HYDRO-ELECTRIC METHODS

IN

MEDICINE.

W. S. HEDLEY, M.D.

Dr. West.
with Compliments.
Edgar F Cyriax

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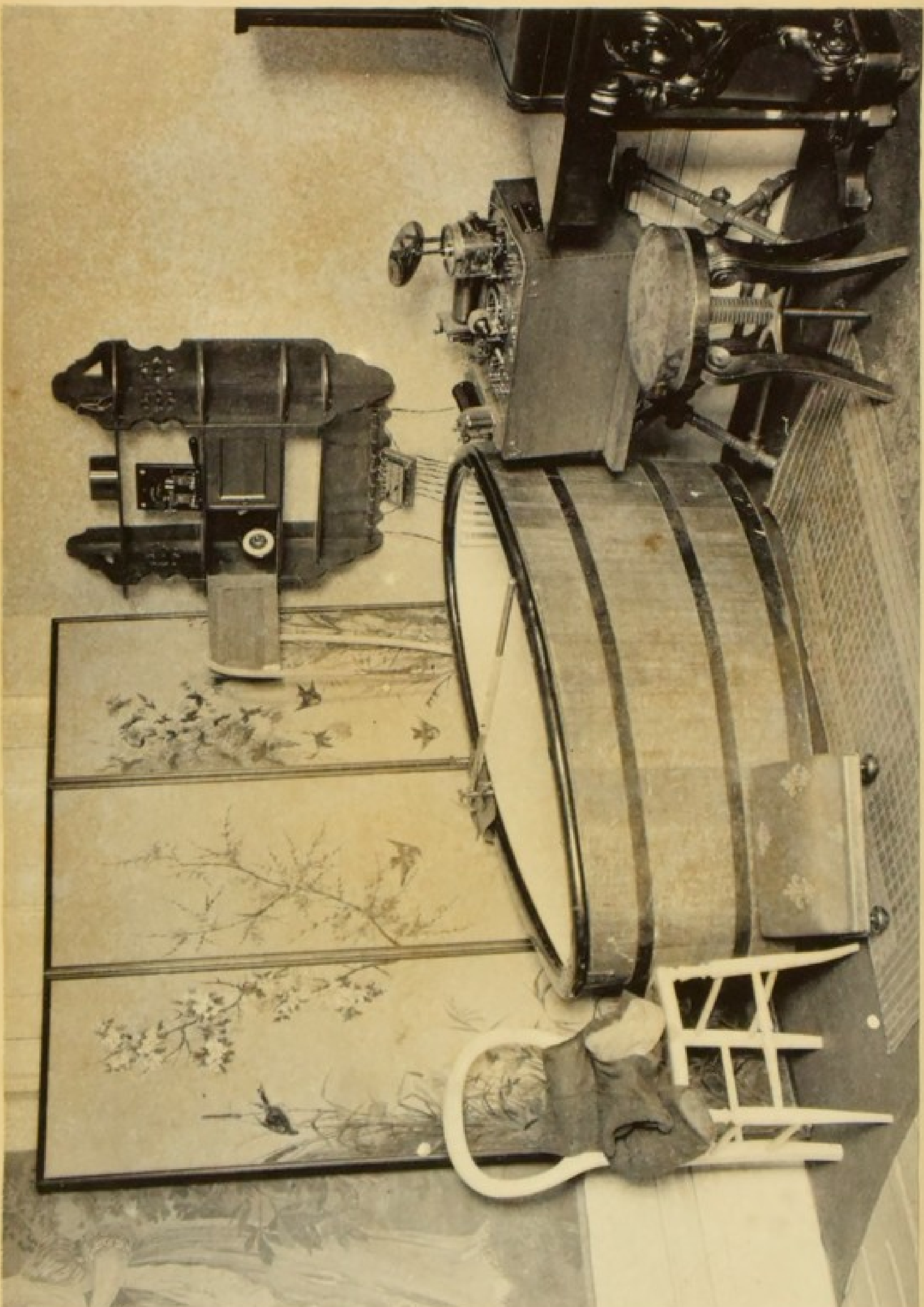

THE

HYDRO-ELECTRIC METHODS IN MEDICINE

WITH CHAPTERS ON

CURRENT FROM THE MAIN, CURE-GYMNASTICS,

ETC.

(The Volume being largely a Reprint or Elaboration of Articles that have already appeared in "The Lancet," "British Medical Journal," etc.)

BY

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PREFACE.

THIS is not a treatise, neither is it a handbook. It is only a collection of electro-medical papers "connected up," not even "in series," but rather "in groups." And the first group gives it a name. Its chief aim is to examine certain questions from some special, perhaps rather neglected, standpoints. Still, inasmuch as it necessarily deals with many points common to all forms of electrization, it is not without a claim to a certain measure of completeness. It tries above all things never to lose sight of the fact that it is necessary to approach questions of this kind by two distinct converging routes, that of medicine on the one hand and of physics on the other.

It is a protest against the idea that electro-therapeutics is merely medicine with a "streak" of electricity through it.* The electrical physician

* The following is an extract from an original article in the *British Medical Journal*, Nov. 28th, 1891, p. 1143 (but of course is only to be taken as expressing the individual views of the writer):—"We may state that the amount of knowledge of electricity that is required to carry out this" (*i.e.*, Apostoli's) "treatment can be very easily acquired by anyone who is willing to devote a little time to obtain it from books and from conversation with electricians, but we consider that something more than a

must be an electro-physicist as well. I do not mean to say that he must have undergone a course of "very serious mathematics," or have fully faced the terrors of "the long *f* and the little *d*." With such a knowledge of arithmetic and simple equations (and may I add of the first Book of Euclid) as every physician is supposed to possess, he is competent to acquire a sufficient electrical knowledge to meet most of the problems that bear on a rational application of his art. He may take the ohm for granted without troubling himself about the intricacies of its "evaluation," in the same way as he may be a rational practitioner without being master of all the subtleties of physiological research. The aphorism that "electricity is measurement" must, however, be recognized. It holds good of electro-therapeutics as well as of other branches of the applied science. But of course with vast differences, vast to an extent that can, perhaps, only be appreciated by the physician himself. When our friends, the "pure physicists," smile (and not without reason, I admit) at the inexactness of our electrical methods, do they always give due weight to the fact that we have to do with

mere smattering of knowledge of diseases of women is necessary to avoid mistakes." In other words a mere smattering of electrical knowledge *is* sufficient. No practical acquaintance with electrical work is necessary to make a man competent to carry out Apostoli's method, *i.e.*, to handle a current of say 200 or 300 milliampères running through a woman's body! But even this modest standard of electrical knowledge does not seem to have been attained in a recent case where a "fully qualified" medical man applied for "a faradic battery to electrolyze unsightly hairs."

an animal organism and not with a carbon filament or a copper wire; that we are dealing with a structure possessing inexplicable vital activities which may respond, in the most diverse and opposite ways, to the same electrical stimulus, that we are working through a heterogeneous conductor of infinite complexity—varying in different individuals—changing even in health from hour to hour, and in disease undergoing alterations that are quite beyond our ken?

In adverting to these points I am not putting in a plea for inexactness, but simply pointing out differences and looking difficulties in the face. After all is said the aim of our investigations and the basis of our art must be measurement. Many electro-medical phenomena that are helplessly put down to "vital" actions and "elective" properties are to be accounted for by the plain laws of electro-physics. It appears to me that if ever we are to pass the stage of pure empiricism, and to succeed in formulating laws for rational electrization, it can only be by, in the first instance, trying to get behind the very complex physical conditions that in electro-therapeutics we invariably have to encounter.

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RETROSPECTIVE.

It is not now doubted that in electrization we have a remedy unique in its action, vast and varied in its power. We know that by properties peculiar to itself it can be made to fulfil indications in the treatment of disease not attainable in any other way. Before, however, finally assenting to this proposition opinion has passed through many phases. There have been periods of exaggerated expectation and of disappointed hope, of enthusiastic research and of cold neglect; and everyone knows how, even in pre-advertising days, unscrupulous charlatanism has more than once found itself in almost exclusive possession of the field.

Attempts to influence the human organism by rude electrical methods are, of course, nearly as old as the history of "the healing art" itself. In the early years of the first century Roman physicians resorted to them in the treatment of disease, and Roman ladies wore amber necklaces to cure their ailments.* A feeble system of magneto-therapeutics seems to have been not unknown to the medical practice of the "middle ages," and with the use of artificial magnets was revived at a later date.† Besides his great discovery of the inherent magnetism of the earth, Dr. Gilbert, of Colchester, physician to Queen Elizabeth, discovered, about 1600, that the attractive power of rubbed amber (known to the Greeks 600 B.C.) was also possessed by other substances such as sulphur, glass, and resin. He referred to these substances as "electrica" (ἤλεκτρον amber), and ever since then the mighty agency that produces these phenomena, and many another world's wonder since, has been called "electricity."‡ Beyond this latter fact Dr. Gilbert's discoveries, brilliant as they were, have no special interest from a purely medical point of view. It is the middle of the 18th century, with the invention of the Leyden jar and improvements in the construction of the frictional machine,§ that brings us to the first systematic attempts at the employment of electricity in scientific medicine. Of course, in the early years of that century electrical phenomena were attracting much attention. "Conduction" had been demonstrated by Stephen Gray, "a pensioner at the Charterhouse" (1730). Dufay

* Was the amber necklet the prototype of some modern "electrical appliances?" It was certainly superior from an æsthetic point of view, and could not possibly be inferior in point of electrical efficiency.

† "Electricity in Medicine and Surgery," Beard and Rockwell.

‡ Prof. S. Thompson.

§ The plate machine replaced "the cylinder" about 1760.

was acquainted with the attraction and repulsion of electrified bodies, and a little later we find him with the Abbé Nollet watching with profound surprise "the first sparks that were ever drawn from the human body." Nor were they alone in their amazement. The whole world wondered and waited for new developments. Even in polite society there was a flutter—indeed, "drawing sparks" seems soon to have become a favourite "society" pastime.*† But there were many serious and earnest observers at work. With keen inquiry and patient investigation a new science was quietly winning its way. Facts of the greatest promise were daily elicited, and even philosophers allowed themselves to dream golden dreams of its possibilities.

Taking up the question at the middle of the 18th century, and confining ourselves to its medical aspect, we find that in 1743 Krüger proposed its employment in medicine, and Kratzenstein seems to have carried the idea into practice. In 1749 Jallabert, a physician of Geneva, wrote a book in which he records a case of paralysis cured by patient and persistent electrization, and this "may perhaps be regarded as the first decided and unquestioned result of the kind that was obtained in the early days of electro-therapeutics."‡ In 1755 De Haen

* "Electricity in Medicine and Surgery," Beard and Rockwell.

† The "electrical kiss" being considered "curious" and "interesting," and requiring, doubtless, a certain amount of experimental investigation. Nor was "practical joking" by means of electricity altogether unknown.

‡ "Electricity in Medicine and Surgery," Beard and Rockwell.

published in his "Ratio Medendi" a more advanced series of observations and a more extended list of cases, and his book continued to be quoted as an authority until the days of static electricity were past.

The new remedy was evidently making progress, but it cannot be said to have received a warm welcome from the medical profession. Outside the ranks of medicine, however, the subject was taken up by some of the most acute and practical minds of the day. In 1759 John Wesley wrote his now well-known book,* in which he has several not altogether complimentary things to say of the "gentlemen of the faculty," as he calls them. He tells us how his friend Mr. Lovett had expressed an opinion that the electrical method of treating disease cannot be expected to arrive at any considerable degree of perfection, until administered and applied by medical men, and by way of comment exclaims that all his hopes are at an end. "Quanta de spe decidi! For when will it be administered and applied by them—truly ad Græcas Calendas? Not, at least, until the gentlemen of the faculty have more regard to the interests of their neighbours than their own; at least, not till there are no apothecaries in the land, or until physicians are independent of them." Had he lived a century or so longer he might have seen that we are not quite out of the "drug age" yet. He prophesies that electricity will share the fate that had befallen other simple hygienic and curative

* "'The Desideratum,' or Electricity made Plain and Useful," by a Lover of Mankind and Common Sense (1759).

measures, *e.g.*, cold bathing, after "it was written about by Sir John Floyer;" cold water, after it was publicly recommended by Dr. Hancock; tar water, when it was introduced by the "ingenious and benevolent Bishop of Cloyne;" "sea water, after Dr. Ruffel wrote his treatise about it." All these methods were in credit for a season, but were "now out of fashion, out of use, and almost out of memory." So would it be with electricity. And so it has been. But to all of them their turn has come round again. Once more they are with us and in the ascendant, and there is ground to suppose that this time, perhaps, they have "come to stay." He details a list of cases (cures), too long to mention, but including agues, inflammations, ringworm, shingles, bronchocele, epilepsy, chlorosis, as well as "toe-hurt" (his medical vocabulary seems to "give out" occasionally), "feet violently disordered," and "knots in the flesh." It is, perhaps, as much to time as to electricity that we have to look for the *vera causa* of some of these successes. Still looking at the book in the light of history, and judging it from the standpoint of modern electro-therapeutics, it must be admitted to contain much of sterling fact and almost prophetic instinct.

By this time there were signs that orthodox medicine at last was up and doing.* France, still the stronghold of static electricity, was the first to shake off its apathy. Attention was thoroughly

* The London Hospitals were supplied with electrical machines, Middlesex 1767, St. Bartholomew's about ten years later. ("Medical Electricity," Steavenson and Jones.)

aroused by a paper read by Mauduyt before the Société Royale de Medicine in 1773. By this and succeeding reports interest was kindled into action, indifference transformed into enthusiasm, and the period immediately following seems to have been one of great electro-therapeutic activity throughout Europe.

An interesting glimpse at the science of the day is afforded us in an essay by Dr. Robert Steavenson, of Newcastle-upon-Tyne, written in 1778, as an inaugural thesis for the degree of M.D.Edinburgh—"De Electricitate et operatione ejus in morbis curandis." * It does not fail, of course, to deplore the want of knowledge of the Ancients—who "were nevertheless entirely ignorant that the power depends on a fluid now called the electric fluid." Still, it has many cures to report and many things to say which are as true of to-day as they were then, and one of them is this: doctors seldom persevere in the use of electricity with sufficient diligence, "etsi electricitas morbos quosdam subito et quasi incantatione tollit, aliis tamen diuturna est utenda perseverantia. . . . Shenstone autem dixit; 'Patience is a panacea, but where is it to be found, and who can swallow it'?"

A few years more and frictional electricity is, for the time, forgotten in Galvani's brilliant discovery†

* Republished by the late Dr. Steavenson.

† In 1786 Galvani discovered that when nerve and muscle touch two dissimilar metals in contact with one another, a contraction of the muscle takes place. More than a century before this, however, Jan Swammerdam seems to have demonstrated something

in 1786 (or rather its publication in 1791), as to the electrical current in the nerves of frogs; and was still further laid aside when, not long afterwards, the Voltaic Pile brought Galvani's discovery within the range of practical medicine.

Electrical treatment, however, being purely empirical, without any approach to formulated laws or methods of precision, and the sources of supply being rude in construction and difficult in management, medical men did not see their way to its rational employment. And so it again fell into disrepute, or rather was quietly ignored, and the ground occupied by quacks. A renaissance, however, was at hand. Faraday's discovery of the Phenomena of Induction (1830) gave birth to a new and fruitful branch of electro-therapeutics.

In its new form of "Faradaism," electricity was once more restored to medical favour, and the so-called "period of the induced current" set in with much fervour, and was adorned with many brilliant names, of which that of Duchenne eclipses all others, and his watchword was "localization." The principle was established that "electrical currents must be concentrated on the individual diseased parts, in order to obtain curative results" (Erb).

very similar. This experiment was probably unknown to Galvani, and there seems some good evidence that Swammerdam had no conception that his experiment pointed to any electrical agency. Of course he was a most distinguished naturalist, but the claim sometimes made for him, that he ought to be placed among the "pioneers of electricity," and not "fobbed off with a footnote," is, I think, far from having been established.

This brings us to thirty years ago, and "the electro-physiological era," associated with the names of du Bois-Reymond and Pflüger and Eckhard.*

It was an experiment of Eckhard, as Erb tells us, that led Remak to apply the galvanic current to the cure of a "contracture." We all know with what results—how the galvanic current once more sprang into professional and public favour, and how the brilliant, but solid and lasting work of Remak's short life marks an epoch in the history of galvano-therapeutics. Soon after this we find Benedick doing good work in the cause of galvanism and the "directional current." And then Brenner comes to the front as the champion of the polar method, which still holds its own.†

The last two decades have been a period of unexampled physiological progress, and, as all the world knows, of brilliant electrical achievements.

* Here, however, we may remark in passing that, deeply as science is indebted to the workers of this era—though they discovered many a fact and formulated many a law that guide us still—it is to be remembered that some of du Bois-Reymond's most "classic" experiments, or rather the conclusions drawn from them, seem to have been perhaps too readily accepted. It is now admitted that "the pre-existence of a current in living uninjured tissue can no longer be maintained;" that in exsected structures the current, now called "demarcation" current, arises from the injury; "that passive, uninjured, and absolutely fresh nerve and muscle are absolutely devoid of current;" that "a true electrical variation, however, in intact muscle has been demonstrated" (Landois and Stirling), *i.e.*, a muscle current accompanies a contraction. This is the so-called "action" current.

† Always remembering, however, that "polar" simply means the application of *one* electrode only, to the part to be directly influenced.

Medicine has profited by the one and by the other. It has availed itself of the fast growing knowledge of electro-physics, and begun to aim at some approach to exact methods. The appearance of Professor Erb's book marks this new departure, and may be regarded as the first systematic and successful attempt to bring electro-therapeutics into line with exact science. Among the many workers of this recent period, more than one name among the most distinguished belongs to our own country and time. It is during this era that science has begun to demand that any sound system of electro-therapeutics must be based on the principles of electrical as well as of medical knowledge. It is the dawn of the period of precision. And this dawn may be said to have approached the stage of daylight with the introduction of the milliammeter and volt meter of the rheostat and commutator, with improved sources of electrical supply, and close attention on the part of the electro-therapeutist to the physical phenomena that underlie all electrical science. With the broadening light we begin to see in electricity an agent that can be employed in a definite quantity to a definite part, with a definite object, and begin frankly to recognize the fact that unless we consent to handle it by exact methods, and with the aid of instruments of precision, the laws that govern its action must ever remain an unsolved riddle, and its employment in medicine but a "blindman's guess."

GROUP I.

Hydro-Electric—(*a.*) Electrothermal, (*b.*) Physics of the Hydro-Electric Bath, (*c.*) Electric Douche, (*d.*) Electric Hot Air and Vapour Bath, (*e.*) Cataphoresis.

Against the hydro-electric methods, more, perhaps, than against any other form of electrical treatment, has been levelled the charge of empiricism. And, perhaps, not without reason. Never having been adequately investigated, their real power is but little known, and their real province but little understood. That commonest, and probably best of hydro-electric methods—the electric bath for example—could anything be looser and more hap-hazard than the way in which it is usually prescribed and administered?

The reason is not far to seek. In this country, at least, this and allied forms of treatment have seldom been accorded due scientific recognition or been investigated by anything like exact methods. This neglect is really their first claim on our attention now, though, of course, they have another and better and stronger one in their admitted therapeutic usefulness. Hydro-electric procedure claims for itself, that not only in some cases is it the best of all methods, but that in certain patients it is the only *possible* method of electrization. The former of these claims will appear tolerably reasonable when we come to examine physiological effects and therapeutic indications. As to the latter, it is a matter of experience that there are individuals who, owing to some peculiarity of constitution or temperament, are unduly susceptible to the action of electric currents, and who, though they find themselves absolutely unable to bear electrization by ordinary methods, yet submit readily and with the best results to the smooth and painless action of the electric bath. Or—to take another case—a case, for instance, where strong peripheral electrical excitation is indicated, it is not surprising that such subjects bear with ease the action of the electrized douche, yet shrink with horror from the application of the "faradic brush."

If, then, it can be shown that by their means electrical treatment can be rationally administered, accurately "dosed," and definitely localized, the methods in question become entitled to take rank with other scientific procedures, and front rank where it can be shown that they have special advantages.

(*a*.) Electrothermal.

Of hydro-electric methods first comes, of course, the Bath, not only on account of its own intrinsic merits, but also in virtue of a very respectable antiquity. More than a thousand years ago there is evidence that South African mothers were in the habit of dipping their sick children into pools of water, in which swam electric fishes; and well nigh another thousand or so before that Roman physicians not improbably treated gout by water electrized in the same way, or possibly by much less primitive methods.*

We cannot here, however, turn aside into the tempting by-paths of archæology. Our business is with the present, and our first step must be to come to an understanding about terms.

The electric bath is correctly and conveniently spoken of as "mono-polar" and "di-polar." The mono-polar is that form in which one electrode only is in the water; the other is applied to some portion of the patient's body (say neck, or arm, or hand) out of the water, and this will be the point of entrance or emergence of the current, *i.e.*, the anode or kathode, according to circumstances. The opposite pole is the whole of the patient's body in contact with the electrized water; or, in other words, the water in contact with the body, constitutes one huge electrode, carrying a very widely diffused current. The advantage of this method of application is that you know exactly and definitely how much current enters the patient's body. The disadvantage is, that it involves a great concentration of the current on one spot. This is an effect

* Too many clever electricians have shared the fate of Tullus Hostilius, who, according to the Roman myth, incurred the wrath of Jove for practising magical arts, and was struck dead by a thunderbolt. In modern language he was simply working with a high intensity current, and inadvertently touching a live wire got a fatal shock (Prof. Crookes).

that the electric bath is especially designed to avoid, except in the modified way, to be hereafter detailed, which is carried out by concentrating and directing the lines of current-flow through the water.

In the di-polar form both electrodes are in the water; that is, the current is led off from the battery or coil, and neither pole is applied to the patient's body direct, but only through the medium of the water. This is the electric bath, strictly so-called. Its painless and widely-distributed current has certain unique advantages which, in some cases, make it an admirable method of administration, and an almost indispensable weapon in the equipment of the electrical physician. That it is wasteful of current will be afterwards shown. But this is not a matter of serious moment, with plenty of electrical power available, and knowledge and apparatus to efficiently control it.

It is obvious that in the mono-polar form the whole of the current must enter the patient's body. In the di-polar the conditions are much more complex, and we shall see by our subsequent investigations that the proportion of current the body receives is very difficult to arrive at.

Either the mono-polar or di-polar bath will be "galvanic," or "faradic," or "galvano-faradic," as the continuous alternating or combined current may be used. It is the province of the electro-therapeutist to decide upon this according to the nature of the case. The general principles that guide him in ordinary electrical treatment will also serve to guide him here, knowing, as he does, the physiological effects and the therapeutic results that experience has taught him to expect, and, at the same time, never forgetting that he must respect the laws of electro-physics.

Of course in this case he must, in the first instance, clear the ground by distinguishing between the electric and the purely thermal effects. The warm bath, *i.e.*, the bath at 95 to 104° F., slightly increases the activity of the circulation, and somewhat retards tissue metamorphosis. It is a valuable soothing agent, but in other respects its effects on the system are almost inappreciable (Shelley). It appears, therefore, that we have not much to expect from the warm bath *per se*. As a means, however, of applying electricity to the body it becomes invaluable.

The physiological effects are thus summed up by Erb.* :—" Respiration diminished by di-polar—temperature slightly lowered by mono-polar—metabolism promoted considerably by di-polar, slightly by mono-polar, and increased secretion of urine. Appetite and digestion are improved, the genital functions are stimulated, circulation and nutrition are benefited, sleep notably restored, and new vigour imparted to the mental and physical faculties. In short, the electric and especially the faradic† bath is credited by all, with a powerful invigorating, and refreshing action upon the human frame."

* Though he leaves something to be desired in the way of definite information as to the form and strength of current used.

† We know more about the galvanic bath since this was written.

Speaking broadly, the painless and evenly distributed current of the bath makes it one of the best methods of general electrization, with, at the same time, a considerable power of concentration on special parts according to the indications of the case. In all states of general debility and impaired nutrition (Erb), in weakness or exhaustion of the spinal nervous system, "nervous dyspepsia," palpitation, hysteria (Erb), neurasthenia, "nervous breakdown," and many of those diseases referable to some derangement of the nervous system without appreciable lesion, commonly called neuroses, it may be resorted to with excellent and unique results. In the treatment of chronic forms of articular rheumatism, it meets probably with greater success than any other single measure. It is used with good effect in some irritative conditions of the spinal cord, in alcoholic or mercurial tremors, plumbism, and even paralysis agitans (Lehr, Erb), and peripheral neuritis from whatever cause, though not, perhaps, in every stage.

