preferred. The alteration in the shape of the vertebræ which may be presumed to be present in cases of long standing, presents in reality no obstacle to the cure.

The same treatment has been found to answer in contracted muscles of the lower extremities.

I have already spoken of the paralysis of children, and of the paralysis from atrophy, as well in children as in the adult: my own experience of the effects of the remedy in scoliosis is as yet but limited. Certain it is, that many deformities, whose causes have hitherto been deemed exceedingly obscure, originate in a morbidly-contracted state of certain muscles, the remedy for which is to call their antagonists into action. I beg leave to direct the attention of surgeons to this point, in hopes of inducing them to give a trial to a method of treatment, which, though occasionally tedious, and unattended by the *éclat* of a brilliant operation, may yet prove in the end to be preferable to the varied, uncertain, and capricious practice hitherto employed in the treatment of these deformities. On this head I may refer the reader to the researches of Dr. Eulenburg,* of Berlin, who says that of 300 patients affected with scoliosis, or lateral curvature of the spine, 264 suffered from an unequal action of the corresponding muscles on both sides of the body,† an opinion corroborated by Wunderlich and Vidal.‡ The horizontal position, though observed for years, will never improve this condition of the muscles, whether it be the cause or the

* Med. Jahrb. Bd. 90, Hft. 1.

† A Manual of the Nervous Diseases of Man, by Dr. Romberg, translated by E. H. Sieveking, M.D., vol. ii. p. 327; also Vidal Lehrbuch der Chir. & Operat., revised by Dr. Bardeleben.

‡ Handb. d. Pathol. & Therapie.

sequel of the deformity; neither can this be effected by machinery. The subject is one no doubt of great difficulty, even as regards the loss of bulk in what may be called the normal muscles, or those of the opposite side to the contracted.

CHAPTER VI.

Hysterical Paralysis.

In this form of paralysis the electro-muscular contractility is always normal, but the muscular sensibility either greatly diminished or wholly gone. The skin partakes of this loss of sensibility. Localized galvanization proves that in the muscles unaffected by the attack, the sensibility and contractility are quite normal, whilst those attacked by the disease are wholly insensible. That the insensibility of the paralysed muscles is not due to an anæsthesia of the integuments is proved by this, that under an insensible skin, the unattacked muscles were quite sensible when roused to action by the electrical currents. These attacks of insensibility of the skin and muscles most commonly follow a hyperæsthesia of the same parts, as if they had been exhausted by the previous sur-excitement. The power of volition sometimes returns whilst the sensibility may still be absent. These peculiarities in the history of this affection may be best illustrated by a few cases.

Case 1.—A patient who had been for some time subject to hysterical attacks suddenly felt violent pains in the shoulder without any assignable cause, followed by cutaneous hyperæsthesia, and terminating in insensibility of the skin and muscles; she was not in the least conscious of a sharp blow on the shoulder, and the muscular strength gradually diminished. A strong galvanic current was now applied to the muscles of the shoulder, causing them to contract powerfully without the consciousness of the patient. Sensation in the other muscles was normal, the skin of the right lower extremity was in some parts completely insensible; but the muscles were not paralysed, as a weak current sufficed to induce powerful contraction in them, and the electro-muscular sensibility appeared to be quite normal.

The want of the muscular sensibility, on being galvanized, did not depend upon cutaneous anæsthesia, as the galvanization of the healthy muscles produced in them healthy normal sensations, although the superlying skin was completely insensible. Anæsthesia of the skin and muscles followed a former existing hyperæsthesia at the same place, which often takes place in hysterical persons. Sometimes the anæsthesia extends so deeply, that even the periosteum loses its electrical sensibility.

In general the voluntary movements are lost, but they may return, without the sensibility at the same time reappearing.

The therapeutic influence of localized galvanism over hysterical paralysis is not unfrequently most rapid in its action, but unfortunately we cannot rely upon its results being equally beneficial in all cases; for, whilst frequently in many of a very obstinate character a most successful cure has been accomplished, it has totally failed in others of a similar nature: hence fixed rules for the prognosis and treatment cannot be deduced from former observations.

As a general rule in hysterical paralysis, we must direct the electrical irritation to the affected organs individually, and continue the treatment for some time after the return of the voluntary motions, in order to establish the cure.

Case 2.—M. R. was suddenly seized with hysterical convulsions, which recurred every two or three months. The patient complained of a heavy shooting pain in the head, a sensation of continuous closing of the throat, pain in the chest, in the left side, above the pubes, and in the region of the lower dorsal vertebræ, pain on pressure on the shoulder and lumbar region, insensibility of the skin of the left side of the back and face, also of the limbs, which had previously been very sensitive and painful; insensibility of the lining membrane of the eye, nose, and mouth, on the left side, and on the same side weakness of sight, loss of smell and taste. There occurred also a loss of sensation in the palm of the hand and sole of the foot. For the last six or seven months the patient complained of muscular debility in the left arm and feet; she dragged her feet in walking, which now became difficult, or almost impossible. After exhausting all the usual remedial means, galvanism was resorted to on the 10th of October. By a few applications of five minutes' duration sensation was restored to the face: the mode of application was by cutaneous irritation with the electric hand. Very powerful currents, when applied by means of the metallic brushes, excited at first no sensation in the skin of the arm; the irritated parts, however, soon became red and hot, whilst a slight tickling, pricking, and lastly an insupportable burning sensation was felt.

The sensibility of the skin was restored at the irritated points, and became uniform after the electrical irritation.

Sensation in the tips of the fingers, on irritating them with a wet conductor, was re-established in ten minutes, enabling the patient to distinguish pins from needles by the touch.

Oct. 12: Return of the menses after three months' cessation. The muscles were galvanized with very powerful currents, but still the patient did not feel the stimulus in the insensible parts, and it was only after a continued application that the electro-muscular sensibility returned, and she was now unable to bear even a weak application. Nevertheless, the skin remained insensible. If the sensibility of the skin was excited at one point, the muscle immediately beneath became of itself sensitive. The sensibility was quickly restored in the left foot. The patient now feels the floor, but cannot walk, not being able to lift the foot owing to a sensation of weight in the calf of the leg.

