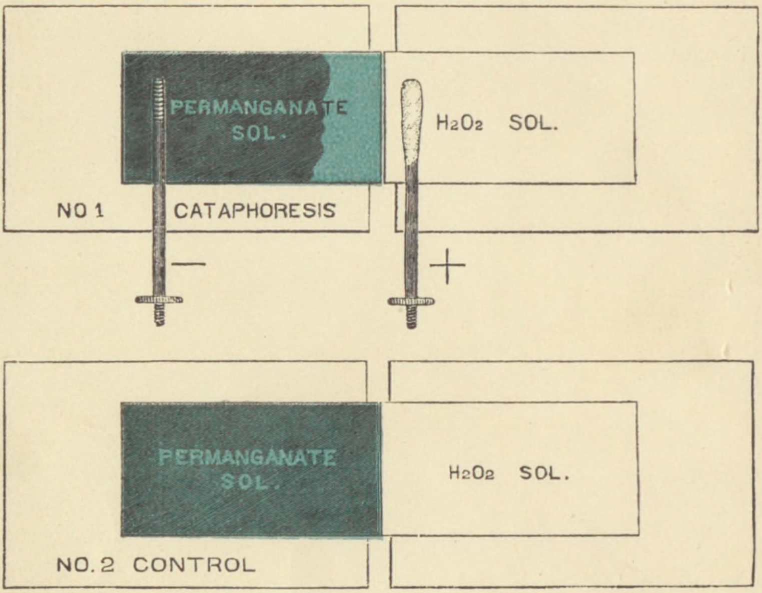

BLEACHING EFFECT OF CATAPHORESIS.

"CATAPHORESIS"

OR

ELECTRIC MEDICAMENTAL DIFFUSION

AS APPLIED IN MEDICINE, SURGERY AND DENTISTRY

BY

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PREFACE.

This treatise has been written at the request of some of my friends, earnest practitioners in medicine and dentistry—particularly in the latter profession—who desire information, not alone in regard to the mere practice of the art of electric diffusion but also in the fundamental principles which govern this art.

For many years, certainly since 1853, this peculiar property of the electric current, of driving medicines into living tissue, has hung, suspended in the air, so to speak, and has never been brought down to practical bearings, in spite of continuous and ingenious effort on the part of numerous individual experimenters. Each effort, while adding something fragmentary to the structure, in itself had never been so completely demonstrative as to reduce the art to a basis where others could invariably and successfully follow.

It so happens, at the present moment, that interest is largely centered in the application of the principle of Cataphoresis to Dental practices, but it takes no special prescience to foresee a time, and that not far distant, when this interest will spread into medicine and surgery, particularly in its relations to the production of an effective local anæsthesia in minor surgical operations. Indeed this latter, as I have for many years demonstrated, is even now an available, but it would seem a much neglected, operation. But since electro-cocaine local anæsthesia is but one branch of a large subject, the writer has thought it best to present the subject in its entirety rather than in a special and therefore limited manner.

The author's aim has been to gather between two covers and to put forth to the medical and dental professions much of what has been done, including his own work upon Electric Medicamental Diffusion.

The perforated electrodes alone, devised by the writer, make possible an extension of electro-cocaine anæsthesia into surgery hitherto impossible.

And here a word as to the subdivisions of this work and the plan upon which it is written. The author has found it impossible to write a book for the dental profession alone without including in it much that had been done in the broader branch of general medicine, for so enlarged has now become the scope of dental practice that it in reality is inseparable from medical and surgical practice. Indeed it should be at once and finally conceded that the dentist is the physician whose specialty is the diseases of the mouth and its appendages, both in a surgical and medical sense as well as in mechanical details. Both dentist and physician, therefore, if he reads it at all, should read the entire work, to gain a comprehensive view.

But it is exactly in the line of dental experience that the author has most keenly felt his own shortcomings and must crave the indulgence of his readers in that profession. His sincere thanks are due to Dr. M. L. Rhein for carefully reading over the advance sheets of Part V, namely, Special Applications to Dental Surgery, and for many valuable suggestions. Also he desires to thank Dr. R. Ottolengui for his courtesy and advice in relation to the

same part. Also, it should be added that this book would never have been written at all except for the initiative taken by the First District Dental Society of the State of New York, upon whose invitation, and before whom, the writer's first address upon this subject was given. Also a similar courtesy was extended by the New York Institute of Stomatology and the Academy of Stomatology of Philadelphia. To Dr. Edward C. Kirk in particular throughout the early period of presenting this subject the writer owes thanks for most valuable advice and assistance, as well as to Mr. William J. Evans of the firm of McKesson & Robbins.

INTRODUCTORY REMARKS.

WHEN the fear of the surgeon's knife was dissipated by the discovery of a means for rendering a patient unconscious to physical and mental torment, the world was grateful.

This power of producing a condition of general anæsthesia by the introduction of drugs into the system through the lungs has been of the greatest value to the surgeon also. His sensibilities are not shattered by scenes of agony caused by his manipulations; the work he does is of a better quality, and so again is the patient directly benefited.

But since the announcement of the great and primary discovery of means for producing general anæsthesia there has been a constant search for means by which *local* anæsthesia might be produced. Some experimenters have worked in one direction and some in another, but all have earnestly hoped to come across a method, or an application, or a process, which would permit, say, a finger to be amputated, or a tooth to be filled, without the necessity for the use of a general anæsthetic.

Lethal, or numbing, or anæsthetic effects were wanted, but it was desired to narrow down their sphere of activity to their sphere of usefulness.

It often happens in medicine that a new method of procedure makes its way to success by a series of steps not seemingly related to each other in time or relevancy. This would seem to be especially true of a number of individual therapeutic measures which have, during recent years, been brought to the attention of those interested in applying electricity to the cure of disease.

A safe, convenient and perfectly feasible method of producing local anæsthesia has been developed, and it will be the aim of the writer to state in this little work the history of this development, the principles which underlie its action and—what will appeal to the practical dentist and surgeon—the technique of operation.

This method of producing a state of local anæsthesia depends upon the peculiar characteristic possessed by an electric current of driving drugs held in solution into human tissue. A great variety of terms have been invented to express special views of the general facts. We hear of "osmosis," "electric osmosis," "anodal diffusion," "metallic electrolysis," "anaphoresis," "interstitial electrolysis," "electric transfer of particles and fluids," and "electric transportation." In place of these terms we will use those forming the title of this book, "cataphoresis" or "electric medicamental diffusion," the latter terminology expressing what will here be demonstrated and enlarged upon, namely, that electricity does diffuse liquids and substances throughout other liquids and substances, and through soft and hard living tissues, including the hard tissue known as dentine.

This property of the electric current is one which will be found most useful in general surgery, and especially in the domain of dental surgery, as will be seen from the following extract from an editorial on the subject which appeared over a year ago in a prominent publication devoted to the interests of dentists :[1]

"In the first efforts at securing dentinal anæsthesia, we were without a specific anæsthetic agent suitable for local application. When the agent was discovered it was found impossible to secure its action upon the pulp through even thin walls of dentine, hence its value in this connection is questionable, if any. The difficulty just noted seems now to have been overcome by enlisting the cataphoric principle of the galvanic current, and the feat of causing cocaine to penetrate to the pulp, producing a total anæsthesia of that organ through walls of dentine having considerable thickness is claimed to be a demonstrated fact. The significance of such a result cannot well be overestimated. If the dental pulp may with impunity be totally anæsthetized by cocaine for a reasonable length of time, the nervous wear and tear upon both patient and operator, which has been little short of a curse upon our work as dentists, will be almost completely removed."

As will be seen by a perusal of the following chapters, the demonstration is a complete one, and enough will be found there disclosed to warrant a belief in the practicability of electric local anæsthesia. Many have already been convinced by personal experimentation as to its value, and it is the sincere hope of the writer that his words will lead others to undertake its practice.

[1] *The Dental Cosmos*, Vol. XXXVIII. No. 3 ; March, 1896 ; page 256.

PART I.—HISTORICAL.

CHAPTER I.

EARLY EXPERIMENTERS.

WE shall be in a better position to understand the *rationale* of medication by electricity if we devote a little time to the consideration of the steps which have been taken in the past by various experimenters and observers in its development.

It will be recollected that the tendency of fluids to mix, or become equably diffused, when in contact, is called "osmose" or "osmosis." This tendency is marked and was first observed between fluids of differing densities and as taking place through a membrance or an intervening porous structure. It was discovered by Reuss in 1807 that this tendency is intensified upon the application of a galvanic current to the two fluids—one battery terminal or electrode being immersed in one of the fluids and the other battery terminal in the other fluid. The first to *claim* the transportation of medicines by electricity was Pirvati of Venice, whose experiments date back to 1747; these claims merit slight confidence. It was found by Porret, in

1815, that the direction in which this tendency manifested itself depended on the direction of flow of the electric current. It is now known that this direction of flow is almost always from the positive to the negative terminal of the battery circuit. This transportation of a fluid through a porous septum is called "Electric Endosmose" (*endosmose* signifying a pushing from without inwardly).

FABRÉ-PALAPRAT. The first account of an attempt to introduce medicines into the animal body by the galvanic current, known to the writer, is that of Fabré-Palaprat,[1] who, in 1833, employed a compress covered with a platinum disk on each arm. The negative battery terminal was attached to the platinum disk over one compress saturated with a solution of potassium iodide, and the positive terminal was brought to the disk over the other compress, which was saturated with starch-water. He stated that after allowing the current to pass for a short time the starch compress became of a blue color, thus indicating that the iodine had travelled from the negative pole through the arms and body to the positive pole. From this experiment he concluded that medicinal substances could be introduced into the human system.

On two occasions I have carefully repeated this experiment and found that the action which was reported does not take place. It is not credible that potassium iodide placed at the negative pole would produce any reaction at the positive as above described.

[1] "Archives générales de médicin," Vol. II. p. 422. Paris, 1833.

As was natural, when Fabré-Palaprat's experiments had been repeated by others and always without success, they were discredited and nothing came of them.

DR. KLENKE AND DR. HASSENSTEIN. In 1847,[1] Dr. Klenke described and claimed the success of a method for the galvanic introduction of medicines, such as potassium iodide and mercury, into the system, while in 1853,[2] Dr. Hassenstein made similar claims, but both failed to convince the medical profession.

G. WIEDEMANN. The researches of this noted physicist have contributed an important share in the development of this subject. He made numerous measurements which demonstrated to him the existence of certain laws governing the diffusion or transportation of liquids by the current. He formulated and published the following laws in 1853 :[3]

"1. The quantities of liquid transported within equal times are proportional to the intensities of the currents."

"2. The quantities of liquid transported by a galvanic current through a porous partition are independent of the width of the partition."

"3. For a given battery intensity, the quantity of liquid transported is independent of the thickness of the porous partition traversed."

RICHARDSON. In 1859, Dr. (later *Sir*) Benjamin

[1] "Zeitschrift Wiener Aerzte," Mai, 1747.

[2] "Chemish-electrische Heilmethode." Leipzig, 1852.

[3] See, "Traité Théorique et Pratique d'Electrochimie," par Donato Tommasi. Paris, 1890, page 42.

Ward Richardson,[1] made a notable attempt to introduce into practice a method of local anæsthesia by the use of electricity and narcotics, terming the procedure Voltaic Narcotism. The medicines employed were aconite and chloroform, as follows:—

Tinc. Aconiti	drachms 3;
Ext. "	scruple 1;
Chloroformi	drachms 2. Mix.

Employing this mixture at the positive pole and applied to the leg of a dog, complete anæsthesia was produced in eleven minutes and later the limb was amputated without pain. He also operated painlessly on a nævus anæsthetized in the same manner, and reported five cases of painless extraction of teeth, using in the latter cases a small wire at the positive pole wound with cotton and soaked in the solution mentioned.

There is little doubt but that Richardson's experiments were in a degree successful, and that, had they not been met with incredulity and extreme opposition, cataphoric medication would long ago have been practically developed. His opponents claimed that the topical application of the aconite and chloroform would produce a similar effect; that the aconite was dangerous by absorption; that the succeeding local inflammation was severe. On the other hand it should be said that discoveries often seem to have been forestalled by the work of others, when, in reality, did we know and employ their exact technique, we should fail. The opposition to Richardson's experiments and conclusions was most marked in the publications of A. Waller,[2] and his

1 "Medical Times and Gazette," Feb. 12 and June 25, 1859.

2 "Med. Times and Gazette," March 19 and July 30, 1859.

views were substantially those of many others, including J. Althaus.[1] It is interesting to note that this opposition was so strong that Richardson was constrained to recede[2] from the position which he had taken concerning voltaic narcotism.

The influence of his work was, however, for a long time discernible in medical and dental literature. Quite a furor in regard to using electricity to annul the pain of the extraction of teeth, both with and without anæsthetic drugs, was excited in this country.[3]

"About 1859," says Dr. J. Foster Flagg,[4] "a man named Francis came along and gave us a secondary current by means of which we were to extract teeth painlessly." The current was applied directly to the tooth through the forceps. "In forty per cent. of the cases the patients said they had felt no pain, another forty per cent. said the method was as painful as any they had ever experienced in connection with the extraction of teeth; and in twenty per cent. of the cases the patients stated they never would have teeth extracted in that way again if they knew it."

"With the aid of a friend (an electrician by the name of Otto Flemming), some time in 1870, I think it was, I developed what is known to-day as the Dental Helix, and instead of getting a secondary

[1] "Wien. Med. Woch.," IX., 1859, page 433.

[2] "Med. Times and Gazette," Feb. 3, 1866.

[3] See "Dental Cosmos," Vol. I. (1859), pp. 104, 142, 177, 300, 350, 551 (Cataphoresis); Vol. IV. (1863), p. 227; Vol. VI. (1865), pp. 582–634; Vol. X. (1869), p. 103; Vol. XI. (1870), pp. 608; Vol. XXIII. (1882), p. 280.

[4] "Items of Interest," Oct. 1896, p. 575.

current we gave a primary current, which is very mild. We did not call it cataphoresis or any other 'resis,' we called it substitution. We simply put into existence another sensation, which overcame the sensation of cutting the sensitive dentine."

CHAPTER II.

MODERN REVIVAL.

THE apparent settlement of the dispute over Richardson's achievements, in a manner adverse to his claims, was undoubtedly the reason why, for over twenty years, practically nothing was heard of the cataphoric administration of medicines. It was not until 1886 that the subject was again brought to the attention of the profession in an article by Wagner,[1] who suggested that possibly anæsthesia might be produced by the combination of cocaine with the galvanic current. This suggestion was not accompanied by the record of any experiments in this direction.

Erb, in 1884, introduced medicines through the intact living skin, and discovered their presence in the saliva and in the urine of the subject. Lewandowski did the same. Boccalari and Manzieri[2] introduced strychnine, atropine, quinine and iodide of potassium through the unbroken skin, frequently changing the direction of the current as first indicated by Erb.

In 1885, Lauret claimed that some substances electrically introduced through the intact skin, and that others were not.[3]

Later on in 1886 Adamkiewicz professed[4] to have introduced chloroform into tissues and thereby pro-

[1] "Wiener Med. Presse," 1886, S. 212.

[2] Rivista clinica, 1888. Reference from article by Fubini and Pierini, Arch. d'Élect. Médicale, Aug. 1897.

[3] De l'introduction, des substances medicamenteuses a travers la peau saine par l'influence de l'eletricité. Montpellier, 1885. Reference from Arch. dÉ'lect Médicalé, Aug. 1897.

[4] "Neurolog. Ctribl," Bd. V., S. 219–497.

duced local anæsthesia. He had found chloroform evaporated so rapidly from the ordinary sponge electrode that some other arrangement was necessary. He therefore devised what he termed his diffusion electrode which was a hollow brass vessel holding about three cubic centimeters of fluid with a piece of moistened linen stretched over the bottom made of porous carbon. He claimed to have employed the cataphoric method with chloroform in rheumatic pains and in some forms of neuralgia, obtaining a gradual anæsthesia with disappearance of pain.

Paschkis and Wagner[1] denied the possibility of chloroform being so used as it was almost a complete insulator. They also said that, although anæsthesia may have been produced, it was only because the chloroform was in contact with the skin. Adamkiewicz answered that although chloroform was a poor conductor yet it did conduct somewhat, and that anæsthesia was produced in four minutes, first to temperature and then to pain.

Many others, including Lombroso and Matteini,[2] have made this attempt with chloroform but with limited success, obviously because of the poor conductivity of chloroform to electricity. The possibility that chloroform may thus act to a certain extent must not be absolutely denied, since the obstacle of its non-conductivity may be overcome to a great extent by methods of technique. The fact that dermatitis, more or less severe, attends the use of chloroform would seem to preclude the hope of its practical employment.