Gout, either in its regular articular form or those irregular manifestations, known as "visceral," "suppressed," "retrocedent," or "cutaneous," is often most successfully treated by electro-thermal methods. Whatever view of the pathology of gout be ultimately accepted, whether it depend on a saturation of the system by uric acid, or diminished nervous power in trophic centres, congestion of liver veins or capillaries, it is not difficult to see, when we consider the physiological and chemical actions of the electric current and study something of its way of working, how it may easily adapt itself to any of these varied hypotheses. The pathology of rheumatism is, perhaps, even more conjectural than that of gout. Is it due to excessive production (or retention) of lactic acid or other *materies morbi*, or is it due to the influence of the "nervous system," or to neither? Whatever hypothesis within the range of ordinary probability be adopted, we have not far to look, among the many demonstrable properties of the electric current, for a probable theory by which electro-thermal treatment is likely to prove eminently anti-rheumatic. And, as a matter of fact, we know that in many manifestations of the rheumatic diathesis, muscular rheumatism, non-acute articular rheumatism, and post-rheumatic conditions of many kinds, it finds some of its most successful applications. Further, we have striking proof of its usefulness in the earlier stages of what, though quite distinct (and more obstinate and later more incurable), is probably a closely-allied pathological congener of rheumatism,—rheumatic arthritis. We, perhaps, tread on more contentious ground when we come to look for a method of treatment suitable to that form of spasmodic spinal paralysis, known as primary lateral sclerosis. There still lingers a remnant of the old superstition, that the electric current is primarily and solely an excitant or stimulant—something only suitable to "kick up" a sluggish muscle into action, that, therefore, like strychnia, it is contra-indicated in such a case as this, in consequence of its supposed tendency to cause increase of spasm. Those who have passed this stage of their electro-therapeutic existence know that some forms of current and some methods of application, and notably the electro-thermal methods, through their modifying soothing and sedative properties, are of the greatest use in the early (the curable) stage of this disease. The same may be said of another form of spasm disease, attributed by its first describer, Raynaud, to "capillary spasm dependent on hyper-excitability of spinal vaso-motor centres." Here, again, we own to ignorance of pathology and need not stop to speculate about it. But it seems scarcely in doubt that there is, in the first place, a predisposing, probably hereditary, excitability or "want of stability" of nervous centres, and that, whatever its exciting cause (and this, of course, might require special treatment), there is locally vaso-motor spasm. Here it is not difficult to see the theoretic usefulness of electrical treatment. But a great deal more than this—we know, as a matter of experience, that in the "syncopal" and "asphyxial" stages, and especially before the disease becomes chronic, the application of the galvanic current, by some of the electro-thermal methods, is often not without a marked measure of success. Lastly, mention ought not to be omitted of one of the latest and probably one of the most useful applications of the hydro-electric bath, in the treatment of the after-effects of influenza, especially of those sequelæ that affect the limbs.

After therapeutic indications naturally comes the question of "dosage." This, in electrical treatment, must always be left a very open question. Of course, in the case of the electric bath, there is the additional complication that, in order to decide the amount of current to be used, it becomes necessary, in the first instance, to form an estimate of what proportion of total current running through the bath will fall to the share of the patient. Individual susceptibility to the action of electric currents, depending partly on peculiarities of constitution and temperament and partly on the physical conditions of the moment (what we may term the electrical capacity of individuals*), varies within so astonishingly wide a range, that any attempt to formulate rules of "dosage" must be hopeless and perhaps not without danger. Both the patient and the galvanometer must be watched, and the current gradually, very gradually, increased or diminished, in order to obviate the chance of pain or shock. Under any circumstances, the period of immersion should not exceed 15 to 20 minutes.

It will be subsequently shown that the amount of current strength available must be very considerable, and I think much in excess of what is generally accepted as sufficient. Of course the quantity of current that the body, or any special part of it, receives will in a great measure depend upon its proximity to an electrode; and therefore by altering the position of electrodes or increasing their number the current strength falling upon any special part

* By electrical capacity, I mean the sum of such widely-varying factors as "resistance," sensitiveness, and susceptibility of different individuals to the action of electrical currents.

may be increased—that is the current may be "localized" for any special indication—say a joint disease, a spinal affection, or a neuralgia. The electric bath is thus seen to be a method of general electrization with a certain power of localization. The head escapes its direct action, and it is well that it does so, considering the strength of current running. "Head treatment" is generally most efficiently carried out by other methods, but any slight cutaneous excitation that may be indicated here, is best effected by the "electric hand" of the physician.

For carrying out treatment by these methods the electrical equipment must be not less complete than that for other purposes. If we allow our mind to revert for a moment to the diversity of the effects we look for, and the magnitude of the currents we may have to employ, the necessity becomes palpably evident of having it under safe, easy, and complete control.

The requirements will be :—

1. A galvanic supply in the shape of a battery with a low resistance, which will work up to a powerful current strength, say, 300 or 400 milliampères, through the estimated R.* If

* In the recent admirable book on "Medical Electricity" by Dr. Steavenson and Dr. Jones, I note at p. 144 the following passage :—"They" (*i.e.*, 60 large Leclanché cells) "will furnish sufficient C. for the electrolysis of nævi, etc., but hardly enough for the electric bath." Dosage is of course a matter of opinion But taking these authors' figures, R. of bath about 120 ohms, E. M. F. of one Leclanché cell 1·6 volts. R. of one (largest) Leclanché cell 0·5 ohms ; and even supposing (say) 50 ohms to be

we take our supply from an electric light circuit, of course it will have to be safe-guarded by shunts and appropriate resistances in addition to a reliable "cut-out."

2. A means of opening and closing the circuit, and regulating strength by easy gradation so as to avoid pain or shock, *i.e.*, "a current-collector," or, in dynamo circuits, an adjustable rheostat.

3. A milliampère meter, *i.e.*, a galvanometer graduated in milliampères, and registering up to, say, 500 m.a.

4. A powerful induction coil for faradic bath or supply from an alternating dynamo.

5. Some means of suddenly reversing the current ("current reverser" or "pole changer") as well as an arrangement for throwing the two currents together for combined use ("current combiner" or "De Watteville key").

6. As adjuncts but not actual necessities may be mentioned a voltmeter, useful for occasionally determining the electro-motive force of the battery, or, any particular cell, and for other purposes. Some galvanometers are also voltmeters.

the R. of the galvanometer (in measuring large currents the R. of galvanometers on the shunt principle is almost negligible) the calculation becomes

$$\frac{96}{120 + 30 + 50} = 480 \text{ m.a.}$$

and taking the same authors' estimate of the proportion the body receives as $\frac{1}{8}$ $\frac{480}{8} = 60$ m.a. passing into the patient.

The arrangements for the proper administration of an electric bath depend, to a certain extent, on individual views and the special indications of each individual case. But there are certain broad rules of general application which may not be neglected, and the first of these is that it is often on attention to a number of small details that efficacy will very much depend.

The substance of which the bath itself is made must clearly *not* be of metal, for the reason that, however carefully covered the metal may be, the current is sure to get at it somehow, sooner or later, and run round it in preference to entering the water. For a similar reason nothing should be added to increase the conductivity of the water, or it will become so much better a conductor than the body, that the current will decline to leave the water, chasing round the patient's body rather than enter it at any part, or in ever so small a proportion. This does not apply, of course, to those cases in which the galvanic bath is used for the elimination of metallic poisons ("lead poisoning," mercurial poisoning, etc.). Then the action is electrolytic and the conditions are as follows: The positive electrode is applied to a portion of the patient's body out of the water, say by a covered bar-electrode grasped in the hand. The negative pole is attached to a metal bath, or to a large copper plate in an ordinary bath. It is found that the metallic impurity is carried onwards in the direction of the current, and leaving the body with the emerging current passes through the water, some of it remaining there, but the greater amount being deposited at the negative pole on the surface of the copper bath, or on the large sheet of copper placed in an ordinary bath, which may be used as a substitute.

The ordinary electric bath is best made of oak or porcelain, perhaps porcelain for choice, if expense need not be considered. Insulation must be carefully attended to, both of conducting wires and waste-pipe, the latter being insulated from earth by a short length of rubber tubing let in near the bath. As we may be dealing with coil currents of an E.M.F. of several hundred volts it is apparent that insulation is a very important matter.

The bath is an ovoid oak tub, 4ft. 10in. long and 2ft. 6in. at greatest width, which is about 2in. nearer head than foot. Height at head 1ft. 11in., height at foot 1ft. 5in. There are five fixed electrodes of bright metal covered only by light removable open wooden framework, size as follows :—

"Cervical," 28 × 29 cm.
"Lumbar," 24 × 17 cm.
"Lateral" (2), 26·5 × 18 cm.
"Gluteal" (circular), 30 cm. (diameter).
"Terminal" (foot), 22 × 38 cm.

In addition to these there is an electrode for monopolar purposes, consisting of a removable metal rod, one inch in diameter, covered with wash leather. This is fixed across the widest part of the bath, and can be conveniently grasped by the hands. These electrodes are connected, by carefully insulated wires, with seven terminals, and these in turn lead to a so-called "commutator," more correctly described as a plug switch-board, so arranged that by the insertion of plugs any electrode can be brought into action, either as anode or kathode. The connection with the battery, coil, or other source of supply, is by means of well-insulated connections leading to two ordinary "binding posts" on the "commutator."

It is best in the interests of cleanliness, if for no other reason, that the electrodes be of bare bright metal, as the cleansing and changing of covers is often very imperfectly attended to, and is a matter of serious consequence sometimes, as several unfortunate instances show.

The size of the electrodes will depend upon the theoretical considerations already advanced, looked at in the light of the following experimental results. But, speaking generally, the sizes and positions of those electrodes already mentioned are suitable. The only further addition (and a very useful one) is the so-called "paddle" electrode. By means of a long insulated handle this electrode can be applied to the vicinity of any part of the body on which it may be desirable to concentrate the current.

As to temperature there seems to be some difference in practice and opinion. Some authorities recommend 98° F. as the lowest, others (Erb) stating that 32° to 37° C. (*i.e.*, 89·6° to 98·6° F.) is the temperature at which it is usually given. The question has to be looked at in two ways: from an electrical and from a therapeutic point of view, which, in this case, are rather antagonistic. It seems to me that if there be no contra-indication, and if the patient can comfortably bear it (which I think improbable for 20 minutes) the lower temperature would give the better electrical result. To increase the temperature of the water is to increase its conductivity, and to increase the conductivity is to diminish its resistance relatively to the body, and so make the water, relatively, a better conductor; and being a better conductor of course the current will elect to travel by it instead of by the body. The influence of temperature on this question may be judged from the resistances taken as the bath water cooled (Table V.)

In England 98° F. seems to be the usual temperature adopted.

It is sometimes stated that the temperature ought to be 100° F. "if the patient can bear it, as the conductivity of the water is increased." But why increase the conductivity of the water? It is already too high as it is. For this reason neither salt nor acid may be added to the dipolar bath.

To allow the patient to recline and at the same time to keep the body from contact with the upper electrode, it is sometimes considered advisable to use some support for the shoulders. Here again individual views and ingenuity must guide us—but one way of effecting the purpose is to use straps, one under the back of the neck, the other supporting the body under the arms. Another method is to have an open frame-work, made of wood and webbing, somewhat like the invalid appliance known as a "bed-rest." Or in the case of a very infirm patient a sort of litter or stretcher, raised at one end for the shoulders, may be used. This can be lifted into the bath, with the patient reclining on it; (of course, *before* the current is running). For spinal affections the wooden back-rest may be modified by having it made solid, excepting a longitudinal opening through its whole length opposite the vertebral column, the upper electrode being of such size, shape, and distance from the part as to allow the lines of current flow to concentrate themselves on this opening. My experience, however, is that with the bath shaped as in the foregoing photograph—the fixed metal electrodes in the positions named, and the " commutator " as explained—the current can be so handled as to concentrate it, or diffuse it, or send it longitudinally, or transversely, or obliquely, through the water as may be desired. The bath being short and the patient in a more or less sitting position on the gluteal electrode,* the straps and frames above mentioned are generally unnecessary.

As to the patient, the ordinary rule of not taking a bath after a full meal ought to be followed. Some light bathing dress may be worn. It is in accordance with traditional practice, and, as a rule, sound principle, to let the faradic current run for a few minutes before the patient leaves the galvanic bath, and whilst he stands up to sponge the body, and especially the spine, with one of the electrodes. An excellent substitute for this proceeding is to run

* Not in contact with it.

over the whole surface with the faradic douche. The danger of taking cold, which is proverbially small after the electric bath, is thus reduced to a minimum. After the bath, exertion severe enough to induce fatigue is to be avoided, but the journey home, weather permitting, is often best made on foot, unless the patient be very weak or the way be very long.

When strong currents are running (and it will be shown that weak ones are probably useless) a medical man ought, of course, to be present, and that medical man must understand the handling of a current of, say, 300 or 400 milliampères.

As already mentioned, apparatus must always in a certain measure depend upon individual views. But the foregoing photograph gives a fair general idea of the *tout ensemble* of a hydro-electric room, and is found to be a good working arrangement. It easily adapts itself to the three possible sources of electric supply. If the supply be C.C. "from the main," the switchboard shown at page 80 must be in use. It will be placed in the shunt circuit as detailed at page 86, and the main current will be protected by the "cut-out" described at the same place. In the figure referred to (p. 80) the connecting wires for the main and the two "binding posts" for the rheophores are shown. The latter will, of course, be connected up with the two terminals on the small "plug switchboard" shown at the head of the bath. The other terminals on the latter switchboard are seven in number, and correspond with the various electrodes of the bath, by the connections which appear in the photograph. By the insertion of corresponding plugs any electrode, or combination of electrodes, can be thrown into circuit, as anode or kathode.

The resistances in the dynamo-current instrument can also be utilized to regulate the C. strength of the stationary battery of large Leclanchè cells (60) which finds accommodation in the adjoining cupboard. Any smooth and easily adjusted high R. can be used for this purpose, or, if preferred, the usual "cell collector." The magnetic "cut-out" is shown on the cabinet, and can remain there when in use, or be easily placed in any more convenient position by a couple of screws—always remembering, of course, that it must be kept level—as the solenoid falls by the force of gravity when once it is drawn from the perpendicular by magnetic action. The douche appears in the photograph, but need not here be further described, as it will subsequently be dealt with in detail. The galvanometer is shown on the portable battery, and is purposely kept movable for convenience, so that it can be put into any circuit. More than one source of supply is always desirable. No one knows better than the electro-therapeutist the occasional vexation and inconvenience of not having "two strings to his bow."

(*b*.) The Physics of the Hydro-Electric Bath.*

I have lately tried by direct experiment to throw light on some of the physical and physiological

* A considerable part of this has already appeared in the *British Medical Journal*.

problems involved in the administration of the electric bath. Of course, in entering upon an investigation of this kind, our first solid standpoint must be measurement. In the case before us this almost resolves itself into the question, "What proportion of the main current passes through the human body when immersed under given conditions in an electric (dipolar) bath?" This is a primary question, but a very complex one. It covers a great deal of ground, and in glancing over the literature of the subject, there appears a tendency to "talk round" this point rather than to approach it by actual experiment.

For the present purpose the following are selected from a large number of experiments bearing on the point. Apparatus used: Oak bath 6ft. long, 2ft. 6in. wide at widest part, the waste pipe being insulated from earth by a short length of rubber pipe inserted near the bath. Battery of 74 Leclanché cells giving E.M.F. of 75 volts, dipolar bath, one electrode (30 × 20 sq. c.m.) resting at each end; plain tap water, 12½in. in bath before immersion of subject; temperature 98° F.; R. of bath water before entry of subject 165 ohms; subject lying in water, having head resting on strap out of water, and body from shoulders downwards completely immersed, shoulders 8in. from + electrode, feet 3in. from — electrode.

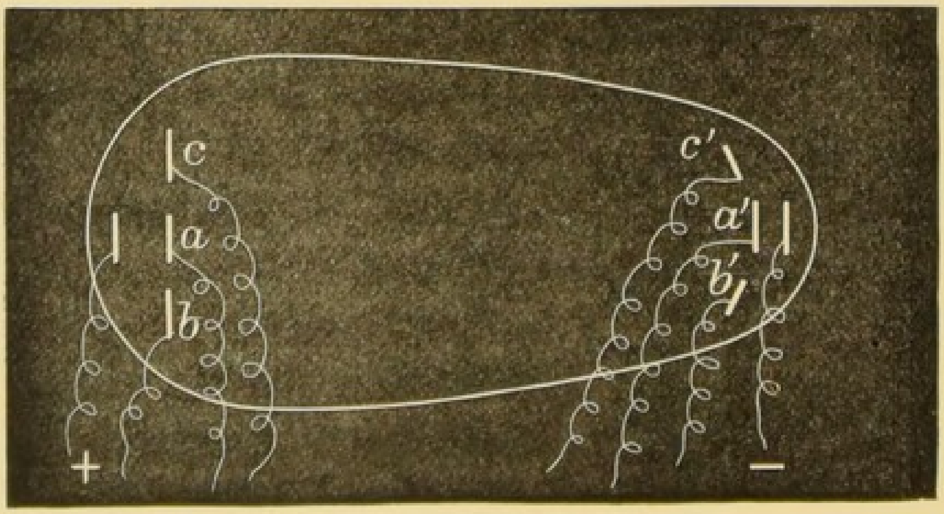
Experiment 1.—A current of 100 ma. passed through the bath. Subject distinctly felt the current as a tingling sensation in his legs, but not in other parts of the body. An intercepting current now arranged, having one electrode (336 sq. cm.) on nape of neck, the other (95 sq. cm.) on ball of great toe and behind it, this portion of the foot being raised out of the water for the purpose. These electrodes were connected with reflecting galvanometer, having R. of 976 ohms. Deflection right off scale, but estimated at 500 microamperes.

Experiment 2.—Intercepting current arranged with a plain handle electrode of convenient size held in subject's mouth and making good contact with mucous membrane; the other electrode (22·5 sq. cm.) watertight on calf; Edelmann's suspension galvanometer (R. 200 ohms); other conditions as in last experiment. Deflection 0·75 ma. = (750 micamp.); constant whilst it lasted for two minutes.

Experiment 3.—Whilst the circuits were still complete the watertight covering of calf electrode was intentionally ruptured, so that the bath water came in contact with the electrode. Deflection 2·5 ma. = 2,500 micamp.

These experiments seem to afford some direct evidence of the proportion of C. passing through the patient's body in dipolar bath. The readings were carefully taken, twice verified, and found constant after C. had been passing for two minutes. They were further confirmed by an observation with alternating current and telephone. I then proceeded to test the point in other ways. After a simple experiment, merely to emphasize (under conditions identical with those of the other experiments) the well-known fact that the chief lines of force do run through the bath water by the shortest and most direct route when not interfered with, the body of the subject was immersed, lying in the direct line of C. flow, as in the ordinary way of administering an electric bath; and the results were a striking contrast. Thus, without the body in the water 44 per cent. of total C. was intercepted in the direct line of C. flow, and only 40 per cent. at the sides. The presence of the body in the water caused this condition of things to be reversed, 30 per cent. only being intercepted in the direct line and 48 per cent. at the sides. This seems to point to the fact that the effect of the presence of the patient's body in the water is to deflect to a large extent the lines of force, so that the greater quantity of C. passes round him and not through him.

The next step was to divide the hydro-electric field into sections constituting shunt circuits (arranged as in following diagram), which could be separately tested without the body and with it.



One main electrode (metal 8 × 12 inches) at each end of bath. *aa′*, plain metal electrode, 8 × 12 inches; *bb′*, plain metal etectrode, *b* 8 × 12, *b′* 4½ × 12; *cc′*, plain metal electrode, *c* 8 × 12, *c′* 4½ × 12.

Results shown in following table :—

Condition of Hydro-electric Field	Current in Main.	Shunt.	Current in Shunt.	Condition of other Shunts.
A Without Body	53 ma.	*aa'*	38 ma.	Closed through R. of 200 ohms each.
	"	"	39 "	Open.
	"	{*cc'* *bb'*}	2·5 each	Closed.
	"	{*cc'* *bb'*}	3·4 "	Open.
B With body (lying in line of col. *aa'*)	53 ma.	*cc'*	32 ma.	Open.
	"	"	25 "	Closed through 200 ohms.
	"	*bb'*	25 "	" " "

These experiments if they do not justify the conclusion that the waste of current in administering a dipolar bath is in excess of what is generally supposed, at least point to a necessity for further investigation. I cannot help thinking, however, that the calculation sometimes made that the proportion of main C. the patient receives is one-fifth, is too high.* This is not an argument against the use of the electric bath in proper hands. The dipolar bath, with its painless—or at worst "pleasantly painful"—evenly-applied, and widely-distributed C., must ever be an admirable method of general electrization. That it is wasteful is not a serious drawback with plenty of battery power behind us—or still less so

* In an original article, *Lancet*, March 28th, 1891, it is stated that "it has been calculated that the proportion of C. the body receives is $\frac{1}{5}$." In the Text Book by Dr. Steavenson and Dr. Jones it is put down at $\frac{1}{8}$. I note with regret that in neither case is the calculation given by which the result is arrived at.

if we are utilizing electric light circuits for electro-therapeutic work.

The question of density, which is so important a factor in "dosage," and which in ordinary electrical applications depends upon the size of the electrodes, becomes a very complicated one in the dipolar bath. Here it is evident that not only the size of the electrodes is to be considered, but also the amount of diffusion the C. undergoes in passing through the water from the electrode to the body; and this will depend partly on the size of the electrode, partly on distance, and partly on the conductivity of the water. In other words we have not only to consider the size and position of the electrodes electrizing the water, but we have to look upon the whole extent of water in contact with the body, as a huge electrode carrying a widely diffused current with a density diminished in proportion to its diffusion.

In all electro-therapeutic work it is absolutely essential to aim at clear ideas about density. In a recent *Textbook of Physiology*, after impressing on the mind of the reader the necessity for distinguishing between "strength" of C. and "intensity," the writers seem to apply the term "intensity" to what it is usual to speak of as "density." "If the size of the transverse section of the circuit varies, the electricity must be of the greater 'intensity' at the narrower parts."* This is "density," and the fact is generally stated by saying that the density is inversely

* *Textbook of Physiology*, Landois and Stirling, Vol. II., p. 669.

proportional to the transverse section of the conductor or $D = \frac{c}{s}$. "The current is comparable to a girl's hair, which may be gathered up into a narrow tress or allowed to flow loosely, without changing the number of its constituent parts."*

In a recent admirable article on the Electric Bath, the writer states that "It can easily be shown that part of the C. traverses the human body when immersed in a bath, even if the feet do not touch the bottom electrode, for if one of the legs be held out of the water the current strength, as registered by the galvanometer, is reduced."† I have succeeded in obtaining the same experimental results. On the same page an experiment of Beard and Rockwell is referred to with apparent approval, bearing on the relative conductivity of the body and water. I quote the quotation:—"That the body conducts better than the water is proved by an experiment we have often made. Place both hands at some distance apart in a bath through which a current of considerable strength is running, and a sensation will be distinctly felt in them. Bring the hands still immersed very close to each other, and the sensation will be very much diminished. When the hands are far apart a considerable proportion of the current passes through the body from one hand to the other. It prefers this much longer and roundabout road to the direct path through the water."

* *Electrotherapeutics*, Erb, p. 55.

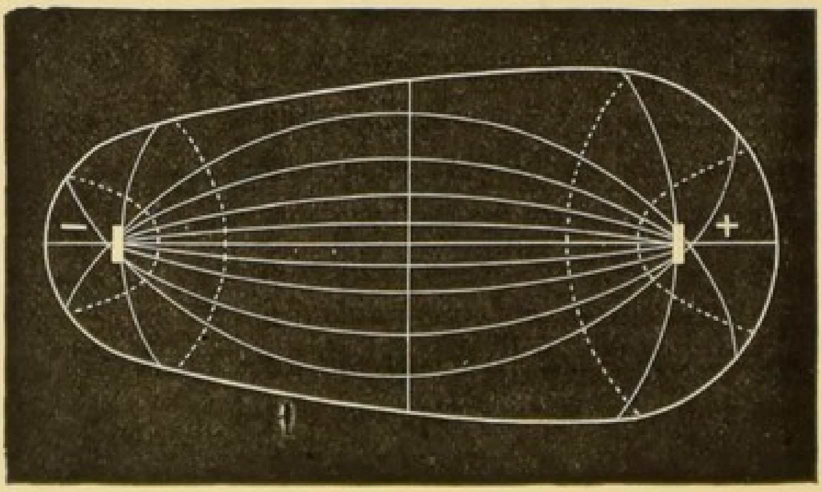
† *Lancet*, March 28th, 1891, p. 710.

No one doubts the experiment. It can easily be verified by the galvanometer. But I think it does not warrant the above conclusion. Does it not point to the fact that the experimenter in approximating his hands was simply removing them from the region of greater difference of potential, and greater current density, to that of less?

The Hydro-Electric Field.

I.