During the night the patient had two fresh hysterical attacks, and the whole body, with the exception of the left foot, again became insensible. A slight electro-cutaneous irritation sufficed to arouse the sensibility. Violent pains occurred in the head and chest after this attack, which however completely disappeared after the galvanization.

Nov. 1: Muscular galvanization for ten minutes. In order to establish the cure, the electro-cutaneous irritation was repeated from time to time.

Nov. 10: Several hysterical attacks, which left no insensibility.

Nov. 24: Sensibility of the skin normal throughout, and the patient has power over the muscles of the extremities. The menses appeared for the second time, though slightly. The patient was visited some months afterwards, and continued well.

Sometimes a single electro-cutaneous irritation suffices to cure hysterical paralysis, even when other means have failed.

In many hysterical patients the loss of sensation is greatest on the left side, and is especially accompanied by muscular debility in the left arm. The electro-cutaneous irritation seldom fails in these cases to restore the normal muscular power. In other cases, sufficiently numerous, the electro-cutaneous irritation appears to exert a greater effect than the muscular galvanization, most probably owing to a kind of reflex action. It is impossible to specify fixed symptoms (by the observation of which it may be decided) whether hysterical paralysis will be cured or not by galvanism; but, reflecting on those obstinate cases which have yielded to the therapeutic power of electricity, a great degree of confidence naturally arises in the use of this remedy, though it is occasionally shaken by its total failure in cases which seem precisely similar. Galvanism appears most suited to the paraplegic form of hysterical palsy. Duchenne says that, in one hundred cases, he cured fifty, after every other method of treatment had failed. Electricity is usually resorted to as the *ultima spes*, and the number of cures effected by it would in all probability be much greater were it employed under the same conditions as other remedies. It is known that hysterical paralysis assumes different forms. Briquet has shown that the greater number of cases of paralysis of motion, of cutaneous hyperæsthesia, anæsthesia, paralysis of the senses, of hearing, smelling, taste, nearly always affect the left side: often, indeed, the paralysis is general, and sometimes it is confined to the lower extremities.

The sensation caused by the electrical irritation, even when it is not very painful, appears to those not accustomed to it so peculiar, that it may give rise to hysterical attacks; the more so as the imagination always excites a dread of such applications. It is necessary therefore to commence with very feeble currents, to accustom the patient to the remedy. A decrease of muscular sensibility requires the application of rapidly intermitting currents, which act upon the sensibility, and at the same time call out the return of the movements. This form of muscular galvanization is not always practicable in the hysterical, amongst whom many patients can bear the strongest and most painful muscular irritation, if the intermissions are but slow; rapid intermissions, on the contrary, always inducing an attack of hysteria.

We should in general direct the irritation to the individual paralyzed muscles, without, however, neglecting the irritation of the nervous trunks. The excitement of the cutaneous sensibility is at times equal to the cure of hysterical paralysis. This is particularly the case when the cutaneous sensibility is very considerably diminished. Therefore we should only employ the electro-muscular galvanization during the first two or three sittings, in order to judge of the effect of this method of irritation on muscular paralysis. Should this yield considerably to the treatment, we may combine the local muscular galvanization with the electro-cutaneous irritation. If no improvement results in the condition of the paralysis, we should then apply the localized muscular galvanism, and the painful electro-cutaneous irritation will then be only required for the restoration of the sensibility of the skin.

CHAPTER VII.

General Remarks.

PARALYSIS may be divided into two classes, according to the amount of electro-muscular contractility which remains in the affected muscles; in one class the electro-muscular contractility is diminished or lost; in the other it is unaffected. To the first class belongs paralysis consequent on injury of the spinal marrow, of the spinal nerves, and of saturnine paralysis, or that caused by the poison of lead, and the paralysis which Duchenne calls vegetal. To the second class belongs cerebral paralysis, (originating in injury done to the brain by apoplectic effusions of blood, tumours, softening, &c.), rheumatic and hysterical paralysis.

CHAPTER VIII.

On the Treatment of Paralysis, and of Rheumatic and other Contractions by Localized Galvanization.

BY far the most important part of our subject is the treatment of the varied forms of paralysis and other diseases and injuries of the muscular and nervous systems by this new therapeutic agent. In this section I shall consider many pathological conditions, which may perhaps, be best treated of, or at least in a more interesting way, when discussing the success or the failure of the remedial means.

All experience teaches us that in the treatment of these diseases appropriate remedies and diet must and ought to be combined with the local galvanization, nor should we trust wholly to one remedy. Constitutional and other affections are often combined with nervous and rheumatic diseases, and to these appropriate remedies ought to be applied. As our experience extends, so will no doubt the number of diseases, to which electricity in its new and most successful form, can be applied; but I here purposely avoid speaking at any length, of such diseases, convinced that there is no surer method of injuring the reputation of a remedy, than the claiming for it a universality of power; admitting, however, that in the case of such an agent as electricity, we might stand excused in claiming for it effects commensurate with its extraordinary powers.

Traumatic Paralysis of the Mixed Nerves. Electrical Symptomatology.—Every traumatic injury of the mixed nerves causes a more or less important disturbance in the sensibility, contractility, and nutrition of the muscular system, supplied by the mixed nerves, over which the voluntary powers of the mind are chiefly exercised; in other words, in those muscles which generally act by our will and with our consciousness. The principal symptom of this form of paralysis is the decrease, or even the loss of the electrical contractility and sensibility as proved by the application of localized galvanization, the sure and unerring test of every diminution in these faculties. I shall consider this matter under the heads of—1st. Electro-muscular contractility. 2nd. Electro-muscular sensibility.

I need not recall to the recollection of my readers the presumed and generally admitted functions of these nerves. They exist within the cranium as well as without, the fifth pair of cranial nerves, being in some measure the type of the system.