1 "Neurolog. Ctrlbl., Bd. V., S. 413.

2 "Sulla cataforesi electrica," "La Riforma medica," July and November, 1886.

Then Dr. J. Leonard Corning,[1] of New York City, produced anæsthesia by the introduction of cocaine through the human skin by making minute punctures through the skin with the old Baunscheidt needles for counter-irritation, together with the use of the electric current. In this way he secured very profound anæsthesia of the parts operated on. He, however, reported no cases.

Other observers repeated and modified these experiments, using cocaine chiefly as the medicament. Among the more prominent of these is Dr. Frederick Peterson, of New York, who, during 1888 and 1889,[2] undertook a series of experiments which settled definitely many disputed points. He reported that the Adamkiewicz electrode was practically worthless and pointed out its defects ; that there was no anæsthesia with cocaine alone ; that there was no anæsthesia with current alone, but that current and cocaine together caused marked anæsthesia ; that the effect was produced only when the drug was in connection with the anode terminal of the electric circuit. He also cited several instances where cocaine had been cataphorically administered for the relief of neuralgic pain with satisfactory results. Dr. Peterson's experiments, however, did not extend to the point of the production of local anæsthesia for the performance of surgical operations.

In 1889, Mr. Newman Lawrence and Dr. A. Harris, both of London, separately and conjointly described the cataphoric method of medication, inventing the term "cataphoric medication" to describe it. Their paper was read before the Society of Arts.

[1] "New York Med. Jour.," Nov. 6, 1886.
[2] *Ibid*, April 27, 1889.

In November of the same year, Dr. Cagney, also of London, treated a variety of diseases by this method, reading a paper on the subject before the Harveian Society. Among other remedies he used iodide of potassium in cases of labyrinthine deafness, lead palsy, etc. These English publications revived the interest in the subject on the other side of the water.

At the International Congress held in Berlin, in August, 1890, a paper was read from Mr. Thomas A. Edison upon the employment of cataphoresis for the relief of gout. He had found that he was able to reduce the size of enlarged joints in a gouty subject by carrying lithium salts into the human body by means of the electric current. He placed the right hand, for instance, in a jar of chloride of sodium solution, and the left hand in a jar containing a solution of the chloride of lithium. He then passed a current of a certain strength from the positive pole or lithium side to the negative or sodium side and lithium was detected in the urine. As a whole these experiments of Mr. Edison were conclusive.

In later years some excellent and elaborate papers upon the same subject have been published in France. Among the writers of these may be mentioned Dr. Leon Danion, M. Labatut, M. Destot and Donato Tommasi. Dr. E. Grosheintz, of Basle, has also written a valuable paper on "Anæsthesia of Dentine and the Dental Pulp" which appeared in the December (1896) number of "L'Odontologie," page 727.

In September, 1891, Dr. Imbert de la Touche, of

Paris, read an extended paper upon the treatment of gout and rheumatism by cataphoric medication. The remedies in solution, principally lithia salts, were applied by aid of a large sponge or absorbent cotton, and made to constitute a positive pole. Cases were carefully reported, and the results were excellent.

Gärtner & Ehrmann,[1] of Vienna, introduced corrosive sublimate cataphorically by an electric bath in syphilitic cases and discovered the mercury in the urine.

About 1855, a Mr. Vergnés, an electroplater, of Havana, Cuba, found that he had an incurable ulcer which had been produced by his having repeatedly to plunge his hands into solutions of cyanide and nitrate of silver and gold. One day, having accidentally placed his hands into a bath already prepared for plating he found the negative element had received a metallic coating. The hint was acted upon, and a number of similar treatments resulted in the rapid cure of the ulcer.

From this incident sprung the Vergnés "electro-chemical bath," as it was named. A Mr. A. W. Royal practised the method in New York City. It will be interesting to note some portions of a circular issued from this establishment under date of May 29, 1885:

"This is the only establishment of these Baths in New York City.

"They are widely known for the cure of Rheumatism, Gout, Neuralgia, Sciatica, Paralysis, Malaria, Liver and Kidney Complaints.

[1] Lewandowski, "Electro-diagnostik and Electro-therapeutic." Wien and Leipzig, 1892.

"By tests made in 1881, it was proved that they are a remedy for Hay Fever.

"The Baths are pleasant and agreeable to take; they operate directly and powerfully on the nervous system, and on all the organs of life.

"Nervous sufferers, from business excitement or other debilitating causes, as well as those suffering from chronic nervous disorders, promptly experience their beneficial effects.

"They are known to the Medical Profession as a specific against metallic poisons. MERCURY—which is the potent cause of so many ills, is thoroughly eradicated by their use."

The vogue of these baths seems to have depended largely on an idea that mercury clung to the system of many unfortunates and should be eliminated by this method. It is scarcely probable that anything more than unusual circumstances would call for the elimination of medicinal substances from the body by means of electricity, since it is probably impossible to prevent their natural elimination, and since, again, other simple means of elimination are available, as, for instance, the administration of iodide of potash in lead poisoning.

In the practice of the Vergnés method of cataphoric demedication the bath-tub was of copper and insulated from the earth. The patient was also insulated from the tub by sitting on a wooden seat. The water (in case gold, silver or mercury was to be eliminated) was acidulated with nitric or hydrochloric acid. The positive pole of a thirty-cell galvanic battery was held in the hands while the negative pole was connected to the copper bath-tub.[1]

[1] See "A Treatise on Medical Electricity," by Julius Althaus. Philadelphia, 1873.

This plan was further advocated and published[1] by M. Poey of Paris.

Vergnès also reversed the current in his bath and claimed to introduce medicinal substances, notably phosphate of iron in a solution to which nitric acid was added, and also quinine. The patient sat in a bath containing the solution of the medicine, holding the negative pole in the hands and out of the bath. No physician could consent to put in practice a method as inexact as that outlined above, unless advantages not obtained by other administrations can be demonstrated. Nevertheless, we see here outlined, in the system of the Vergnès baths, both medicating and demedicating, a crude germ of practice which may easily expand into fruitful results.

For, a careful study of the physics and physiology of the subject will convince even the most sceptical of the fact that medicine can be introduced through the unbroken skin by immersing the patient in a fluid electrode which, in fact, such a bath constitutes. Mr. Edison's experiment of causing the patient to immerse the hands in fluid was in reality a limited electric bath, and now that we have his authority as well as that of Dr. A. E. Kennelly, who personally superintended the experiments, we may accept without shrinking the principle of the "medicated" electric bath. While we must grant the solidity of the physical facts, we yet need much clinical experience, and the time has not yet come for a judicial expression as to the value of these methods.

[1] Manuel d'Électricité, etc. Par le docteur A. Tripier. Paris, 1861, p. 603 and Comptes rendus de l'Acad, des sciences, 1855.

CHAPTER III.

DEVELOPMENTS IN DENTAL SURGERY.

It is interesting to note which of the many experimentalists was the first who "obtunded sensitive dentine" by cataphoresis. This is, perhaps, a minor consideration, as it goes without saying that if other tissues have been thus anæsthetized, dentine could be. Still it is noteworthy that the distinction of having first put himself on record belongs to Dr. D. F. McGraw, of San José, California. He has written a letter on the subject which appeared in the October (1896) number of the "International Dental Journal," pages 678 and 679, in which he recalled the fact that he had read a paper before the Minnesota State Dental Society at its annual meeting in the summer of 1888, and also before the Southern Minnesota District Society at its semi-annual meeting in the fall of 1888, as well as at the twenty-fifth annual meeting of the Chicago Dental Club, held in the Grand Pacific Hotel on Feb. 5, 6 and 7, 1889. The transactions of this Chicago meeting were printed in the February (1889) number of the "Dental Review," and subsequently in book form, his paper appearing at page 113 of that volume. Dr. McGraw states that at the Chicago meeting, Professor Weeks, of the Dental Department of the University of Minnesota, also read an article on the subject. The attention of the latter had been called to the application of cataphoresis by the papers Dr. McGraw had read in 1888.

As a bit of history, the following extract from Dr. McGraw's early paper will be interesting :

"This method that we shall present to you at this meeting to gain insensibility in the teeth is the following :

"To a twelve per cent. solution of cocaine, add an equal amount of absolute alcohol, making a six per cent. solution of cocaine in alcohol. In connection with this I use the galvanic current, varying the power as the needs of each case may indicate. The method of application is as follows :

"First apply the rubber dam ; wet a pledget of cotton in the solution, placing it in the cavity of the tooth, pressing the point of the positive pole on to the cotton, and the negative pole, with sponge attachment thoroughly wet, to the cheek, turning on the current. Rarely will more than four cells be necessary, if the battery is in good working order.

"An application of three minutes, with an interval of three minutes, and then another three minutes application, are sufficient in the majority of cases, although I have to occasionally make the third application, then dry the cavity thoroughly and begin excavating. My deductions as to the physiological effects are as follows : The galvanic current acts as a vehicle for conducting the medicinal agents ; the cocaine anæsthetizes the odontoblastic cells and the pulp ; the styptic properties of the alcohol act upon the dentinal fibrils, they being of an albuminous nature, causing contraction and increased density and firmness.

"My reasons for drawing these conclusions are these:

"I have found that the most sensitive teeth can be obtunded; that after a certain period of rest sensitiveness returns, but never to that degree that existed before the application of the obtundent. Therefore I conclude that a change had taken place in the dentinal fibrils, which I maintain is due to the styptic properties, and not to the electrolytic actions of the galvanic current. Another reason is, that a tooth in which the pulp is devitalized is a non-conductor of the electric current. A tooth which had been extracted was subjected to a twelve-cell current of a freshly-charged battery and proved an absolute non-conductor.

The next we hear of the application of cataphoresis in dentistry is from a paper[1] read before the Dental Society of the State of New York on May 12, 1892, by Albert C. Westlake, D. D. S., of Elizabeth, N. J. The method used by Dr. Westlake in the preparation of cavities, is set forth by him in his description of a case where the patient was a lady, age thirty-four, of a nervo-sanguine temperament. He says "The two cuspids on superior arch presented labial and approximate cavities. The dentine was hypersensitive, and there was slight recession of the gum. Before applying the rubber-dam, I gave her the negative electrode to hold in the hand, and fitted a thin wire of silver in one of Kidder's universal holders, attached to the positive pole. I wound a few threads of cotton around the wire, and saturating it with a ten per cent solution

[1] See "Dental Cosmos," November, 1892, page 887.

of cocaine, applied it to the margins of the gum. I first passed about one milliampere of current, and gradually increased it to four, which I continued for less than two minutes. I then adjusted the rubber-dam, pressing the gum well up, with no apparent pain to my patient.

"Before excavating the cavities, I saturated the cocaine crystals with ten per cent. solution of warm carbolic acid, into which I dipped the cotton on the positive electrode, and found that after applying about eight milliamperes of galvanic current for fully one minute I could prepare the cavity without the patient protesting. I joined these cavities in each tooth, making almost a circle, and filled them with gold by aid of the electric mallet. She does not appreciate the thermal changes complained of before filling, and the teeth are comfortable."

Dr. Westlake proposed that when teeth were to be extracted the electrodes should be applied to the gum, one on each side of the root or tooth to be extracted. He says, in the article above quoted from, that the ends of the electrodes applied to the gums are in the form of a cup "within which is placed sponge or cotton saturated with a four or six per cent solution of cocaine, or absolute alcohol, ether and chloroform combined, or some other properly selected vegetable anæsthetic, and if the current is turned on gently to the required degree, this preparation can be forced into the tissue sufficiently to cause local anæsthesia." This method and the electrodes he proposed for the purpose will be spoken of in the following chapter.

Another department of work in which Dr. Westlake has been interested is that of bleaching of teeth cataphorically by the use of pyrozone. He described some of his experiences in an article which appeared in "The International Dental Journal," on page 213 of the April, 1895, number. He there says: "This first experiment in cataphoresis for bleaching took place on Friday, March 8." This was apparently in 1895.

In 1891, Dr. J. S. Marshall presented a paper[1] before the American Academy of Dental Science on "Electricity as a Therapeutic Agent in the Treatment of Hyperæmia and Congestion of Pulp and the Peridental Membrane." This article demonstrated that the continued use of applications of electricity for morbid and irritable conditions of the pulp did not produce any ill effects on the pulp itself. Dr. Marshall did not employ cocaine or any other anæsthetic drug.

While during all this period a great amount of work was being done in the field of general medicine with cataphoresis, little attention, if any, was paid to its application in anæsthetizing sensitive dentine for several years after the publication of Dr. Westlake's paper, in 1892. The next publication on the subject was an article which appeared in the "Dental Cosmos" for January, 1896, under my own signature. This article not only referred to the anæsthetic properties of cocaine when used with electricity, in dental work, and especially upon sensitive dentine but described a new medicament—that of guiacol-cocaine—for the same purposes, the whole forming a natural sequence to what I had already published concerning the bleaching of teeth. (See my

[1] "Dental Cosmos," November, 1891.

article on the cataphoric use of pyrozone for bleaching which appeared in the "Dental Cosmos," for June, 1895). The next chapter has been devoted to my personal investigations and these matters will there be gone into more fully.

The following month (February, 1896) an article appeared in the "Dental Cosmos," written by Henry W. Gillett, D. M. D., of Newport, R. I. This was a paper he had read before the American Dental Association on August 8, 1895, but which had not been published until this time. He said, in the article referred to:

"Is there any one pain that has been more dreaded by the civilized race than the pain from the sensitive tissues of the human tooth, when it becomes necessary to treat those tissues surgically?

"Is there any one object for which our profession has sought more earnestly, and less successfully, than it has to find a generally applicable means for preventing this pain?

"We have striven unceasingly with caustics, with desiccants, with anæsthetics both local and general, with administration of drugs and applications of washes, but with all our strivings we hear it constantly reiterated in our discussions, that the keen excavator and the firm touch are our main reliance.

"We have been able to soften the blow sometimes, but very generally the profession seems to have come to feel that prompt and heroic measures are best, and have prepared themselves for action on these lines.

"In common with the rest of the profession I have many times had cause to be grateful, in individual cases, for some of the above enumerated aids, and I would by no means discredit the bridge when it has safely carried me over a chasm ; but, after many trials and many failures, my sense of relief in having a means for the control of sensitive dentine which seems to be universal in its application, and the relief afforded to some otherwise untreatable cases has been so great that I am anxious to have the knowledge of the success of this method more widely spread than it now is, to the end that human suffering may be made less. As I have intimated, in my own practice this step in advance has been made by using cataphoresis."

Dr. Wendell C. Phillips, of New York, who was interested in Dr. Gillett's early work, writes of it as follows :[1] "Dr. Gillett's first experiments and demonstrations were made with an ordinary adapter. In showing him the apparatus which I had, and which was used for the ordinary "(therapeutic)" purposes of the continuous current, he said he thought it might be used in obtunding sensitive dentine. The next day he brought a patient, the first experiment was made, and it was successful. But we found that when the current was increased the patient experienced pain, and he thought it was necessary to overcome those jumps of the current in order to make a perfect application of cataphoresis. A successful application of cataphoresis in obtunding must depend upon the relief of one pain without the introduction of another. Dr. Gillett purchased one of the same adapters. He

[1] Paper read before Central Dental Association of Northern New Jersey on March 16, 1896. See "International Dental Journal," July, 1896.

made some changes in it from time to time, but finally found it would not answer the purpose unless the current could be so controlled that the changes in its gradations or steps would not be painful to the patient. He called to his assistance Mr. G. M. Wheeler, of the Electro-Therapeutic Company, and explained what he wanted. The result of his suggestion, in conjunction with Mr. Wheeler's mechanical and electrical skill, is the instrument known as the Wheeler fractional volt-selector. * * * Dr. Gillett says the voltage must be turned on in steps of less than half a volt. * * * The fractional volt-selector will give you gradations of less than one-quarter of a volt, and with that perfect control of the current the possibility of giving pain to the patient is extremely remote. After careful experiments I have found that it will do the work."

In the "International Dental Journal" for February, 1896, appeared a paper[1] by Dr. Gillett on "Electrical Osmosis for the Treatment of Living Dentine." In this paper he covers the ground of his experimental and practical work with candor and completeness. He says: "I approached the matter with great hesitation because of my lack of knowledge of electrical principles. Finally, however, I found the key which simplified the problem for me. It has taken much labor to reduce the matter to a point where it is practicable. Since March (1895), I have been able to command, for daily use, a process for the control of the sensitiveness of dentine, which seems to be practically universal in its application, and from which I can conceive no possibility of ill

[1] Read before the "New York Institute of Stomatology" on November 26, 1895.

results. As I go on I find others have considered the same possibilities. The earliest efforts along this particular line that I have been able to hear of are those of Dr. D. F. McGraw, now of California."