The following diagram gives a general idea of the distribution of potential in a body of water with no disturbing conditions:—

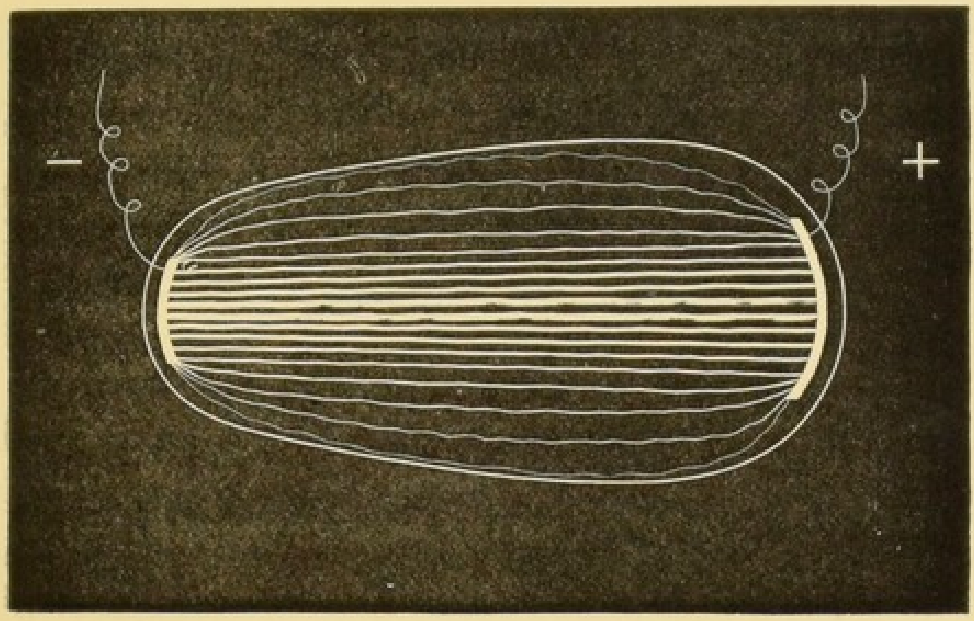


+— "Line of C. axis."
b.b. Line of "Zero potential."
Dotted lines are lines of equipotential.
All other lines are lines of "diffusion." *

* Lines of current flow ought to cut equipotential lines at right angles.

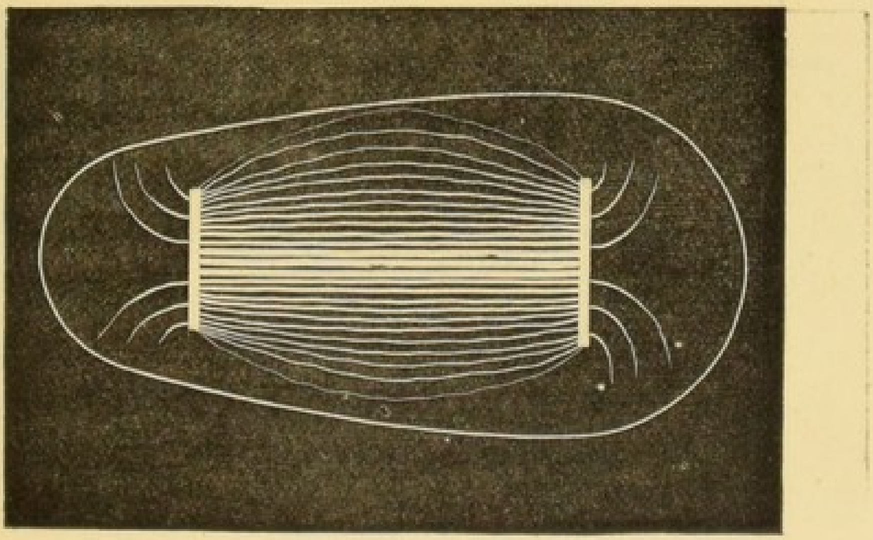
II.

Alternating C. Tested bath with hands (coil full on) and with telephone (coil 1 m.m. on). Found evidence of lines of force as follows :—



III.

Moved main electrodes inwards, and on testing with telephone found

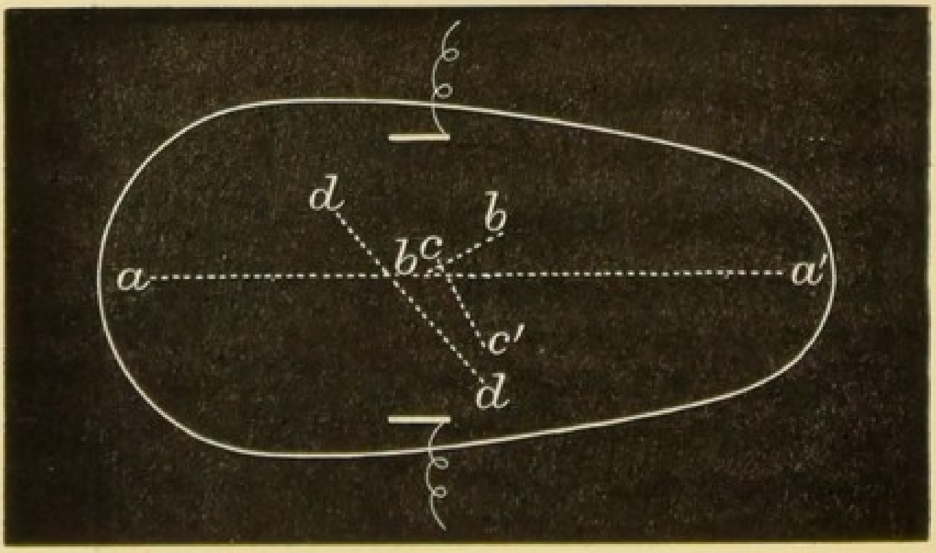


showing slight lines of flow at back of electrode—possibly a direct issue therefrom, probably merely lines of wide diffusion.

IV.

Continuous C.

	Main C.	Position of Shunt Electrode.	Deflection of "Universal" Galvanometer.
1.	50 M.A.	12 inches from each end of bath	22 M.A. =44 °/₀ of total C.
2.	,, ,,	Distances as above, but at sides	20 ,, =40 °/₀ ,,
3.	,, ,,	Lengthways along bath at right angles to Main C. (which is across)	Slight agitation of needle.
4.	,, ,,	As in following Diagram :	*aa* Deflection=0 *bb* ,, ,, 5 M.A. *cc* Deflection =1 M.A. opposite direction. *dd* Deflection =6 M.A. opposite direction.



V.

R. of bath water taken as it cooled. (By Wheatstone Bridge.)

Temp.		R.
98° F. ...	...	... 165
92 ,, ...	...	... 194
87 ,, ...	...	... 264
70 ,, ...	...	... 440 *

VI.

Bath resistance at various levels. Taken by Wheatstone Bridge method (Edelmann's suspension galvanometer).

Height of water	15 in.,	with body	...	162	ohms.
,,	,,	12 ,,	,,	...	205	,,
,,	,,	10 ,,	without body	...	245	,,
,,	,,	7 ,,	,,	...	357	,,
,,	,,	5 ,,	,,	...	510	,,

(Bath had in this case slightly different dimensions.)

VII.

Dipolar. Subject in bath. Continuous current. "Universal" galvanometer attached to "shunt" circuit.

Experiment 1.—50 m.a. in main circuit. Subject in bath. + main electrode eight inches from shoulder. — electrode three inches from feet. Intercepting poles in water away from subject and at sides of bath.

Deflection = 24 m.a. = say 48 % of total.

Experiment 2.—50 m.a. in main C. Subject in bath as above. One intercepting pole in water just in front of subject's chest, and the other between the ankles (*i.e.*, in just what would have been the main line of current had subject not been in bath).

Deflection = 15 ma. = 30 % of total.

* These figures only show the alterations in R. owing to temperature, and the *actual* R. in *this particular bath*. R., of course, varies with volume as well as with temperature.

VIII.

Alternating current. Dipolar bath. Plain water. Temp. 98° F. Main C. electrodes at extreme ends of bath. Positive eight inches from subject's head, negative three inches from feet.

C. in Main Circuit.	Position of Shunt Electrodes.	Tests with Telephone.
1. Coil full on	Neck and ball of great toe just clear of water.	Sound distinct
2. ,,	Neck out of water and near feet in water.	,, much increased
3. ,,	Mouth and ball of great toe just clear of water.	,, weak
4. ,,	Mouth and near feet *in* water.	,, louder
5. Coil half on	In mouth out of water and on calf in water.	,, well marked
6. ,,	On calf in water and near subject's head in water.	,, increased
7. ,,	On calf in water and on head out of water.	,, slight
8. ,,	Both in water—one near head, one near calf.	,, increased
9. ,,	One watertight on calf, the other in mouth.	,, well marked
10. ,,	Mouth electrode removed from mouth and moved in water near head.	,, increased
11. ,,	Calf electrode still remaining in position; the other moved to shoulder and head.	,, less than when pole in mouth, but still distinct, least on forehead (quite faint)
12. ,,	Watertight covering of electrode on calf ruptured, allowing water to come in contact. The other electrode in mouth.	Sound increased on water getting access to electrode, but not to very great extent

The foregoing experiments are detailed not with the idea that by any one of them we may expect to arrive at a decisive solution of a most complex problem, but rather in the hope that they may act as landmarks to guide us on our road. I have stated that some of them seem to afford reason for thinking that the amount of current the body receives in the dipolar bath is apt to be over-estimated. With a view to arriving at more definite conclusions I have followed the question up, and in a somewhat different way.

Experiment 1.—Bath 4ft. 10in. long, 2ft. 6in. at greatest width. Nearly perpendicular sides. Surface area of top electrode 130 square inches, of bottom electrode 117. Temperature 98° F. Water at high level 17 inches. Water at low level 15 inches (the difference being the difference in level due to immersion of body).

(*a.*)	Low level, with body	...	current	91 m.a.
	High level „	...	„	100 „
(*b.*)	High level „	...	„	100 „
	Low level, without body	...	„	90 „

(The body having been gradually withdrawn, the current still running.)

(*c.*)	High level, without body	...	current	100 m.a.
	Low level „	...	„	90 „

Many similar observations were taken, the mean "value" of which I find to be that when the size of the conductor is increased by the immersion of the body the C. is increased 10·3; when it is increased to the same extent by the addition of water the C. is increased 9·7—a difference of ·6. Now, does this show (1.) That the body in the bath is a slightly better conductor than the water? (2.) That 10·3 milliampères represents the amount of C. that the body under the above circumstances receives? I think neither. The question is by no means so simple as this, as the following experiments show:—

Experiment 2.—(*a*) Height of water in bath, 17in.; temperature, 98° F. Subject immersed in bath up to nipples, with the + electrode (548 sq. cm.) applied to body. Right arm in a separate vessel up to elbow, with—electrode (387 sq. cm.) applied to it. R.=540 ohms (Wheatstone Bridge—Edelmann's suspension galvanometer).

(*b*.) Bath water alone; electrodes size as above; about same distance apart as in previous experiment. R.=140 ohms.

In the face of this R. test it seems impossible to assume that the body receives the increase of C. that its presence produces. It appears more justifiable to consider that such increase of C. is mainly due to the higher level of the water, and consequent increased cross sectional area of the total conductor, or other physical conditions not fully explained.

The foregoing experiments put us in possession of the following data:—(1.) The body forms about one-eighth of total conductor. (2.) Under conditions as nearly as possible approximating those of the bath the R. of body=540 ohms,* or (making an allowance for somewhat less immersion), say, 440 ohms. (3.) R. of bath water in this experiment=140 ohms.† (4.) C. passing in total conductor (body and water)=100 m.a. (5.) C. passing in water alone at same level, 99·4 m.a.

Now, supposing the body to receive C. in proportion to its relative R., and in proportion to its share of total volume of the conductor (one-eighth), and at the same time not withholding from it the C. represented by the increase passed through the composite conductor as compared with the water

* This was the R. in this particular series of experiments, but of course it is difficult to secure an absolute identity of conditions. In other observations I have found the R. of the body rather higher, but never lower.

† Of course the relative R. of bath water and immersed body will vary with the amount of water in the bath. The greater the volume of water the less C. the body receives.

only, at the same level (0·6 m.a.), the calculation resolves itself into the following:—

$\frac{100}{8} \div \frac{440}{140}$ (say 3) $+ 0{\cdot}6 = \frac{125}{3} + 0{\cdot}6 = 4{\cdot}18 + 0{\cdot}6 = 4{\cdot}78$ m.a.

received by the body when immersed in a dipolar bath under the above conditions, say, 5°/$_{\circ}$ of total C. running through the bath.*

(*c.*) THE ELECTRIC DOUCHE.

At page 281 of his book on *Electro-therapeutics* Erb mentions the electric douche. No information, however, is given beyond a reference to a paper by Trautwein. I have not been able to get access to this article, nor am I aware whether the subject has any other literature. It is, therefore, because it may possibly interest those who are in the same position that I venture to put together the few following points, which are the outcome of an experimental inquiry recently undertaken for my own information. The action of electrized water by means of the electric bath has long been recognized

* There are certain surface phenomena in the shape of marked skin reddening and tingling sensation in the hydro-electric bath which seem to me to be out of proportion to the amount of C. the body receives; even if the usually much higher estimate than the above be accepted. Is it absolutely necessary to assume that every line of C. flow contributing to these effects enters the body? Of course we must remember that we are not dealing with a material current, still, it has many of the properties of such. Is there fair ground for the suggestion that possibly a considerable proportion of the lines of force impinging on the body—beating on it or bombarding it, so to speak—do not enter, but encountering great R. simply pass round the body and complete the circuit by the better conducting water? If a tenable one, this would be a useful hypothesis.

as by far the least painful way of applying the current to the body. But the efficacy of this procedure depends in most cases on a general and distributed action rather than on any strictly localized effects. The electric douche, therefore, seems to have been devised as a means of retaining the advantages of the electro-hydriatic method, and at the same time presenting facilities for strict localization and accurate dosage, and securing the advantages of a labile as well as a stabile action. The method of application, apart from certain non-essential details, is much of the nature of what would be known in hydrotherapeutics as the "movable jet douche" (douche mobile), and the nozzle is so arranged that the electrized stream escapes in the form of a more or less condensed jet or jets, which, with a certain minimum of pressure, remain unbroken and continuous for a reasonable distance after emerging from the pipe, and therefore, for that distance retain their electric conductivity. (Of course there ought to be a means of regulating temperature and pressure.) With this arrangement one pole may be placed in contact with some indifferent part of the patient's body, while the other is connected to the internal metal of the douche; with the result that when the douche is set in action the second pole is brought to the patient by and in the fluid, and may be concentrated as a single jet or distributed as many small jets. The fluid is, in fact, the second electrode.

Let us inquire, then, by direct experiment, how much current this water conductor carries, and how much enters the body of the patient. The following experiments are necessarily only a selected few, but a sufficient number of results are quoted to give some general ideas. Details of the apparatus are also as much as possible omitted. It need only be mentioned that, permanent water pressure not being available, a hand pump drawing from a suitable vessel was used for the douche, which was fitted with a nozzle or rose (having its outer edge insulated with india-rubber) of the size mentioned below. The electric apparatus consisted of a Leclanché battery of seventy-four cells (with a milliampère meter in circuit) and a fair-sized induction coil. One pole was attached to a large electrode on which the patient sat, and the other was connected with the metal of the nozzle or rose. Well insulated wire was used for the connections. The following results were obtained :—

TABLE A.

Plain water at 90° F., continuous current.

Nozzle.	E. M. F.	Pole to douche.	Distance of nozzle from body.	Current passing.
1. ¼in. jet (single).	75	—	1·5in.	5 milliampères.
2. Do. do.	,,	,,	0·5in.	15 milliampères.
3. Rose 2in. diam., forty-nine perforations.	,,	,,	1in.	5 milliampères.
4. Single jet.	,,	+	18in.	Deflection (taken on reflecting galvanometer) right off scale. Probably quite 100 microampères.

TABLE B.

Salt water (½ lb. to 7 gal.), temperature 90° F., continuous current.

Nozzle.	E. M. F.	Pole to douche.	Distance of nozzle from body.	Current passing.
1. Rose.	75	—	1·5in.	7·5 milliampères.
2. Single jet.	40	+	18in.	20 milliampères.

TABLE C.

Plain water, temperature 90° F., alternating current.

Nozzle.	E. M. F.	Pole to douche.	Distance of nozzle from body.	Current passing.
1. Rose.	x	+	1·5in.	Subject cried out "Stop." Milliampère meter (alternating current) in circuit did not register.
2. Single jet.	,,	+	12in.	Noise marked in telephone. Subject felt current.

Several readings were taken with alternating current and salt water, all showing that the effect was much stronger with salt water than with plain. These experiments seem to show that electricity can be imparted to the human body by means of the electric douche, provided that sufficient electromotive force be used and the stream of fluid be continuous. Table B shows that when salt water is used strong currents may be passed over considerable distances with a very moderate electromotive force. Table C shows that by using coil currents, which always possess a comparatively high electro-motive force, as much current as a patient can comfortably bear may be passed over many inches of space. Its current-carrying capacity being thus established, we may glance for a moment at its possible therapeutic effects.

There was a time, in the days of "brutal hydro-therapeutic empiricism," when both physician and patient had a (not altogether inexplicable) dread of the "hydrostatic douche." This, however, has given way before a more enlightened method of administration, and the douche is acknowledged to possess stimulating and alterative properties of no mean order. It seems not unreasonable, therefore, to suppose that in the combined electric and hydriatic procedure we may have a therapeutic agent of considerable power. It claims that, according to variations in temperature, force, and duration, it may be resorted to as an agent more gentle and adaptable than even the "electric hand" of the physician, or may be made to become so potent and concentrated as to prove a veritable electro-hydriatic moxa. It presents itself as a means of general electrization by bringing the various parts of the body successively under its influence; it claims an action that may be strictly localized; and, further, offers itself as a means of producing, through various motor inhibitory and secretory reflexes, those influences on nervous centres and glands which can undoubtedly be brought about by other and more painful methods of peripheral electrical excitation. If it can establish claims of this kind, a field of usefulness seems to lie before it in a class of cases which readily suggest themselves.* †

Attempts have been made to attain the above ends by the use of spray or vapour. But such attempts have failed, because the conducting medium had been so broken up and disintegrated that it ceased to act as a conductor. It is manifest that any stream of conducting fluid can only retain its conductivity so long as it remains whole, continuous, and unbroken. Spray is composed of numerous small globules, sometimes appearing as many fine, continuous streams, but actually possessing no real conductivity in the sense that applies to the matter under consideration.

It has not been attempted in the above paper to particularize the multiplicity of cases to which such

* O. Naumann found that weak electrical stimulation of the skin caused at first contraction of the blood-vessels, especially of the mesentery lungs and web with simultaneous excitement of the cardiac activity, and acceleration of the circulation (Frog). *Strong* stimuli, however, had an opposite or depressor effect. . . . Pinching the skin causes constricting of the vessels of the pia mater of the rabbit. . . . Cold dilates the vessels. . . . These results are due partly to pressor and partly to depressor effects. But the chief cause of the dilatation of the blood-vessels is the increased blood-pressure due to the cold constricting the cutaneous vessels (Landois and Stirling). The observations of Nothnagel, and the experiments of Rumpf on vascular reflexes, may also be referred to. The secretions of the liver and kidney are affected through the nervous system by its modifying the pressure and velocity of the blood current in them, and the hepatic secretion may be affected also by those nerve fibres which, according to Pflüger, terminate directly in connection with liver cells.

† The foregoing remarks on the electric douche are reprinted from *The Lancet*, Feb. 27th, 1892.

a very adaptable method may lend itself. Neither is it intended to do so now; but there are a few leading features in connection with its possible therapeutic uses which may be briefly referred to.

Electrical applications to the head are always more or less difficult. Amongst the factors that make them so are the high insulating power of the hair, the underlying plate of bone, and the sensitiveness of the trigeminal nerve.* It is not difficult to see how the electric douche may here be useful; inasmuch as by using a suitable "rose" the current may be made to flow freely over the whole scalp, and thus adapt itself, as no other electrode can, to the nature of the surface, and other special conditions with which here it has to deal. When coil currents at a high rate of vibration are used, it is a matter of experience that a very refreshing effect is thus produced. Of course I do not for a moment mean to say that such an arrangement is suitable to drive a localized current through the brain, in order to act at the site of a lesion in the case of, say, an extravasation or a softening; but in many slight cases it will be a safer and preferable current because a more diffused one. When, for example, a general refreshing effect is sought, or a stimulating action on the circulation and nutrition of the scalp, or when it is desired to effect alterations in morbid conditions of cerebral blood-pressure (hyperæmia and anæmia, which there is every reason to consider are very freely influenced by reflex action from the skin), it becomes a very suitable procedure.

* It is very different at the *back* of the head.

There is nothing doubtful, at all events, about the effects of electrization on the circulation and nutrition of the skin itself, and, therefore, of the scalp. It is interesting to remember that in the thesis already quoted of more than 100 years ago, and while static electricity was the only form in use, we find electrical applications mentioned as curative of baldness and useful in promoting growth of hair.*

The action of the electric douche as a means of general electrization by bringing the various parts of the body successively under its influence, and as a local application by bringing it to bear on any special part, have already been referred to. Used in this way we shall not fail to find in it a nervine tonic "heightening cutaneous sensibility and quickening motor excitability." It will influence nutrition and absorption by its control over the distribution and circulation of the blood current. It will act favourably also on local diseases, such as chronic joint affections, and promote absorption through its influence on the circulation. Its usefulness in states of general debility, and malnutrition, neurasthenia, spinal debility, and exhaustion, and any case in which want of tone is the prominent feature, needs

* Let us hope that the day is far distant when some enterprising Figaro will see his way to acting on this hint, and electrizing his "hot and cold head douche." It would add a new and real terror to the ordeal of hair-dressing if in addition to the usual question "shampoo?" the further query "electrized?" came always to be added; though it is impossible to stifle the conviction that such a procedure in proper hands would prove a better "application for the hair" than any of the numerous "restoratives" of the tribe of Macassar.

no showing. These effects will be brought about in more ways than one, but chiefly, perhaps, by the enormous range of reflexes that, by so effective a method of cutaneous stimulation, are brought into action.

Its adaptability to some forms of internal application cannot fail to suggest itself. How frequently is an ordinary douche resorted to for its tonic, stimulating, sedative, or germicide properties—on certain cavities and organs? Why should not such a douche be electrized? Suppose, for example, a uterine displacement dependent on an enfeebled condition of the organ or a relaxed state of the pelvic floor. We know the useful effects of faradic or galvanic treatment in such a case. Why not apply it by means of a water electrode? Why not—to the mechanical thermal or medicated action of the ordinary douche—add the powerful additional factor of electrical stimulation? The external auditory meatus, uterine cavity, bladder, vagina, naso-pharynx, and even "the cavities of discharging abscesses," are all open to its influence by means of the most simple mechanical contrivances. Insulated metal tubes with suitable interchangeable nozzles, or a recent ingenious and simple arrangement by which the turning of a tap on the delivery pipe changes the flow from rose to jet, may be used. Or if preferred the ordinary leather or rubber flexible tubes, lined by a metallic spiral as a conductor, can easily be adapted to the purpose.

This simple and unpretending method has been called "hydro-electrization."

(*d.*) The Electric Vapour Bath and the Electric Hot Air Bath.

The so-called electric vapour bath requires a short mention here. Of course, it is not an electrized bath; it is simply an application of electricity to a patient in a vapour bath. In certain cases, however, it is not without much to recommend it. The best and most suitable apparatus for the purpose is that known in hydro-therapeutics as the steam box bath, in which the patient sits, the head not being included. It consists of a steam-tight box, with a coil inside and a steam generating apparatus outside. The steam can be admitted into the cabinet by a valve or allowed to escape outside. In the latter case the arrangement becomes a hot air bath (*étuve sèche* of the French). The seat of the cabinet is in connection with one pole of the battery, and the other pole is attached to a plate below the feet, or is applied to some special portion of the body, according to the effect desired. The arrangement to be used will be vapour or hot air, according to circumstances, remembering only that the hot air can be borne at a higher temperature than the vapour bath (radiation, of course, being greater in the former and skin action more profuse). The vapour bath may be administered at, say, 96° to 104° F., or exceptionally up to 112°; the hot air can be borne at a higher temperature. It may also be remarked that in the vapour bath a higher temperature can be borne than in the hot water bath, but for a shorter time, since the circumambient vapour interferes with hea radiation from the body (Shelley).

If the above arrangement be not available a very efficient substitute may be extemporized by seating the patient on a chair with a large covered electrode on it, placing another under his feet, covering him over, except head, by a large blanket and mackintosh, and placing a couple of red-hot bricks in a pan of water. An extemporized hot air bath is managed in the same way, excepting that a spirit lamp only is lighted beneath the chair. By means of placing a vessel of water over the spirit lamp the body becomes subjected to the action both of hot air and steam. The process ought to last about fifteen minutes and be followed by a light douche, electrized or otherwise, and a good rubbing.

There cannot be a doubt as to the efficacy of these methods. They not only assist the process of electrization by diminishing skin resistance (by the hyperæmia and congestion they induce), but also, through the same action, have a directly beneficial effect of their own on the morbid condition (say neuralgic, or rheumatic, or stiff joint affection), in which their co-operative influence would probably be sought. The usual contra-indications to their use, such as diseases of the circulation, fatty heart, and conditions of old age and debility, will, of course, hold good whether accompanied by electricity or not.