1. Electro-muscular contractility. When the injury done to a mixed nerve is deep and of a serious character, involving all the primitive fibres, the muscles receiving branches from the injured nerve likewise lose their contractility. But there is something capricious under these circumstances which our knowledge of the physiology of the nerves does not fully explain; the power of the will over the muscle is at once lost, and speedily the electrical contractility; but some fibres will show it whilst others have lost it altogether. Sometimes, and this is most difficult to understand, certain muscles lose a portion of their electrical contractility, but preserve the voluntary motions. On the other hand, in other cases, the affected muscles preserve sometimes their normal electrical contractility and lose what may be called their voluntary contractility. In such cases we must infer from the results, that the nerves could not have been seriously injured, as the paralysed muscles speedily recover their voluntary contractility. An hypothesis may also be offered here in the absence of a rigorous demonstration, viz., that when a nerve is seriously injured, the mobility is not only affected in the muscles it directly supplies, but also in others whose nerves have not been injured. In a case of injury to the nervus ulnaris which was bruised, the muscles supplied by other nerves became also paralysed.

2. Electro-muscular sensibility. This faculty suffers less in muscles whose nerves have been thus injured than the faculty of contractility. Thus in luxation it sometimes happens that, although the nerves of the arm have been so injured as to lessen their contractility, the sensibility may

still remain in a considerable degree, as proved by localized galvanization: in fact, the injury must be serious and deep before the muscles lose their sensibility to electric action. The cutaneous sensibility is still less affected, and in many cases, it continues almost normal; and accordingly it speedily returns under the influence of electricity. Occasionally, however, the cutaneous and muscular sensibility are both destroyed or completely extinguished. In such a case it may be inferred, that there exists no longer any communication between the nerves of the paralysed limb and the spinal marrow and brain, or cerebro-spinal axis, and the prognosis is then most unfavourable.

By local galvanization the condition of the paralysed muscles in traumatic lesions of the nerves may be unerringly diagnosed, and by this method only. Besides, we have the history of the case, and can trace it to a concussion, luxation, contusion, or other injury. But occasionally real traumatic paralysis exists when its cause cannot be detected, as in the case of exostoses or deep-seated tumours.* If the electric contractibility be diminished in the paralytic muscles the case is one of traumatic injury to the nerves supplying the paralysed muscles; if the electro-muscular contractility continues, then it is a case of cerebral, rheumatic, or hysterical paralysis, for in these the electro-muscular contractility remains unaffected. It is not so easy to distinguish saturnine from traumatic paralysis; but even here, supposing the case to be one of paralysis in the muscles supplied by the radial nerve, the

* From some late pathological inquiries I have reason to believe that many cases of atrophy, contraction and paralysis of the limbs, supposed to originate in a traumatic cause, have in reality a rheumatic origin simply.

same muscles would, no doubt, be affected in both, but in a different order, and this order of succession, as I have already explained, is characteristic of saturnine paralysis, in a diagnostic point of view.

Slight cases of local paralysis have been known to follow an injury done to nerves by the arm or limb having been retained too long in a painful twisted posture as during sleep. Such may be classed with traumatic paralysis. They yield readily to localized galvanization. They occur, I think, not unfrequently in the aged, and notwithstanding the advanced years of the patients, might generally be remedied.

Muscles which have lost their electrical sensibility and contractility inevitably become atrophied; but this does not in every case prevent the recovery, although in such cases the prognosis must always be unfavourable; but when the electric-sensibility remains, there is better hope for recovery. Both the diagnosis and prognosis must thus be regulated by electrical experimentation.

It is now generally admitted that nerves, when divided, re-unite; and if the cicatrix be not precisely of the same nature as the original nervous fibril, it at least offers no resistance to the influence, whatever it may be, which passing from the cerebro-spinal axis gives to the muscles their sensibility, perhaps also their contractility, and regulates their nutrition: when this cannot take place through the cicatrix, the nervous influence, like the arterial blood, finds other channels whereby to reach the paralysed muscles. Thus the case is not hopeless, even under such unfavourable circumstances.

Therapeutic effects of local Galvanization on the Traumatic Paralysis of Mixed Nerves.—Paralysed limbs which at first are insensible, become sensitive as the local galvanization proceeds, and a hyperæsthetic or excited state is a sure proof of an approaching recovery. I have already remarked that this fact was known to the ancient electricians, derived from what they saw take place in the severe rheumatic paralysis with contracted and distorted joints, usually described as caused by rheumatic gout, aided by exposure to cold and hardships. Local galvanization quickly removes the pains which accompany such cases at all times, and which are especially excited by attempts made to move the joints. The increased sensibility spoken of above, disappears on a return of the voluntary power over the muscles.

It is a remarkable feature in the history of traumatic paralysis, that this form of paralysis is frequently, if not uniformly, accompanied with a sinking of the temperature of the limb, to an extent occasionally of 5° or 6° difference between the healthy and the affected limbs. The patient, moreover, complains of a sensation of cold in the paralysed limb. When the lower extremities are the seat of the disease, the circulation is imperfect, the saphaena as it were, contracted, and the skin bluish and œdematous. By local galvanization these symptoms quickly disappear, often indeed after a few applications. The therapeutic effect of galvanism acts more slowly, it is true, in the restoration of the nutrition of the limb, but even over this it at last exercises a restoring influence.

Effects of Electricity on Muscular Contractility.—It is usual for the voluntary power to precede the return of the tonicity of the muscles. Thus, under the influence of local galvanization, in cases where the paralysis depends on an injury to the radial nerve, the fingers may be seen to extend and the wrist to be raised or extended long before the patient can act thus voluntarily. The cure takes place, first in the muscles nearest the centre or larger trunks of the nerves, and the order of the return of the functions is first the hyperæsthesia of the muscles, next the nutrition, then the tonicity appears, and lastly the voluntary power.

It is a singular and anomalous circumstance in the history of these pathological conditions of the muscles, that occasionally the voluntary power may have returned whilst the electro-muscular contractility may continue lost for a long time; and yet this contractility is present in persons recently dead.