"The effect of the cocaine in these applications does not seem to reach deeply into the dentine in most cases. By prolonging the application, however, the pulp itself may, in favorable cases, be anæsthetized, even through a layer of dentine."

"It is quite often the case that a ten or twelve-minute application will anæsthetize the dentine deeply enough to allow the greater portion or all of the cutting to be done painlessly, but for deep grooves it may be necessary to repeat the application. In cases where there is much sensitiveness, and consequently there will be much time required to prepare the cavity at all, I find the time required for applying the cocaine is fully made up by the increased speed possible after the sensitiveness is under control."

"I do not need to enlarge upon so familiar a fact as the comparative consumption of time in preparing cavities, similar, except for their degree of sensitiveness, or to recall how, in the case of a sensitive cavity for a nervous patient, it often requires an hour to do what may be done in ten minutes after the cavity has been thoroughly anæsthetized."

"This treatment renders it possible to do for these nervous and hypersensitive organizations desirable operations, which, without some such means, are utterly impossible."

In this paper Dr. Gillett explains his method of application in detail, and gives some experiments tried by him which corroborate those tried by Dr.

Peterson in 1888 and 1889. He also cited four cases in which he had applied cataphoresis successfully in the obtunding of sensitive dentine. Dr. Gillett, in all his work, used the Edison 110 volt street current as his source of power.

Immediately following my publication of January, 1896, Electro-cocaine anæsthesia of sensitive dentine useing aqueous or guaiacol solutions of cocaine was quickly adopted in Europe. The first to practice it were Dr. E. Grosheintz and Dr. Respinger, of Bâle, Switzerland, both of whom met with great success. Dr. Marcus and Mr. Liebmann, chemist of Frankfort (on the Main), assisted by Prof. Freund, likewise made successful experiments.

CHAPTER IV.

THE WRITER'S CONTRIBUTIONS.

My interest in cataphoric medication was aroused when I purchased, in 1873, the "Treatise on Medical Electricity," by Julius Althaus, M. D., published in Philadelphia. This volume described the experiments of Fabré-Palaprat, Klenke, Hassenstein and Richardson, as well as those of Vergnés, the electroplater of Havana, with his electric baths. I repeated the experiments of Fabré-Palaprat on several occasions without obtaining the results he had reported. From this time up to 1886, when Wagner suggested that cocaine might be used cataphorically for producing local anæsthesia I did little with the principle except to make use in my practice of medicine and before my classes of that application which tends to concentrate at some point in the tissues, fluids which have been drawn from other points.

In common with many others I was much impressed by the suggestion of Wagner and the experiments of Adamkiewicz and especially because of my previous experiments. The electrodes which I first devised for use in continued research in these directions were quite large and held considerable fluid. The metal terminals in these electrodes were some distance from the tissues upon which the electrodes rested and I soon found that the very small degree of success I met with was due to the fact that my current of electricity was being used to set up an action in the medicated fluid of the electrode instead of being effective in driving the medicated fluid through the tissues. This led to my invention of a perforated disc-electrode which brought the medicine and the metal terminal down close to the tissue where all the electric energy was available to project the drug into the tissue.

In the "New York Medical Journal" for April 25, 1891, I described a new method of cataphoric medication which I had devised and which, in my experience, afforded much better results than the old. I gave the name "Anæmic Cataphoresis" to this new method and spoke of it as follows (p. 474):

"To introduce a drug into the human system by the mouth hypodermically or by cataphoresis as ordinarily practiced is to introduce it by means of the blood stream into the entire body. To reach a local part we saturate all parts.

"By the method here described I cause it to act upon that part alone for which it is intended. This I accomplish by cutting off the blood stream in the part to be treated by means of an Esmarch bandage (See Fig. 1) or by a rubber ring, especially for the

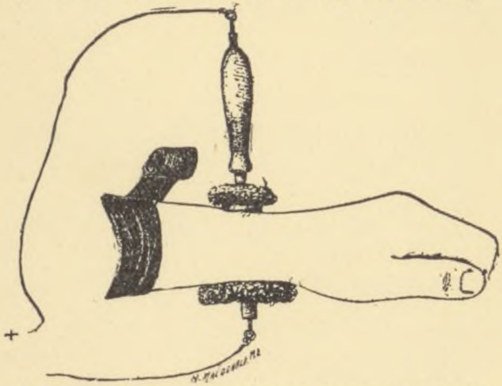


Fig. 1.—Anæmic cataphoresis with Esmarch's bandage.

fingers, after the fashion of an umbrella ring (See Fig. 2), and then treating by cataphoresis.

FIG. 2.—Anæmic cataphoresis with a rubber ring (electrical applications as in Fig. 1).

"By means of the anæmic method of cataphoresis here outlined, the medicine employed, or some electrolytic modification of it, comes in direct contact

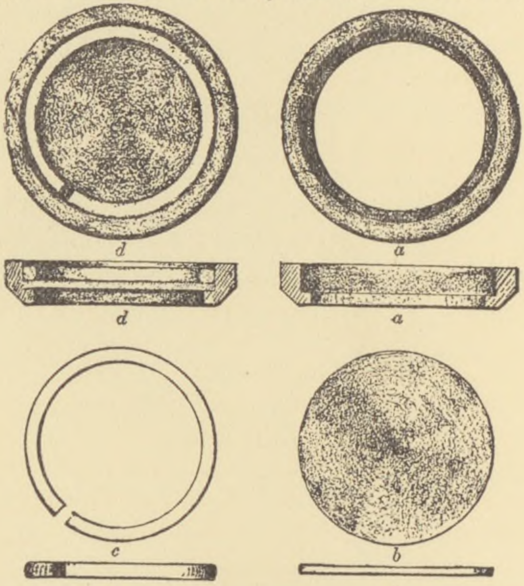


FIG. 3.—A cataphoric disc adapted to use with ordinary electrodes, *a*, *a*, an ebonite ring; *b*, *b*, a metallic plate; *c*, *c*, a spring to hold the plate in place; *d*, *d*, the parts united for use.

with the affected tissue or the tissue to be affected, and remains for a considerable time (as long as the bandage remains on) in relation with it."

In this same article I described my small disc-electrode, mentioned above (see Fig. 3), as well as a further innovation for which I was responsible. This was to incorporate the medicine in a small plaster composed of *conducting* material not capable of electrolysis. "Such a material is pulverized gas-carbon, though other non-electrolytic conducting substances may be used. Cohesion into a plaster and adhesion to the skin are obtained by gelatin or other adhesive substances. The gelatin, carbon, and medicine in measured dose are mixed, formed into a small plaster, and dried."

I also there mentioned an experiment which I had tried upon myself and which showed the ease with which even solid particles might be driven into tissue by the action of an electric current. Some finely-powdered lamp-black or graphite was incorporated with some salicylate of soda and placed on my arm under the positive electrode. The current was turned on and the particles of graphite were carried into the sweat follicles, making small black spots, like bird shot, which were so deeply embedded that they did not disappear for several weeks. In the third of a series of clinical lectures on Electro-Therapeutics which I delivered before the New York Post-Graduate Medical School, on Feb. 8th, 1892, the following language was used :

"Whether iodide of potassium, salts of lithium, cocaine, etc., be employed we should bear in mind that there are reasons why medication by this method should be superior in selected cases to medication by any other method. By selected cases I mean, for instance, diseases of the skin and mucous membranes, and of growths immediately beneath the mucous membranes; diseases resembling lupus, carcinoma or open neoplasms, or such lesions as superficial syphilitic gummata. But you ask, Why not introduce the medicines by the mouth or hypodermically? The answer is that by cataphoresis the medication may be localized and driven in upon the diseased tissue. There is also a theoretical reason why medication by this method should be of extraordinary value, *i. e.*, these remedies are carried into the part to be affected, in their nascent condition, when they are remarkably active."

At this period I was constantly experimenting and making numerous researches on original lines. I found that the resistance of the fluid conductor had a great bearing upon the success of cataphoric applications and in a paper read by me[1] on October 4, 1892. I summarized my observations concerning these points as follows: "If the fluid has little resistance, as in acidulated water, there is little or no movement, but if the resistance of the fluid is increased the rate of flow is increased and for a given resistance its flow will be proportional to the current strength. On the other hand, the resistance may be so increased that there is no cataphoresis, as in the case of oils, but there is also little or no current. May we not assume, to explain the transfer of fluids by cataphoresis that the action is mechanical, that the partially conducting molecules which constitute the electric resistance are borne along bodily, to use a rough comparison, like chaff

[1] See "Trans. Am. Electro-Therapeutic Assn.," 1892, p. 62.

before the wind—become in short, since the mass is fluid, a resistance which may be moved along, while the conducting molecules dissipate the energy they receive to form the current? We might designate this a theory of movable resistance." Several experiments were then cited in support of this view.

Another paper on this same general subject was read by me at the Fourth Annual Meeting of this Association,[1] on September 25, 1894. It was at this time I coined the phrase which has been used as the sub-title of this book. After describing the various phenomena of cataphoresis I said :

"It matters not whether the medicine in solution be applied by a sponge or blotting-paper against the skin (cataphoric medication), be held in solution in the water of an electric bath (again cataphoric medication), be injected into a cavity and decomposed (interstitial electrolysis), be dissolved by the action of a current off of a needle perforating the tissue (metallic electrolysis), or be dissolved from an electrode held in contact with mucous membrane (also metallic electrolysis) ; the result is the same—a foreign substance in solution, viz., a medicine is caused to enter and permeate the tissue. It therefore seems to me to be a proper time to generalize the entire facts under the term of electric diffusion of medicines into human tissue, or, simply, *electric medicamental diffusion.*"

This paper also gave quite fully a statement as to the beneficial effects resulting from the use of

[1] This paper was subsequently printed in "The Journal of the American Medical Association," for May 4, 1895, as well as in the Trans. Am. Elec. Ther. Ass'n., for 1894.

"soluble" electrodes, or electrodes which, when imbedded in or applied to tissue, would become decomposed electrolytically and the chemical products so formed be projected into the tissue. I noted the early experiments with these electrodes but remarked: "It remained for Dr. Georges Gautier, of Paris, to grasp the broad idea of diffusing metallic salts from soluble electrodes and to inaugurate by a series of experiments this new system of procedure.[1]

"At once appreciating the far-reaching merits of the new method, I established its use in a great variety of cases in my clinic at the New York Post-Graduate Medical School and Hospital as early as 1891, and also at the same time in private practice. The method was taught to matriculates by actual demonstrations. Experiments were made of its effects in trachoma, hypertrophic nasal catarrh and ozena, gonorrhea and keloid, and continued in a great variety of diseases, and with a variety of metals at the positive pole. Obviously, the method once understood implies its application to a large number of cases and by any soluble metal." I also illustrated various forms of needle and bulb electrodes for this purpose, several of which were devised by me. These were of the "protected" type, allowing the electrolytic action to take place at a given point only. These had been made by me early in 1894. I also cited cases, cured by cataphoresis, of the following diseases: chronic Tinnitus Aurium, Trachoma, Hypertrophic Rhinitis and Pharyngitis,

[1] "Revue Internationale d'Electrothérapie," July, 1891, August and September, 1892. Also "Technique d'Electrothérapie," by Drs. Gautier and Larat.

Follicular Tonsillitis, Urethritis, Tumors and Sycosis Parasitica.

It was well known that peroxide of hydrogen, when applied to human teeth topically, tended to bleach them, but its action was slow and merely superficial. In an article[1] on "Cataphoresis and solution of H_2O_2 for Bleaching Teeth," I demonstrated the efficiency of hydrogen dioxide for this purpose when diffused into the tissues of teeth cataphorically. With a view of ascertaining if discolored teeth could be actually and practically bleached by this method I performed a number of experiments, being assisted by Mr. Wm. J. Evans, of the firm of McKesson & Robbins.

These experiments showed a most important fact, namely, that while ethereal solutions of H_2O_2 do not conduct electricity, and cannot therefore be used by themselves for cataphoric action, still this effect can be readily obtained when the porous material which holds such an ethereal solution has been previously moistened with a solution of sulphate of soda or some similar conductor, thus constituting what I termed a "solution electrode."

So far as relates to the anæsthetization of sensitive dentine the early experimental work of Drs. McGraw and Westlake seemed to have had no permanent effect in the practice of dentistry. They were buried in that limbo of forgotten observations which their authors had not the time or conviction to follow up to the point of making them an established procedure. The first publication and *published* cases of record which produced a real effect

[1] See "Dental Cosmos," June, 1895, p. 484.

upon the members of the dental profession, causing them to at once adopt cataphoresis largely, as a practical procedure, were those of the writer published in the "Dental Cosmos" for January, 1896. Cataphoresis immediately became a burning issue and was placed upon a scientific basis which every prac titioner could easily comprehend—what is more important, could easily practise. The procedure was at once adopted by a great number of practical dentists throughout America and Europe, this paper of January, 1896, having been extensively read and quoted at home and translated into German and French and published in foreign dental journals.

Several cases were mentioned in this paper of mine, two of which are quoted below.

These cases are of special interest as they were the first cases in which guaiacol in combination with cocaine was first employed.

"*Case* 1. Patient, Miss M. W., age eighteen, brought to my office by Dr. M. L. Rhein, and operations on the teeth by him. Patient of extremest hyperesthetic state. Deep crown cavity in second superior right molar, almost to the horns of the pulp of the buccal root. Very sensitive, especially as it approached the horn of the pulp. Electro-guaiacol-cocaine anæsthesia, seven minutes in two applications. Result, perfect anæsthesia to hand excavation. Patient experienced no pain from the current."

"*Case* 2. Same patient. First right superior bicuspid, posterior approximal and crown cavity. Had attempted to prepare the tooth at a previous sitting, but on account of the extreme sensitiveness, work had been abandoned before the cavity had been entirely excavated ; the bottom of the cavity was covered with asbestos paper, over which was packed a filling of gutta-percha. On removal of the filling, after having been in place about six weeks, the tooth was found exquisitely sensitive to the slightest touch. Electro-guaiacol-cocaine anæsthesia. The first approaches of the current (not noted on the milliamperemeter) gave severe pain, which gradually subsided, and each subsequent increase of current caused pain. Three applications on cotton were made. After seven minutes of about one-tenth of one milliampere I was able to carry the current up to two-thirds of a milliampere without pain. Complete anæsthesia. On exploration, it was found that after the removal of a thin film of leathery dentine, the point of an excavator readily entered into the pulp-chamber without any consciousness of pain on the part of the patient. Completely successful. No hyperesthesia of the tooth the next day.

Although these two cases were first printed in January, 1896, they had been first mentioned in a paper I read before the First District Dental Society, State of New York, at the regular meeting held in the Academy of Medicine, New York city, on December 10, 1895.[1]

In the previous chapter it was developed that Dr. Westlake had suggested that for tooth-extraction it would be proper to use a double electrode which would fit the gum both back and front of the tooth to be operated on and that one of these terminals of the electrode should be made positive and the other negative. This method I did not approve of as was

[1] "Dental Cosmos," March, 1896, page 210.

indicated by my lecture, mentioned above as having been delivered on December 10, 1895, when the following language was used :

"I want to say right here that the effect of a medicine placed at the positive pole only extends half way. That is to be borne in mind. It does not extend all the way. If you apply to one side of the gums the negative pole, and to the other the positive pole, and the positive has cocaine on it, the cocaine effect will only reach half-way ; the other half will rather be hypersensitive than anæsthetized." Later on in the same lecture, after trying certain experiments demonstrating the carrying capacity of electric currents, the subject was again reverted to, as follows :

"You cannot get the effect of any medicine all the way from a positive to a negative pole. Its effect will go just about half way, measuring by resistance. This was a deficiency in the electro-cocaine electrode made by Dr. Westlake for producing anæsthesia in extracting teeth. One of the cups was placed on one side of the tooth and the other on the other side ; cocaine was placed in the cups on a sponge. One side was made positive and the other negative, and it was expected that the cocaine would be driven through from one side to the other, and make the gums, all the way across, so numb that the tooth could be drawn without pain, but that is impossible. One side would be numb and the other would not and the patient would experience pain. It would be impossible with this apparatus to pull a tooth without pain."