Purely local effects by vapour or hot air baths can be secured by means of special "receivers" adapted to special parts of the body, and the local galvanic or faradic water-bath by simply placing the part in a vessel of water containing the desired electrode.

The ordinary morning sponge bath, with or without salt, may be converted into a faradic or galvanic bath in several ways. One way is simply by putting one electrode in the water and attaching the sponge to the other wire, the sponge being carried by an insulating handle, or held in the hand wearing an indiarubber glove. But these self-applied devices need only be alluded to as possible "health-aids" for those in good health.

(*e*.) CATAPHORESIS.

The so-called "cataphoric" action of the electric current, already mentioned, has been taken advantage of to introduce drugs into the body through the skin. It can easily be shown that medical substances in solution applied to the skin at the positive pole traverse the skin, enter the body, and can be detected in the excreta and secretions. "Cataphoric medication" has probably a future before it as experience and experiment gradually develope its capabilities. The + electrode must be saturated with the solution it is desired to pass, and be only sufficient in size to cover the area to be influenced. The negative electrode must always be much larger than the other, and the current must *not* be reversed as, in order to prevent polarization, is sometimes recommended. Reversing the current is reversing the onward progress of the drug. Polarization due to the current can easily be overcome by simply increasing the current strength. Suppose hydrochlorate of cocaine, the drug to be used — say, a 10 or 20 °/₀ solution. Soak the + electrode with it and use the — electrode of large size in the ordinary way. Use, say, 15 ma. of current — for a time varying from 20 to 40 minutes. The drug will find its way from the + towards the — pad by "mechanical transference" ("cataphoresis"). Here there is also another action. The cocaine, taking the place of the alkali in the salt, will pass from + to — pole electrolytically, *i.e.*, we have the electrolytic arrangement of particles, according to the well-known law "the migration of the iöns," helping the cataphoric action.

This method has at least one recommendation. It eliminates the possibility of poisoning. The quantity passed being so small the toxic effect is *nil.* And why is this infinitesimal quantity of service? Suppose it is wished to subject a special joint or a special gland to the influence of potassium iodide — suppose further that 5 or 10 grain doses be administered by the mouth, how much of that drug reaches the affected part? Probably not so much as the diminutive quantity brought directly to bear on it by cataphoric action. Medicinal substances must often act at an advantage by being introduced into the body close to the area of their expected action. Regarding it from another aspect, nothing is better known than the destructive effect of drugs on the process of digestion; may we reasonably hope that the therapeutic methods of the future will take more account of this? When only a comparatively local effect is sought or when the digestive organs are not themselves at fault, why deluge the whole system with medicine through the stomach, if the same effect can be produced by a localized introduction, and a much smaller quantity? There is in modern therapeutics a wholesome tendency to singleness in prescribing. I do not mean to say that in trying to get the therapeutic effect of a drug it is never necessary to combine another with it, to guard and guide it; but that combination of remedies known as a "mixture," and in America as "shot gun therapeutics" (many pellets being put in in the hope that some may hit the mark) is scarcely holding its own against the competition of simpler, more elegant, and exact methods—the compressed tabloid and hypodermic injection. In many cases, of course, it is possible to go still further and replace the use of drugs altogether by the acknowledged nutrient tonic sedative, absorptive and stimulating effects of the electric current. But, when they cannot be dispensed with, it will be a still further approach to the therapeutic millennium, if the introduction of drugs through the uninjured skin by cataphoric medication, ever become a practicable method and a recognized practice.

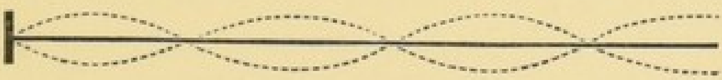
GROUP II.

Electricity—Electrical Phenomena—Current.

Science is not yet in a position to entertain any definite hypothesis as to what electricity really is. The question even has not yet been answered whether it is double or single in its nature. Have we to deal with a positive and a negative electricity, or is it all a question of quantity or distribution? Is an electrical atom some definite quantity like the atoms of a chemical element; or without possessing atomicity, does it give itself to such elements in different definite quantities, and so determine their character and ultimate composition? Not improbable, but not proved. Is it in any sense "matter" or "energy?" Prof. S. Thompson remarks that though it is neither of these, it resembles both, in that it cannot be created nor destroyed. The conservation of matter is an accepted doctrine, so is the conservation of energy now, and what Prof. Thompson has called "the conservation of electricity" seems on the high road to become so. On this view you cannot create or destroy it, you can only alter its distribution, or, in other words, disturb its equilibrium, and this is what our so-called "generators" do.

We approach somewhat firmer ground in speaking of "electrical phenomena." The modern conception is that they depend upon vibrations of "the all-pervading ether;" and this brings us face to face with the present day theory of molecular physics. It begins by assuming the existence of an "almost infinitely thin," "almost infinitely elastic," "fluid" called "ether," and Lord Kelvin holds that "all we know of matter consists of vortices or whirlpools of this ether." Without entering into the details of this hypothesis or its probability, we pass on to what is at all events an established fact of science, that light is propagated through space by ether waves, and that now it is also experimentally demonstrable that electrical and magnetic undulations are propagated in the same way. We know more of light waves than of electrical waves. Not only are they of a certain length, but we know of an organ, the eye, which can receive and register them in the colours of the spectrum. Now, turning aside for a moment into the region of speculative science, is it altogether inconceivable that, as Prof. Crookes suggests, in some special part of certain brains there exists a spot which can take cognizance of these electrical and magnetic waves as well?

Many circumstances have led up to the demonstration of the electrical wave. Postulating the existence of the universal ether, and assuming that light and electric phenomena are both modes of motion thereof, Clark Maxwell proposed an electro-magnetic theory of light. The analogy between the rectangular direction of forces resulting from electric displacement, and the fact that the "vibrations (displacements) which constitute a ray of light are at right angles to the direction of propagation" (*i.e.*, the medium oscillates perpendicularly to the extension of the waves) taken together with the remarkable agreement in number between the vibrations of light as experimentally determined, and of electric vibrations as theoretically calculated, seemed to point to a strong resemblance, if not to an actual identity in nature between light radiation and the radiation of the electric current. This question has now been taken out of the category of conjecture by the recent experiments of Hertz, who by means of his resonators has not only demonstrated the existence of the electric wave, but actually measured its velocity. The following diagram and remarks* will give form and shape to our ideas on this point :—



"If we fasten a rope at one end and swing its free extremity, a wave is propagated along the rope as far as the place of fastening; from the latter a new wave emanates in the opposite direction, thus representing a reflection of the first wave. By uniformly swinging the rope and reflection of the various waves, we at last receive the impression as if certain points of the rope, at equal distances from one another, remain at rest. These points at which the two kinds of waves cross each other we call 'nodes,' the vibrating parts between them 'crests.'

* *Electricity*, April 29th, 1892.

The distance from node to node is equal to half the wave length, and affords, together with the duration of oscillation, the means of calculating the speed of propagation of the wave. Hertz reflected his electric waves from a polished zinc surface, and increased the distances of the nodes. . . ."

"The apparent difference between light and electricity lies in the speed with which light vibrations succeed each other, so that we can electrically produce light waves . . . by constructing resonators of extremely high rate of vibration." So much for these undulations of the ether, these vibrations produced by electrical displacement. Now there is a phenomenon known to science as "sympathetic vibration." This receives an illustration in the fact that two pendulums of equal length at opposite ends of a brass rod will oscillate together (by reason of the vibration transmitted through the rod) if one of them be set in motion. A vibrating tuning fork will set another tuned in unison into similar vibrations. The same fact receives a further illustration in a familiar experiment with two wine glasses. The pendulums must be the same length, the tuning forks set in unison, and similarly an electrical radiator must be of the same conditions as the receiver. Now, plunging into speculation once more, can it be that a passive brain may under some conditions act the part of "receiver" to a suitable "radiator," and have its ideation set in motion by sympathetic vibration?*

* See a paper by Prof. Houston, read before the Electrical Section of the Franklin Institute, U.S.A.

We cannot assign to any special part of the brain the function of ideation. It may be that the doctrine of Fleurens is correct, which assumes that the whole of the cerebrum is concerned in every psychical process. This question does not affect the matter under consideration. The point is this,—given the possible existence of such a receiver, and knowing what we do of the propagation of electrical waves, and further being aware that certainly some, and probably all, vital processes, are accompanied by the development of electrical phenomena, the so-called "action" current, and that amongst others an electrical variation almost certainly accompanies cerebration—can we conceive that a brain in action may, by imparting wave motion to the surrounding ether, actually transmit its own vibrations to another brain, which by some physical conformation or other circumstance is in a condition of receptivity—that thus the radiating brain may reproduce its ideas on the receiving one, or at least modify in the receiving one a pre-existing train of thought. Can we thus frame a hypothesis that will bridge over a hitherto unspanned distance? Can we connect up mind with mind? Can we see a way in which the electrical outcome of the cerebration of one brain may be propagated to another? * May we, in fact, recognize a possible physical method of what Prof. Crookes boldly calls "thought transference" direct from brain to brain? May we thus obtain a clue to the

* Of course this has nothing to do with those hypnotic phenomena, which are sufficiently explained by the doctrine of "suggestion with a time element in it."

explanation of some cases too well authenticated to doubt, too unaccountable to believe, too frequent to be explained as coincidence, or on the doctrine of chances, in which one mind has apparently been influenced by the workings of another at a distance?

Such speculations are doubtless infinitely wide of the mark, but perhaps not altogether useless. Without violating any canon of physical law, or electrical possibility, or due scientific caution, they tend to bring physics into line with psychology, and perhaps give a glimpse into regions far beyond. They, at all events, broaden our ideas of the possible, and act as an antidote to that timid scepticism which in higher things has taken the form of the old-fashioned objection, "How can these things be done?"

Current.

The "electric current" is a term which has survived the fluid theory, in connection with which it was originally used. It is for convenience retained, but of course does not now imply a material current. It has been defined as the dynamic result, or result of motion, from the destruction of electric equilibrium in a conductor and the effort to restore it by means of another conductor (Bigelow). In making this effort, or, in other words, trying to find its own level, this current may be called upon to do work, to drive a motor, light a lamp, decompose water, or pass through the body of a man. This is electric power or electric force (not electro-motive force),* and is capable of being converted into other force or power. It is not, however, electricity itself, but the result of the disturbance of electric equilibrium. Therefore to speak of electricity as a "force," or an "energy," or "mode of motion" is not quite accurate. Steam power, if you like to put it so, is a mode of motion capable of being converted into other power or mode of motion; but no one with clear conceptions would conclude therefrom that steam itself is a mode of motion. Similarly electric power is a mode of motion, but electricity itself is not.

* Electro-motive force is an abstraction—an imaginary force (Dr. De Watteville). It is not force at all, for it does not act on matter, but on electricity, and tends to move it (Prof. S. Thompson).

GROUP III.

Medical Currents—(*a.*) Continuous Current, (*b.*) Coil Currents, (*c.*) Static Discharge, (*d.*) Currents of High Frequency and Potential.

Admitting the correctness of the modern idea of electrical phenomena, we are still very much in the dark as to the nature of electro-therapeutic influence. The manner in which vital processes (for example, the process of metabolism or tissue change) are affected, still remains to be explained. It is only one of many similar mysteries in medicine. How does nux vomica act as a "general nervine tonic?" What is the nature of those finer alterations in nerves upon which so-called "functional derangements" depend? What is the molecular change in a nerve that accompanies pain? What do we know of the cerebral changes that accompany the condition of psychical action—the processes of "thinking or willing?" An act of volition, whence does it arise? Is it called into existence by pre-existing cerebral conditions—impressions that are stamped on the brain as the result of past experiences, or is it "spontaneous." Physiology does not like the word spontaneous. About these and endless similar questions we are profoundly in the dark. Yet the physician does not fold his arms in helpless inaction and wait for complete illumination. He can and does effect much in the treatment of functional disease. He can and does do much to relieve pain, and to keep in good working order "the seat of all the psychical activities." Similarly with the "electric current," though we know little of its intimate nature, and though we are most imperfectly acquainted with its way of working, it is a great deal to know, and quite sufficient to warrant us in its use, that it has certain properties, that it follows certain laws, that its application is followed by certain effects, and that, in fact, electrization can profoundly and favourably influence the human body in disease.

The Continuous Current.

The continuous current has hitherto been called the "galvanic current" from the fact of its always having been obtained from a galvanic battery. It is, however, practically identical with that obtained from a continuous C. dynamo, and therefore is perhaps best spoken of as the "continuous current."

The continuous current is pre-eminently the "current of nutrition." Its influence on the absorptive and nutritive processes is supposed to depend upon a more or less combined action of the five following factors :

I. Its effect on the pressure and velocity of the blood current. (1) By direct action on the muscular coat of the blood-vessels. (2) By direct or reflex stimulation of the vaso-constrictor or vaso-dilator nerves. (3) By direct or reflex stimulation of the dominating vaso-constrictor or (assumed) vaso-dilator centres in the medulla; or (4) of such subordinate centres in the cord.

II. Its influence on the lymph current by acting on the lymph vessels and their nerves.

III. Its direct action on nervous centres and nerves, as well as an enormous range of reflexes, motor, secretory, and inhibitory. And in addition a probable influence on trophic nerves and centres, and possibly even on those very hypothetical thermic and electric nerves "which have been surmised to exist." Indeed the action direct and indirect of the electric current on the body through the nervous system gives it a possible range of action of bewildering extent and complexity.

IV. Its property of mechanical transference termed "cataphoric action," whereby it carries substances through the skin and tissues in the direction of the current—aiding the ordinary process of osmosis, or even overcoming and reversing it. How this action affects the question of "vital absorption" through the skin, if it affect it at all, is not quite clear.

V. Its electrolytic or chemical action—that is, to take one of its simplest manifestations, the action of which the effect is seen in decomposing water at the poles, or, perhaps, an analogous action short of this in every vital structure through which the current passes. The passage of strong currents through moist structures, such as those of which the human body is composed, produces the well-known phenomena of polarization, originally called by du

Bois-Reymond "the internal polarization of moist bodies," a condition assumed to be caused by electrolysis of the fluids. In the body this action is admittedly very obscure but doubtless very real. We know that outside the body urea has been formed from ammon. carb. by the action of voltaic alternatives.

Now it seems probable enough that an electric current passing through living tissue may, by actual electrolytic action as well as by "supplementing a due amount of nerve force," so modify chemical processes and influence metabolism as to prevent the formation, or bring about the destruction and elimination, of morbid chemical products. Is it that by the prevention of the formation of fatigue-stuffs (phosphoric and carbonic acid) electrization gives a muscle greater power of endurance, and by the decomposition and elimination of such products enables it to recover from fatigue and energize again more quickly? The effects of strong currents in reducing the size of certain tumours is now generally admitted. The mode of action is not quite so clear as the therapeutic effect. Probably, however, the result is brought about by both polar and inter-polar action—the former by direct galvano-caustic action at the active electrode whereby nutrient blood vessels are actually destroyed; the latter (inter-polar) by the passage of the current through the diseased structure setting up, in some admittedly obscure way, a process of subsequent disintegration. The same drug does not necessarily produce the same effect on a diseased structure that it does on a healthy one.* In the latter case its influence is cut down or abolished by the stronger vital tendency towards the normal. In a similar way it is not difficult to see how electrization may disintegrate a morbid growth like a fibroid, without exercising any unfavourable influence on neighbouring normal structures.

It has been pointed out by, I think, Dr. Althaus, that as a matter of fact, demonstrable by microscopic observation, cancer cells are more easily destroyed than healthy ones. In the light of recent experience, it would appear that the electrical treatment of some malignant tumours is likely to receive a fresh impulse. The effect of such treatment in diminishing pain, and lessening probability of recurrence, is even now scarcely in doubt.

The above-mentioned effects on the animal organism are often classed together as "catalytic." Catalysis, as used by R. Remak and explained by Erb, may be taken as "the expression of the current's influence on absorption and nutrition." The term has perhaps been useful in its day, but seems hardly worth retaining, as it adds no definiteness to our knowledge and no light to our ignorance. The matter stands thus: That the electric current has marked effects on nutrition and absorption is certain; that it has all, or nearly all, of the above so-called "catalytic" properties is also well-established; that these two facts have the relation of cause and effect is a probable but un-

* De Watteville.

proved hypothesis. Probable, however, as the theory is, it is perhaps more likely that in addition to these known physiological and chemical effects its influence on the nutritive and absorptive processes depends on some subtle molecular action over and above and independent of any of them.

VI. The constant current "when closed or opened, or its direction reversed, or its current strength altered, acts as a stimulus to nerve and muscle."

This stimulating and exciting action is well known, and is the popular idea of medical electricity. It was originally the only action sought or thought of in electrical applications; and they were mostly limited to paralytic affections, and consisted in a rather indiscriminate electrization of muscle, nerve, or skin. Such a proceeding constituted the whole art of electro-therapeutics of not very long ago, and is still regarded, even amongst those who ought to know better, as the supreme and only object of an electrical application.

VII. The influence of the continuous current on nerve excitability, sedative or stimulant, according to its mode of administration, and generally discussed under the term electrotonus, is known as its *modifying* influence. This modifying action, however, is of a much less transitory character than those conditions of altered excitability known as "anelectrotonic" and "katelectrotonic."

VIII. Its efficacy in fatigue diseases, and its effects on artificially exhausted muscle, demonstrate its so-called *refreshing* action.

IX. To the above must be added its power to sterilize fluids and destroy disease germs — its antiseptic or germicide properties, a subject, however, which demands some further experimental investigation.

Faradic Current.

The term faradic is generally limited in medical electricity to that form of alternating current produced by galvanic induction (Erb). Other forms of interrupted current, however, have also to be considered, namely, the so-called interrupted "direct," which can be obtained from the primary circuit of an induction coil, and the interrupted alternating which may be obtained from an alternating dynamo. Putting aside for the moment the last named, it is perhaps more convenient to speak of "coil-currents." Of course a coil current *must* be "interrupted." It represents, however, an energy not different from that of the continuous current; but this energy is presented under such very different physical conditions, and possesses such very different physiological effects, that for therapeutic purposes the alternating and continuous current may be regarded as almost two different agents. At the same time, it must never be lost sight of that the difference, strictly speaking, is one of degree— that it depends upon their being differently "cooked," so to speak, before being "served." By the time the continuous current has been run through the coil and chopped up by the interrupter, and, through inductive action, made more pungent and penetrating by the addition of electro-motive force, it has become a very different thing, and "a little of it goes a long way." In other words, if a galvanic and interrupted (primary) current of the same electro-motive force and current strength be made to intermit with the same intervals their effects will be the same. The interrupted primary, owing to self-induction, gives, of course, a considerably higher E.M.F. than when it leaves the generator, but the current strength is reduced. It need scarcely be added that its effective action varies with the frequency of the interruptions, and that the current strength of the primary is, of course, always greater than that of the secondary and its E.M.F. less.

No little misconception seems to exist as to the respective qualities of the current from the primary helix (short and thick wire) and the secondary (long and thin wire), and the various accessory coils (of wire varying in thickness and length) sometimes supplied with a "faradic battery." Of course, speaking generally, the current strength of the short thick wire is comparatively high, and its electro-motive force comparatively low; but it does not *necessarily* follow that because a short thick wire is used you get a larger current strength through the patient. Another factor, namely, resistance, has to be taken into consideration. Unless the electro-motive force is sufficient to get it through the resistance of the skin, current strength is thrown away, and the long thin wire, with its high electro-motive force (the factor which overcomes resistance) and small current strength, will succeed where the other failed.

For medical purposes, coil currents, either from the primary or from a secondary Helix of low R., are generally resorted to when a purely stimulating or exciting action is sought. They stimulate both nerve and muscle. They are not stimulants to nutrition in the same way as the continuous current, but by increasing blood and lymph supply and augmenting functional activity they improve it indirectly. When the C. strength is sufficiently reduced (as is effected most conveniently by secondary or accessory coils), and especially if the rate of vibration be increased, it is not difficult to see how such a current, administered perseveringly in small doses, will act as a general or local tonic. Indeed, this is one of its most valuable uses, and finds an application in a variety of constitutional diseases, and conditions where impairment of nutrition and want of nervous and muscular tone are leading features.

The "pain-killing" properties of the interrupted current are sometimes very marked. These effects are brought about not only by the relative "values" of the E.M.F. and C. strength (depending upon the construction of the coil as already indicated), but also on the rate of vibration. Whatever the explanation may be, I think it is admitted that the quicker the vibration of an electrical stimulus the less will be the effect as regards pain. It may be that the stimuli follow each other so quickly that the psychosensory centres cannot so easily take cognizance of them. (By diminishing the sensibility of the brain to their own stimuli they will also diminish its sensitiveness to other co-existing pain.) Or it may be that the action is of the nature of a nerve shaking, or nerve vibration, whereby the molecular arrangement of a nerve may be affected, both as to its carrying power and peripheral receptivity. "In hyperæsthesias and neuralgias faradic currents are applied with the object of over-stimulating the hypersensitive parts, and thus benumbing them."*

As a matter of fact it is of importance in any coil apparatus to have an arrangement by which several different rates of vibration can be secured—a much wider range being desirable than that supplied by the ordinary instruments in use in this country. At least three well-defined rates ought to be easily available. Say, *a*, giving 200 per second, or as many more as may be obtainable (it is difficult to say in the light of recent non-medical work where the rapidity of vibration ought to end)†; *b*, say, 50; *c*, say, under 10. Thus "a" would be used as a sedative and pain-killing current, "b" as a nerve

* Landois and Stirling's *Text Book of Physiology*, p. 710, Vol. II.

† Some of these experiments are conducted with currents alternating at a rate of more than a million a second. It has been found that a current at 50,000 volts alternating with extreme rapidity cannot be felt. With this we compare in astonishment, the comparatively insignificant voltages of the currents that kill. Ampèrage must be considered as well as voltage.

tonic and for ordinary muscular stimulation, and "c" for maximum muscular contraction.

It has been stated that in certain conditions unassociated with inflammation the interrupted primary has certain special analgesic properties, and that it will often relieve pain when not only other forms of interrupted current, but even galvanization, have failed.

Static Electricity.

Static or frictional electricity (the one term denoting its stationary character, the other its method of production) was, of course, until Galvani's discovery, the only form of electricity known. During the course of this century, however, it has been almost completely displaced by its younger rivals. It has a much more limited range of usefulness, and some disadvantages in the way of bulkiness of apparatus and uncertainty of action. Still, it is not without a special usefulness of its own, particularly for the relief of certain forms of pain. Its employment has recently been revived in Paris, and seems to have been followed by a large measure of success. If this be so, an apparatus for its production, more compact in form and more certain in action, will, doubtless, be devised. An immense stimulus would thereby be given to the use of high potential currents in medical work. Static electricity may yet repeat some of its eighteenth century triumphs.

The recent experiments of M. Nikola Tesla go to show that induction apparatus may produce electrical conditions similar, if not identical, with those hitherto considered peculiar to the static discharge. The same investigator has also drawn attention to the rise in skin temperature of the insulated human body on being subjected to what he calls a "bombardment, by alternating current of high frequency and potential." The procedure is novel and very interesting, and not improbably has a therapeutic future before it. But, as the matter is scarcely yet out of the experimental stage, it need not detain us now.

GROUP IV.

Other Sources of Electrical Supply—(*a.*) Current "from The Main," (*b.*) The Continuous Coil Helix, (*c.*) Accumulators.

Considering the magnitude of the currents we have to employ for the bath, the question of electric supply becomes an important one. A comparatively portable battery of small cells will soon "give out" if used for bath work. If, however, a fixed battery of cells of sufficient capacity be available, it would suffice for bath as well as for other purposes for a considerable time. If not, it would be necessary to get, say sixty large cells, which could be placed in any convenient position. A cell collector or a rheostat would, in this case, be necessary. If a suitable electric light circuit be available, *i.e.*, a constant supply of continuous current, and it be considered advisable to use it for electro-therapeutic purposes, it is not difficult to do so, and the problem of supply is at once fully solved.

The question of Battery v. Dynamo Currents must, of course, for some time remain *sub judice*. But for the convenience of those who think the matter worth consideration, the following paper is submitted as a first step towards forming an opinion :—

CURRENT "FROM THE MAIN."

(Reprinted from *The Lancet*, December 19, 1891.)

"With the electric light circuit at our doors, the question of utilizing it as a source of supply for electro-therapeutic work is literally brought home to us. I propose at present merely to point to some methods by which this can be done with comparative ease and safety. The *advisability* of so using it is another and larger question, which it is not intended to enter into now.