Duration of the Treatment.—The average period necessary for the treatment of traumatic paralysis has been estimated by Duchenne, Meyer, and others at three months, but many cases require several years; my own experience confirms this view: even when it fails in effecting a cure, it greatly alleviates the suffering of the patient, and seems to delay, if not to prevent altogether, those sad results which are sure to follow when the disease is left to take its own course.

Time of Application.—Formerly the opinion prevailed that the application of electricity to the paralysed muscles soon after the coming on of the disease, might contribute to prevent the atrophy sure to follow such accidents. Experience has shown the opinion to be unfounded and erroneous. The electrical agent cannot in any way replace the nerve-influence, or prevent the coming on of atrophy: the speediest application possible of electricity in any form fails altogether in preventing the coming on of atrophy in muscles whose nerves have been deeply injured. But after a period of six or ten months, the muscles begin again to be nourished and developed, and this so constantly that Duchenne at last drew the conclusion, that the remedial effect of local galvanization was speedier in old cases of traumatic paralysis than in recent ones. So long, indeed, as the atrophy is proceeding, it would seem that the local galvanization of the muscles is useless, or even hurtful; but there comes a moment when the treatment may be commenced with a prospect of success. The following rules in respect of this important matter have been laid down by the experienced physicians so often referred to throughout these Contributions.

1. In traumatic paralysis, not accompanied with a loss of the electro-muscular contractility, the treatment by local galvanization cannot be commenced too soon.

2. In those cases wherein the electro-muscular contractility has been lost or greatly diminished, it will be preferable to wait from four to ten months before commencing the treatment, and always the longer in proportion to the diminution of the muscular sensibility. Again, every muscle must be galvanized according to the actual condition of its electrical contractility, sensibility, and nutrition. A strong and quickly striking current is to be transmitted through muscles which are much atrophied, insensible, and but little contractile.

The duration of a sitting may be limited to ten or fifteen minutes; to a single muscle the application for the space of a minute is often sufficient. A good deal of manipulative dexterity, combined with a careful previous electrical exploration of the individual muscles, is essential to the successful treatment of every case. It is needless to say that, as in all practical arts, this can only be acquired by experience.

It were easy to support the preceding observations by numerous cases which have occurred in the practice of Duchenne, Meyer, and myself; I shall allude, however, to but a few, and in preference, select those which seem to me best calculated to elucidate and give support to a rule of practice.

After luxations of the humerus, it occasionally happens that the patient does not recover the use of the limb; that although the reduction be speedily and completely effected without any unnecessary violence, and even with much dexterity on the part of the surgeon, the limb begins to waste away, whilst the patient has lost over it all voluntary power. A case of this kind occurred in the practice of M. Duchenne. Despite the application of local galvanization in the hands of the inventor of the method, the atrophy of the limb continued to make progress, until the muscles of the arm and fore-arm lost their rounded outlines, and resistance and firmness under pressure: the hand was withered up; the thenar and hypothenar eminences in the palm of the hand disappeared; the tendons of the flexor projected in the hollow of the hand, and on the back of the hand were deep furrows, showing the atrophied or wasted condition of the interossei. The muscles of the shoulder showed a somewhat less development than those of the arm.

During the treatment, the deltoid recovered first; a sur-excitement of the nerves of the arm followed; soon afterwards the same took place in the fore-arm, and now the voluntary power began to appear first in the region of the wrist joint: the first movement of this kind observed, was the bending of the wrist, and of the two distal phalanges of the fingers, next the extensor of the proximal or first phalanges, the extensor of the thumb, and lastly those of the wrist. In a few months more the supinator longus had recovered its full development and power; and yet these muscles did not as yet contract under the influence of the strongest electrical currents, showing the voluntary contractility to be distinct from the electrical and yet capable of being restored by local galvanization. The accident occurred in February, 1850: in February, 1852, besides great improvement of the muscles of the arm and fore-arm, the interossei had regained their power over the phalanges, and the ball of the thumb was also being again developed; but still the movements of the limb were not complete; the limb was cold, showing how much the capillary circulation had suffered. The patient finally recovered the use of his limb to a great extent. The muscles of the hand were the last to recover.

It were interesting, did time permit, to follow the application of the new method to those injuries of the shoulder and other joints in respect of which it is admitted that the pathology is most obscure, and the treatment by the ordinary means all but useless. I allude to the train of symptoms and pathological changes following a blow on the shoulder, symptoms which have puzzled the best anatomists and pathologists, and what is still more unfortunate have defied generally all the ordinary therapeutic means. With the outline of one such case, I shall conclude this view of traumatic paralysis.

But before proceeding, it is but doing justice to Dr. Duchenne, candidly to admit how minutely and carefully he watched each case; the result was the discovery of the true action of many muscles, and more especially of the interossei of the hand. Respecting the true functions of these muscles anatomists, as we have seen, had been always in doubt, and the matter had been debated since the times of Vesalius and Columbus of Padua. A single well-conducted, well-observed case of paralysis of the arm, enabled Duchenne to decide this long-disputed point.

A man named Haumont, æt. 45, was struck on the shoulder by a woman falling on him from the fourth floor. On awaking from the stupefaction caused by the blow, he felt neither pain in the shoulder, nor any inability in the use of his arm; but on the next day he could not abduct it or remove it from the trunk, and on being taken to the hospital, the surgeons diagnosed an injury done to the nervus circumflexus humeri. For two months he was attended to in the hospital with no benefit, and in the October following the injury, he first applied to Duchenne. On examination it was found that the deltoid muscle was becoming atrophied; there was pain in the limb; the movement of abduction, and I presume, of extension or elevation, was lost; the flexion of the fore-arm was difficult: a feeling of cold in the shoulder, but the sensibility was normal. On the local application of galvanism, it was ascertained that the two anterior thirds of the deltoid did not contract when galvanized; the remaining third contracted, though not so strongly as in the normal state. The supinator longus had lost much of its electrical contractility. The remedy was now applied as strongly as possible, and in two months the cure was complete; but the deltoid muscle had not in six months recovered fully its electrical contractility.