I then showed that better results would be obtained if the two cup-electrodes were made positive with the negative electrode placed elsewhere, as in the patient's hand. I also pointed out that under certain circumstances it would be necessary to use other methods, for I said: "But to successfully extract a tooth painlessly by electro-cocaine anæsthesia I have found it necessary, if the pulp is not dead, to go still further when a cavity exists and benumb the contents of the pulp-cavity by applying the same solution electrically to absorbent cotton placed in a cavity in the tooth."

The two cases quoted above from my article published in January, 1896, referred to "electro-guaiacol-cocaine anæsthesia," and it is my desire to briefly state, at this point, what this means. My December, 1895, lecture (printed in March, 1896) first described this method and I had this to say on the subject:

"A few weeks ago I made some experiments with guaiacol for producing local anæsthesia electrically. I made over one hundred experiments, and I was determined to find something that would enable me to use it. Guaiacol is one of the plenols. It is an extract from creasote, which you know is one of the violent escharotics, and produces intense dermatitis. I rubbed the cork of the bottle containing creasote on my arm and on Mr. Evans's arm, not knowing how violent it would be, and I have still a sore spot on my arm, and I presume he has too. Guaiacol, however, is almost absolutely bland. It is creasote freed from its irritating hydroxyl. It can be used without producing pain. I use guaiacol alone or eight per cent cocaine with guaiacol, and then I have the most beautiful local anæsthetic effect I have ever seen." Again, later on in the same lecture:

"In my experiments upon soft tissues, as well as upon dentine, I find that guaiacol to which cocaine is added enables me to reduce the time ordinarily required to produce anæsthesia about two-thirds, and, what is still more important, enables me to reduce the current strength of electricity required also two-thirds. The important feature of guaiacol is that it holds on chemically to the cocaine and thus prevents quick absorption into the general circulation and consequent toxic effects. To prove this assertion take a ten per cent solution of hydrochlorate of cocaine and shake it for a considerable time with an equal bulk of water. One-eighth of the cocaine only will be found to have gone to the water, and seven-eighths to have remained with the guaiacol. This is a very remarkable fact, and it bids fair to open the way to the adoption of electro-guaiacol-cocaine anæsthesia as in reality a practicable and useful procedure in minor surgery, since aqueous solutions on large electrodes might allow of too much absorption."

I also made the suggestion in this paper that though guaiacol is a non-conductor "it has this peculiar property, that it absorbs one two-hundredth part of water, and water with additions will conduct. To this may be added one drop of sulphuric acid, which makes a dilute sulphuric acid. If you give the mixture a quick shake you have an emulsion of water, sulphuric acid and guaiacol, and you have a good conductor; and as soon as you use it in that way, with one drop of sulphuric acid and one two-hundredth part of water, you can get guaiacol local anæsthesia, which is again entirely new. For any one who wishes to try two new preparations I will give these two receipts :

" ℞—Guaiacol, one drachm ;
Cocaine hydrochlorate anhydrous, six grains. Mix.

" ℞—Guaiacol, one drachm ;
Acidi sulphurici, one minim ;
Aquæ dest., two minims. Mix.
Sig.—Make emulsion."

Speaking of this second mixture in my January, 1896, paper, I said : "This also may be used to produce local anæsthesia cataphorically, but its application causes slightly more pain initially, and to obviate this initial pain a very small amount of cocaine may be added if desired." Thus far, present practice favors aqueous and guaiacol solutions of cocaine only.

In this same paper I described my reservoir electrode made of pure block tin with hard-rubber covering. It had two screw joints, so that it might be easily taken apart and cleaned. When in use, blotting paper is placed over the face of the perforated disk, which is chambered at the back to receive the medicine. This electrode is shown in Fig. 4. I summed up the paper as follows :

FIG. 4.—Morton's Reservoir Cataphoric Electrode.

"1.—Electric medicamental diffusion '(cataphoresis)' is not only a possible but also a practical procedure, since,

"2.—Sensitive dentine may, with the greatest ease, be so thoroughly anæsthetized that operations upon it and in it cause no pain.

"3.—The dental pulp, even though not fully exposed, may be anæsthetized so that instruments may enter the pulp-cavity without causing pain.

"4.—By employing a properly constructed electrode, soft tissues like the gums may be completely anæsthetized to the pain of cutting and tearing operations.

"5.—Soft tissues like large areas (three inches by one and one-half inches by one-half inches deep) of the derma and subjacent tissue may be completely anæsthetized for surgical operations.

"6.—Guaiacol alone, and other similar substances and derivatives, in themselves non-conductors of electricity, by the addition of a very minute quantity of some innocent substance of an electrolytic nature, may be caused to penetrate tissue by the aid of electricity, and thus exhibit anæsthetic effects unobtainable without the aid of the added electrolyte.

"7.—Guaiacol restrains the action of cocaine to local territory; increases the rate of its cataphoric penetration through the epidermis and other tissues; slows the rate of its absorption into the system; prevents consequent toxic effects and adds its own anæsthetic qualities to those of cocaine."

In the "Dental Cosmos" for April, 1896, appeared a paper written by me on the outfit and technique for Cataphoresis including Guaiacocaine Cataphoric Anæsthesia, as a consequence of the many inquiries made of me on the subject. These matters will not be gone into here as they more properly fall under a later portion of this book.

I have also found that guaiacol may be mixed in equal parts with sulphuric ether and hydrochloate of cocaine be added to any per cent. required and this mixture sealed into a cavity will by pressure of the evaporating sulphuric ether produce prompt local anæsthesia. The process is exactly the same as when bleaching teeth by a 25 per cent. sulphuric ether solution of peroxide of hydrogen.

I would here also call the attention of those who wish to thoroughly study the subject of electric diffusion of Medicaments, to the summarization of a great deal of experimental work, contained in a chapter in this book on electric staining of tissues for microscopical examination.[1]

So far then as refers to my own contributions to the subject treated of in this book their most important outcome has been to establish (*a*) a practical procedure for anæsthetizing sensitive dentine by aid of electricity and aqueous or guaiacol solutions of cocaine, (*b*) a practical procedure for electrically sterilizing dentine or other tissues of or about the tooth, (*c*) of a practical procedure for producing local anæsthesia of skin and mucous membrane areas for minor and even for major surgical operations, based upon a similar initiation by means of new electrodes and of combining guaiacol with cocaine.

And, whatever opinion may be entertained concerning the use of guaiacol in combination with cocaine for the anæsthetization of sensitive dentine in preference to an aqueous solution, there is no question of doubt as to the fact that its use with cocaine upon soft tissues and mucous membranes for local anæsthesia is an immense stride in advance

[1] From a paper read at the annual meeting of the American Electro-therapeutic Association, New York, Sept., 1894.

and affords results beyond any possibility of success attainable by aqueous solutions. In fact, as regards soft tissues alone, aqueous solutions of cocaine are impracticable while the combination with guaiacol solves the problem of electro-local anæsthesia in surgery.

PART II.—PHYSICS AND PHYSIOLOGY.

CHAPTER I.

ELEMENTARY ELECTRICAL PRINCIPLES.

THE historical section of this book has treated of a number of questions in a general way and with a necessary lack of detail, in some instances, which will be supplied as we proceed.

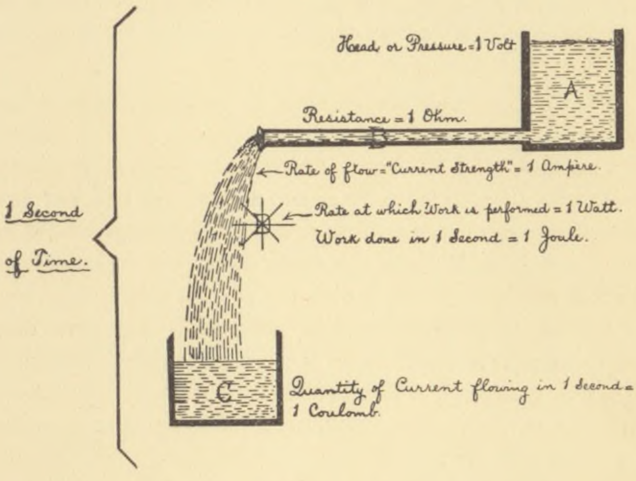
It is almost needless to say that one reason why more physicians and surgeons are not actively employing electricity in the cure of disease and as an aid in the relief or prevention of suffering is because of a conservatism born of lack of knowledge. Our older practitioners, appreciating that giant strides have been made in recent years in the development of electrical processes, feel that their grasp of the underlying principles is not sufficient to warrant experimentation by them. This is undoubtedly the proper position to take in relation to most of the departments of electro-therapy, for much harm can be done by the ignorant application of electricity. As careful restrictions should be applied to the uninstructed practice of electrical methods in the cure of disease as to other methods.

In that branch of the general subject, however, dealt with in this volume, the phenomena are so simple as to be readily understood. It is safe to assume that the reader contemplating the use of electricity for the purpose of producing medicamental diffusion is aware of the physiological action of a given drug, so it will be our purpose to here briefly outline the general principles involved and describe the terms employed. Those readers who feel themselves fully informed on those points are, of course, at liberty to skip this chapter.

No one has yet been able to demonstrate what electricity is. Professor Houston defines it as "that thing, matter or force, or both, which produces electrical phenomena." But, although we are not sure as to the nature of electricity, we know how to produce it, and we are aware of many of its characteristics.

We know that electricity possesses one predominant quality, upon which depends almost every electric action. This quality is *Pressure*; it gives electricity its power to overcome obstacles (*resistance*) in its path and to perform useful work. Some scientists even consider that electricity possesses no other quality than pressure, and that its phenomena can be measured in terms of Pressure. Various names have been given to this quality besides Pressure, among which may be mentioned Potential, Difference of Potential, Potential Difference, Electro-Motive Force and Voltage. A certain amount of this Pressure is called a *volt*, which is the unit by which the quality is measured. A volt is about the Pressure to be obtained from a single cell of that class of batteries known as the Daniell.

Electrical Pressure may be likened to the pressure which a column of water exerts on its containing chamber. In explaining these points to my classes I find the following analogy, which I have devised for the purpose, very useful, not only to indicate the fundamental importance of Pressure, but of the other relations of electric measurements. In Fig. 5 we have a vessel, A, containing an amount



of water which has a "head" or exerts a Pressure which we will call *1 volt.* The popular conception of electricity is that it "flows" as a *current* through a *conductor*, overcoming such *resistance* as the conductor offers to the passage of the current. If we insert a long pipe of small diameter B at the bottom of the vessel A the 1 volt pressure will tend to force the water out through the pipe B. But owing to the small size of this pipe or conductor B, it offers a resistance to the passage of the water. We will say that the pipe is of such a size that it offers an amount of resistance which we will call *1 ohm.* The effect of this resistance is to determine the *rate of flow* of the current of water from the flaring end of the pipe (where the resistance ends). With the pressure of 1 volt expended upon the resistance of 1 ohm in the pipe B, we will have a *rate of flow* of *1 ampere*, and if we allow the current to flow at this rate for *one second* we will have allowed a *quantity* to have flowed into the jar C, which is called *1 coulomb* of electricity.

It is desirable to keep in mind this distinction between amperes and coulombs, or rather, between the rate of flow and thequantity which flows in a given time. Water may flow from a pipe at the rate of 10 gallons a minute, but the entire 10 gallons will not have flowed from the pipe until the entire minute has gone by. In the same way we can say that a current of electricity is flowing at the rate of one coulomb per second (one ampere, in other words), but one coulomb of current will not have passed through the conductors, unless the one ampere rate is continued for one second.

As is well known, mechanical pressure cannot be expended in overcoming resistance without doing *work.* The same is true of electricity. If we expend one volt of pressure at the rate of one ampere we will be doing work at the rate of *one watt.* If this rate is maintained for one second we will have done an amount of work called *one joule.* In our diagram we have inserted a water-wheel to convey the idea of work being done.

We will recapitulate these terms as follows :

Volt=Unit of pressure or electro-motive force.
Ohm=Unit of resistance.

Ampere=Unit of current strength or rate of current flow (usually simply called "current").
Coulomb=Unit of quantity of flow.
Watt=Unit of rate of doing work (Volts $\times$ Amperes=Watts).
Joule=Unit of quantity of work (Watts $\times$ seconds=Joules).

From what has been said it will be seen that there is a close inter-dependence between these various units. If, for instance, we double the volts expended on a given resistance we shall double the amperes. If we maintain the number of volts but cut down the resistance to one half of its former amount the amperes will again be doubled. In the words of Ohm's Law the current varies directly as the pressure and inversely as the resistance in a circuit. The conventional method of expressing Ohm's Law is the algebraic method where C=current (in amperes), E=electro-motive force or pressure (in volts), R=resistance (in ohms):

If $C=\frac{E}{R}$, then $R=\frac{E}{C}$ and $E=C \times R$.

It will thus be seen that if we know the amount of any two of these terms we can find the third.

Example 1: How much current will pass through a patient if the resistance of the circuit is 1000 ohms and the pressure applied is 20 volts?

Answer: $C=\frac{20}{1000}=.02$ amperes.

Example 2: What is the resistance of a circuit which includes the patient if .015 amperes flow under a pressure of 30 volts?

Answer: $R=\frac{30}{.015}=2000$ ohms.

Example 3: What pressure will be required to force .012 amperes of current through a circuit having a resistance of 10,000 ohms?

Answer: $E = .012 \times 10{,}000 = 120$ volts.

Example 4: At what rate will work be done in a patient by an electric current being expended at the rate of .015 ampères under a pressure of 30 volts?

Answer: .015 ampères $\times$ 30 volts$=$.45 watts.[1]

Example 5: How much work will have been done by the electricity under the terms of Example 4 if the current is permitted to flow for 60 seconds?

Answer: .45 watts $\times$ 60 seconds$=$27 joules.

The engineer who deals with large quantities of electric power finds the *watt* unit inconveniently small for his purposes so multiplies it by 1000 and calls this amount a *kilo-watt.* In the same manner the electro-therapist, who uses very small currents, finds the *ampère* unit inconveniently large for his purposes so divides it by 1000 and calls this amount a *milliampère.* Thus, instead of speaking of, say, 15 thousandths of an ampère, we call this amount of current 15 milliampères. The usual abbreviations for this term are m. a. or ma.

There is one more simple formula deduced from Ohm's Law which will be useful in making various calculations and also in gaining an appreciation of certain conditions of work. We have seen that one expression of the value of E (volts) is $E = C \times R$. We have also seen that the number of watts being expended equals the volts (E) multiplied by the ampères (C).

Therefore $C \times R$ (volts) $\times$ C (ampères)$=$watts;

Or $C \times (C \times R)$=watts;

Or $C^2 R$=watts.

This means that the work being done in any por-

[1] It may be interesting to have in mind that 746 watts equal one electrical horse-power.

tion of a circuit equals the square of the current passing through the circuit multiplied by the resistance of the portion of the circuit under consideration.

Example 6. If the operator is using electricity from a 120 volt electric-light circuit with an external resistance of 5,000 ohms *in series* with the patient, and the milliampère meter indicates the passage of 12 milliampères of current, how many watts will be expended *in the patient?*

Answer: We must first find the total resistance of the circuit and from that subtract the amount of resistance in series with the patient: R—$\frac{120}{01}$—10,000 ohms.

> 10,000 ohms (total)—5,000 ohms (in series)—5,000 ohms (resistance of patient).
>
> .012 × .012 (C^2) × 5,000 (R)—.72 watts.

Example 7: If a resistance of 3,000 ohms is put in series with the patient and the positions of the electrodes are changed so as to increase the resistance of the patient to 7,000 ohms, how many watts will be expended in *the patient?*

Answer: The total resistance being the same as in Example 6 the amount of current will be the same, namely, 12 milliampères; therefore .012 × .012 (c^2) × 7,000 (R)—1.008 watts.

It will thus be seen that the physiological effects —including the effect of the current upon the patient's sensibilities—will not always be the same even though the same number of milliamperes is passing through the patient. This is of especial importance in dental applications and points to the desirability of using a form of external resistance (called a "rheostat") which will permit of very gradual changes in the resistance of the circuit. The nerves of the teeth are very sensitive to sudden changes in the rate of current flow.

It should be remembered that the rate of flow is the same in all parts of the circuit, but that the rate at which power is being expended or work done in any portion of the circuit is strictly in accordance with the formula above indicated, that watts equal the square of the current flowing multiplied by the resistance of the part of the circuit under consideration.

CHAPTER II.

SOURCES OF ELECTRICITY.