"We have, first of all, to face the fact that the light current is generally supplied to houses at not less than 100 volts, and that the quantity used for even a single incandescent lamp is much in excess of that ordinarily required for medical purposes. It is manifest, therefore, that some modifying arrangement must be adopted before the current from the ordinary light circuit can be used with safety. Let us take an instance—a house containing incandescent lamps requiring fifty watts to properly light them. The electro-motive force of the supply is 100 volts, so the current must be half an ampère or 500 milliampères.* Many lamps now take only thirty watts, making the current 300

* To be quite in accordance with what is occurring in actual practice at the present time, it would be well to assume that the 16 candle lamp requires a supply of about ·6 ampères, *i.e*, 600 milliampères.

milliampères. We may therefore assume that the safety-fuse of such a lamp (and every lamp ought to be so protected) would act if more than 500 milliampères passed, and automatically break the circuit, so that no harm could be done to the lamp. Here, then, we have the maximum current obtainable from a single lamp lead of an ordinary light circuit, viz., 500 milliampères. This maximum for medical and surgical purposes, of course, leaves an excessive margin, and could doubtless be reduced if desired by using a safety-fuse adjusted to break the circuit with a smaller current; but considering the power that must be available for, say, the di-polar bath, and the current strengths that have been talked of in connection with the electrolysis of fibroids, there does not appear to be any real reason for fixing our limit of safety at less than 500 milliampères.

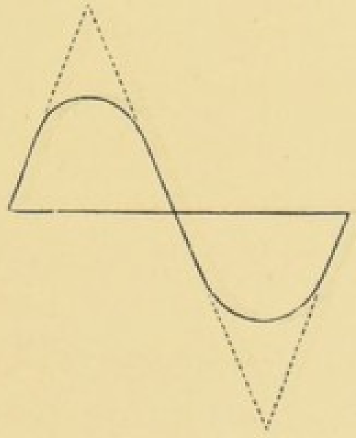
"The next question is how best to modify this maximum so that we may use little or much of it at will. For this purpose, if the current supplied be the continuous one, an adjustable rheostat is all we require, provided we keep a milliampère meter, or at least some current measurer, in circuit. Such rheostat ought to possess quite 50,000 ohms resistance, working down by steps not exceeding 1,000 at a time to zero. The objection to such an arrangement is that, in the event of the electro-motive force in the mains rising suddenly from some disturbing cause, the safety-fuse may act and (automatically cutting off the current) give a more or less violent shock to any patient under treatment at the time.

Further, that if, as sometimes happens, the fuse be somewhat sluggish in its action, a current considerably in excess of that intended may pass through the patient for the instant previous to the automatic breaking of the circuit. In a well-regulated current supply, such as that now provided by our English electric light companies, the risk of accidents of this nature is very small. Still, it is well to bear in mind that, in using a current from an electric light main, we must be prepared against an unexpected and undesirable *increase* of power, instead of the unexpected, undesirable, and vexatious *decrease* of power which frequently accompanies battery currents.

"Since commencing this article, I have been informed that an instrument has been devised, and will shortly appear, which provides for the utilization of continuous current installations for galvanization, faradization, electrolysis, etc., and which affords perfect protection in the use of such currents; being so arranged that it is impossible for more than the maximum current to which the instrument is set to pass to the patient. The maker supplies me with the following particulars: The instrument contains two switches for turning on the continuous or the faradaic current. Either of the two has to pass through a 16 or 32 candle lamp to prevent (in case of short circuit) the destruction of galvanometer, coil, etc. The current strength is graduated by means of four graphite and one metal rheostat. The latter contains altogether 1,000 ohms on 28 subdivisions; the former contains 1,000, 10,000, 50,000, and 100,000 ohms respectively, which can be varied *without any shocks.* All the other connections—current reverser, De Watteville's key, etc. —are exactly as in the combined batteries by the same maker.

"In dealing with alternating currents from dynamo circuits, the necessary modification for therapeutic uses can be easily made by means of a 'transformer.' The function of a transformer is, of course, to 'transform,' *i.e.*, to alter the relative values of electro-motive force and current strength as supplied by the mains; and the special use of the medical transformer is not only to render high potential currents safe by 'transforming down, but also (by means of the Du Bois Reymond sledge arrangement) to secure the necessary regulation of current strength. One advantage of such transformers is that the current obtained from the secondary circuit, which is that used for therapeutic purposes, does not come direct from the main, and therefore the risk of 'shock' to the patient is reduced. It is, however, as necessary that a safety-fuse, or some automatic 'cut out,' form part of the circuit with alternating as it is with continuous current. A special transformer for alternating current (by the same maker as the continuous current arrangement already referred to) was recently described in *The Lancet.* It acts as a reversed induction coil, *i.e.*, a weak intermittent current of high electro-motive force passes through the primary coil, which is wound with many turns of fine wire, and induces strong currents of low electro-motive force in the secondary coil wound with a few turns of thick wire. The instrument seems to work very satisfactorily, and I can personally testify to the regular, even, and pleasant character of the current obtained by its use when attached to a lamp lead upon the Grosvenor Gallery circuit in London.

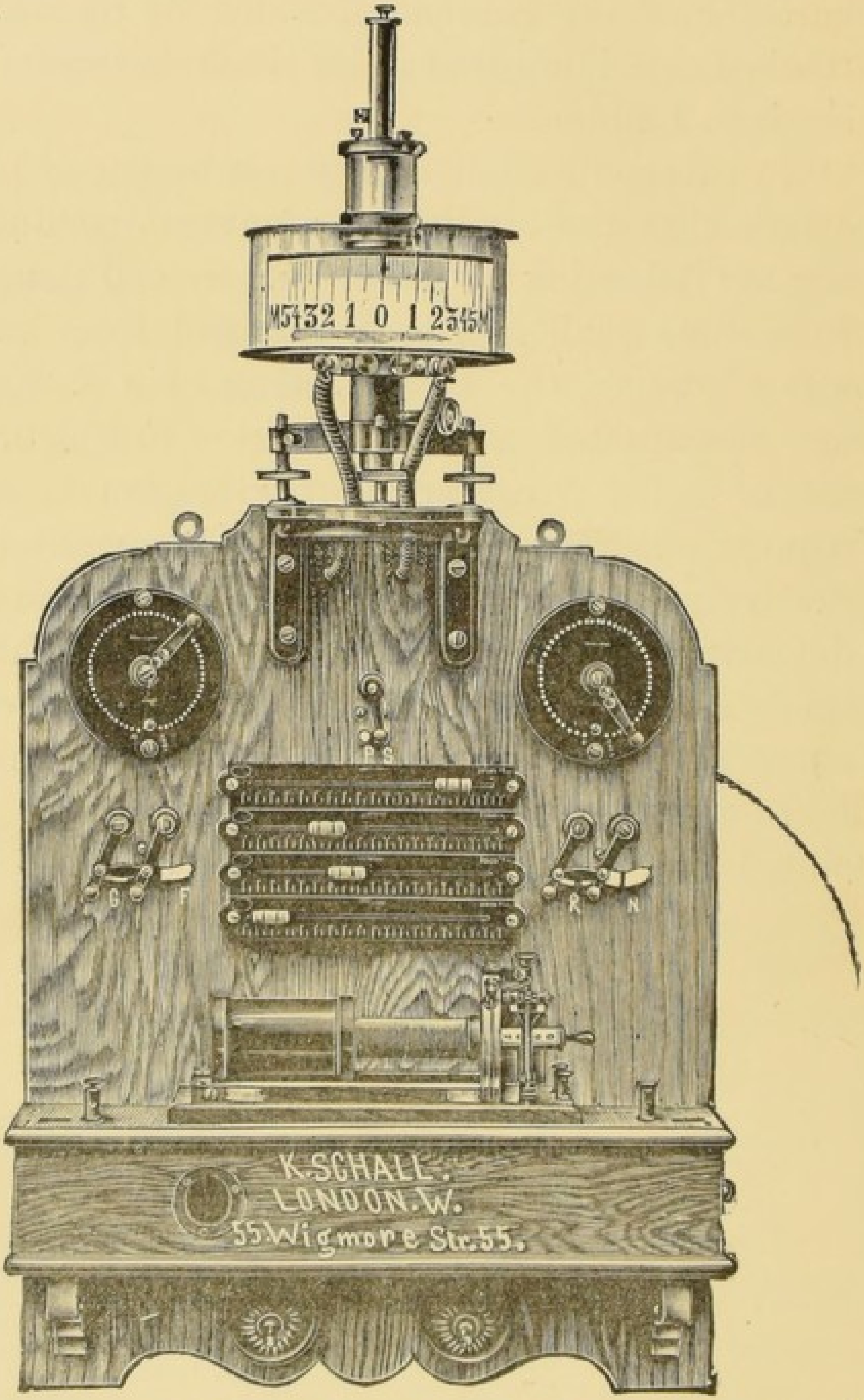
"In this connection it may not be out of place to remark that the quality of a current produced by galvanic induction in the secondary coil is not *quite* of the same quality as that obtained from an alternating dynamo, the former being of a sharper and more accentuated order, in addition to which, in the best of coils, irregularity of vibration is a very frequent occurrence. The dynamo current is comparatively smooth and wavy, the alternations being 'demarcated' by a neutral point smoothly and rapidly passed, rather than by an interval. A 'curve of sines' represents it.* In the following diagram the sine curve is shown as well as the pointed character of a coil's alternations :—



"The outcome of our inquiry, therefore, seems

* Though in practice the true sine curve is seldom found.

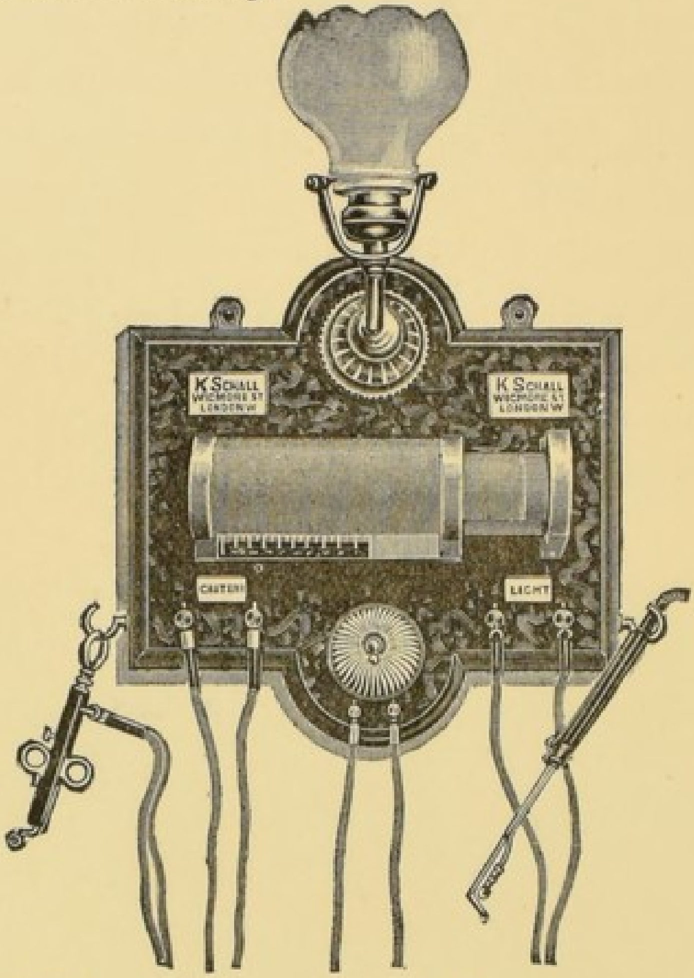
to be this: That whilst it is clear that electric light circuits cannot be used for medical purposes without the strictest measures of precaution against the influx of strong currents, there is also good reason



to suppose that efficient protection can be secured by the adoption of the above-indicated or other suitable methods."

As to relative cost and convenience, on neither point is it very difficult to institute a comparison between battery and dynamo currents. To purchase a battery with suitable attachments, capable of producing, say, 500 milliampères of current, could scarcely be much less than the outlay involved in providing a satisfactory arrangement for modifying and safe-guarding the light current, *i.e.*, a switch-board of much the same form as that on the face of an ordinary combined battery, but with resistances (say, 120,000 ohms) instead of a cell collector.

The preceding figure shows the arrangement for using the 100 volt continuous current incandescent light circuit. It contains resistances amounting to about 130,000 ohms, made up of four of graphite (seen in centre of the figure) containing respectively 10,000, 24,000, 39,000, and 50,000 ohms, and two metal resistances (the two circular sets of studs at right and left of upper part of figure), amounting together to 6,000 ohms. A 16-C. lamp (which cannot be switched out of circuit) is inserted before the fuse wire, and is "in series" with the rheostats or coil. The ordinary "normal or reversed," "galvanic or faradic," "primary or secondary" switches are seen. The wires for connecting up with the main are shown, and the two terminals for rheophores. The lamp when lit appears through the circular opening just below the coil. The fixed galvanometer is conveniently situated for those who have a separate galvanometer for each circuit. When it is desired to use currents of quantity, as for cautery work, the introduction of a transforming apparatus is necessary.



For utilizing alternating dynamo-currents the "Woakes Transformer" may be used; shown in the foregoing illustration. As already explained, it consists of a (long, thin wire) primary coil, with a sliding secondary composed of three separate circuits. By this arrangement a supply is obtained —(1) to light an 8-C. lamp; (2) to heat a cautery, or (3) to supply alternating C. for ordinary therapeutic use. By a modification of the arrangement it may be used to change or transform C.C. into A.C., much after the fashion of the ordinary induction coil. But it must be clearly borne in mind that though in such a case the instrument receives continuous current it cannot *give out* continuous current. To utilize continuous C. from dynamo *as* continuous current such an instrument as the one last described (it still awaits *a name*) is necessary.

The cost of "maintenance" might, perhaps, at first sight appear to be in favour of the battery, but when the "life" of the battery has to be taken into account, this difference considerably diminishes. To take a very high estimate;—suppose the amount of current required to be the quantity necessary to supply one 16-candle lamp. The additional consumption in a house possessing several such lamps would not increase the supply meter record to a very appreciable extent. In Brighton the cost of burning a 16-C. lamp is (per hour) 0·4 of a penny; that is, for something less than a halfpenny a supply of between 500 and 600 ma. is at disposal. Or, to put it in another way, such a supply is available for two hours a day at a cost of about twenty-five shillings a year. The expense of keeping in order, recharging and renewing a battery of equal power might easily exceed this.

As to convenience, it needs no showing to prove that, provided the current be delivered to the mains during the whole day continuously, such a supply is incalculably more convenient than any arrangement in use at present. It requires no attention, and is "ready to hand" at a moment's notice. There is no battery to renew, or repair, or "run down," or "polarize."

Even if such a source of supply can be made available without danger, or the risk of painful shocks, I would hesitate to affirm that it will quickly establish itself as the medical current of the immediate future. But it is, in any event, safe to say that its use would do much to soften the lot and sweeten the temper of many a sore tried medical man.

The nature of the precautionary measures necessary are briefly indicated in the following paper :—

CURRENT "FROM THE MAIN."—No II.

(Reprinted from *The Lancet*, April 9th, 1892.)

"The instrument foreshadowed in my recent communication* has now appeared. That electric light circuits are easily available for electro-therapeutic purposes may be accepted as an established fact. The time, therefore, seems to have arrived to carry the inquiry a stage onward, and to ask, with what measure of safety? The danger is the possible influx of strong currents. It is clear that against this risk our ultimate protection at present must lie in the safety fuse or 'cut-out.' It seems to me also clear that with a really reliable 'cut-out' between him and the mains, the physician may, by suitable methods, handle electric light circuits without misgiving. But what is a really reliable 'cut-out,' and where is it to be found? I think it is not to be found in a large proportion of the ordinary fuses used in electric lighting. First, because in light installations a fuse that acts within from five to ten per cent. of the normal current is considered to be safe and satisfactory—*e.g.*, a fuse set to break at one ampère would be within a sufficiently close percentage if it acted at 1·1 or 0·9, a margin of possible variation amounting to 0·2 or 100 milliampères in 500. This is not sensitive enough for us.

* *The Lancet*, December 19th, 1891.

Secondly, in electric lighting it is the practice to insert a fuse whose breaking point is from 50 to 100 per cent. above the normal current. Thus, to protect a three ampère circuit a fuse marked to break at five would probably be used. This adds another element of uncertainty and danger.

"We must have a device that will automatically break a small current circuit with unfailing exactness, or shunt the greater portion of any sudden influx through another circuit. On making known my requirements, I have lately been supplied with the former, and I regard it as a most ingenious and reliable instrument. It can always be in full view of the operator, can be set to exact requirements, can be tested at any time, its working parts are of the simplest description, and, set as it is now, it breaks circuit with unerring accuracy at 500 milliampères. It is the invention, I believe, of Mr. Cunynghame,* and its description is as follows:—The two ends of a copper solenoid dip into two mercury cups, and on the current reaching the predetermined amount, the solenoid is 'sucked over' by (*i.e.*, drawn back upon) a fixed iron core. The solenoid is pivoted at the bottom, so that, as soon as it deviates a little from the centre, it drops by the force of gravity, carrying its ends out of the mercury, and so breaking circuit. A magnetic 'cut-out' of this description seems to me to have certain advantages over a fuse, the chief of which is that the exact breaking point can always be ascertained without destroying it. This instrument seems all that could be desired as a circuit breaker.

* Manufactured by Woodhouse, Rawson, United, Limited.

Of course, as already mentioned, it is in the highest degree improbable that it would often be called upon to act. Still, the possibility should not exist that a current strong enough to call it into action might pass through the body. To make this impossible the electro-therapeutic circuit ought to be a shunt circuit—*i.e.*, only receiving a certain proportion of the possible maximum—a proportion that can be adjusted according to requirements in a way somewhat similar to that by which we shunt a galvanometer to read 5, 50, or 500 milliampères. Resistances up to, say 100,000 ohms, should be available for this shunt. Suppose the predetermined amount of current that the 'cut-out' will allow to pass to be 500 milliampères; in a one-fifth shunt the possible maximum would be 100 milliampères, capable of reduction by the adjustable resistances to any required minimum, which could not be exceeded even were the 'cut-out' protected circuit breaking at 500 milliampères. But a break of even the smallest current may be prevented by means of an arrangement that will, instead of *breaking* the main circuit, *shunt* the greater portion of it. Thus, then, we are safe-guarded. Our first line of defence is an effective 'cut-out' to break the current at a predetermined amount, or to shunt any sudden influx. Our second defence consists in the fact that we are working on a by-circuit, and not on one that allows a current of 500 milliampères through all resistances to pass before it breaks. Our third line of defence lies in the adjustable resistances, whereby we can bring down the shunt-reduced maximum to any desired figure, however small. These resistances are absolutely reliable, and afford, in fact, a smoother, safer, and more satisfactory method of regulating current strength than even the cell collector, upon which, in this country at least, many of us are accustomed so implicitly to rely."*

I am not able to supply any actual therapeutic experiences of dynamo currents. The continuous current circuits which I have examined, either by watching the voltmeter or by experiment on my own person, have all shown remarkable steadiness. It is scarcely necessary to say that a current fluctuating beyond certain limits would be unfit for medical use.

Any definite opinion as to the therapeutic value of dynamo currents must necessarily be held over for the present. The whole of this part of the question must await, in the first instance, further experiment, and then the verdict of experience. One of the earliest and gravest points may not improbably prove to be the question, To what extent will a current working through such resistances as above indicated lose its *diagnostic* value?

All that the foregoing remarks claim to show is that light currents can be used for medical purposes with ease and safety.

Accumulators.

From a recent book on medical electricity (which has appeared since the above remarks

*A paper by the author, reprinted from *The Lancet*, April 9th, 1892.

were written) I quote the following sentence: "In case of direct current distribution, no doubt the best method of utilizing the current so supplied is to charge accumulators with it."* This refers to the use of electric light mains for ordinary medical work. In the absence of stated reasons,† and in the present stage of the question, this statement strikes me as somewhat "axiomatic."

To get the effect of a battery of 60 large Leclanché cells about 45 of these costly accumulators would be necessary (say, 90 volts by 45 cells at two volts). If initial outlay need not be considered, and skilled attention be available, such an arrangement may perhaps be practicable; but for the individual practitioner it seems to me quite out of the question. Under any circumstances, it would prove by no means so simple as the above passage seems to imply. Secondary batteries are notoriously difficult to manage for any length of time, even by practical electricians. Doubtless with improved construction this drawback may in course of time be overcome. At present, however, the difficulties of their management, and the probabilities of their mismanagement, are such that few medical men would care to encounter. At the same time, it is quite clear that a small battery of these secondary cells (say, 2-6 at most) is most convenient for special purposes—say, to heat a cautery or light an exploring lamp. The E.M.F. is con-

* *Medical Electricity*, p. 149. Steavenson and Jones.

† Many reasons *against* using accumulators are given on p. 138 of the same work.

stant, and beyond the regulation of C. by a rheostat not much further attention is requisite. Charged accumulators can now be hired, and when few are wanted this plan is a good one, but for a large number the cost would be prohibitive.

Cautery work always requires special arrangements. The introduction of some transforming arrangement into continuous current circuits may effect the object; but as already stated nothing could be more convenient for this special branch of work than (say) a couple of secondary cells. To use accumulators for ordinary purposes of medical work is to go to unnecessary cost and trouble. With the precautions detailed in the foregoing remarks, continuous C. may be drawn direct from the mains. In comparison with accumulators, I cannot help thinking that such a source of supply will be found equally safe and incomparably more convenient.

The Continuous Coil Helix.*

A special kind of induction coil—the so-called continuous coil helix—seems to have met with distinguished approval in America. It is claimed for it that in point of efficiency, range of action, and quality of the current it is much superior to the ordinary "separate" coil induction instrument. It is termed "continuous" coil because though made up of several distinct coils (each successive coil "increasing in length, but decreasing in thickness) they make direct connection with each other," and

* A paper by the author which appeared in *The Provincial Medical Journal*, June, 1892.

so they not only receive inductive influence, but the primary inducing current also is actually "carried over."

I propose to follow the description given of the instrument by one of its most distinguished exponents, in the eighth edition of a work which is universally acknowledged to be a vast mine of valuable experience. But before going further it may be well to clear the ground by adverting to some of the views of this author as to the ordinary induction coil. "We may say that currents have elective properties . . . but the reciprocal relations between the nervous system and the action of electricity are not yet sufficiently understood to offer a satisfactory explanation of the interesting fact that in external local faradization the so-called current of tension is the most effective . . . while in internal local faradization the so-called current of quantity acts most vigorously."*

Now my impression was that if there is one thing more generally admitted in electro-therapeutics than another it is that the greater electromotive force (the factor that overcomes resistance) is sufficient to account for the one, and the greater current strength (and therefore effectiveness in internal applications where there is no high resistance) accounts for the other. This, the ordinary view of the matter, seems more satisfactory than an explanation that assumes the existence of any "elective" property. Yet almost as the primary

* *Medical and Surgical Uses of Electricity.* Beard and Rockwell, p. 413.

current runs through the whole length of the instrument, so does this primary idea of "election" seem to run through the author's description of it. The following extracts explain his views: "The current from the primary or first induction coil corresponds very closely with the current from the coil of the separate coil apparatus . . . the important practical point . . . is the extraordinary increase of energy that is manifested when application is made to parts within the body."* Why extraordinary?—though the electro-motive force remains the same the resistance in the second (the internal application) is less, and of course the current strength is proportionately increased, and this increased current strength is the increased energy referred to. But so far from this being extraordinary, it seems exactly what might be expected.

As to the second current, that proceeding from the primary and secondary coils of the combination, I continue to quote. "Externally applied it is comparatively weak, although far stronger than the other, but when applied to uterus or vagina its extraordinary action on motor or sensory parts will hardly be credited. . . . This is what may occur. . . . You shift the slide so as to exchange the current of great for one of lesser tension, which according to all experience of external applications is infinitely weaker — instantly a shock is occasioned." Yes, in this proceeding you are really strengthening the primary current, and therefore increasing induction in the secondary because you

* *Ibid.*, pp. 414, 415.

are getting the "extra" current *with* you instead of *against* you. This form of diminishing the current is like switching out a cell or a modified form of "break shock"—a procedure by which the "extra" current (according to the well-known law concerning induced currents of rupture and demagnetization) becomes direct—and therefore no longer acts to cut down the electro-motive force of the primary, but to assist it. This being so, it is not difficult to account for the shock produced by diminishing the current when applied to internal parts. The same thing is not felt in the external application because the high resistance of the skin delays the sudden increase of electro-motive force and prevents this momentary effect.