Cases of complete paralysis of the deltoid muscle not unfrequently present themselves to the surgeon, in which the muscle has become paralysed as it were without a cause. On exploration with localized galvanism, it will, I think, be discovered that in such cases the paralysis is not confined to the deltoid, but includes other muscles, as the trapezius, the pectoralis major, the serratus magnus, wholly or partially.

Such diseases have been known to come on suddenly during sleep, even in middle-aged persons. It is not unusual for physicians to ascribe them to some cerebral or intracranial affection, but to test such a diagnosis we have only to apply local galvanism, and ascertain by its means the exact condition of the nerves and muscles. In cerebral paralysis, the muscles retain their electrical contractility, and do not become atrophied: in the cases I now speak of the muscles affected lose at first more or less completely their electrical contractility, and become atrophied.

It has happened that an exostosis from a syphilitic origin or otherwise, has proved the exciting cause of such a disease as the one last alluded to, by injuring the brachial plexus.

The benefit to be derived from localized galvanism is not confined to such cases as I have just described: it has been used with much advantage in paralysis of long standing, caused by necrosis and abscess of the humerus. In one such case, the disease had existed for several years; notwithstanding, the patient recovered perfectly the use of his arm. I prefer mentioning these cases to others, because most of them were treated in public hospitals, and in presence of many distinguished surgeons.

One of the most remarkable was a patient of the name of Musset, aged 29, whose right fore-arm had been injured by machinery, and who had in consequence lost the use of his hand. Four years after the accident, and after the failure of all other treatment, he was placed under the care of Duchenne in the hospital La Charité, where in time he so recovered the use of his hand as to act as a clerk to Duchenne. The treatment was continued for nearly four years, but this slowness of recovery was undoubtedly due to the frequent interruptions of the application. A recovery under such circumstances constitutes one of the most remarkable cases in surgery.

The treatment has been equally successful after gunshot accidents, and cases are given in support of this statement. One fact comes out prominently from the numerous details I have examined, namely, that time alone does little or nothing for such cases. 'Expectant surgery' is here of no avail.

The treatment of the saturnine paralysis is to be conducted on the same principles as the traumatic; the sittings are not to be extended beyond ten to fifteen minutes, and the electricity transmitted through the nerves affected, by quick intermitting currents.

CHAPTER IX.

On Paralysis caused by Cerebral Apoplexy.

Of all the cases of paralysis to which electricity has been applied, those originating in cerebral hæmorrhages have proved the most untractable, and the same may be said of hemiplegia originating in a disordered state of the cerebro-spinal axis, in which, however, the mental faculties have not at any time been disturbed. Nevertheless it is certain that many paralyses caused by cerebral hæmorrhages have been cured, and others greatly improved, by electricity as now employed. On the other hand, a spontaneous cure takes place in many cases, commencing first with the lower extremities, and extending thereafter to the arms. M. Duchenne commences his treatment after the lapse of four or five months from the time of the apoplectic attack, by which period it is hoped that the effused blood may have been mostly absorbed. The results were as follows :—

In a twentieth part of those treated for cerebral paralysis, the cure by electricity was complete ; in about a fourth part of the whole number, the patients were improved, but generally no visible change could be perceived. The reason of this want of success depends no doubt on the unfavourable pathological condition of the organ injured.

It was remarked, that those patients who did not suffer from a contracted state of the flexors, in addition to the paralysis, were quickly improved, and even cured by localized galvanism ; but it was the reverse with those who exhibited such a symptom. In all cases, great caution must be used in applying electricity, for it has happened that a new apoplectic attack has immediately followed its use.

On the other hand, paralysis of the face and tongue which occasionally remains after the disappearance of the other symptoms, readily gives way under the use of electricity, even in long standing cases. In a patient fifty years of age, in whom this form of paralysis had existed for seven years, the disease was removed by twenty-six applications. A careful diagnosis must first be made between cerebral paralysis, and that arising from an injury to, or some local affection of, the facial nerve. A medical friend assures me, that about thirty years ago it frequently happened that physicians mistook the one for the other. In cerebral paralysis of the muscles of the face, these muscles possess their electric contractility, whereas in the other class of cases, they have lost it. Thus local galvanization is at once the best means for establishing a correct diagnosis, and effecting a cure. To apply galvanism with safety, and so as to avoid any cerebral reflex actions taking place, the conductors must be placed as near as possible to each other.

Long sittings are to be avoided: if after fifteen or twenty applications of the remedy the muscles have not regained their voluntary power, we cannot hope for much success from a longer continued application of the treatment; but the treatment may be resumed at a future time.

PART THE SIXTH.

We have now to consider, in the last place, the application of electricity by induction to certain other pathological conditions, many of which have proved intractable under the ordinary modes of treatment. Alive to the uncertainty pervading all such inquiries, to the necessity for a most extended experience, to the uncertainty even of experiment itself, though planned by genius and executed by the most skilful hands, I shall, I trust, speak with all due caution, anxious and desirous neither to undervalue the facts of others, nor to mislead my professional brethren by giving to my own experience an undue value.

The failures of preceding experimenters in the pathological part of my subject have been already glanced at, and I need not, therefore, further allude to them: the methods at present in use, the scientific character of the observations, the superiority of the electric machines now employed, and the publicity with which many of the cases have been conducted, assure to this therapeutic agent, as it is now employed, not only a vast superiority over all previous observations, but further entitle the method to the most attentive consideration of the medical profession.

As it is not my intention by a systematic enumeration of the various diseases in which electricity has been employed by myself and others, to lay claim to the merit due only to an elaborate treatise on electricity as a therapeutic agent, I shall confine my remarks chiefly to those cases of paralysis, muscular contraction and other diseases I have myself observed in practice, and to those observations of others of the authenticity and correctness of which I feel well assured.

CHAPTER I.

Morbid Affections of the general sensibility of the Cutaneous Surface.