ELECTRICITY can be produced or excited or generated or developed in a large variety of ways but it is only necessary, for the information of those who will study this work, to sketch briefly the principles which underlie the operation of such sources of electricity as may or might be used in connection with cataphoric applications. We cannot do better than quote from a book, entitled the X-Ray or the Photography of the Invisible,[1] as this subject is there discussed with care:

FRICTIONAL OR STATIC ELECTRICITY. — When electricity is excited by friction, two mutual and equal phases of excitement are always developed, which are called positive and negative charges. These two phases have a strong affinity for each other and are always trying to come in actual contact with and neutralize each other. When this is accomplished there is a *discharge* which leaves the electrified bodies without any charge of electricity. If the charge is sufficiently great it will not be nec-

[1] "The X Ray, or Photography of the Invisible," Part II, chapter I, by W. J. Morton, M. D., 1 vol. 12mo. Cloth. American Technical Book Company, 45 Vesey Street, New York City.

essary for the positive and negative surfaces to come in actual contact before there is a discharge, as the accumulated potential will force a discharge through the air from positive to negative, in the form of a bright spark or electric flash like a lightning discharge on a small scale.

Whether a substance rubbed by another substance will be positively or negatively charged depends on the nature of the rubbing substance as well as on the nature of the substance rubbed. For instance, the following list (from "Ganot's Physics") gives a number of substances, each of which will become positively electrified when rubbed by any which follows it:

Positive.

Cat's-skin,
Glass,
Ivory,
Silk,
Rock-crystal,
The Hand,
Wood,
Sulphur,
Flannel,
Cotton,
Shellac,
Rubber,
Resin,
Guttapercha,
Metals.

Negative.

Machines have been made upon the principles suggested here, whereby powerful charges are produced by the revolution of glass disks arranged with proper rubbers, collectors and inducing strips. There are a number of these electrical machines, some strictly frictional and some so-called "influence" machines, those best known and in use being the Holtz and Wimshurst machines. Fig. 6 is an illustion of a Holtz machine as modified by Wimshurst and made by the Galvano-Faradic Company, New York City.

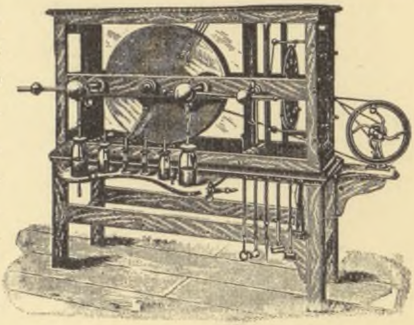


FIG. 6.

CHEMICAL ELECTRICITY.—Under this head may be grouped two very important sources of electricity, viz., *Primary and Secondary Batteries*, which we must now learn something about.

(1.) When plates of two different metals or one metal and one non-metallic body (such as carbon) are placed in a liquid (called an electrolyte) and the two plates are connected together outside of the liquid a current of electricity is generated. This combination of plates and electrolyte is known as a *cell* of Primary (or Galvanic) Battery. A very simple form of primary battery is made by taking a plate of copper and one of zinc and immersing them partially in a solution of sulphuric acid and water. This constitutes the original cell of Volta. "A battery" may be made up of one "cell" or two or more "cells" connected together. A copper-zinc cell is illustrated in Fig. 10 which it would be well to study a little. When the two wires leading from the copper (c) and zinc (z) plates are connected the sulphuric acid is decomposed, forming hydrogen gas at the copper plate and combining with the zinc to form sulphate of zinc. The electricity developed by this chemical action flows from the plate most acted on (the zinc in this case) through the liquid to the other plate (the copper), and from that through the external conductors back to the first plate again. This is indicated by the arrows in Fig. 7. It will also be noticed that the signs plus (+) and minus (—) are used. This indicates that the portion of the zinc plate in the liquid is *positive* (+) to the portion of the copper plate in the liquid, which is therefore *negative* (—); also that the exposed part of the copper plate is positive to the exposed part of the zinc plate, which is therefore negative. It is the practice to call that plate *from which* the electricity flows, outside the liquid, the *positive pole*, and the plate *to which* the electricity returns, outside the liquid, the *negative pole*, and to refer to the plate within the electrolyte from which the current starts as the *positive element* and the other plate within the electrolyte as the *negative element.*

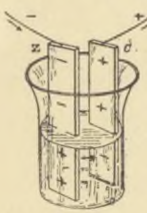


FIG. 7.

A number of different forms of primary batteries have been devised but all can be divided into two classes, namely, *open-circuit* and *closed-circuit* batteries.

The open-circuit class contains those varieties which work best when not constantly in use, on bell-circuits, hotel-calls and signal-circuits generally.

The best of this class of batteries is the "Leclanché" which is very widely known and exclusively used. The elements used are of zinc and carbon, placed in a solution of sal-ammoniac; the carbon is surrounded by powdered black oxide of manganese. When the Leclanché cell is made to supply electricity continuously for any length of time it soon "runs down" and will do no more work until given a "rest," but when only used occasionally and for short periods it is very efficient and satisfactory. Fig. 8 is an illustration of a Leclanché cell. Such a cell gives a potential of about 1.47 volts. The closed-circuit class contains those varieties which work best when in constant use or when the circuit is normally "closed." The best representative of this class is the "Gravity" battery, which is a modification of the "Daniell" battery.

FIG. 8.

The Daniell cell, a sketch of which is given in Fig. 9, is made up of zinc and copper elements separated from each other by a cup of porous clay in which is put the copper plate surrounded by sulphate of copper crystals; the zinc is immersed in dilute sulphuric acid. The electromotive force is about 1.072 volts and is remarkably constant. It only differs from the original cell Volta in the addition of a porous cup in which is placed the copper element and sulphate of copper crystals. The serious disadvantage in the use of the Daniell cell is the fact that the copper

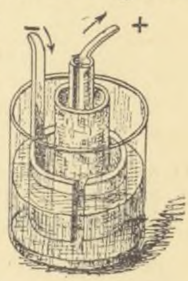


FIG. 9.

formed by the chemical processes within the cell is gradually deposited in the pores of the porous cup, increasing its resistance. This trouble is not met with in the Gravity cell illustrated in Fig. 10. As will be seen, the copper strip is at the bottom of the jar and the zinc wheel or "crowfoot" is near the top; a sulphate of copper solution is poured over the copper and a quantity of copper crystals are also put in and on top of this solution of sulphate of zinc. The *specific gravity* of these two solutions is so different that the heavier or sulphate of copper solution always remains at the bottom. The zinc sulphate solution as a substitute for the sulphuric acid of the Daniell's cell gives a somewhat lower voltage but makes the action of the cell even more constant.

FIG. 10.

(2.) When two plates of the same metal (usually some form of lead) are placed in a solution which normally does not attack them (usually dilute sulphuric acid) no electrical action takes place. But if a current of electricity generated in some outside source is allowed to pass into one of the plates and then through the solution to the other plate and back to the source again, we set up a chemical action in the solution which decomposes it and causes a different deposit to be made on each of the plates. Fig. 11 shows a cell made up of two lead plates immersed in an electrolyte of sulphuric acid, into which current is flowing from an out-

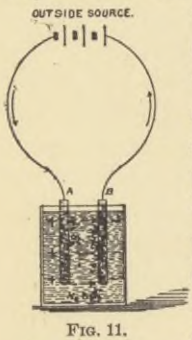


FIG. 11.

side source. We notice in this figure the current is passing into the plate A then through the electrolyte to the plate B and out again. The chemical action spoken of above forms peroxide of lead on the plate A (chemists write peroxide of lead PbO_2) and spongy metallic lead (known by the letters Pb) on the plate B. So we see that whereas we started by forcing electricity into this cell with the plates A and B alike and incapable of themselves setting up an electrical action we now have two *different* elements (PbO_2 and Pb) in an electrolyte (H_2SO_4) capable of acting on them. In other words, a cell incapable of generating electricity becomes *an active source* after electricity has once passed through it. If we now connect this cell to a small electric lamp, or other device, as in Fig. 12, a current of electricity will be generated and one atom of oxygen (O) of each molecule of the PbO_2 will be transferred from plate A to plate B and joining the Pb of plate B will form monoxide of lead, PbO, and plate A will then also have become PbO and both plates will be alike. When this is accomplished over the entire surface of the plates no more current will flow from the cell and it will be necessary to once more *charge* the cell from an outside source as before if we wish to obtain more electricity from it. The peculiarity of such a cell to be put into it before any can be obtained from it has caused the cell to be named a "Storage" or Secondary Battery. Although the effect we obtain

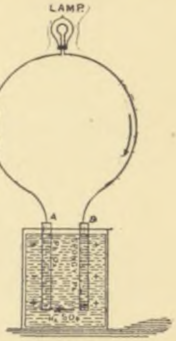


FIG. 12.

is the same as if the cell was a reservoir in which we *stored* electricity until it was needed we do not *really* store it, for we have seen that what happens is *for the current to make a primary battery of the cell by altering the nature of the elements.* What we in reality "store" is chemical energy and not electricity. If we observe Fig. 11 we will see that the *charging* current is coming into the cell at the plate A and passing out at the plate B. In Fig. 12, however, we see the *discharging* current comes out at the plate A returning to the plate B. In other words, a secondary battery discharges in a direction opposite to that in which it is charged.

The potential of a cell of secondary battery is about 2 volts. In secondary a batteries, as in primary batteries, the potential difference of a cell does not depend on the size of the elements but on their nature and that of the electrolyte. The quantity of electricity to be obtained from a cell of any kind of battery is directly dependent upon the area of the elements exposed to the electrolyte.

INDUCED ELECTRICITY.—When we move a loop or coil of wire towards or away from a magnet or move the magnet towards or away from the loop or coil, momentary currents are *induced* in the coil of wire, and these momentary currents will first go in one direction and then the other, depending on the direction of the movement to or fro. These principles were discovered in 1831 by Michael Faraday, the noted English scientist, and upon them all mechanical generators or dynamo-electric machines of the present day are constructed. Batteries cost too much to run to permit their being largely used for electric lighting or power purposes. It costs much more to burn up zinc in a battery than it does to burn coal in a steam-boiler of the same power. There are two general classes of dynamo-electric machines named after the character of the currents delivered by each. These are (1) *alternating current* and (2) *continuous current* dynamos, and a few words may be written about each.

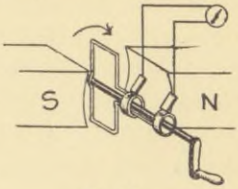


Fig. 13.

(1.) If we take a loop of wire and mount it on a

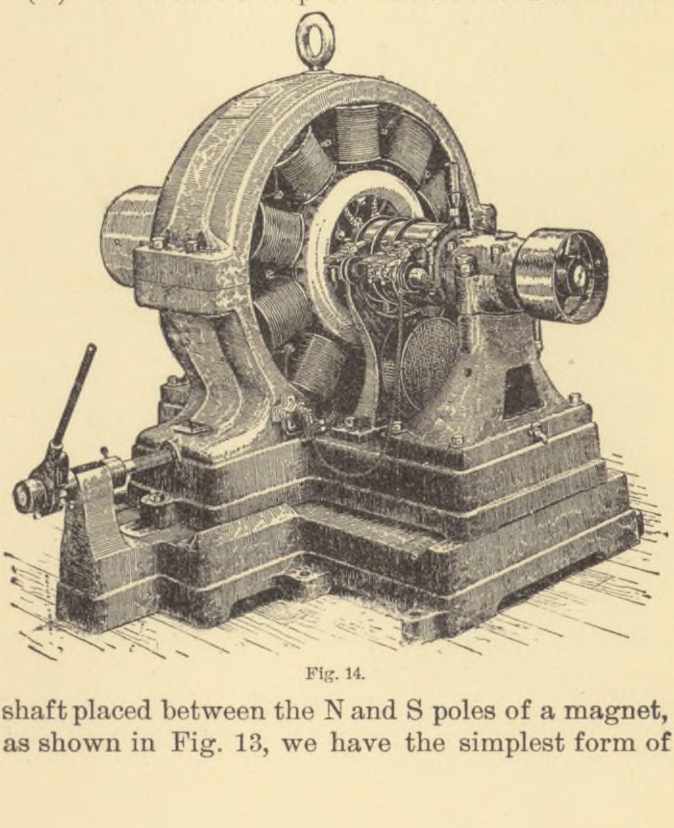


Fig. 14.

shaft placed between the N and S poles of a magnet, as shown in Fig. 13, we have the simplest form of dynamo. Were we to connect the ends of the loop of wire to two metallic rings also mounted on the shaft, we can adjust springs or brushes so as to rest on such rings, and at the same time be connected to a galvanometer. If we now turn the crank-handle in the direction indicated by the arrow, a current will be induced in the loop in one direction as it approaches the horizontal position and in the opposite direction as it approaches the vertical position. These currents flow through the loop to the rings and collecting brushes or springs and thence to the galvanometer and back. Being induced first in one direction and then the other they are known as *alternating* currents. If we use a number of loops on the revolving shaft and a number of pairs of magnet-poles instead of one we will get greater voltage when they are properly connected. Fig. 13 is a theoretical dynamo, but Fig. 14 is a practical alternating current dynamo capable of supplying many hundreds of electric lights or many horse-power to electric motors.

(2.) Were we to take the simple loop of Fig. 13 and connect its ends to the two halves of a split-tube (instead of the rings) as shown in Fig. 15 we will find a different character of current flowing to the external circuit which may include a galvanometer as before). The mere use of the split-tube in

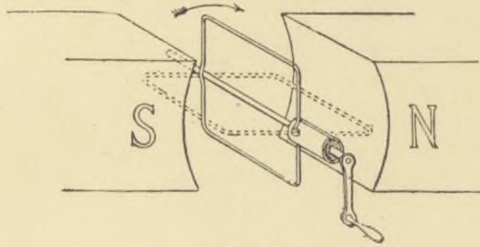


Fig. 15.

place of the two rings so alters the conditions that instead of delivering an *alternating* current to the external circuit, we deliver a *continuous* current or one which always travels in the same direction. This is because the two brushes or metal springs resting on the split-tube (known as the "commutator") first press on one-half the tube, and then the other half as the shaft revolves, so that although the alternating current is still induced in the loops it is delivered as a continuous current. This is readily

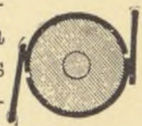


Fig. 16.

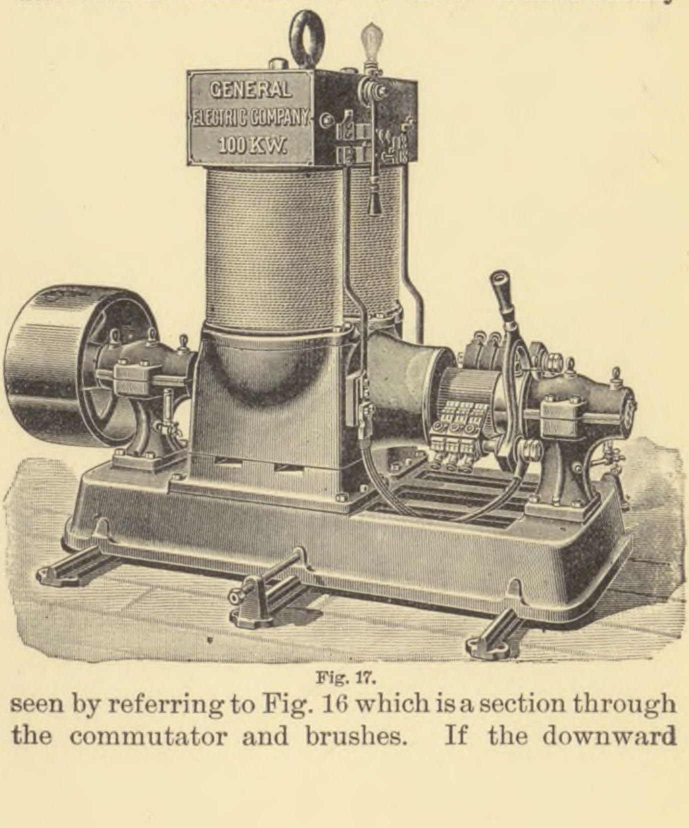


Fig. 17.

seen by referring to Fig. 16 which is a section through the commutator and brushes. If the downward moving half of the loop is positive, the upward moving half will be negative, and it will be readily seen that the positive half in one position will be the negative half when it reaches another position.

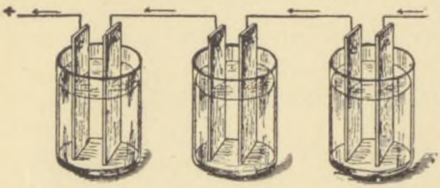


Fig. 18.