To proceed with the description. "The third current of the series, that proceeding from the primary and second and third induction coil, is of unique quality so far as relates to its effects when applied externally. . . . The peculiarity of this combination of the coils is that the maximum power to contract the muscular tissue when the application is made through the skin is here obtained. Why the maximum of current strength is reached in the combination of the primary with the second and third induction coil it is difficult to say, excepting as we ascribe it to the law of harmony or polarization that is brought about by properly conditioning the magnetic centre of the helix—the several coils composing the helix—and the battery influence acting on the coils."* Is it necessary to fall back upon

* *Ibid.*, p. 416.

so ponderously complex an explanation as this? This current acts powerfully through the skin, because its E.M.F. (the factor that overcomes resistance) is great. The description thus continues: "This current, possessing far less quantity but far greater tension" (it was current strength in the last sentence) "than the two preceding already described, exerts by no means the same influence over the contraction and sensibility of the vagina."* No—of course—current strength is gradually being got rid of as the coils and their accumulated resistance are increased, so that when it would be really effective in these internal applications (where there is no high resistance to be overcome) it is no longer there. It has vanished into E.M.F. (which is not wanted), and has otherwise disappeared in the complicated physical actions inseparable from this very complex arrangement. But the E.M.F. "told" when the skin resistance was to be overcome. The description continues (still speaking of the third current): "Its energy of action in this respect" (*i.e.*, its effects on contraction and sensibility) "is greatly superior to the fourth current of the series next to be described."† Yes, when the fourth current is arrived at more current strength has disappeared. "The currents from the two preceding combinations" (*i.e.*, second and third) "are exceedingly harsh and cutting in character . . . this" (*i.e.*, the fourth) "is always agreeable; at least not painful."‡ Yes, current strength and E.M.F. have

* *Ibid.*, p. 416. † *Ibid.*, p. 416.
‡ *Ibid.*, p. 417.

both to a great extent disappeared. A current has at length been arrived at weak enough to be useful and comfortable. Perhaps the explanation is that owing to the added resistances of the coils, and the counter electro-motive forces acting as resistances, the efficiency of the apparatus as a "generator" of electricity has been greatly diminished. Or to put it differently, such energy as the instrument is capable of has been frittered away in performing useless work upon itself.

The author states that by different combinations of these four coils ten different qualities of the current can be obtained. It is not necessary to follow them further, and a more complex problem in electro-physics it is impossible to imagine. The rough general points to bear in mind with reference to the electro-physiological action of the continuous coil helix are somewhat as follows: (1) It has the primary current running through it, its whole length. (2) The induction current of every succeeding coil is reversed in direction. (3) Each coil receives inductive influence from the neighbouring coils, as well as from the primary current, and also from its own self-induction—its own "extra" current. (4) The forces at work to cut down the current are to be considered, viz., the increased R. of the added coils and the counter E.M.F. due to the inductive action acting as a resistance. Take, for instance, the third coil when used with the first and second. It would have the extra current of the primary with it, and the induction of the secondary opposing it. (5) All these opposing electro-motive forces run right through the entire series of combinations.

The practical result to the physician of the foregoing considerations will probably be—first, to ask himself the question whether this continuous coil helix has advantages over the ordinary induction instrument in proportion to its complexity. I think the more he examines the point the more he will incline to the opinion that a coil constructed on the ordinary principle without the numerous complications inseparable from this arrangement (viz., the numberless extra currents, the various directions of the inductive action, and the accumulated resistances of the numerous coils), one with its secondary helix containing less wire than the many coils we have been considering, would give the same amount of electro-motive force. Further, I venture to think it scarcely doubtful that the second practical result of the inquiry would be to strengthen in his mind the conviction, that puzzling and complicated as the electro-physics of the question is, it is there and there only that the explanation of most of the above-described therapeutic effects is to be found. That to call in any assumed "elective" properties, by way of explaining the phenomena, is not only unnecessary, but seems almost to imply a misapprehension of the physical laws that govern the action of all electrical currents. The more we reduce the question to the relative values of electromotive force, current strength, and resistance, the more clearly, I think, will we be able to see our way through this bewildering maze of coils and combinations.*

Note.—Of course, it must never be lost sight of that into some of the above phenomena the question of "nervous supply" enters as a complication. Speaking broadly, it is obvious that the effect of an electrical stimulus (of the same electromotive force and current strength) will be much more marked when applied to a very sensitive organ than when applied to a slightly sensitive one, in some cases even if the former have the higher resistance.

* Helices differently constituted, as to length, thickness, and number of turns of wire, are in fact simply to be looked upon as a means (perhaps the best) of obtaining currents with different physical characters, and thus securing a wider range of physiological effects. It seems desirable not to over-complicate the conditions of their production.

GROUP V.

The Electrotherapist.

For the application of electricity to the human body countless methods have been devised. Of these some are simple and effective—others, as a large section of the British public is beginning to know to its cost, are simple and *in*effective. But, whether simple or complicated, electrotherapy only concerns itself with such as can adapt themselves to the ever-varying conditions of the body by exact methods and under measured control.

The art of the electrotherapist consists in selecting or devising the best method for each individual case (Erb), and carrying it out in the best way. That is, he must not only be able—taking into consideration the disease, age, temperament, and susceptibility of the patient—to decide upon the best form of current, its amount or dose, involving the factors of current strength, density, duration, and perhaps direction—the most suitable form of electrodes, their best relative position, and other similar points—but he must also possess the ability, only attainable by special training and practice, to carry out the details of its administration. It is tolerably evident that selection of method, as here described, and manipulative skill, embody the whole art of medical electricity; and these two things cover a very wide field. No medical insight is necessary to see that there is involved, in the first place, a knowledge of the nature of the body, to which the current is to be applied (anatomy and physiology); a knowledge of the disease for which it is to be applied (pathology); a clear conception of the object to be attained, *i.e.*, of the electrophysiological and electrochemical effects to be produced (therapeutics); and, not least, an extensive practical acquaintance with the physical laws that govern all electrical applications (electrophysics). Any medical man, who, from want of time, want of special training, or want of instruments of precision, may not intend to carry out electrical treatment himself, is well aware that he must not imagine that he can prescribe a definite quantity of electricity in the same way as he can order so many ounces of "mixture" to be dispensed and administered to a patient. He knows that it would be equally reasonable to suppose himself able to prescribe the amount of chloroform to be administered in a certain case to produce a given condition of narcosis—instead of leaving it, as he necessarily must, to the judgment and skill of the anæsthetist. Neither is the case of the physician who prescribes, and the electrotherapist who carries out electrical treatment, to be compared to that of the composer who "creates" and the instrumentalist who plays from the written score. To make the cases analogous, the composer would have to say to the instrumentalist, "A certain musical effect is required—will you, according to the rules of your art and the dictates of your experience in like cases, play such music as will, by adapting itself to the mood of the listener at the time, and the other varying conditions of the moment, be likely to bring about this result." This is being a good deal more than a mere "performer;" and the *rôle* of the electrotherapist would be analogous. That much-sneered-at doctor who vaguely advised his patient to "try electricity" was really a safer guide than one who glibly orders so many milliampères of current for "so long a time," and thinks that "anyone" can carry it out. In the former case the patient will understand that it is part of the advice to put himself into proper hands for this portion of his treatment—the latter has a sort of quasi-scientific exactness about it which is utterly deceptive.

An injudicious use of electricity, either in medicine or surgery, may be attended with serious ill-effects.

This danger is, perhaps, not fully brought home to the public mind because possibly a large proportion of the popular "electrical appliances" may be electrically powerless either for good or harm. But once the electric current ceases to be a mere plaything of the patient or money-making device of the charlatan it cannot any longer be trifled with. The late Dr. Steavenson writes :—" For the purely surgical application of electricity a technical knowledge and an intimate acquaintance with the manner of using the different forms of battery is most essential. I know from the number of applications I have from members of the profession asking for details of the operation for the electrolysis of fibroids, the best batteries to use, etc., etc., that an indiscriminate use of this mode of treatment is being made by men without the slightest previous knowledge of electricity." And then follow instances within his own experience of accidents, some of them of an alarming nature, which have occurred from a want of electrical knowledge on the part of the medical man. I commend this to the notice of a writer, already quoted on the first page. Dr. de Watteville writes thus:—"The popular theory is that carrying out an electrical investigation requires no special training, and is within the reach of anyone possessing a battery and a superficial knowledge of the medical applications of the current to the human body . . . . Electricity is a branch of experimental science, and science is no respecter of persons. The ablest physician, the most consummate neurologist, if he has not submitted himself to the conditions required and passed through the ordeal of discipleship, will fail to obtain reliable results. The statement of such results, even when expressed on oath in a court of law, is devoid of the least weight, and as experience has shown more likely to be wrong than otherwise. It is less than an opinion, it is a mere guess.* . . . The old mode of torture by putting a copper cylinder in each hand and sending tremendous shocks through the patient is to my

* *Medical Electricity*, by Dr. de Watteville, p. 121.

knowledge still too often inflicted by doctors upon unfortunate patients for the relief of neuralgia, paraplegia, and many other such disorders. . . . It must not be forgotten that it is not so much electricity that cures as electrization, that is the rational and skilful application of electricity." *

From the other side of the Atlantic come similar warnings. In the preface to the eighth edition of their splendid work Drs. Beard and Rockwell lose no time in making it clear that they are not writing for those physicians "who suppose that he who has held two sponges to a patient has compassed the whole of electrology." The following extract is from p. 255 of this book:—"The temptation on the part of the people to use electricity themselves, and on the part of the profession to allow them to do so, is very strong. The majority of physicians know little more of electrotherapeutics than their patients. Some have a theoretical but not practical acquaintance with it. Then there are those who are well practised in the art, but too closely occupied to employ it. They have no apparatus, or if they have it is very likely out of order. Perhaps no specialist is accessible. The physician . . . forgetting that there are three kinds of electricity in common use, and many different methods of application, every one of which is capable of various modifications, forgetting that there are certain temperaments which will not bear electricity, however applied, and that there are others who must at first be treated with great skill and caution, on whom

* *Ibid.*

the current and method employed must be studiously varied during course of treatment, in short, forgetting that electrotherapeutics considered as a science or an art is wonderfully complex and exacting, orders the patient to *get a battery and try electricity.*"

Professor Erb writes in his book on electrotherapeutics :—" Who ought to carry out electrical treatment? To my mind there is but one answer—the physician himself; and if possible one who devotes himself to electrical pursuits. We are often asked whether electrization cannot be performed by patients themselves, servants, or attendants. The answer is imperatively—No." *

* *Electrotherapeutics*, Erb, p. 310.

GROUP VI.

"The Current that Kills."*

An investigation of the currents that cure may, perhaps, be assisted by a glance at "the current that kills." I do not mean the current that a daily paper refers to as "the disruptive discharge of the storm-battery" (and which plain people call "lightning"), but what in the best electrocution circles in America is termed "the lethal energy of the electric current." This subject has lately received much attention, and, in connection with electrical executions, has been ably (and otherwise) discussed in medical societies and in electrical journals. It has an interest for us, not only by its bearings on electro-physiology, but an even more practical one in connection with those accidents on electric light circuits which occasionally occur.

When we read of 1,500 volts and seven ampères being sent through the body of a man, the mind not unnaturally turns to the case of a human body "struck by lightning." Though we know that it sometimes happens that a person may be killed outright by lightning, without symptoms of any kind or signs of injury, still we are also aware that generally there are symptoms of collapse, paralysis

* This question is ably dealt with, from the electrical standpoint, under the above heading, in *The Electrical Review*, June 17th, 1892.

or convulsion, wounds where the current has entered or left the body, hemorrhages, clothes burned or torn, boots torn off the feet, and even (what it seems is not uncommon) nails driven out of the soles of the boots.*

What is observed here? I turn to the official record of seven cases of the "infliction of the death penalty by means of electricity," and find reports which may be briefly summarized as follows: In comparing the details of six autopsies† on the bodies of the six criminals electrically executed at "Sing Sing" Prison, Dr. MacDonald,‡ following the report of Dr. Ira van Giesen, amongst many other points, draws attention to the following:—"The passage of an electrical C. of the pressure employed in these cases (approximately from 1,400 to 1,700 volts) and in this manner§ does not do any

* Dr. Poore's *Electricity in Medicine and Surgery.*

† These cases do not include the *first* case of electrical execution. Kemmler was executed at "Auburn" Prison.

‡ As reported in *New York Medical Journal.*

§ The "manner" was briefly as follows: Source of supply, alternating C. dynamo making about 150 periods per second. Voltometer gave readings from 1,458 to 1,716 volts. The ammeter showed a C. varying from 2-7 ampères; one electrode so applied as to cover the forehead and temples, the other placed on the calf of one leg. In one case, and presumably in all, the electrodes were of sponge backed by metallic plates, the sponge being kept thoroughly wetted with cool salt and water, the area of each being about 100 sq. c.m. From the time the prisoner entered the execution-room to the time he was absolutely dead the longest period in these six cases was about six minutes. The shortest period seems to have been three minutes thirty seconds (Jugigo's case); of this two minutes fifteen seconds was taken up in predamage to any of the internal organs, tissues, or muscles. None of these parts are lacerated or changed in volume. Neither are there any gross chemical or morphological changes or alteration of their finer structural features. The local thermic effects at the electrodes are limited to the outer scarf skin . . . which may be separated from the deeper skin," and the state of the parts "resembles in this way an ordinary blister from which the fluid has escaped." The microscopical examination of the tissues (in Jugigo's case, and the others are much the same), "showed no sign of mechanical violence, such as tearing, fracture, or disintegration of the protoplasm." As to the central nervous system, the "ganglion cells seem to be normal in size, or, at least, do not show any striking reduction of volume." There seems to have been rapid abolition of the reflexes. In the last case (McElvaine) the reflex action of the voluntary muscles was tested, "two or three minutes after the breaking of the last current," with the following results :—"The patellar reflex was tried in the usual way without any re-

liminary preparation. In this case three contacts were made of fifteen seconds each. Three minutes of the time is thus accounted for, leaving thirty seconds for the interruptions, wetting of electrodes, and ascertaining stoppage of heart beat. "Probably both conscious and organic life were absolutely extinct even in a less time than the aggregate duration of these contacts" (45 seconds). In all these six cases the contacts were made in the positions above stated, but in one (McElvaine's) of the two contacts made the first (of 50 seconds) was (in view of the opinions expressed by electrical experts) through the hands immersed up to the wrists in tepid salt water. The second contact was through the head and leg, and lasted thirty seconds.

sponse in the muscles either of the electrode side, which was rigid, or the knee of the other side, which was relaxed." Similarly nipples and "exposed" rectus, no reflex. "Activity of involuntary muscle not interfered with; peristalsis of intestine and cremasteric reflex could still be elicited." The report proceeds, referring to one case (Smiler), "It would thus appear, from this examination, that beyond the scalding effects at the electrodes, current passed through the body in this way produces no change in the body but minute petechiæ, and it is doubtful if these are not some indirect or secondary consequence of the current," and further, referring to all six cases, "these minute hemorrhagic spots are not a constant feature of these cases."*

* It is interesting to compare these autopsies with one reported by Dr. Buchanan (*Lancet,* March 19th), "An accident by an electric light alternating current of 2,400 volts." The man had "struck at the induction wire off which the insulating india-rubber was fusing." After having *raised* the bar to strike the wire he fell back with a cry for help, and was carried away insensible. When seen face livid and lips congested. Death about a quarter of an hour after the accident. Post-mortem 30 hours after death. No marks of violence. Congestion of nearly all internal organs; left ventricle firm and solid; left auricle empty; blood "tarry." The cause of death here was clearly asphyxia. A black and fluid condition of the blood is a usual feature of such a case apart from any electrical agency. But the "tarry" effect spoken of here seems to be considered something more than this. Electrical execution has little in common with a case like this. This man was done to death by the clumsy agency of an accident. There was time for a cry for help, there was fluttering life for a quarter of an hour; death was from the lungs; it was tantamount to strangulation. Had the current been *laid on* to kill it would have done its work, as in the above cases, with certainty and swiftness.

The first "case" of electrical execution (Kemmler) differs in some respects from the above, but not very materially, and the difference seems to have depended on inferiority of apparatus, and necessarily the want of experience of like cases. On the back (the space between the second and fourth sacral vertebræ, corresponding to the position of one electrode) there was a burn. On the vertex (the other electrode was on the vertex) there was a slight vesication. The scalp in this situation was desiccated, and on removing the calvarium the meningeal vessels were black and carbonized, and in the pre-Rolandic area on both sides the meningeal vessels were filled with carbonized blood. Over the left cerebral hemisphere there was a deep carbonized spot, corresponding with the desiccated portion of the calvarium. Both vesication and burning are attributed to the comparatively prolonged contact; the former due to the current raising the moisture on the electrodes to boiling point, and the burning to letting the sponges "dry out." It is clearly justifiable in looking at the whole question to leave out of consideration the local effects in this the first (and necessarily more or less experimental) case; in the other cases such effects were "altogether trivial," and no doubt by a modification of methods it will be found that they can be completely avoided.

There is one other point of interest in the case just referred to. In handling the pons and medulla they were found to be warm, and a thermometer inserted into the fourth ventricle showed a temperature of 97° F. The area of this temperature corresponded with an area of high temperature on the back of the neck; a temperature of 99° F. was noted there three hours after death, the temperature of the room being 83°.

How then does electrical execution kill? That it does not kill by producing any gross changes in tissues and organs, or by altering the histological elements of a structure, is clear. Is it by electrolysis, molecular disintegration, that the passage of such currents so applied bring about functional and organic death? There is not evidence of this, and such an explanation is quite insufficient. Neither does it seem necessary. There are two ways, by one of which it seems to me that electrical execution may kill, and the other by which it must kill. As to the former, physiology tells us of the paralyzing effect of strong stimuli applied directly to the heart. We know, too, how the direct application of a powerful electrical stimulus will produce those "arhythmic," "fibrillar," ventricular contractions, spoken of as "delirium cordis."* It may be that a rush of current passing through the body, either longitudinally or transversely, may strike the heart, and by direct impact paralyze it. This would depend upon strength, density, and direction (position of electrodes). It appears to me that the methods employed in the above cases would allow too great a diffusion of current in the thorax to make this a probable explanation here. And neither does it seem to have been aimed at. The intention was to strike the heart through the nervous centres.

* *Text Book of Physiology*, Landois and Stirling, p. 90.

We are acquainted with a large class of cases in which the sequence of events is probably not dissimilar from this electrical killing. A person receives a sudden fright, or a blow on the epigastrium, or a severe gunshot wound, and he may never rally. Paralysis and even death have been recorded after a very hot or very cold bath. We say that such cases have died from "shock," and we mean that the heart's action is suddenly arrested through the nervous centres. Too intense a stimulus has been applied. The normal irritability of nervous structures has been paralyzed by hyperstimulation. It is something like being blinded by too bright a light; the retina is paralyzed by the very strength of the stimulus. What has occurred in these executions? A current of great strength is driven (say) through the vertex or forehead. Entering the skull, it diffuses itself through the brain, sweeping away in its onward rush the faculties of sensation, intellect, will; concentrating itself again it makes a dash for the foramen magnum (the line of least resistance), smiting on its way and with increased density that vast collection of conducting paths and nervous centres, the medulla oblongata.* In the presence of such a stimulus, what becomes of the delicate mechanism by which vital functions are governed from the bulb; the respiratory, the vaso-motor, but above all those cardio-inhibitory and accelerating

* The concentration of current and great R. that it must necessarily meet in passing through so small a channel may account for the high post-mortem temp. found in the medulla and corresponding external parts in the case above detailed.

centres on the balanced relationship of which probably the thread of a life depends?

Electrical execution seems to open up no new principle of killing. Except in its magical suddenness, and the certainty with which it can be directed to its fatal purpose, its mode of working does not materially differ from many well-known ways of death. Yes, in yet another way it differs from them all. It eliminates the possibility of pain. Long before the slowly-moving nerve-borne pain stimulus can travel from periphery to centre and produce sensation, the electrical excitation rushing onward with a velocity incomparably greater, has anticipated it, annihilating consciousness, sensation, and volition; perhaps even it has already dealt a deadly blow at the very source and centre of the circulation; or, acting through the medulla, has already bid the heart stand still.*†

* In connection with some of the above cases some interesting calculations of body R. are given by Mr. Kennedy. Taking the voltage at approximately 1,600 and the C. at 2-3 ampères, the R. from hand to hand (the hands immersed in salt water) came down from 800 to 516. Head to calf, taking the voltages as approximately 1,500 and the C. at seven ampères, the R. was 214 ohms.

Any such observations taken under definite conditions are of great interest, and useful if we fully keep in view all the circumstances of the case. For instance, in the second observation it is to be noted that the C. had been running for fifty seconds, and it is difficult to say to what extent such a C. had broken down R.

† In the article above referred to it is pointed out that it is to ampèrage rather than to voltage that we must look for "useful effect." Voltage alone is nothing without C. strength behind it. Currents of enormous voltage may sometimes be handled with impunity.

GROUP VII.

Body Resistance.

Our knowledge of body resistance is not extensive, yet somewhat difficult to summarize. We know that the body in its ordinary conditions is a very poor conductor of electricity; that, in other words, it has a high resistance; that this R. exists mainly in the epidermis, which may, to a certain extent, be regarded as an insulating envelope enclosing softer and moister contents, which are themselves comparatively good conductors. We are aware that "skin resistance" is of importance in very many ways. It contributes by far the largest share of the total R. of the body, and unless it be overcome by a sufficient electromotive force it is obvious that no current can reach the underlying structures. It is influenced in the most astonishing way by ever acting, ever varying natural causes, and can be marvellously modified by artificial conditions. Skin R. is of no little diagnostic importance also, inasmuch as its increase or diminution may account for phenomena which otherwise would have a grave pathological significance. For ordinary medical work all other R. may, comparatively speaking, be left out of consideration.

The two chief factors at work in determining skin R. are as follows:—(*a*) The amount of surface area in contact with the electrodes; (*b*) the condition of the skin at the points of contact. In other words, it is the sectional area of the conductor and its condition at the moment that, with a given E.M.F., determines the C. strength. Moisture, temperature, vascularity, number of sweat and sebaceous glands and hair follicles, activity of the sweat glands, length of time the C. has been flowing, the number of closures and reversals, all have their influence upon the conductivity of the body.*†

It is clear, therefore, that we cannot speak of the normal or essential resistance of the body as we speak of the normal *temperature* of the body. The case is rather analogous to the temperature of the air. We do not speak of a normal or essential air temperature, but of an actual temperature under certain conditions. Neither can we in electrotherapeutics speak of an essential body resistance. The various and widely diverging estimates that have been given of body R. are partly to be explained by want of uniformity in conditions, and the greatest factor in the confusion seems to me not unfrequently to have been a want of due appreciation, on the part of the observer, of the importance of surface contact

* Cataphoresis vascularity and sweating acting in favour of conductivity; polarization against it.

† The possible effect of psychical causes (acting of course through their influence on physical conditions) has not, so far as I know, been investigated.

area, *i.e.*, the size of the electrodes or cross-sectional area of the conductor.*

This holds good, not only of the early observers, Humboldt and Ritter, but Weber (1836), who gave great attention to the question, and was well aware of the difference in conductivity between a thick and dry skin and a thin and moist one—who knew that mucous membrane "conducted better" than skin, and that blistering and wound diminished R.—does not, so far as I know, lay any stress on contact area. Eckhard, who made many "classic" experiments as to the R. of the various tissues, seems to have thought (like Dr. Stone, later) that "the real and essential point to ascertain was the conductivity of the deeper structures." This may assist us in our speculations as to what happens after the current enters the body—it may throw light on the question of diffusion, a point which, as it can only be theoretically determined, has afforded a fine field for the play of imagination, ingenious simile, and effective diagram. But it does not help us here. The current must first be got through the skin.

In 1883, Mr. Lant Carpenter made many observations bearing on body R., using socks with tinfoil soles as electrodes; the R. from foot to foot was found to be 10,300 ohms with the skin dry, falling to 1,200 after an hour's soaking with salt and water. There is no evidence that he recognized in what way surface contact area is of importance.

* Wetting, by improving contact (in other words, by increasing number of points of contact), may so far be looked upon as increasing cross-sectional area of conductor.

Dr. Stone, in 1886, found R. from hand to hand (the hands being in brine) to be about 1,000 ohms. He insists on the necessity of eliminating " surface contact R. " by " having the poles very large compared with the C." In this way he considered that skin R. was reduced to zero. But there is nothing in his experiments to demonstrate the latter; and he scarcely seems to have recognized *why* it is that the size of the conductors is so important. He seems to have put it down to contact being better, and scarcely to have apprehended the important part that the sectional area of a conductor plays in C. strength. That he does not do so becomes evident when he afterwards speaks of thus " securing a contact superior to the introduction of needles 3in. deep into the tissues." But it is clear that the small contact area of the needles vitiates this experiment for comparative purposes.* Erb attacks the question in his usual masterly way, and so far as I know is the first author who clearly puts forward the conditions on which body R. depends; though we cannot now go with him so far as to consider that the experiments of Jolly and Gartner " have finally decided this point."

The R. of the skin, " as commonly dealt with in physiological experiments," is put down (very

* In order to compare the " value " of skin R. in this experiment with that of the interior of the body it would be necessary to have the electrodes *under* the skin ot the same surface area as those *upon* the skin.

approximately) at 1,000 to 100,000, according to moisture.* A distinction seems to be sometimes drawn between what is termed "essential" R. and "total" R. The former (following Dr. Stone, who considered that he eliminated skin R. by his large electrodes) is put down at about 1,000 ohms.† "The total R. may be 3,000 or 5,000 or even more."‡ We, therefore, arrive at this, that the lowest body R. given by the most recent authors is about 1,000 ohms, and it seems to be considered that this result is obtained after eliminating skin R.§ Such is a most imperfect retrospect of what has been done, and such, so far as I know, is the state of the question as it confronts us now. Coming out of this historical parenthesis, therefore, let us take up the question at the point to which it has brought us.