The disease of which I now speak assumes two forms; in one the sensibility is exalted to a painful extent; in the other, it is so diminished that the skin becomes insensible. A theory based upon physiological experiments on the lower animals, but unsupported as yet by any direct appeal to pathology, would ascribe to a lesion of the posterior fasciculi of the medulla spinalis and their membranes, certain of these hyperæsthesias of the integuments. In all such cases it is evident that a careful diagnosis must first be made, inasmuch as, should the hyperæsthetic condition be caused by inflammation of the spinal cord, the employment of electricity would most assuredly aggravate the symptoms. It is such accidents as these which render the employment of electricity dangerous in any but medical hands; and its hap-hazard employment in former times contributed, no doubt, greatly to lower its character with the more prudent of our profession. But in the hysterical hyperæsthesia, Duchenne, with the aid of powerful electrization, has met with real success in the treatment of such cases. He admits, however, that at least a half of the patients treated for this disease have been but momentarily relieved, and that the cutaneous hyperæsthesia of hysterical women is one of the most obstinate of complaints.

It is otherwise with cutaneous anæsthesia, or loss of sensibility, general or partial, of the integuments; we have the assurance of Duchenne (and he gives many cases in support of his statement) that this disease yields readily to the use of the electricity of induction. Where the loss of sensibility is complete, or nearly so, the apparatus employed must be at its maximum of power with rapid intermissions, and the metallic brushes retained in their place on the skin until it becomes red, showing that an organic action is taking place. Sensation now returns and the electric action must be sustained until the feeling becomes intolerable. For the brush, flat conductors are now to be used, and by these means it has happened that the sensibility of a limb has been restored in a few minutes. But generally, and especially where the loss of sensibility is general, the electric power must be widely and repeatedly used over extended surfaces, for the very fact of localization, so valuable a power under other circumstances, here limits the benefits to be derived from electricity to the anæsthetic surface acted on. Hysterical women are frequently the subjects of general anæsthesia, which is apt to return after having been once or twice removed, but this may also be overcome by a frequent renewal of the operation.

The palms of the hands and soles of the feet are subject to attacks of loss of sensibility; against these complaints, especially when the disease attacks the soles of the feet, no remedy will be found more successful than electricity as now used; but we must not be too sanguine in such cases, for all who have practised localized galvanization must have repeatedly met with complete failures in cases in which they had hoped for success.

CHAPTER II.

On the Treatment of the various forms of Neuralgia by Localized Galvanism.

HAVING already discussed the important subject of paralysis, of muscular rheumatism, of consecutive contractions, and of what the ingenious discoverer of localized galvanism has called the pathological physiology of contracted limbs, of atrophy and paralysis of the muscular system, and of special muscles or groups of muscles, I shall sum up in this part of my work the amount of progress made in respect of some affections which seem to depend upon or to be more immediately connected with the nervous system; admitting always, however, that the consideration of the two classes of disease cannot well be held as distinct, since it is through the nerves that we act in all. To these I shall add what has been made out in respect of the diseases of the deeper organs, those I mean which derive from the sympathetic system of nerves the peculiarities of their vitality or mode of life.

1st. Neuralgic affections of the various nerves are admitted to be a class of diseases of the most intractable nature, resisting at times every form of treatment. The resistance offered by the disease to every attempted remedy, extends even to modes of cure of an extremely severe nature, of which one at least was derived from the veterinary art: I allude to the cauterization of the helix (external ear) for sciatica. One fact resulting from these somewhat coarse experiments seemed to be the establishment of a law or principle, namely, that a sudden and acute pain developed at any point of the cutaneous surface was attended with the effect or result of profoundly modifying certain sciatic neuralgies. Now in order to produce such a painful impression there exists no method so safe and so sure as galvanization of a part of the surface. In every respect it is superior to cauterization by the heated iron, which disorganizes the structures and leaves a slough with all its unpleasant and painful consequences. To produce this sudden and acute pain, it is not sufficient in general to electrify the cutaneous surface over the course of the sciatic or other nerve affected; a more sensitive point must be sought for, and this may be attained by applying the conductor to the helix, or to the nasal septum. This must be done with the greatest caution. Nevertheless, the electrization of the pained part proved the most successful method in the hands of Duchenne, and is likely to supersede the employment of blistering plasters, of acupuncture, &c. He succeeded in the most obstinate cases, after every other method had failed, and he selected such cases in the hospitals that the superiority of the method might be satisfactorily demonstrated.

2nd. In the painful and distressing disease called angina pectoris, originating occasionally, no doubt, in a neuralgia uncomplicated with organic lesions,* electricity has been employed to relieve the alarming symptoms accompanying a paroxysm of the complaint. It seems to be from this paroxysm that the chief danger to the patient flows; to arrest it, therefore, is of the utmost importance. Now the remedial agents hitherto employed, have all but completely failed in procuring relief, and this led Duchenne to attempt the method of galvanization. He selected for his experiments two patients in whom the angina seemed to be *essential*, that is, uncomplicated with any organic lesions, and he succeeded in both. To future inquirers must be left the task of supporting and confirming these first attempts.

CHAPTER III.

On Paralysis of the Vesica Urinaria.

THERE remains then but two forms of disease of which I think it necessary to speak in this chapter; the first is, the paralysis of the bladder, of the intestines, and of the muscles assisting their functions; the second, a condition of the muscular system called atrophy, a result of which is, no doubt, a form of paralysis, constituting indeed one of the most striking and troublesome symptoms of the disease.

1st. Surgeons are, perhaps, occasionally too hasty in their inferences respecting the condition of the sub-mucous muscular fibres forming the muscular tunic or tunics of

* Handbook of Physiology, Dr. Baly's ed. vol. i. p. 666.

the bladder, and in ascribing to a paralysis of these submucous fibres, what is really due to paralysis of the abdominal walls themselves. Surgeons would do well to review carefully the evidence afforded by the application of electricity to such diseases, and by a careful and well-matured diagnosis discriminate between cases which must have for their origin causes entirely opposite. I feel assured that in many cases of this painful affection electricity might be safely used as a substitute for the passage of the catheter. I even think, that dysuria may arise from paralysis of the diaphragm. Such is Duchenne's opinion; but he does not deny the existence of paralysis of the muscular tunic of the vesica urinaria itself. To remedy this morbid condition, he sometimes introduces a silver sound, free at its extremity, but isolated by a canula of caoutchouc throughout the rest of its extent; a second excitor is placed in the rectum, and he applies the olive shaped excitor over the fundus of the bladder. In all cases the bowels must be emptied, otherwise the electrization will assuredly extend to the sacral plexus.