The brushes do not revolve but always "collect" the current at the best + and — points. Fig. 17 illustrates a modern Edison continuous current dynamo similar to those in use all over the world for lighting stores and houses.

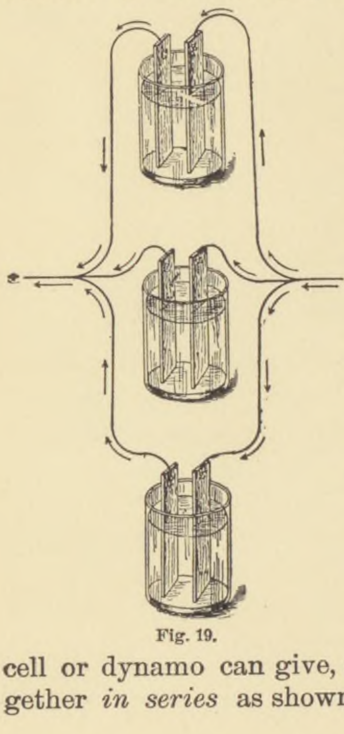


Fig. 19.

The magnets of all modern and practical dynamos are made of iron wound with wire and supplied with electricity. The reader will recognize that these are therefore not permanent magnets but electro-magnets.

In closing this chapter it should be stated that batteries and dynamos are alikein these respects:

(1.) If a greater potential is needed than one cell or dynamo can give, connect two or more together *in series* as shown in Fig. 18, that is, connect the + of one unit to the — of the next and the remaining × and — to the outside circuit. In Fig. 18 the total potential would be three times as high as if one unit was used, but the amperes or rate of current flow will not be increased;

(2.) If we want a greater flow of current but at no increase of potential we connect our units in *parallel* or *multiple-arc* as shown in Fig. 19. All the + poles are connected together and all the — poles are similarly connected. Here we have the ability to obtain three times the rate of flow than if but one unit was used;

(3.) If we wish to obtain more potential and greater rate of flow at the same time (without increasing the *size* of our units) we must combine the two previous methods in the *multiple-series* method of connection as shown in Fig. 20. In this case we obtain three times the voltage and twice the amperage of a single unit.

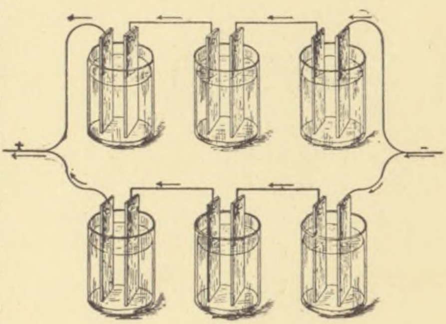


Fig. 20.

CHAPTER III.

SIMPLE OR CHEMICAL OSMOSIS.

Osmosis or *Osmose* is, broadly speaking, the tendency in fluids or gases to become equably diffused, when in contact. As ordinarily employed in Chemical Physics, however, it is narrowed down to the tendency in fluids of different densities to become equably diffused, when separated by a porous partition or septum. By "equably diffused" we do not mean such an adjustment as will bring the same quantity of the mixture on each side of the porous partition, but, rather, such a mutual diffusion that, if the process is continued for a sufficient length of time, there will be a similar chemical mixture on each side of the septum.

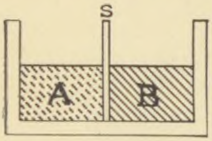


Fig. 21.

For instance, in Fig. 21, we have a vessel divided into two compartments by the septum *s*. If we pour pure water in the compartment A and an equal quantity of strong salty solution in the compartment B, the following action takes place: The pure water is of less density than the salty solution and has a tendency to pass through the septum *s* from A to B; at the same time the salty solution has a tendency to pass from B to A; there are thus two currents set up, in opposite directions, but the fluid of *lesser* density has this tendency in largest measure with the result that there is finally a difference of level as in Fig. 22. As soon as there is this difference of level produced by the action of osmosis, there is a filtration from the higher to the lower level due to the pressure of the column of liquid in B, as compared with that in A. Finally, after the lapse of sufficient time, these mutual actions and reactions result in a perfect admixture at the same level as illustrated in Fig. 23. The facts of prime importance, however, are (*a*) that there is a tendency towards diffusion and (*b*) that the predominating tendency is from the fluid of *lesser* density to the fluid of *greater* density ; "to him that hath, shall be given."

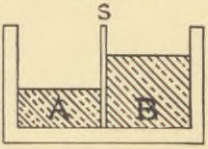


Fig. 22.

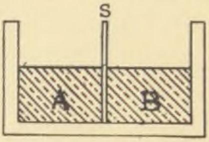


Fig. 23.

Of the two osmotic currents set up, the one which is from the fluid of lesser density (as from A to B, Figs. 21 to 23) and is directed to the higher level is called the *endosmotic* current and this flow of current is called *endosmosis ;* the current which flows from the fluid of greater density and is directed to the lower level (as from B to A) is called the *exosmotic* current and this flow of current is called *exosmosis.*

The rapidity with which diffusion takes place varies, according to Graham, with the following circumstances :

(*a*) With the chemical composition of the fluids, the action generally being most rapid with acids, next with alkalies and last with fluid albumen, gelatine and gums.

(*b*) With the temperature; the higher the temperature the more rapid the action.

(*c*) With the relative degrees of concentration of the fluids.

(*d*) With the difference between the densities of the fluids; the rapidity of action is greater with weak than with concentrated solutions when the difference in densities is constant.

Two very pretty and simple experiments may be tried as a demonstration of endosmosis and exosmosis, with the use of gases instead of fluids.[1] A

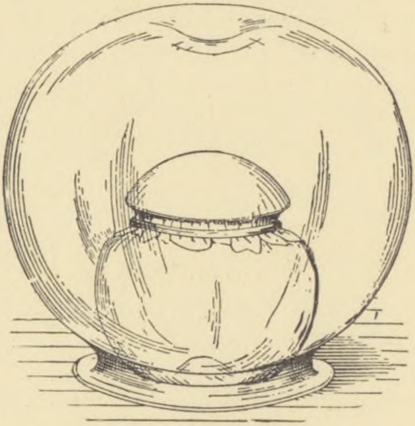


Fig. 24.

medium sized fish-globe, a very small fish-globe which will pass into the larger one, and a piece of bladder are the requisites for these experiments. The small globe is filled with carbonic acid gas, and the bladder, previously moistened, is placed loosely over the mouth of the jar and tied so as to render the connection between the bladder and the globe

[1] See "Experimental Science," by G. M. Hopkins, 1893, p. 70.

air-tight. A good way to insure a good joint is to stretch a wide rubber band around the neck of the globe before applying the membrane. The large fish globe is filled with hydrogen or illuminating gas, and the small globe is placed under it as shown in Fig. 24. As the hydrogen passes inward through the membrane much more rapidly than the carbonic acid passes outward, the membrane is distended outwardly. It requires a little time to produce a visible effect. If the smaller globe is filled with hydrogen and the large one with carbonic acid, the membrane will be distended inward, as shown in

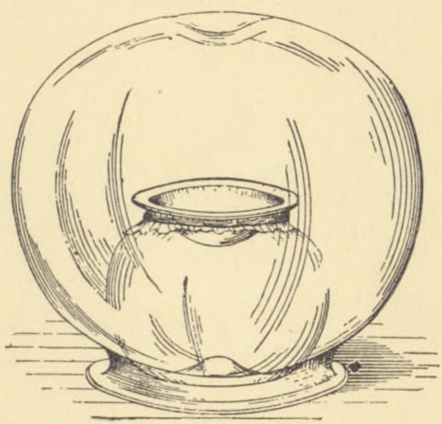


Fig. 25.

Fig. 25. In this latter case the experiment may be performed with the least trouble by placing the large globe with its mouth upward, and closing it by a plate of glass.

CHAPTER IV.

ELECTRICAL OSMOSIS OR CATAPHORESIS.

WE have thus far noted that there is a tendency for fluids to mix, even though separated by a porous partition; also that there are two currents set up during the process of diffusion, of unequal strength and in opposite directions, and that the most active current is from weak to strong solution or from lower to higher level. We have also seen that the process is a long one, simple osmosis taking place very slowly.

If we now take a vessel similar to that shown in Fig. 21, divided by a porous partition and filled by water on one side and a saline solution to an equal height on the other, as before, we can dip a platinum wire in the weak fluid, A (Fig. 26), and another wire in the strong fluid, B; the wire in the solution A is connected to the positive (+) pole of our battery and the wire in the solution B is connected to the negative (—) pole. As soon as the electrical circuit is completed we notice that what required several hours to complete by simple osmosis was now performed in a very short time. It

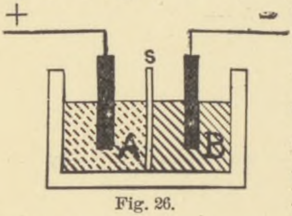


Fig. 26.

is apparent at once that electricity has accomplished a definite amount of work, as in Fig. 27. If we start afresh and reverse our electrical connections so that the positive (+) terminal of our battery is in the compartment B with the strong solution, and the negative (—) terminal in the compartment A with the weak solution, we find that the predominant osmosis takes place in a direction opposite to that of simple chemical osmosis, as in Fig. 28.

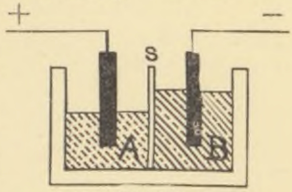


Fig. 27.

The skin and other membranes and tissues of the human body may be regarded as septa, and, this allowed, it follows that electric osmosis may be made to take place through such septa. Electric osmosis has many synonyms; its phenomena are most frequently spoken of as *cataphoresis :* I prefer the term Electric Diffusion, which may be defined as the capacity possessed by an electric current for diffusing or transporting liquids and whatever they may contain in solution from one polarity toward the other, preferably through porous septa—thus being applicable to the tissues of the living body.

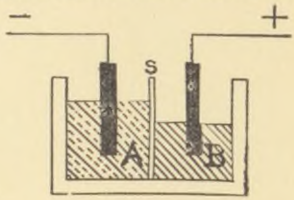


Fig. 28.

Having, therefore, knowledge of this power of electricity, we can vary our solution at the one pole or the other, generally the positive pole, to suit our needs and project it through tissue where we wish.

But osmosis alone is not sufficient to explain all the phenomena of cataphoresis. For example, if a small globule of mercury, M, be placed in a glass tube such as is shown in Fig. 29, and the tube is

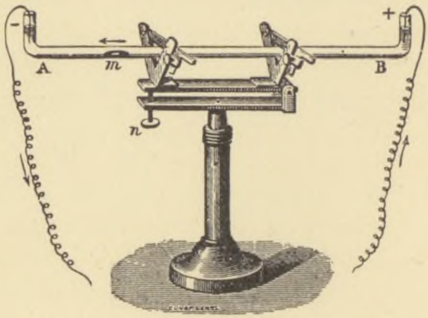


Fig. 29.

almost filled with dilute sulphuric acid, we can apply the terminals of our battery to the two ends of the fluid in the tube. As soon as the circuit is complete a current of electricity flows through the fluid and we see the globule of mercury elongate and move towards the negative pole. If the position of the battery-terminals be reversed the direction of the current flow is reversed and the globule of mercury travels backward. If the tube be inclined toward the positive pole the mercury will still be moved with the current. If the inclination of the tube be still slowly continued a position will be reached at which there will be an equilibrium established between the impulsive force of the current and the weight of the mercury. In a former chapter I have also described how I drove particles of graphite into my arm by the action of an electric current. Another correlative fact is that in an arc light there is a disintegration of particles from the positive carbon which are projected toward the negative carbon.

Again, we find that although the almost uniform action in cataphoric applications is for the salt or other chemical held in solution to be from the positive to the negative pole, there are exceptions to the rule. Gore, in 1881, found that occasionally the flow was from negative to positive, as with a saturated alcoholic solution of bromide of barium. Dr. G. Weiss[1] also noted the same fact; employing U-shaped tubes filled with solidified gelatine and plunged into a solution of eosin, he found that under the influence of a current even so small as one-tenth of a milliampère the eosin travelled from the negative to the positive pole. Methylin blue, on the contrary, under the same conditions travelled in the classical direction from the positive to the negative.

In 1871 Becquerel tried some interesting experiments with static machines and induction coils to determine not only the existence of a transportation of particles but the direction in which the transportation took place. These are summarized by Tommasi[2] in a very satisfactory manner.

Becquerel took two pieces of blotting paper, one of which he moistened with ferrocyanide of potassium and the other with sulphate of iron. These papers were placed on platinum electrodes and the iron-paper was connected to the positive pole of the static machine and the potassium-paper was connected to earth (negative). When the two strips of

[1] "Technique d'electrophysiologie." Paris, 1890; p. 130.

[2] See "Traite Theorique et Pratique D'Electrochimie," by Donato Tommasi; Paris, 1890; page 38.

paper were separated from one to two centimetres the machine was put in action and a blue precipitate was formed on the paper moistened with the sulphate, indicating that the electric spark had transported ferrocyanide of potassium from the negative to the positive pole, where it had reacted on the sulphate of iron. It was also found that when the direction of the spark was reversed no reaction had taken place. Other combinations were experimented with and the following results noted :[1]

1. Chloride of cobalt + Ferrocyanide of potassium —	Brownish-red precipitate on the chloride.
2. Nitrate of silver + Ferrocyanide of potassium —	Precipitated on the nitrate.
3. Nitrate of silver + Bichromate of potash —	Chromate of silver precipitated on the nitrate.
4. Sulphate of potash + Chloride of barium —	Sulphate of baryta precipitated on the sulphate.
5. Nitrate of silver + Chloride of potassium —	Precipitate of chloride of silver.
6. Nitrate of silver + Chloride of sodium —	Chloride of silver precipitated on the nitrate.
7. Chloride of magnesium Potash	Neither precipitated in either direction.
8. Sulphuric acid — "Sunflower paper" +	The paper is reddened.

[1] In this table the + sign signifies that the solution was connected to the positive electrode and the — sign signifies a negative connection.

9. Caustic potash + Protochloride of iron —	A yellowish-red precipitate on the potash.

Tommasi continues: "We see, from these results, that the salts transported by the electric discharges from the negative electrode to the positive electrode and not in the other direction are:

1. Ferrocyanide of potassium;
2. Bichromate of potash;
3. Chloride of barium;
4. Chloride of sodium;
5. Chloride of potassium;
6. Sulphuric acid;
7. Protochloride of iron.

"The substances which are not transported by the electrical discharge, with the current passing in either direction, are:

1. Chloride of cobalt;
2. Chloride of platinum;
3. Nitrate of silver;
4. Caustic potash;
5. Sulphate of potash, etc."

These experiments simply show that there are exceptions to the general rule that fluids are transported in the same direction as the current flow.

My own experiments teach me that most simple fluids, including glycerine, syrup, pure water, etc., are conveyed from the positive to the negative of the discharging rods of an influence machine across a spark-gap. I have also made many experiments upon the introduction of medicines by static electricity, a number of them successful. In this relation I have used principally the "static induced" current from the positive pole.

In the experiment of the U tube and the mercury globule, noted above, it was found that only a very small quantity of sulphuric acid was needed in the water; if an excess is used the experiment will not succeed. In other words, as has been previously indicated, the success of a cataphoric application depends upon the electrical resistance of the fluid. If the resistance is very high, as in chloroform, sulphuric ether, alcohol, glycerine, etc., little or no current is conveyed and no cataphoresis takes place. On the other hand, if the electric resistance is too low, as in strong saline and acid solutions, much current passes but no cataphoric action takes place. The obvious deduction is that for therapeutical applications the acid and saline solutions must not be too strong and that if the other drugs named are to be used considerable ingenuity must be exercised to secure their transfer or introduction into tissue.

A series of experiments instituted by the writer demonstrated the remarkable fact that substances like sulphuric ether, alcohol and chloroform may be induced to exercise their specific cataphoric action on tissue by incorporating with them a foreign substance, or what I have previously spoken of as a "fluid electrode." For instance, in the case of a hydrogen dioxide twenty-five per cent solution, i. e., H_2O_2, 25 %, and sulphuric ether, 75 %, the H_2O_2 solution fails to act until it is incorporated with a conducting fluid such as sulphate of soda or chloride of sodium.

To define the true nature of cataphoresis we must be able to define the nature of the electric current and this we cannot do. Cataphoresis is essentially a property of currents. The fact that the transporting power of the current diminishes, and finally ceases, in direct ratio to the diminution of resistance, indicates to me that in liquids we have to deal with what I have called a "movable" resistance in contradistinction to what in solids (metals, etc.), might be termed "stationary" resistances. From this point of view a fluid is projected or moved along in bulk simply because it does offer resistance.