Experiments made in connection with dangers from electric light circuits seem clearly to point to the conclusion that up to a certain point at least,

* *Human Physiology*, Waller, p. 307.

† What then becomes of the approximate skin R. minimum of the physiologists?

‡ *Medical Electricity*, Dr. Steavenson and Dr. Jones.

§ The experiments of Count du Moncel are referred to by the above quoted author. But as it seems necessary, in order to explain results, to call in to an unusually large extent the aid of that obscure agency, "polarization," they need scarcely be considered. Whatever counter force may have been set up, it appears that unintentionally, but very effectually, skin R. was abolished by electrolysis; as the scars on the Countess' wrists bore witness.

the physical conditions being the same, R. is diminished in direct proportion as surface contact area is increased. It is, of course, not easy to carry out experiments to prove this in its extreme limits; my own observations, however, give me no reason to doubt the general accuracy of the statement.

Not less important than contact area, and really very much mixed up with it, is the question of moisture at the points of contact. Even wetting by plain water the contact surfaces, at any given contact area, reduces R. by one-third. If suitable acid or saline solutions be used it is still further reduced.

That "polarization" occurs in the body is, of course, certain. That is, "the electrolytic processes occur wherever the current passes from another conductor into an electrolyte, where two electrolytes are in apposition, and also in the interior of more solid masses which are permeated by an electrolyte, and through which a current is flowing."* This process occurring in the body, either externally or internally, is "polarization," and opens up endless complexities. But as a matter of fact a simple experiment shows that as the result of the electrolytic process going on in the animal body during the passage of a current the body becomes, in a sense, a "secondary" or "storage" battery, whereby a counter E.M.F. is established, which acts to cut down the strength of the main current. This prevents a strictly accurate measurement of the R.

* *Electro-therapeutics*, Erb, p. 61.

of the body by continuous C., either by Wheatstone Bridge methods or calculation from ohm's law. For very delicate diagnostic purposes this may have to be considered, but for ordinary work the complication is not a serious one, so far as resistance is concerned, because (1) this counter E.M.F. is more than counterbalanced by the diminished R. of the skin by the passage of the C.; (2) it is total R. in the circuit that the physician has to deal with, and in most cases it matters not to him whether this be all genuine R. or whether it be composed partly of R. and partly of counter E.M.F. acting as a R. The question, however, is well worth experiment. The amount of polarization and consequent E.M.F. depend very much upon the strength and duration of the current, and probably there is a regular proportion between them, but I am not aware that the exact relationship has ever been formulated.

It has been found that the R. of the body is much less to alternating C. than to continuous C. This difference has been taken as evidence of the extent to which polarization goes on in the body. It is easy to believe that there is no polarization with alternating C. of ordinary therapeutic strength; but it seems scarcely probable that the entire reduction in R. is due to this cause, and for the following reason; the difference in the R. of the body to the two forms of C. is greater when the skin is dry than when wet. The polarization would be at least equally great in the second case, yet the difference is less. The diminution in R. no longer bears the proportion 100 to 150, but of 100 to 110. It seems clear, therefore, that the alternating C., apart from the fact that it does not set up counter E.M.F., possesses, so to speak, a penetrating power* beyond others.

In attempting to grapple with this question of body R. we thus find ourselves drifting about amongst a confused mass of uncertain speculations, and figures of doubtful value, owing, for the most part, to the imperfect records of the conditions under which they were obtained. Personally, I have tried to steady my ideas by a few limited observations, which I subjoin; but the question demands exhaustive experiment. First, I recall to mind a former experiment with small metal electrodes, where I found R. as great as 800,000 ohms; while under the most favourable circumstances that I could secure of moisture temperature and contact area (see Electrothermal) it came down to 540. Though it is useful to bear in mind that such a range of variation *can* occur, and is not so uncommon even in practice as might be imagined, it is clear that for ordinary practical work it is not with dry skin and electrodes the size of a shilling—nor with the feet in brine, nor with tinfoil soles—nor in the hydro-electric bath—nor with needles thrust three inches into the tissues—nor even in the "lethal chair"—that we want to know the R. of the human body; but what is sought is a useful working average under the conditions of ordinary electro-therapeutic work.

* Due probably to the interruptions.

A.

Resistance of Body.

Taken by Wheatstone Bridge method with current from 6 Leclanché cells. Electrodes, metal covered with flannel, wet. Three "subjects" tested.

Position of Electrodes.	Total Contact Area.	Condition of Skin.	R. in Ohms.	Average R.
1. Neck and right foot	140 sq. c.m. (neck 20, foot 120)	Moistened with warm water	6,200	6,120
2. ,,	,,	,,	6,000	
3. ,,	,,	,,	5,200	
4. ,,	,,	,,	4,300	
5. ,,	,,	,,	8,900	
1*a*. Neck and right calf	(neck 20, calf 120)	,,	7,400	7,400
1*b*. Neck and right fore arm	(neck 20, arm 120)	,,	7,500	7,750
2*b*. Neck and left fore arm	,,	,,	8,000	
1*c*. Neck and epigastrium	(neck 20, epigastrium 120)	,,	16,400	19,200
2*c*. ,,	,,	,,	22,000	

B.

Effect upon body resistance of the passage of 5 m.a. of Continuous Current for 5 minutes (electrodes remaining *in situ*.)

Position of Electrodes.	Total Contact Area.	Condition of Skin.	R. in Ohms.	Result.
Neck and right foot	140 sq. c.m. (neck 20, foot 120)	Moistened with warm water	before 5,200 after 3,900	1,300 decrease.
Neck and right fore arm	,, (neck 20, arm 120)	,,	before 7,500 after 2,300	5,200 decrease.
Neck and left fore arm	,, ,,	,,	before 8,000 after 3,100	4,900 decrease.

Average decrease 3,800 ohms, or 55 per cent. of average initial R.

A few experiments were carried out to show the relative effect of water and the immersed human body on resistance. These need not be tabulated, but they point to the fact that the effect of adding the body to the water is to reduce the conductivity, *i.e.*, increase the R. of the resultant composite conductor (water and body).

From the foregoing considerations it appears that we reach the following conclusions :—

1st. That we must disabuse our minds of any idea that the R. of the body can be spoken of as a definite quantity—as we speak of the R. of so many yards of wire of certain kind and size. It is an ever-varying quantity--varying within an enormous range and varying with causes that are constantly at work. We have traced it though a range descending from 800,000 to 540 ohms.

2nd. Under circumstances approximating those under which the electrotherapist works, it has been found in a small number of experiments, in three persons, to have an average of 7,090 ohms, reduced after 5 minutes passage of a 5 milliampère C. by 55 per cent.

3rd. It is necessary, in making observations and recording them, to note the following points :—

(*a.*) Size and description of electrodes.

(*b.*) Condition of skin as to moisture and vascularity.

(*c.*) Strength of current and length of time it has been running, as well as closures and reversals.

(*d.*) Temperature at contacts.

(*e.*) Nature of moistening fluids.

4th. If ever we are to arrive at a reliable standard of body resistance, it can only be by a multiplicity of observations, under a uniformity of conditions.

GROUP VIII.

Aids to Electrical Treatment (Movement, Massage, and Medical Gymnastics).

In the year 1776 was born at Ljunga, in Sweden, Pierre Henri Ling. The thirteenth year of the present century saw him, after much "official snubbing" and many discouragements, at the Central Institution at Stockholm, under Government patronage and State aid, teaching and practising a system of gymnastics of a novel and peculiar kind; at least, his friends said that the system was new and original—his enemies, of course, averred that it was only a revival of old, forgotten methods which ages ago had been practised by Chinese sage and Indian brahmin, and Egyptian priest. There is no reasonable doubt that, from time immemorial in China and India, muscular exercises had been practised for the symmetrical development of the body and the cure of disease. And it is certain that these methods had been still further developed in the systems of Greece and Rome. It is further true that in 1573 Mercurialis, as the outcome of many years of research in the Vatican library, published a treatise, *De Arte Gymnastica*, in which, evidently inspired by a careful perusal of the literature of Greece, movements were described under the headings of "active," "passive," and "mixed."* These "mixed" movements, however, are altogether different from those compound or combined movements of Ling's system, the essence of which is the "combination of movement and resistance." It is these latter movements which have given name and fame to the so-called Swedish movement cure, and which constitute the basis of many modern systems of cure gymnastics.

"Gymnastics" is the general name for "every systematically regulated movement of the body."† Thus gymnastics may be athletic, military, scholastic, medical. There are gymnastics of the eye, of the lips, of the voice; there are even gymnastics in which the person exercising has to make no effort of his own; he remains passive, and the movement is communicated by some external agency. Dissimilar, however, as these things are, they have one characteristic common feature—they all consist of systematically regulated movements.

These movements may be (1.) "Active," *i.e.*, dependent on the muscular effort of the individual, as in lifting a dumb-bell or running a race. (2.) They may consist of those compound or "resistive" movements already adverted to in which two

* Sydenham (1624-1689), although not an *iatro*-mechanist proper, but rather more inclining to Hippocratism, was a great advocate of bodily movement as a means of cure, and upon his experience Fuller built further in his *Medicina Gymnastica* (Busch).

† Busch.

forces participate—the one *making* the movement, the other *resisting* it. For example, the person exercising flexes the forearm, the operator, using a certain carefully graduated amount of force, "opposes." The utility of these "resistive" movements is universally recognized, but the theory of their action does not seem quite so clear.

Ling's idea seems to have been that in exercising a particular group of muscles he ought to "isolate" them for treatment by putting their antagonists out of action. This he considered he did by doing the work of the antagonists for them through "resistive" movements. In other words, he looked upon antagonistic muscular action as a counter force which ought not to be strengthened against weakened opponents by exercising the whole muscular system of the part. The more modern conception of muscular antagonism seems to be that it is to a certain extent "co-operative;" that the action of opposing muscles assists in some way the group in dominant action at the moment. At the same time, all experience admits the usefulness of Ling's "resistive movements." In order to reconcile these two things it seems necessary to assume that though Ling's procedure is right, his hypothesis was wrong.

The dictum that "normal voluntary movement of any given group of muscles is usually associated with contraction of the antagonistic muscles" * may be accepted. Ling was aware of the fact. But the question is, to what extent are antagonistic

* *Human Physiology*, Waller, p. 341.

muscular contractions "co-operative?" Some of the reasoning by which this co-operative action is supported is to my mind not quite convincing. "When the fist is clenched it will be obvious that contraction of the flexors is accompanied by contraction of the extensors."* Do the observed phenomena in this case all point to muscular contraction? To what extent does the *hardness* due to simple elasticity or tension of the stretched extensors complicate the observation? In proceeding to illustrate the co-operative nature of antagonism, by pathological cases, the fact is pointed to that in Plumbism with "wrist drop," though the flexors are not paralyzed, movements of flexion cannot be carried out. How far does this involve "co-operative" antagonism? In wrist drop what has happened? With the extensors paralyzed the hand hangs from the wrist, from having nothing to support it, and nothing to counteract the unrestrained influence of the flexors. The wrist, therefore, is flexed, with the result (so far as the fingers are concerned) that digital flexion cannot be completely carried out because the corresponding extensor tendons (when the wrist joint is flexed) are too short to permit of the movement. They act like a tense cord across the back of the hand. This is "passive insufficiency." Put the hand back to the median line and the flexors (unless themselves involved in the metallic poisoning) will duly energize until the point is reached where they are again prevented by physical causes. Now as to the

* *Ibid.*

wrist. If the wrist flexors are called on to act they are attempting to do so under crushing physical disadvantages. The wrist is flexed and they are shortened. "The more a muscle is shortened the less work it will do."* Their origin and insertion have been too much approximated, they cannot act, they have too much "slack" to take in. "They cannot contract any further than the extent of the shortening from which they begin to be active."† This is "active insufficiency."

Such cases do not seem to me to have much to do with the friendly help which the word "co-operative" implies.

Further, if muscular action depend on the integrity of an antagonist, why is this rule not invariable? It is admittedly not always so. That a contraction of all the muscular fibres which act on an articulation may brace up the joint at the very beginning of a movement and thus make the movement steadier and more accurate is not difficult to imagine. That accuracy may be further assisted by peripheral reflex influence depending upon the soundness, even of an antagonist, is also conceivable. In this limited sense the doctrine of co-operative antagonism may easily be accepted."‡ Perhaps,

* Landois and Stirling, *Text Book of Physiology*, Vol. ii., p. 624.

† *Ibid.*

‡ We know that the functions of the brain can be localized with some definiteness; that in the "motor area" subdivisions can be differentiated, constituting special areas for special movements. But the lines of demarcation are not very sharp and well defined; and at the best these areas are close together. We know that an

however, the usefulness of the resistive movements of Ling may be best explained by altogether putting aside this question of muscular antagonism, and falling back upon the simple hypothesis that nutrition is improved by the increased metabolism that occurs in a muscle energizing against a carefully graduated opposing force. It is doubtless this improvement in nutrition which is at the root of that great distinguishing difference between a muscle and a machine. "By frequent exercise the muscle becomes stronger and is capable of accomplishing more work." *

(3.) The third class of movements comprised under the term gymnastic are those "communicated" or purely passive movements in which the person exercising is moved by outside forces independently of any effort of his own; he neither assists nor opposes, *e.g.*, travelling in a carriage; † or movements of joints, such as flexions, extensions,

electrical stimulus may become diffused and propagate itself more or less faintly to a neighbouring area. Perhaps the same is conceivable of a volitional stimulus. Suppose a stimulus of the will acting somewhere about the centre of the convolutions bordering the fissure of Rolando, flexes the forearm; such a stimulus may spread by "diffusion." It may be part of the mechanism of normal voluntary movement that the volitional stimulus is propagated to the neighbouring antagonistic area, and the muscles under its influence compelled into slight momentary action, perhaps helpful in its nature.

* *Text Book of Physiology*, Landois and Stirling, Vol. ii., p. 606.

† Riding is a "mixed" movement, and these mixed movements, of course, come partly under one class and partly under another.

etc., communicated by the hand of an operator or by apparatus ("machine gymnastics"), or, lastly, those movements independent of the joint mechanism which may be applied to any suitable portion of the body, such as frictions, kneadings, squeezings, pressings. These last bring us face to face with nothing more nor less than modern "massage" —*ce vilain mot*—a word that not very long ago had an evil ring in orthodox ears, and that has been the battle ground of many a "wordy war." But my point for the moment is that it is neither possible nor desirable to separate the consideration of massage from that of gymnastics. Both for hygienic and curative purposes they are in practice intimately associated—closely connected "therapeutic kinsmen"—twin agents for desired ends. The movements and manipulations of massage are, in fact, a branch of gymnastics. This is their proper and philosophical position. But the branch has of late become so much enamoured of its own importance that it has shown a tendency to overlook its connection with the parent stem. Its recent success has not been a gradual "growth," but rather a leap into fame. A long time lying neglected, and the exclusive domain of charlatanism, the very name had come to be objectionable. Now it finds itself a fashionable remedy prescribed by physicians the most orthodox, and possessing a literature of amazing extent, if not of high scientific standard. Looking back through its past life it points with pardonable pride to the fact that it has had the approval, though not always under its modern name, of such men as Sir Astley Cooper, Hey (of Leeds), Bonnet, Piorry, Nelaton, Billroth, Esmarch.

Massage is not new. It is a new method of an old art. In some form or other it has been practised by all primitive peoples, and was certainly elaborated into a system in the ancient civilizations. It lay in long neglect, and was well-nigh forgotten when Mercurialis in the middle of the sixteenth century unearthed much long-buried gymnastic lore. Massage shared this resurrection, and has been more or less systematically practised ever since. But the period of its complete renaissance only dates from 1863, when Estradère wrote a memorable thesis recording its history, entering into its physiology, detailing its procedure, and giving it its "terms." Many things, however, led up to this. To go back a little. Early in this century Sir Astley Cooper wrote thus:—"Friction has of late years got into repute for the cure of indurated and stiffened joints . . . and" (speaking of Mr. Grosvenor) "this was his hobby, and like all other hobbies occasionally carried its rider into the mire. . . . In many instances, when judiciously employed, the most beneficial results have been obtained." He then goes on to give the case of a gentleman in the neighbourhood of Nottingham who when shooting received a severe injury to the knee; how there remained after inflammation considerable swelling, stiffness, and induration; how the gentleman was under his care, and the means used were inadequate to afford relief; and he continues: "I advised him to go to Oxford to consult Mr. Grosvenor. This he did, and as soon as Mr. Grosvenor saw him, and heard that he had been kept quiet, told him to walk to the bottom of Christ Church meadows, and then return and dine. This he really did. Friction was used in this case with the greatest success, for within six weeks after he went to Oxford he called upon me in town quite recovered, and thanked me for recommending him to Mr. Grosvenor. Friction accelerates circulation and absorption. The late Mr. Hey, of Leeds—a man whose mind was free from every petty prejudice, most eminent in his profession, and ever anxious for truth—had a son who met with a most serious injury to his ankle joint, and, after trying all he could to relieve it, he sent him to Mr. Grosvenor, and under his care, by the judicious application of friction, the joint was completely restored."

This Mr. Grosvenor was Professor of Surgery at Oxford about 100 years ago, but devoted the later part of his life exclusively to the treatment of such cases as could be benefited by movements and friction. In fact, he was a specialist in massage. His method and the almost uniform success that attended it in his hands are fully detailed in a book, the third edition of which was published in 1825, entitled " A full account of the system of friction as adopted and pursued with the greatest success in cases of contracted joints and lameness from various causes, by the late eminent surgeon, John Grosvenor, Esq., of Oxford, with observations by William Cleobary, M.R.C.S."

A similar system had been favourably noticed by

Piorry, Maignier, and Ribes. Bonnet, of Lyons, had written about it and practised it about the end of the first half of the present century. Alex. Mayer also had done much by his writings to bring this form of treatment to the notice of his contemporaries, and had even coined a name for it, "Massotherapie."

Notwithstanding all this it cannot be said that massage during the first part of this century held a sound position. Orthodoxy for the most part stood aloof, and the empirics had it nearly all their own way. But its day was coming, and France was foremost. In 1856, Lebatard, adopting the best part of the procedure of the irregular practitioners, reduced it to a system, and formulated rules and methods for its rational employment. Soon notices began to appear in the medical papers of the excellent results that followed its use. Modern massage, however, as already stated, practically dates from Estradère's Treatise in 1863. Then its literature came thick and fast—books, and lectures, and magazine articles. It was suddenly somehow discovered that "nearly all thinking people" had always all along believed in this wonderful agent; that the oldest Chinese book, *Cong Fou*, besides telling all about medical gymnastics, tells also of those physicians who were "artists in mechanical therapeutics" (massage); that the Toogi Toogi of Tonga, and Lomi Lomi of the Sandwich Islanders, were really nothing more nor less than massage. Then began the era, now on the wane, of exaggerated praise, which glorified it into undue importance, and made it a cure "for all sorts of incurable diseases." By the timely appearance, however, of one or two notable books, and the countenance it has received from scientific medicine, its claims have been brought within the bounds of reason, its scope more accurately defined, and "massotherapeutics" now begins to occupy its proper place, and that no unimportant one, in rational treatment.

It is noticeable that up to about 1870 France had done everything for massage—witnessed its renaissance, given it its terms, its literature, and its name.* After that Holland, Sweden, and Germany "took up the running," and distanced the French school. Mezger, of Amsterdam, modified the procedure according to methods of his own, and soon by his persuasive advocacy, and successful practice, his system became famous throughout Europe, and pupils and patients came to him from far and near. In 1873, Bergmann and Helleday, Swedish medical men, went to Amsterdam, made themselves acquainted with Mezger's system, and took it back with them to Stockholm. The year 1876 was a veritable epoch in the history of massage, when Mosengeil made known his experiments which for the first time explained the manipulations of massage on a demonstrable physiological basis. He

* I do not know exactly when the term "massage" was first applied. Piorry, in his *Dictionaire* (1818), speaks of "le massement des peuples de l'Asie." There is a Thesis (1843) on "Massage dans les anchyloses legères." This is the first use of the term that I know of. The root is the Arabic word "mass," to press softly.

also published a detailed account of the procedure, which does not differ materially from the method of Mezger. In 1884 a work appeared by Dr. Norström, of Stockholm, in which he demonstrates the efficacy of massage in almost every form of articular and periarticular mischief, and in countless derangements of the nervous and muscular systems. In the same year Dr. Graham, of Boston, U.S., published a most ingenious and instructive volume, which does full justice to the history, physiology and therapeutic effects of massage, and in addition gives details of a number of convincing cases—not forgetting at the same time to satirize by the way the pretensions of those charlatans and "shrewd superannuated aunties, who having learnt the meaning of the word massage have it printed on their card, and go on with their 'rubbin'' as before."

In 1885 Dr. Weir Mitchell published at Philadelphia the fourth edition of his book, called *Fat and Blood*, in which he advocates his now well known system of the treatment of certain neurasthenic cases by rest, seclusion, and massage. But, as he is careful to explain, not the "rest" of "the rest-cure." It must be rest combined with passive movements; rest deprived of its evils by massage; "rest that does not mean rust." "If we ask ourselves," he says, "why massage does good in cases of absolute rest, the answer, at least a partial answer, is not difficult. The secretions of the skin are stimulated by the treatment of that tissue, and it is visibly flushed, as it ought to be, from time to time by ordinary active exercise. Under massage the flabby muscles acquire a certain firmness . . . the muscles are by these means exercised without the use of volitional exertion or the aid of the nervous centres, and at the same time the alternate grasp and relaxation of the manipulator's hands squeezes out the blood and allows it to flow back anew, thus healthfully exciting the vessels and increasing mechanically the flow of blood to the tissues which they feed."

Any attempt to make clear the manipulations of massage without actual demonstration is, I think, hopeless. But a descriptive glance at the procedure may be an aid to obtaining clear conceptions of its objects and effects. Every *séance* of massage begins with :—

I. *Effleurage.*—Strokings or passes of varying lightness with the flat of the hand, or finger if the space be too small, in a direction (and this is an almost universal rule in all operations of massage) from the extremities towards the trunk, and as far as possible in the direction of the muscular fibres. The effect of this procedure is (1) to produce an excitation of the skin, and to hasten circulation in its vessels; (2) to increase the activity of osmotic changes between capillaries and tissues; (3) to stimulate the lymphatics and make them take up extravasations and exudations, and (4) mechanically to drive all the fluids onward and away from the diseased part.

II. *Massage à frictions.*—Here both hands must work together, but not with the same kind of movement. One works in a circular or elliptical manner and with considerable pressure, mainly exercised with the ends of the fingers, while the other follows with stroking motion; the idea being that one "disaggregates" the morbid products, *i.e.*, separates and perhaps breaks them down, the other pushes them on into the circulation, or at least distributes them over a larger area, making absorption more easy.*

III. *Pétrissage.*—A fold of tissue is grasped "in a peculiar way," and a squeezing, rolling, twisting movement is imparted, one hand following the other and taking over from it, so to speak, the fold of tissue as the other gives it up. Both hands travel steadily from the extremities towards the cardiac centre. Of course, as above stated, it is hopeless to attempt to convey an idea of this proceeding without a demonstration. Now, what is the object of this complex manipulation? A muscle in action is something "like a beating heart"—every contraction forces out a volume of blood, and in relaxation fills again, and so the circulation is helped on. The alternate pressures and relaxations of the hand in pétrissage by emptying the muscles (like

* It is usual in this connection to quote a well-known experiment of Mosengeil, in which he injected the knee-joints of a rabbit with Indian ink. One was massaged at intervals during twenty-four hours, the other left alone. The animal was then killed. The *un*massaged joint was found to be filled with fluid, whilst in the other it had disappeared, and the lymphatics of that side were discoloured by the Indian ink; an experiment which, taken with others, fairly proves that lymphatic absorption is promoted by massage.

squeezing a sponge) and letting them fill again, mechanically reproduce one effect of exercise. Like a muscle in action this manipulation helps forward the circulation; and at the same time internal organs are relieved of congestions by "derivation" of blood to the muscles. The benefit of exercise is thus secured without such an expenditure of nervous force in the person exercising, as is involved in ordinary forms of "exercise." The "tone" of a muscle is also improved by this manipulation, and flabby and exhausted muscles recover. This is demonstrable. It is observed that the fibres become redder and firmer by a course of massage. But its results are even more immediately shown by a much quoted experiment of Zabludowsky. A person placed his arm flat on a table, and then flexing the elbow, raised at intervals of one second a weight of over 2lb. 840 times; the arm was exhausted and could do no more. It was then "massaged" for five minutes, and the weight was then lifted 1,100 times without inconvenience.* Of course there are several reasons why this, standing by itself, is not an absolutely conclusive experiment, but it probably points in a direction not far from the truth.