When it is impossible or unadvisable to introduce an instrument into the bladder, electrization may be practised by the rectal excitor alone, aided by a humid excitor carried externally over the surface of the hypogastric region.

The vesica urinaria is subject to anæsthesia as well as to paralysis; for this, localized galvanization is recommended to be applied to the inner surface of the bladder, and the same method has been found of service in anæsthesia of the reproductive organs in man and woman; but it is needless for me to remark how careful the electrization must be in all such cases.

Connected with this subject is the application of localized galvanization to incontinence of urine, constipation and descent of the rectum in consequence of atony of the sphincter. Observations are given in Duchenne's work tending to the establishment of the pathology of this latter disease, differing much from all preceding views. To discuss this matter would lead me into details, which of necessity would extend this chapter beyond its prescribed limits, and I beg leave, therefore, to refer my readers to what has been said respecting it by continental authors of repute.

CHAPTER IV.

On Muscular atrophy accompanied with paralysis; the fatty atrophic palsy of Children.

ALTHOUGH the diseases I now consider, the *muscular atrophy*, *fatty* and *progressive*, and the atrophic *paralysis* (also fatty) of children, have been already alluded to in the chapter on paralysis, I have thought that as the subject involves other considerations as well as the mere paralysis, a brief outline of their pathology might conveniently follow the various forms of disease I have touched on in this contribution.

The progressive muscular atrophy is a disease, which, up to 1849, all physicians regarded as constantly fatal. Once developed, its progress could not be arrested. It is looked on as hereditary, and terminates in some cases, at least, by an asphyxia caused by a destruction of the respiratory muscles.

Since that period Duchenne has been fortunate enough to arrest the progress of this afflicting and sad disease, so long as the fatty degeneration which accompanies the atrophy has not seized on the whole of the muscle; having proved in a way satisfactory at least to himself, that the fatty degeneration begins only in the last period of the disease, and that the atrophic period which precedes this, and is characterized by fibrile contractions and by the presence of irritability is of very long duration. The atrophic condition is ascertained by a simple inspection of the patient; the absence or the presence of the fatty degeneration, can be determined only by localized galvanization applied over the trunks of the nerves supplying the muscles with motor power. It was on such patients, as I have already remarked, that Duchenne performed those interesting electro-physiological and electro-pathological experiments which the method of localized galvanization enabled him to do.

But it must still be confessed that the theory of this disease is most obscure, whilst, as yet, the mysterious therapeutic agent, whose powers we now discuss, has but partially succeeded in relieving the symptoms or in arresting that *progression* towards destruction which constitutes so prominent a symptom. The muscles become atrophied because they are not nourished;* or, as in the case of young persons, they are never developed. A friend informs me of two cases of this formidable disease, for which he was consulted, and for which every remedy (excepting localized galvanization) was tried in vain. They were the two sons of a family of wealth and rank,

* Aran. Archives générales de Med. 1850, and Oppenheimer Ueber progressive fettige Muskelentartung. Heidelberg, 1855.

and both died about the same time, the one at about fourteen years of age, the other at twelve. There was a peculiarity in the limbs and form of the father of these young gentlemen which led my friend to ascribe it to an hereditary, or, at least, congenital defect. Sir Charles Bell was consulted in the case but with no advantage. Now, why this defective condition of the nutrition of the muscles? Monsieur Cruveilhier* calls the disease atrophic palsy, a name which, Duchenne says, gives not only a completely erroneous or inexact idea of the complaint, which is, in fact, a disease of nutrition, but leads to a dangerous neglect on the part of the physician of the stage of the disease, during which a cure is possible. It leads, in fact, to the idea, that the paralysis is the first symptom, and, accordingly, in accordance, I think, with this view, has been devised and applied that theory which would ascribe to an atrophic condition of the anterior or motor roots of the spinal nerves† the disease we now consider. But the pathological condition of these nerves has not, I think, been fully proved in these cases, whilst it is difficult, in accordance with the admitted facts of modern physiology, to see in how far the nutrition of the voluntary muscular system can be so dependent on a sound state of the motor nerves. In conclusion, it may be remarked, that the volume of the muscular fibre is not diminished in atrophic palsy.

Every physician knows that children, and more especially infants, are subject to a paralysis, which, at times, may be removed with great rapidity under a variety of treatment, at other times resists all therapeutic agents.

* Bulletin de l'Académie de Médecine. Paris, 1853. T. 18.
† Touvenet, Gaz. des Hop. 1851.

According to the researches of Duchenne the form of paralysis, accompanied with a fatty degeneration of the muscular fibre, is distinct from that which may continue for a great length of time without any such degeneration taking place. In the former the paralysed muscles lose by degrees their contractility and electric sensibility. When these happily return, they do so along with their voluntary contractility. But should the symptoms persist, they are followed by deformities of all sorts; of the shoulders and trunk, pelvis, feet, &c. He concludes, from his observations, that the disease has its origin in the spinal marrow. Some are readily cured by a salt-water bath, and a few simple remedies; others resist all treatment. A medical friend informs me that a case of complete paralysis of the lower half of the body which occurred in a child two years of age, was cured in a fortnight by sea-bathing and never returned. Such cases must have occurred to all who have enjoyed an extensive field of observation; but so also must the reverse. Thus the prognostic becomes extremely uncertain, and ought to be given with every caution. Whatever view may, in the progress of pathology, be taken of the true nature of this complaint, it seems evident, that no remedy presents more *rational* hopes of success than localized galvanism; other forms of electrization are not safe in children and ought not to be employed. Thus no one would venture to recommend in very young children the electrization by reflex action, which most assuredly would act on the nervous centres, so delicate and excitable in children; nor should we use the electro-cutaneous excitation, the galvanization by rapid intermissions. But no such objections can be made to localized galvanism as proved by repeated experience.