A rough comparison of this view of cataphoresis may be made to a belt moving rapidly through a trough containing a fluid of slight density. Under such circumstances very little fluid will move with the belt, but if the friction between belt and fluid is increased there will be a greater conveyance. It is as if the molecules which do not conduct were enmeshed in and among the molecules which do conduct. The non conducting molecules are swept along by the current conveyed by the conducting molecules. We can conceive of the resistance of the fluid in the trough being increased to such an extent that the belt cannot move through it. This extreme will, of course, also mean no conduction. A simple view which may be taken of this phenomenon is that where there is no resistance there will be nothing to move.

Another peculiar feature about cataphoric phenomena is that the effect of the transported drug only reaches about half way from positive electrode to negative electrode. This has been previously mentioned, but as some may be inclined to question the possibility of this condition existing we will consider the following experiment:

Take four pieces of glass, and on each place a piece of blotting paper 1 × 2 inches in size, as in Fig. 30. (See frontispiece.) Moisten each piece of blotting paper with a solution of sulphate of soda. Then place a piece of ozone test-paper of the same size as the blotting paper on each piece of blotting paper, and the ozone paper in this way will become slightly moist with the solution beneath it. We then group these four glasses with their papers in pairs, as shown in the illustration, with the papers of each pair brought in contact with each other. We then put a twenty-five per cent. ethereal solution of H_2O_2 on the right-hand paper, which immediately become blue, as the white ozone paper gives a bright blue reaction to dioxide of hydrogen. In group No. 1 we notice a very slight discoloration of the left-hand paper, but only at the point of contact ; but if we apply two electrodes to group No. 2 (positive to the right, negative to the left) and pass fifty milli-amperes from one to the other the result will be most striking and conclusive. The H_2O_2 solution under the electric influence straightway begins to invade the previously white paper to the left and colors it blue for half of the distance toward the negative electrode, and cannot be made to go to a greater distance. This demonstration is a simple one, and falls right in line with the observations made on the interesting phenomena resulting from the passage of electricity through bad conducting fluids by O. Lehmann.[1] He found that with bad conducting fluids certain changes start from each electrode and meet in the middle where a precipitate

[1] See "Wiedemann's Annalen," Vol. LII., page 455; also "The Electrical Review," London, Oct. 26, 1894, page 419.

is produced. Solutions of the aniline colors showed the phenomena very distinctly. Where a current of 70 volts was sent through an aqueous solution of Congo red, sharply defined halos were formed about each electrode; the halo proceeding from the positive was of a beautiful blue color, and that from the negative was somewhat paler than the solution, though distinctly defined by a darker outline. Both halos spread quickly, and finally met in the middle, when a dark blue precipitate was suddenly formed next to the positive electrode, while the color was completely discharged from a corresponding space next the negative electrode. Where the dark blue and colorless layers met the fluid was thrown into violent agitation, while the rest of it remained undisturbed. These observations were made with a a microscope, but the phenomena may be seen with the naked eye by inserting the electrodes in a block of very loose jelly at a distance of about 3½ inches and turning on the current for about 10 minutes, when the halos will meet in the middle and produce the precipitate, as in the solution above mentioned. When the precipitate is formed a violent agitation is observed at the place of meeting inside the mass of jelly; the precipitate is re-dissolved and the gelatine melted by the great heat evolved.

Lehmann explains these actions by saying that the positive and negative electrification of the electrodes is handed on from molecule to molecule until, finally, positively and negatively electrified molecules stand opposite each other in the middle of the fluid or jelly, where they are violently attracted to each other.

In bringing this chapter to a close it is only necessary to say that although cataphoresis is essentially a feature of constant or galvanic currents, yet it may be produced by static machines (*vide* Tommasi, above) or by the currents from induction or spark-coils. In this latter case the currents are alternating in character, but, as is well known, there is a *predominating* positive and a *predominating* negative which almost overshadow currents which travel in the opposite direction and consequently we are able to observe cataphoric phenomena by its use. So far as we have yet determined, the continuous current is the only one suitable for practical work.

CHAPTER V.

ELECTROLYSIS AND CATAPHORESIS.

As Lodge so beautifully shows,[1] *water* may be made to travel from place to place only by two methods, viz., it may be pumped along pipes, or it may be carried about in jugs. In other words, it may travel *through* matter or it may travel *with* matter. Just so it is with *heat* also ; heat can travel only in two ways : it can flow *through* matter, by what is termed "conduction," and it can travel *with* matter, by what is termed "convection." For *electricity* the same is true. Electricity can travel with matter by convection or it can travel through matter by conduction, but in no other known way.

If we connect the poles of a galvanic battery together by a piece of copper wire we get what we call a "current." It is a true flow of electricity among the molecules of the wire, whatever electricity may be. The molecules of copper do not flow along but the electricity may be said to flow through or among them by conduction.

If our galvanic battery is connected to a liquid, such as a chemical solution of acids, alkalis, salt and water, or saline solutions generally (which classifi-

1 "Modern Views of Electricity," Lodge ; London, 1889 ; page 65 et seq.

cation includes the tissues of the human body), a current of electricity will pass, but in a manner very different from that we noticed in the case of the copper wire. These fluids are called "electrolytes" and when electricity passes through them it is by electrolysis.

Faraday's laws of electrolysis may be summarized as follows :

(1) Electrolytic conduction is invariably accompanied by chemical *decomposition* and only occurs by means of it.

(2) The electricity does not flow *through*, but *with*, the atoms of matter, which travel along and convey their electrical charges somewhat after the manner of a pith-ball statically charged.

(3) The electric charge belonging to each atom of matter is a simple multiple of a definite quantity of electricity, and this is an absolute constant quite independent of the nature of the particular substance to which the atoms belong.

Electricity is conveyed through an electrolyte in what has been called a "double progression of atoms" ; when the electricity passes in this manner the molecules of the electrolyte are decomposed and one set of atoms is positively charged and moves from positive to negative element (or electrode) while another set of atoms is negatively charged and moves from negative to positive element (or electrode). Therefore it is by a double progression of atoms that the current is transmitted. The process is of the nature of convection, for the atoms act as carriers. In electrolysis the charge each atom carries is the same, but the speed at which different atoms move through the electrolyte varies according to the character of the atom. Hydrogen travels faster than any other kind of atom and the conductivity of a liquid depends upon the sum of the speeds of the two opposite atoms in the compound. In general, therefore, acids conduct better than their salts.

Another interesting fact is, that it seems there is another action which takes place in an electrolyte when electromotive-force is applied to it, independent and additional to the double progression of atoms above referred to. This is, that apparently but a small per cent. of the molecules are decomposed and that the remainder of them may be moved along with one progression or the other, either from positive to negative or from negative to positive.

Thus, when electrodes holding a drug in solution are brought in contact with tissue and an electromotive force is applied to them, there is undoubtedly an electrolytic action set up which tends to and does decompose some of the electrolyte ; but, in addition, there is a mechanical transfer of the medicament through the tissue. Again, if we place electrodes capable of being decomposed in direct contact with the tissues, and apply the electromotive-force, the product of this decomposition is transmitted through the tissue but only to a point halfway between the positive and negative electrodes. Or, if we place electrodes (not capable of being attacked by the current) in direct contact with the tissues, we find that there is a transfer of the *fluids* of the tissues to the negative electrode while the tissue in the neighborhood of the positive electrode is relatively dry.

Some observers are inclined to credit all the phenomena of cataphoric medication to electrolysis, and others claim that electrolysis has essentially nothing to do with these phenomena.

According to the theory of Arrhenius, upon solution in water, salts (including acids and alkalies), split up or dissociate into free electrically charged atoms ; if, for instance, common salt is dissolved in water the solution contains salt and the products of its dissociation. The ions Na and Cl, the Na charged with free positive electricity, the Cl. charged with free negative electricity. The undissociated chloride of sodium molecules must be regarded as electrically neutral.

Upon placing electrodes in such a solution, they will exert attraction or repulsion on the free ions, displacing them and causing a double progression of ions. This migration of the ions, all concede, constitutes the familiar electrolytic current or galvanic current in an electrolyte.

The theory of Arrhenius as to the free and electrically charged ion advances our views as to the nature of electrolysis and electrolytic conduction, but I cannot see that we are yet entitled to assume that the electrolytic double progression of the ions, which occurs in only a small per cent. of the molecules which constitute the solution, is, in reality, that movement known as cataphoresis or electric diffusion.

If I were to suggest a view it would be to the effect that the directive movement of fluids by electricity is a property of the current coincident with electrolysis, but that electrolysis is only useful in so far as it insures the existence of a current and allows of a propulsion of undissociated and electrically charged molecules constituting the medicament, along with it.

This view would involve the relation and behavior of electrostatically charged molecules to electrostatically charged tubules of small calibre, namely to porous septa.[1] However, in the present state of our knowledge, it would seem that we must await further research as to the true nature of electric diffusion. In the meantime there is one practical result that can easily be attained. This is, by careful experimentation, to determine at which pole each individual medicament shall be placed. Specific directions as to this point are already available, as has been seen, in regard to a certain number of remedies. The time is not far distant when all the important remedies will be tabulated under their appropriate respective polarities for purposes of electric diffusion.

[1] See Transactions of the American Electro-therapeutic Association, 1892, pp. 42, *et sequitur*. Articles by Dr. A. E. Kennelly, Prof. Edwin J. Houston and the author.

CHAPTER VI.

PHYSICAL AND PHYSIOLOGICAL EXPERIMENTS.

NUMEROUS experiments have been given in detail in the three preceding chapters, used there as illustrations of the argument being made. Several others of a miscellaneous character will here be given as of general interest but without any studied arrangement.

Experiment 1. Take a ball of moist clay and insert in it your positive wire; put the negative pole platinum wire into some other part of the ball of clay and turn on the current. It will be found that soon the moisture of the clay will be gathering at the negative pole and will roll out drop by drop.

Experiment 2. Insert two platinum needles in a piece of raw meat, connecting one to the positive and the other to the negative pole. The same transfer of the tissue fluids to the negative pole will be noticed, as in Experiment 1.

Experiment 3. This is illustrative of the same principle and is quoted by G. N. Stewart. He passed a hollow-metallic electrode into the vagina of a living rabbit; when this electrode was negative, fluid was forced through it while none appeared when it was positive.

Experiment 4. Take a piece of raw meat and stick a copper needle in it and make it a positive electrode ; the negative electrode should be a needle of any metal placed in the meat some distance from the other. When the current is turned on it is seen that the copper positive needle is being dissolved and that the green oxychloride of copper is being diffused through the meat tissues.

Experiment 5. Take a hard boiled egg and insert the electrodes as in Experiment 4, and the green stain produced by the cataphoric diffusion will be even more noticeable than before. Zinc, silver, iron or other oxidizable metals may be used experimentally in this way.

Experiment 6. Illustrative of the same principle and quoted from Dr. Gautier. He took the uterus from a live rabbit and inserted in the same a copper sound which he used as a positive electrode. He says[1] : "The deposit of the copper salts on all the internal surface of the uterine mucous membrane is very noticeable; the penetration of these salts into the tissue is complete; the exterior as well as the interior is colored an apple green ; one of these salts is the insoluble oxychloride of copper; the other is a soluble organo-metallic salt. If we place on different points of the region penetrated by this soluble salt a plate or sheet of steel or iron, we have, after several seconds, a deposit of metallic copper on the plate."

Experiment 7. Cut a hard-boiled egg lengthwise and take out the yolk. Place a white section in a saucer containing a solution of iodide of potassium and fill the hollow of the egg with a weak solution of starch water. Connect the solu-

[1] "Technique d'Electrotherapie," Vol. 1, page 174.

tion in the saucer with the negative pole and the solution in the egg with the positive pole and there will be a very pretty illustration of electrical osmosis demonstrated by the discoloration of the starch-water as the iodine reaches it.

Experiment 8. Shows a most unique phenomenon of the directive power of the electric current (called by some writers "Galvanotropism") upon rapidly moving ciliated Infusoria, *e. g.*, Flagellata. This is quoted from "Electro-Physiology," by W. Biedermann,[1] and the illustration, Fig. 31, is reproduced therefrom.

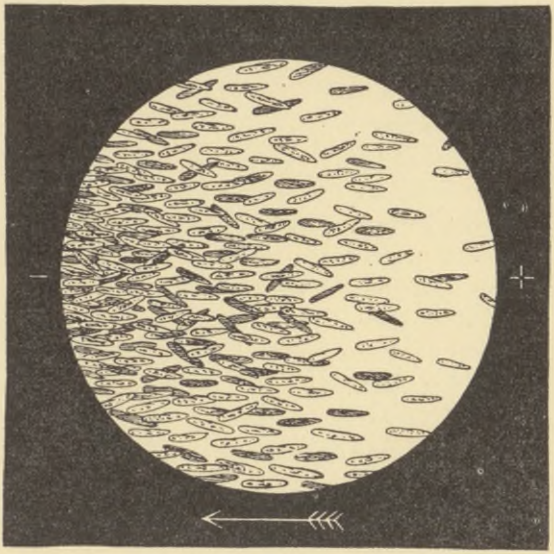


Fig. 31.

"If a few drops of hay infusion swarming with Paramæcium are placed between clay electrodes

[1] Published by The Macmillan Co., New York, 1896.

upon an object-glass, and traversed by a sufficiently strong current, the following effects (as pointed out by Verworn) are observed, either with the naked eye or with a magnifying lens : 'At closure the Paramæcia turn all together as if at the word of command, with the anterior pole of the body toward the negative electrode, and swim in this direction with uniform speed.'

"In a short time the anodic side of the drop is completely cleared of Paramæcia, not one being left behind ; the whole mass is crowded to the cathode. As long as the circuit is closed the protozoa remain thus ; if the current is broken the Paramæcia turn instantly with their anterior ends towards the anode and swim away in this direction. The cathode is quickly deserted and the majority of the organisms are now collected around the anode. The crowding is, however, by no means so complete as that produced at the cathode by make of the current and the Paramæcia soon begin to swim about in all directions and in a short time are once more uniformly distributed throughout the drop. This manœuvre is repeated as often as the current is closed, with the same precision."

The reader is referred to the chapter on the Electric Staining of Tissues for Microscopical Examination for further experiments and suggestions in this line.

PART III.—APPARATUS AND OUTFIT.

CHAPTER I.

ELECTRODES FOR MEDICAMENTAL DIFFUSION.

ALTHOUGH the applications of electric medicamental diffusion are so numerous and their virtues so great, the devices needed to obtain excellent results are few in number and readily manipulated; moreover, they are comparatively inexpensive.

The electrodes required for a particular application may be a stock article with the operator or at least with the supply-house, but cases may arise where it will be necessary to devise or arrange a special electrode and here the ingenuity of the operator must be called into play.

In a broad sense, electrodes may vary in size from the "liquid electrode" of an electric bath to the finest needle. As has already been pointed out, the patient may sit on an insulating stool in a bath-tub surrounded by a medicament which is acted upon by an electric current and diffused through the body. Or the scheme of Gärtner and Ehrmann may be employed, consisting of a large jar or tub in which the patient stands immersed, say, to the waist, in a medicated solution; an impervious partition is then snugly fitted around the patient and more solution poured on top; the upper section of the bath was of one polarity and the lower compartment of another; this arrangement depended for its activity on the action of the patient's body as a porous septum.

I have devised in Fig. 32 a special form of electrode for use in a jar or tub filled with solution, in

Fig. 32.

which the patient is more or less immersed. It consists of a hollow rod of ebonite, perforated down its length and capped with a metal connector for the battery wire at one end; a wire of platinum or other metal extends through the rod from the upper or connector end to the lower end. The effect of this arrangement is to permit a free access of the liquid to the metal terminal, and at the same time keeps the patient from making a contact therewith.

In Fig. 33 we have an electrode made after the plan of Dr. Peterson. As will be noticed, this electrode is a metal disc about $1\frac{1}{4}$ inches in diameter surrounded by a slight rim just high enough to accommodate a round piece of blotting paper

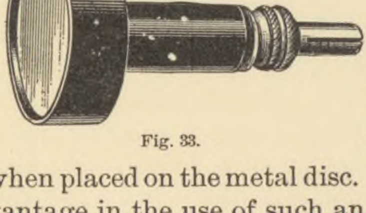


Fig. 33.

when placed on the metal disc. There is a great disadvantage in the use of such an electrode arising from the fact that when it is applied to the skin with some necessary pressure the medicamental solution held by the blotting-paper is squeezed out and the paper becoming dry in spots there is a great resistance formed at the surface of the skin and a "burn" or a failure is often the result. The larger the disc in this style of electrode, the greater its disadvantages.