The pathology of fatigue is obscure; it is not improbable, however, that the "sensation of fatigue" is intimately associated with chemical changes that occur in working muscles (sense of

* The effect of massage in enabling a muscle to recover quickly from fatigue is one of the proofs that the material change which accompanies the sensation of fatigue is partly, at least, peripheral.

weariness is felt after injection of a dilute solution of phosphoric acid or dissolved extract of meat).

"Muscle is fatigued far more rapidly than nerve, and the fatigue begins in the muscle and not in the nerve. It seems to be the weakest link in the chain between nerve and muscle which is affected during excessive action, viz., the motor end plate."* By increasing the activity of the circulation these waste products are removed or altered. In this way, again, the effects of voluntary muscular effort are secured without any expenditure of nervous force, which a patient, perhaps, may be ill able to spare.

The action of massage on nerves is as great as on muscles. By making the circulation more active their functional activity is exalted. "Massage acts on the nerves, but chiefly by favouring the blood and lymph streams which wash out the waste products from the muscle. The ancient Roman practice of rubbing after a bath and after exercise was one conducive to the restoration of the power of the muscles."†

It may be that some so-called functional nervous disorders consist in a derangement of the molecular elements of the structure. Therefore, it seems probable enough that such stretchings and twistings as are practised in massage may alter this morbid condition and bring about a normal rearrangement. We know how useful in some cases is the surgical proceeding of "nerve stretching." The masseur

* Landois and Sterling, *Text Book of Physiology*, p. 615, Vol. ii.

† *Ibid.*, p. 614, Vol. ii.

claims that by his art, *i.e.*, by the twistings of "pétrissage," he can effect a stretching very much akin to this.

IV. The fourth and last set of massage procedures are such as are conveniently classed by Mosengeil under the head of "tapotement;" percussions in various forms, with a percuteur—with the finger or with the ulnar border of the hand, etc.—as well as vibrations or shakings. The therapeutic value of these proceedings is undeniable. Their action is not, in one sense, so directly mechanical as most of the proceedings we have already considered, as, *e.g.*, emptying a muscle or forcing on a blood or lymph stream by direct pressure. The mechanical stimulus in this case acts like a chemical or electrical one, directly and in a reflex manner. Its object is to produce an excitation of muscular fibres and vaso-motor nerves. We have just seen that probably many nervous affections depend upon a morbid alteration in the molecular structure of nerves. It is not difficult to realize, therefore, how a shaking or vibratory movement (as well as a pressure or elongation) may produce such a rearrangement of the ultimate anatomical elements of nerve structure as may lead to recovery.

In massage, then, we have a practice which is excellent, yet dangerous. If we wish to promote the circulation of blood and lymph, to produce the breaking-up and absorption of morbid products, to stimulate contraction of muscular fibre, to excite nerve action, to elevate local temperature, we have a ready and effective agent in massage. What a vista of medical practice these general indications open out! Consider the profound influence that may be thus exercised over all the processes of alimentation and assimilation. Chronic joint troubles, sprains, muscular rheumatism, post rheumatic affections, irregular muscular innervations (*e.g.*, writers' cramp), feeble circulation, neuralgia, neurasthenia, and many another obstinate morbid condition may all in suitable cases be made to yield to the magic touch of the expert and judicious masseur.

After the forms of "passive" movement classed together under the term massage, we arrive at a consideration of "gymnastics" in the more ordinary acceptation of the word. Under favourable conditions the general effects of exercise consist in an increase in the functions of circulation and respiration, increased skin action, increase of appetite and assimilation of food and drink, the strengthening of various tissues—muscle, bone, fibre—freer action of joints and better control over the whole locomotor apparatus. Then there are the important effects of exercise on the nervous system and general moral condition. Further, in most forms of exercise there is also an action of the mind. An intellectual act co-operates with the physical effort to perform exercises, and the cultivation of this harmonious action of body and mind leads to a more perfect combination and regulation of movement. Exercises, in fact, are a mind training as well as body training. The general brain circulation and the circulation through other internal organs is, of course, improved by the effect of exercise. Mind troubles (*e.g.*, hypochondriasis) are relieved ; every-one knows how "spirits" and energy depend upon the condition of the abdominal organs.

But it is a cardinal rule, as it is simply a rule of common sense, that the strength must not be over-taxed. The history of athletics has a woeful tale to tell of heart affections, disease of the large arteries, lung hemorrhages, muscular atrophy, rupture, fracture, sprain, induced by excessive or injudicious physical effort. From an educational and medical point of view the matter has a serious aspect, and closely concerns us here. Ordinary school games and sports are in many ways admirable and much to be encouraged, but the risk of permanent bodily injury from over-exertion, begotten of keen rivalry and excessive competition, especially amongst children that are "not strong," must not be lost sight of. Over-pressure of body is to be deprecated, at least, as much as over-pressure from mental work. A writer in the St. George's Hospital Reports, 1874-6, points out that between the ages of 15 and 17 the greatest amount of physical development takes place, and if a great strain be put on the strength it may interfere with future growth, or even lay the foundation of constitutional disease. The same writer refers to the neglect of any classfication of games at school and allowing the weak and the strong to engage in them indiscriminately. Buck, in his Treatise on Hygiene, says, "In a well-arranged course of gymnastics the amount of exercise may be regulated, deficiencies of development corrected, and a proportionate development of the bodily powers secured, with a greater degree of certainty and less danger of injurious results than is possible with any single form of exercise." Leaving this interesting question of scholastic gymnastics, glance now for a moment at those forms of exercise which lie on the borderland of "medical gymnastics." They may be termed hygienic, and are such exercises as walking, riding, rowing, which people in health ordinarily use for the purpose of recreation, but which have been in time-honoured use also as remedial agents.* Riding, as everyone knows, is frequently prescribed in many forms of chest, liver, and other disease, and, no doubt, it is an excellent form of exercise, combining as it does active with passive shaking movement without involving too much fatigue. About a hundred years ago the mechanical horse was recommended by Corp, a physician of Bath, for jaundice. It is now recognized that some forms of jaundice are successfully treated by massage and movements. Rowing in moderation (and *not* competitive) is a good hygienic exercise, and an excellent remedy in some cases of muscular debility. I do not know of any kind of exercise, even boxing,† more calculated to develope the "calm eye and steady hand," strength and suppleness of body, than fencing.

* It may, however, be conceded at once that the "gymnastic prescription" of that physician of ancient Greece, who ordered a patient to walk from Athens to Megara to cure his disease, contained rather a "heroic dose."

† Not the πυγμή of the Greeks—with the armed fist; nor the modern prize fight—with the naked fist.

As a health aid for the healthy, the modern pursuit of cycling has much to recommend it. It is a feature of the century, and claims attention. There are men and women of every condition and class who have reason to be grateful to it. Perhaps none more so than that middle-aged man just passing the narrow line that separates (what he calls) "putting on flesh" from (what his friends call) corpulence—who is getting too heavy for his legs (the legs of such men are often not their strong point)—whose walking days are nearly over, and who without his "Singer" or his tricycle would have no alternative but to lapse into absolute inactivity. Involving a comparatively slight amount of exertion, and with fewer counter-balancing disadvantages than perhaps any other form of exercise, cycling produces in a pre-eminent degree that feeling of exhilaration, energy, and "entrain" which are the common result of all forms of moderate physical exertion in sound men. Like other exercises it is also to be regarded not only as a recreative and hygienic pursuit, but actually curative of many minor ailments in the shape of dyspepsia, liver congestion, nervous apprehension, and mental depression begotten of sedentary pursuits, excessive brain work, or "worry."

Suppose the rider to have acquired a good "seat." He is placed on his machine fairly well over the pedals, which are duly adjusted to his length of leg. The handles are of due height and prolongation backwards, relatively to the position of the saddle.* He is not screwed up in that faulty and unsightly position of forward bending so often seen.† He is on a saddle that suits him, and which is, perhaps, provided with some device for obviating the danger of undue perineal pressure.‡ By attention to such details, a position is secured which supplies a good fixed point for the action of the respiratory muscles, and enables the organs of respiration to have proper play. No undue strain is placed upon the circulation. Injurious pressure is avoided. The body is supported and weight taken off the legs. The saddle being fitted with good springs, the wheels with "pneumatic roadster tyres," vibration and jar are reduced to a minimum. We have thus a unique and, in some respects, an ideal form of exercise, one certainly less exhausting (as sphygmographic tracings show) than many of the ordinary forms of recreation or sport.

But, over and above all this, the cyclist has also certain special advantages in his recreation which

* Mr. Girling gives the following judicious general rule for the position of the rider :—"For comfortable riding on a safety, have the peak of the saddle about one inch to the rear of the centre of the bottom bracket. Have the handle two inches above the saddle and brought well back; for long distance and quick riding the saddle can be shifted two or three inches further back. The handles should remain high and still be brought well back.

† Not unfrequently even in brilliant short distance riders.

‡ Removing the saddle further back will often be found to accomplish this. The cyclist cannot be guided by "rules" in the choice of a saddle. In point of size, shape, and construction, he must find by his own experience what suits him best.

immensely enhance its value. There is the immeasurable charm of feeling that he is doing effective work; that, without unduly taxing his bodily strength, he is getting splendid locomotive results; his mind is diverted from his cares; his attention agreeably occupied by a variety of interests and the charm of ever-changing scene. It is far different from that weary effort after health—the hated "constitutional." In all healthful and recreative pursuits, a most important element is this consciousness on the part of the person exercising that "something is accomplished, something done"—this feeling of always getting "forrarder." But here comes in sight a "caution to cyclists." They must never forget that their favourite pastime, in common with all forms of exercise, may, injudiciously pursued, injuriously overtax the physical powers; that bodily over-pressure is a fruitful source of premature ageing and endless infirmity; that competitive riding is only for the fewest of the few, and for that few comparatively seldom, and only after careful "preparation." Middle-aged men (especially) beware of overdoing it. However fit you feel, you are structurally on the down-grade—your limbs are less supple, your arteries less elastic, strain is comparatively a greater danger. In comparison with younger men, you recover more slowly from over-exertion. You do not so easily cast off that *débris* and worn-out tissue which is the product of your exercise, those "fatigue stuffs" which accumulate in your system as the result of over-exertion. Competitive riding and record-breaking is certainly not for you.*

Lastly, the case is to be considered of those who, though in health, are not quite sound—who, perhaps, suffer from rupture, hemorrhoids, varicose veins, possibly slight valve disease of heart, or disease of arteries, or tendencies in that direction. It would be a great deal too much to say that cycling is absolutely contra-indicated in all such cases. Each special case must be carefully scrutinized, and decided on its own merits.

We are not now, however, concerned with athletics. But to clear the way it has been useful to glance at scholastic gymnastics as well as those forms of exercise which may be classed as "hygienic." We must now get to close quarters with medical or therapeutic gymnastics in the stricter and narrower sense of the term, *i.e.*, movements chosen with a definite purpose and systematically carried out with a view to curing disease or deformity. Since Chas. Pravaz, 1827 (who, his eulogist says, has "decharlatanè l'orthopedie"), showed that the dynamic causes of lateral deviation of the spinal column are the forces which act habitually on it, and explained how the exercise of an art, or profession, or habit brings about a corresponding alteration in the forms of the body and secondarily leads to disease of the bones, and how curvatures can be redressed "avec le

* The *carrying capacity* of muscular tissue until it ruptures, is in the following ratios for youth, middle age, and old age : nearly 7 : 3 : 2. (Landois and Stirling.)

secours d'exercises gymnastiques d'élection," and how "les exercises les plus simples et les moins penibles sont en general ceux qui conviennent le mieux dans les cas de déviation de l'épine," a change has come over the art of orthopædics. Though his opinions of the true sequence of events in the occurrence of bone disease in connection with spinal deformity are not, perhaps, absolutely in accord with more modern ideas, still he has led the way to more rational and certainly less brutal methods of treatment. Before the time that Pravaz wrote, say about the third decade of this century, it was the "classic" treatment in spinal curvatures to enforce the horizontal position for two years or so. Imagine a young girl in the most active period of her development condemned to such a course as this. Would she not get up at the end of those two terrible years with bone and muscle more than ever weakened, and therefore with two fresh factors towards the production of deformity and disease. Then came "extension beds" and "rigid plates," and "screw pressure," and their day is gone too now for the treatment of such cases as these. It is now demonstrated, and of English surgeons Dr. Roth may be considered foremost in the work, that by the selection of carefully-devised exercises lateral spinal curvature may in certain stages be most successfully combated, or in the absence of osseous deformity, cured. The commencement of lateral spinal curvatures (skoliosis), leaving congenital conditions out of consideration, may often be traced to general (and especially muscular) debility

10

—"habitually faulty positions" — and unequal operation of weights. Cases proceeding from such causes, and attacked in a comparatively early stage, *i.e.*, when osseous deformity is absent, may be treated with almost uniform success by carefully regulated positions and exercises, with occasional massage. In later stages (supposing the absence of osseous coalescence) the curvature may be retained ("fixed") by shortening and contracture of the muscles of the concavity, their antagonists on the convexity becoming lengthened and very much atrophied.

Devise exercises, therefore—(1) to produce an opposite curving and reverse the former "pressure relations;" (2) preserve mobility; (3) by acto-passive movements strengthen muscles that have become stretched and weak. The indication for determining the positions and movements likely to be of benefit in any particular case is to get what Dr. Roth calls the "key note." This is arrived at by observing what position of trunk and extremities most favourably influences the spinal curvature, and then working on these indications.

The exercises may be conducted with or without apparatus. But in whatever way carried out it is to be remembered that every movement or position has a definite object in view with reference to the disease or deformity. Take a case in detail. An exercise is required having for its object powerful exercise of the muscles of the back. It would be termed "raising from the freely horizontal position," and thus described :—"The patient lies upon a slightly padded table (the so-called divan) with the upper part of the body swinging freely over the edge of the table. . . . Downward bending of the hip-joint to right angles; up-raising from the bent position and backward bending of the body until the trunk forms an arch convex forwards. . . . Increase of the back-curve by hand pressure of the assistant against the shoulders. Three times repeated."* Or to take a milder way of obtaining a similar end, suitable for an earlier period of the treatment, thus described by Dr. Roth as one of his twelve preliminary exercises:—"Patient astride a narrow table with arms down and hands supinated; trunk flexion at lumbar vertebræ; patient resisting; followed by trunk extension, surgeon resisting. Repeated six to eight times." The above exercises are instituted to redress an antero-posterior (postural) deformity, and to produce a general strengthening effect on the muscles of the back. The latter series include the procedure of the system of Ling.

It is scarcely necessary to allude to the extent to which the patient may assist the surgeon by carrying out suitable exercises of position and movement himself when once put on the right track. "Home rules" as to position in bed, position at study, and instruction as to exercise and repose, perhaps even simple "resistive" movements which can be carried out by mother, nurse, or friend, ought always to be given to him for his guidance. Here is one, for instance—one that would be almost instinctively used:—"The patient stretches out his

* Busch.

arm, fixes it, and then tries to bend his back in the opposite direction to the curvature, and he may press against the convexity of the curvature."

Massage here, as elsewhere, ought to accompany the exercises. Even apart from the fact that a preliminary massage generally much lightens the pains that exercise sometimes at first causes, we have only to refer to the general indications to see how useful it may be expected to prove in some deviations of the vertebral column. In "high shoulder," "high hip," or "round back," where we have the ordinary influence of weight telling against lax ligament and weakened fibre—if there is anything in what we have said of the tonic and strengthening effect of massage on muscular fibre—these are clearly cases for massage in combination with gymnastics.

I have taken spinal curvature as a means of illustrating my points. But of course the application of gymnastics and massage for curative purposes extends over the whole field of orthopædics, and it need scarcely be added a good deal further. Take another surgical case—one of a different nature, where the symptoms are acute—a recent severe sprain. Is massage permissible here, and if permissible, is it likely to be efficacious? A heavy person has just slipped off the kerb-stone or in alighting from a carriage his foot has "turned under him"—there is no fracture, but pain, heat, redness, hourly increasing swelling—is this tender and swollen joint to be subjected to massage? "Yes" and "No." Certainly not in the very earliest stage, and certainly not *in any stage* to the "massage" of the Turkish bath; but certainly "yes" to the delicate effleurage of a refined and educated surgical touch. And even that would have a respect for the painful point, and would confine itself at first merely to the *neighbourhood* of the suffering joint, and use its gentle stroking to help forward the circulation there, and so indirectly relieve and disembarrass the affected tissue until itself tolerant of touch. And how about movement? It comes a little later, but still comparatively early in the treatment of the case, for its object is to keep mobility intact and prevent an ensuing stiffness. But imagine this sprain in a possible, and very probable, further phase of its existence. Suppose that after carrying out the ordinary routine treatment of rest and fixation, stiffness and impairment of mobility remain; adhesions have perhaps formed, fibrous structures have shrunk, and muscle has lost bulk and contracting power from long disuse. These are difficult cases, but under the manipulation of the dexterous masseur, followed by carefully regulated movement, adhesions will break down, tissues will recover their suppleness, and movement will be restored to the joint. Take yet another example. A case of acute joint trouble attended with general fever and high temperature—say, rheumatic fever, or what is sometimes apt to be mistaken for it, pyæmia. May we "masse" here, and if not, why not? Here there is, perhaps in the first case, and certainly in the second, a morbid material of a specific kind fixing itself on joints. In the one case a "turbid, flaky, albuminous fluid," in the other, perhaps, pus. This is a serious condition, but forms no excuse for chasing such products from the joints and letting them loose again into the general circulation. The time may come for massage, but not yet. It is in *post*-rheumatic affections and also in the so-called "muscular" rheumatism that massage has its most successful field of operation. Take such a case; it differs altogether in kind and feature from any of the foregoing. Its occurrence is as common as its nature is obscure. A person hot and perspiring sits in a draught—is suddenly seized with severe pain in the back, or neck, or shoulders, or the same pain comes on, perhaps, after some sudden movement; in fact, it is a case of what is known as "muscular rheumatism," or acute rheumatic muscular pain, or rheumatic myalgia. But whatever its name and whatever its pathology we know well what the "regulation" treatment of such a case would be: rest, antiphlogistics, mustard plaster, liniment, or, perhaps, mechanical appliances to secure immobility. The more modern and altogether more satisfactory measures would be electrization with massage. The former might be by the galvanic or Faradic bath, or by ordinary methods, with either continuous or coil currents. If by the latter, avoid powerful, muscle-contracting coarse wire currents, but use an alternating C. of little volume and high rate of vibration. If the object is to be attained by powerful peripheral excitation, the "Faradic brush" may be usefully replaced by the Faradic douche. A mild continuous C. (say 3-8 M.A.) with the anode on the painful spot is the method not unfrequently found to be the most effective. Massage will begin with light effleurage and frictions, going on to the powerful manipulations of pétrissage (kneading, squeezing, twisting), followed by strong percussions by one of the many methods, but preferably, perhaps, that chopping movement with the ulnar border of the hand, known to the school of Estradère as "hachage." Then will follow the prescribed gymnastic exercises, involving flexions, extensions, rotations, etc., to be accomplished by carefully-devised exercises and passive movements. By considering special cases we perhaps get the best idea of the process by which the masseur and medical gymnast go to work; but, of course, it is only by applying general principles and bringing experience to bear on individual cases that either this or any other mode of treatment can be practised with safety and success. What, then, does this system claim to do? When is it to be used? When avoided? It is to be regarded as means by which —

I. To accelerate circulation of blood and lymph to produce more energetic oxygenation, and the removal of worn-out tissue, strengthen fibre, promote metabolic change in tissue, and thus produce an invigorating and strengthening effect on the whole body. Use it then in conditions of general debility, neuralgia, morbid conditions of sensibility, muscular rheumatism, anæmia in its many forms, that state of lowered vitality known as neurasthenia or "nervous breakdown," those depressed conditions which are the result of anxiety, or grief, or that favourite modern word "worry."

II. To promote absorption and destroy adhesion. Resort to it then in certain stages of sprain, some joint troubles, some forms of œdema, after some fractures, in the stiffness and rigidity of joint and fibre that comes of long disuse.

III. By manipulations and exercises blood may be diverted into muscles, making them act as so many blood reservoirs, and thus relieving internal organs. We see a use for massage, therefore, in some cerebral congestions and engorgements of internal organs.

IV. Nerve action is stimulated, and through it muscular fibre, both voluntary and involuntary. Use it then in some forms of paralysis and muscular atrophy, in atonic conditions of intestinal canal, certain cases of digestive disturbance, especially in that train of symptoms connected with simple dilatation of the stomach.

V. By systematic exercises and massage, muscle, nerve, and brain are strengthened and brought into harmonious action. Resort to them in chorea, writer's cramp, and other of the so-called irregular muscular innervations.

VI. This very property of promoting absorption, breaking down morbid products, and setting them loose in the general circulation makes the procedures in question in some cases fraught with danger. The surgeon must guard against this and ask himself many an anxious question. Is there such morbid material present? Is there tubercle? Is there pus? It must never be imagined that such a line of treatment "if it does no good can do no harm." It is in the strictest sense necessary that each individual case be thoroughly scrutinized before being subjected to such a procedure.

Such are the general aims, objects, and contra-indications of cure-gymnastics. The field is extensive, but not ill-defined. In them we have a curative agent of undeniable usefulness. But the procedure must be adopted with a definite object in view, and preceded by a careful diagnosis. The "gymnastic prescription" must be carefully considered, and often carried out by the surgeon himself. Medical and surgical massage have little in common with Turkish bath rubbing and pounding. It is not the luxurious process of the East. Its administration is often at first attended with no little suffering. Gymnastics and massage have had a common origin for ends but remotely connected with medicine. But the lessons of antiquity, and the astonishing success that has attended the development of modern methods, tell us plainly how they can be pressed into the service of rational therapeutics.

The more we examine the capabilities of electrization, massage, and medical gymnastics the more clearly stands out the fact that there is a certain limited area in the field of therapeutics eminently suited to their joint action. I do not mean that there is a resemblance in anything but their object. Electricity has perhaps a wider range, and is infinitely more subtle and diversified in its action and generally more obscure in its way of working. But in a well defined though limited class of cases there is clearly an identity of aim and a definiteness of object about these three methods that bind them together into a triple weapon wherewith to attack some of the most obstinate forms of disease that have ever to be encountered either in surgery or in medicine.

The following remarks are from a communication by the present writer to the *British Medical Journal* of March 5th, 1892, and dwell further on the same point:—

"The 'Swedish movement cure,' in the recent acceptance of the term, includes not only that 'combination of movement and resistance' which is the characteristic feature of the system of Ling, but comprises also those movements and manipulations (known to Ling, but not much practised by him) consisting of stroking, friction, kneading, rolling, percussion, etc., which constitute modern massage. France, the country of its renaissance, has naturally given to massage its name and terminology. The manipulations are variously described, but best, I think, under the names of (1) effleurage, (2) massage à frictions, (3) pétrissage, and (4) tapotement, terms which have come to possess a definite meaning much more comprehensive, of course, than the simple meaning of the words. There are several reliable books descriptive of these operations, one or two well known ones which may be considered authoritative being in our own language; but both in this country and abroad a large proportion of the books and pamphlets on massage are more or less 'popular' in their style, and do not rise above the level of what is sometimes described as 'Bath literature.'

"Every medical man who performs massage, and is not a mere 'rubbing doctor,' in addition to those active and passive movements with which he generally concludes a *séance* of massage, supplements it also in suitable cases (and most cases are suitable) with 'resistive' movements; but it is especially necessary not to confound these delicately adjusted 'combined' movements with the violent rotations, circumductions, twistings, and flexions with which the ordinary bath attendant usually 'finishes up' his so-called massage.

"In the 'compound' or 'combined' movement two forces participate, the one making the movement, the other resisting it; for example, the patient may flex the forearm and the physician (or 'gymnast') opposes. Ling called this a 'combined centripetal movement'—'combined' because the patient and operator work together, 'centripetal' because the patient's muscles have to overcome a resistance which hinders flexion against the trunk. The efficacy of these resistive movements has been fully recognized, and the procedure absorbed into every modern method of therapeutic gymnastics. . . .

"In certain non-acute rheumatic and post-rheumatic affections in 'old chronic' forms of rheumatism and chronic joint trouble, where joint-stiffness, thickening of periarticular fibrous structures, and muscular enfeeblement ('atrophy from disuse') have to be dealt with, 'the Swedish cure,' in the above sense, is an admirable method of treatment—indeed, second to none, and, combined with electricity, probably first, though generally resorted to last. The *modus operandi* of masso-therapeutics in the cure of diseases of the above class becomes tolerably clear if we look into the *rationale* and analyze the procedure of modern massage—that is, the massage of Mezger and of Mosengeil.

"The term 'electrical massage' . . . doubtless means one or both of two things—(*a*) performance of the above massage manipulations by the 'electric hand;' or (*b*) an ordinary massage preceded or followed by an electrization. The latter not infrequently takes the form of the electric bath.

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