Here, as in all other cases of paralysis, the first object is to determine what muscles possess and what muscles have lost the power of electro-muscular contractility; for, on its presence, though not wholly so, depend the hopes of a more or less speedy return of voluntary contractility, the object and aim of all treatment; and with it, to a certain extent at least, the nutrition and development of the muscles affected. Thus the electro-muscular exploration becomes at once a means of diagnostic and a method of cure.

CHAPTER V.

On Paralysis of the Organs of the Voice; Aphonia.

In cases of this troublesome affection, which, in particular seasons of our ever-changing climate, attacks so many persons, I have repeatedly found the application of localized galvanism immediately to remove the complaint. Miss C—, a young lady about eighteen years of age, and of a nervous temperament, caught cold and lost her voice. This faculty was completely suppressed. For some time the electricity was applied to the front of the throat but without any good effect. I now changed the mode of galvanization, applying one conductor directly over the line of the inferior laryngeal nerves in their ascent towards the larynx, and another over the muscles of the larynx itself. So soon as the current was established the patient gave a loud scream and shortly afterwards completely recovered her voice. Thus does localized galvanism prove in man, what physiologists from Galen to Majendie, by oft-repeated vivisections, had endeavoured to establish and never very satisfactorily, that the recurrent nerves are the instruments by which the will acts on the intrinsic muscles of the larynx, and that the phenomena of the voice depend on their integrity.

Many cases have been recorded of persons who had been treated successfully by electricity long prior to the discovery of the inductive currents and of localized galvanism. Such a case is recorded in the 'Memoirs of the Academy of Sciences in 1753.' A girl, aged 14, had lost her voice, and became at the same time paralytic from fright; she recovered by the application of the common electricity of friction. The unknown and mysterious power of the will over the nerves and muscles of the larynx, suspended, interrupted, and destroyed by the influence of terror, was here restored by merely exciting that contractility of the muscle over which electricity exercises its influence. Neither physiology nor pathology, it is true, give us any clue to the explanation of such cases, but the facts which most interest man, still remain unassailed; the loss of voluntary power over a muscle implies no permanent injury done to the contractility of the muscle nor to the conducting power of the nerve, as proved by the muscle obeying the influence of electricity transmitted to it through a peripheral portion of the nerve supplying it. That the condition so generated in a portion of the nerve, should, in the first instance, extend to the muscle, is not so much to be wondered at as its retrograde action towards the sensorium commune, yet the facts I have already mentioned and to which many others might be added, prove that this is the case. Cæsar

Pellegrine,* cured of aphonia in twelve applications a young man, aged 24; the disease was of sixteen months' standing. Dr. Walter† was equally successful in the case of a man of 45. In the journal containing these cases will be found in the number for 1847, the case of a woman, aged 24, who lost her voice, in consequence of chronic laryngitis, caused by syphilis. She recovered completely on the third application. Duchenne also gives two cases in which the electricity used, as here recommended, proved entirely successful. The first was that of a young lady, aged 17, who suffered from aphonia for seven months; she recovered in thirteen applications; in the second case, the loss of voice was of two and a half years' standing; the disease yielded to four applications. In this latter case every imaginable remedy had previously been unsuccessfully resorted to. Lastly, electricity succeeded in the hands of M. Sédillot,‡ after every other method had failed. I should tire the reader were I to mention all the cases already recorded of the success with which localized galvanism has been applied to aphonia, under a great variety of circumstances; but this may be said of them that they seem fully to warrant the encomiums bestowed.

CHAPTER VI.

Paralysis of the Pharynx and Gullet.

THESE affections come on suddenly or by degrees. The cases on record in which electricity was had recourse to,

* Canstatts Jahrbücher, 1843. † C. J., 1845.
‡ Acad. de Science, 24th Dec. 1855.

lead us to form a high opinion of its efficacy.* Monro, among several successful cases, relates one of a patient who was only able to swallow when sitting upon the electric stool.

Thus gradually has the application of electricity to the diseases of the nerves and muscles, been so improved as to merit a high place in the list of the therapeutic agents which man brings to bear on the evils afflicting humanity. On its first introduction, we are told that M. Sauvages relieved so many persons affected with palsies that a sort of furor was raised in the public mind to such an extent, that the priests were obliged to interfere to protect him from the populace, who ascribed his success to witchcraft. A reaction naturally followed this extravaganza, and the method being devoid of all scientific basis, practised by the empirical and by those to whom the anatomy and physiology of man were unknown, fell speedily almost into abeyance, and the phenomena exhibited by this the most powerful of Nature's great physical agents came at last to be exhibited to children and to the ignorant as something amusing, and at the same time wonderful; a prejudice even arose in the public mind against it, in consequence of the foolish practice of giving severe shocks to persons not dreading nor expecting such a trial. Rescued at last from this low condition, and recognised by practical men of the highest eminence as a most powerful, perhaps the most powerful of nervous excitants or stimulants, we may, with all safety, predict a new career for medical electricity. That much remains to be done I am free to admit; the facts, as they appear, must be reconciled to the admitted physiology and pathology of the

* Romberg, vol. ii., p. 345.

day, or that physiology and pathology at once abandoned. There was a period in medicine, I allude to the commencement of the present century, when, influenced perhaps by the labours of the illustrious pathologists of a past age — Lieutaud and Morgagni, Bonetus and Baillie, diseases accompanied with organic changes of the organs were held to be uniformly incurable; we now know that they are not so. There was a period, and that not a remote one, when amputations of the limbs were practised for diseased conditions which the modern surgeon now treats without mutilation; in this new phasis of medicine and surgery, medical electricity enters and takes its place, not without well-grounded expectations of its therapeutic powers being shortly fully recognised and acknowledged in all the departments of the healing art.

THE END.

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