To overcome these troubles and obtain an electrode which would keep up its supply of fluid all through the application I conceived the idea of perforating the disc with a large number of holes and providing a reservoir back of the disc to hold a supply of fluid. This arrangement is shown in Fig. 34,

Fig. 34.

which illustrates a small electrode with a disc only half an inch in diameter. This variety of electrode with the long handle and reservoir back of the disc I use in different sizes, but seldom with discs more than an inch in diameter.

I found that in larger electrodes, or in smaller electrodes used for powerful drugs like cocaine, etc., it was not necessary for me to drill the holes all the way through the metal discs but only for about $\frac{1}{8}''$ or $\frac{3}{16}''$. The multiplication of holes permits the reserving of a surprisingly large amount of fluid, which is fed through the blotting-papers as the demand is made for it. This arrangement of parts permits the use of very large electrodes and the application of medicaments to very large surfaces with the certainty that all parts of the surface will

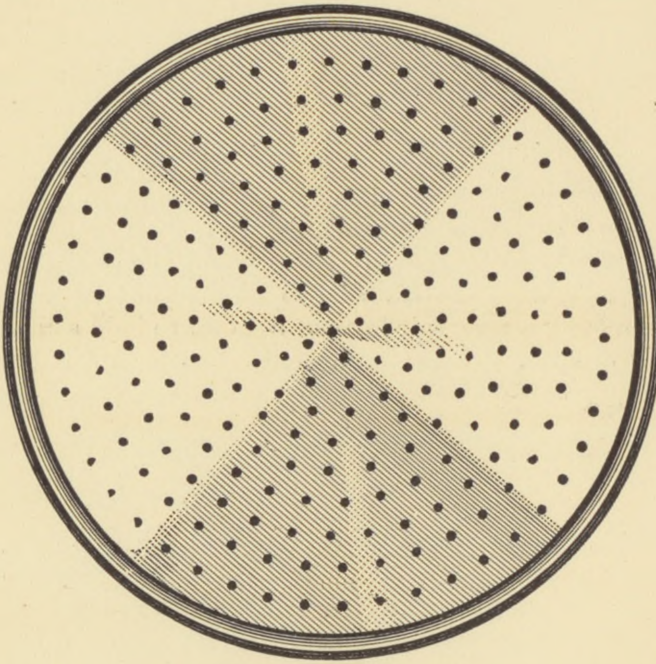


Fig. 34 *a*.

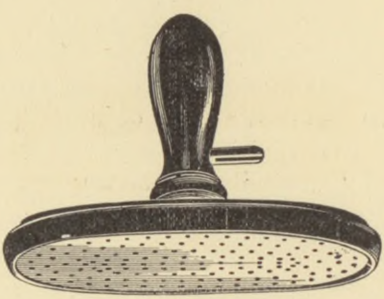


Fig. 34 *b*.

be affected. Fig. 34 *a*, shows a face view of one of these electrodes 6 inches in diameter, while Fig. 34 *b* shows a perspective of an elliptical electrode 5

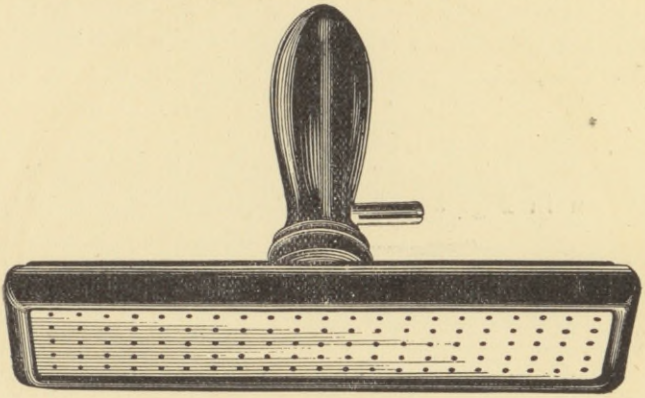


Fig. 34 *c*.

Fig. 34 *d*.

inches long by 2¼ inches wide. It will be noticed that the terminal for the battery cord is on the side of the handle.

In Fig. 34 *c* we have an oblong electrode of this same class whose dimensions are 6 inches by $1\frac{3}{8}$ inches and in Fig. 34 *d* we have shown another elliptical electrode 4 inches long by 2 inches wide ; in this the connection is made at the end of the handle. All these electrodes are constantly in use in my practice and daily prove their capacity to medicate or anæsthetize large areas.

Another new departure now used in electrodes is shown in Fig. 35. This I call the hypodermatic

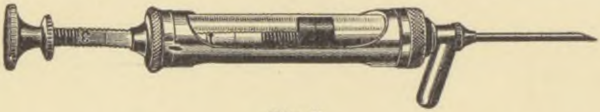


Fig. 35.

injection electrode, and it is to be used in that branch of electric medicamental diffusion where a cavity is filled with the medicament and then the current is applied to it. As will be seen from the illustration this instrument consists of a small syringe at whose outlet end is a hollow, sharpened needle with a connector for the battery terminal made a part of the same. In action the needle (which is made of platinum and insulated down to its point) is made to puncture the tumor or other tissue to be treated and a medicament is forced into the same through the needle. When the current is turned on cataphoresis takes place.

Or, the needle is made of copper, zinc, or other oxydizable material, insulated to near its end ; a weak solution of chloride of sodium, or of hydrochlorate of cocaine is forced into a cavity in order to furnish by its decomposition, oxygen or chlorine to act upon the metal of the needle in case there is a lack of these elements in the tissues.

Another special electrode is shown in Fig. 36; this is for applications to the nose. The illustration shows the electrode in section; it is made of metal covered with ebonite or hard rubber as indicated by the heavy lines. A fountain syringe is attached to the opening at the right and, as will be seen, the battery terminal is applied at the connector coming out from the side. As the medicated solution passes up through one nostril and out the other the electricity performs its cataphoric function.

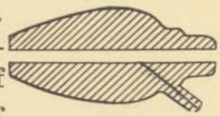


Fig. 36.

In Fig. 37 is shown a special electrode of well-known form for applications to the ear. The fluid medicament is injected into the cavity of the external meatus and the funnel occluded with absorbent cotton and a plug of soft gutta percha. The cut shows its construction and its method of operation is obvious.

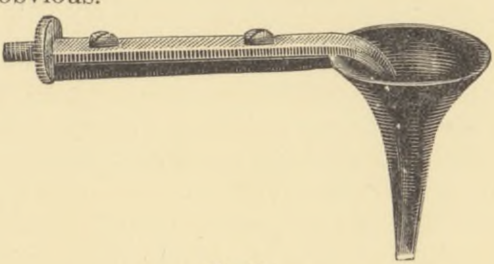


Fig. 37.

In Fig. 38, we have an electrode devised by me for the treatment of nævi and skin diseases. As will

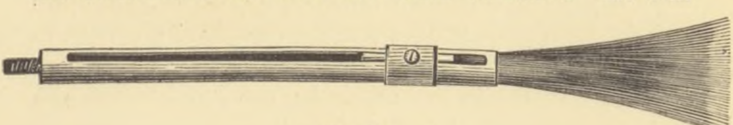


Fig. 38.

be seen, it consists of a copper-wire brush which may be moved in or out of an appropriate holder. In operation the copper brush may be dipped in a solution of common salt or hydrochlorate of cocaine and applied to the surface to be treated. Naevi are very satisfactorily treated by this method. The stain of the oxy-chloride of copper forced into the skin is most obvious to the sight.

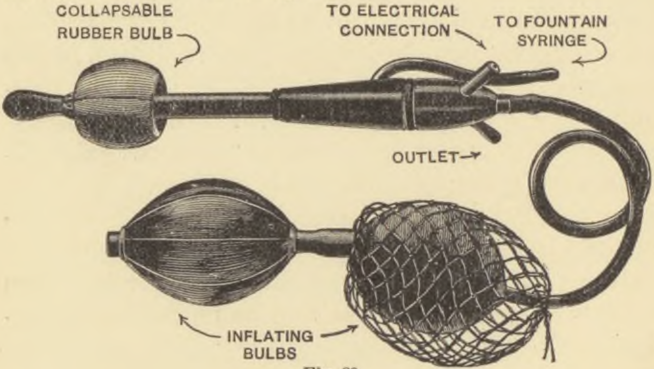


Fig. 39.

Another most valuable electrode apparatus for the treatment of diseases of the uterus and its appendages is shown in Fig. 39. With the ordinary electrode for this purpose there is great difficulty in making such an application as will do away with a leakage of the medicated solution—in fact, it is impossible to maintain a tight joint. By the apparatus I have devised, however, this difficulty is done away with, as will be seen. It consists of a long hollow tube with a perforated nozzle on the end and a collapsable rubber bulb near such nozzle. Ordinarily the bulb is collapsed and can readily be introduced into the vagina. If the inflating bulbs are attached to the central stem at the right and a slight pressure given, the bulb in the vagina is more or less inflated and acts as a perfect stopper. Medicated solutions can then be introduced into the vagina from a fountain syringe and the current being turned on at the connector (shown at the right) passes through a wire or rod to the inside of the nozzle where it is effective upon the "solution electrode" or medicated solution inside the vagina. When the application is completed a valve on the outlet shown in the illustration can be opened and the fluid withdrawn and then the connection to the inflating bulbs may be taken off and the collapsable bulb is deflated and is readily withdrawn.

Dispersing or indifferent electrodes may be made of various sizes and shapes applicable to different parts of the body. I prefer to use them made of punk or the amadou of the French, which keeps moist for a long time and is much superior to any form of sponge electrode.

CHAPTER II.

ELECTRODES FOR METALLIC ELECTROLYSIS.

As we have seen, metallic electrolysis is the action which is set up when a soluble electrode is made to perforate tissue or is placed in contact with mucous membrane and a current is sent through the tissue from the same—a "soluble" electrode being one which, when attached to the positive pole, is attacked by oxygen or by chlorine formed at that pole by decomposition of the tissue. The newly formed metallic salts are then transported into the tissues.

Active electrodes to be used for this purpose may be made of copper, zinc, iron, silver or other attackable metal. Such electrodes are mainly of two varieties, needles and bulbs.

Fig. 40 shows some needles, which may be made of any desired metal. I use, preferably, copper, zinc, silver, and iron at the positive pole, or aluminum at the negative. These needles should be about 1 millimeter in diameter and about 8 centimeters in length, as they will then fit an ordinary holder. They may be bare or insulated down to the neighborhood of the point, as desired.

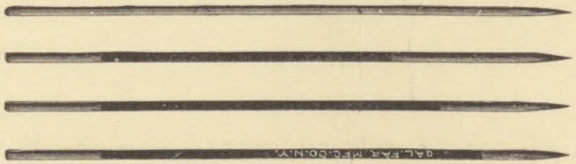


Fig. 40. "Soluble" Needles.

Bulbs may also be made of a variety of metals. For convenience they are constructed in sizes of the French catheter scale, each bulb capable of being attached by a screw-thread to a universal holder. Figs. 41 and 42 show sets of bulbs of different lengths and diameters.

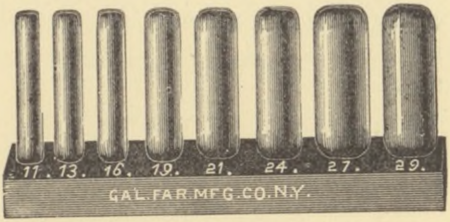


Fig. 41. "Soluble" Bulbs.

Fig. 42. "Soluble" Bulbs.

It often happens in making applications to the rectum, urethral canal, cervical canal and other

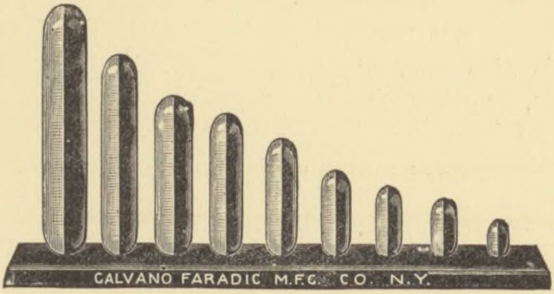


Fig. 43. Protected Soluble Electrodes.

canals, sinuses or cavities, and in the treatment of trachoma, that it is undesirable to attack approximating surfaces at a single treatment; again, it may be desired to protect a given surface.

To meet these conditions the writer devised a style of bulbs well suited to this class of work. They are shown in Fig. 43 and consist of bulbs divided longitudinally so as to be one half of metal and the other half of ebonite. Fig. 44 shows such a protected bulb with its handle.

Fig. 44. Protected Electrode and Handle.

The handles for these bulbs may be of different shapes for use in special localities. Fig. 45 illustrates two common forms of handle with soluble bulbs attached.

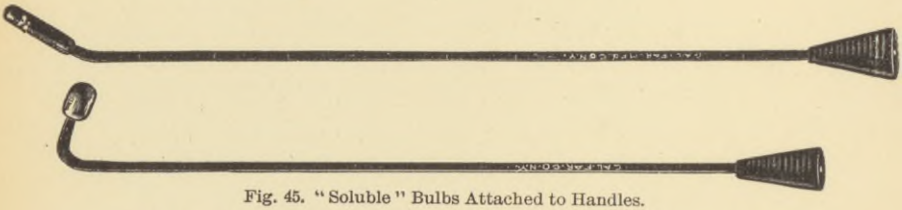


Fig. 45. "Soluble" Bulbs Attached to Handles.

It is also convenient, at times, to use needles, sounds, or other long electrodes, which are supplied with an insulating sheath which protects the tissue from cataphoric action except at the desired point.

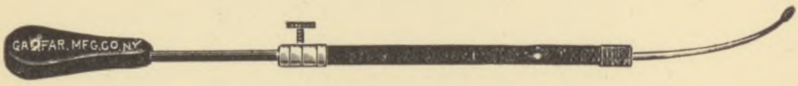


Fig. 46. Protected Sound of "Soluble" Metal, Copper, Zinc, Iron, etc.

Fig. 46 shows one of these protected sounds and Fig. 47 shows a nasal electrode protected in the same manner.

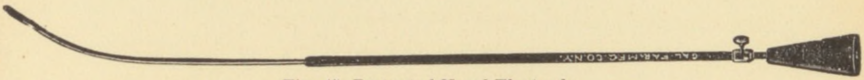


Fig. 47. Protected Nasal Electrode.

Fig. 48 is an illustration of an olive-tip electrode for rectal application. This may be made of any metal as desired.

Fig. 48. Rectal Electrode, Olive Tip.

CHAPTER III.

DENTAL ELECTRODES.

In dental practice the dispersing electrode is of great importance, perhaps more so than in other applications because of the sensitiveness of the nerves of the teeth and the desirability of keeping up a steady flow of current.

Fig. 49 shows a dispersing electrode made of a circular disc of carbon, about three inches in diameter, covered with two layers of sheet punk or amadou bound at the edges by an *insulated* wire wound in a groove. This electrode may be held

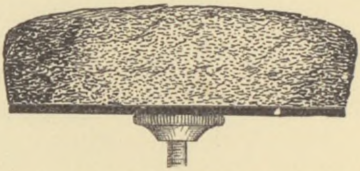


Fig. 49. Dispersing Electrode, of Carbon covered with Amadou.

in the hand, or placed upon the cheek, or in some other convenient position. Fig. 50 shows a form of electrode intended for use on the tongue. It is, ordinarily, not so convenient a form as the carbon electrode illustrated in Fig 49.

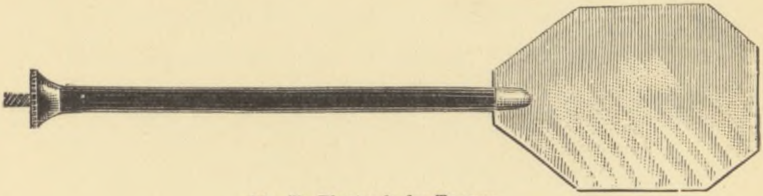


Fig. 50. Electrode for Tongue.

The standard active electrode for the mouth is that shown in Fig. 51. Its chief characteristic is the form of disc used, which is about half an inch in diameter. This disc is made of carbon or block tin and is one-quarter of an inch thick. The carbon

Fig. 51. Morton's Mouth Cataphoric Electrode. (1 inch diameter.)

or tin is perforated freely to about two-thirds of its depth by drill holes one millimeter in diameter, or is perforated completely with a shallow reservoir provided behind it to hold an excess of solution. The metal disc is surrounded by ebonite, which rises as a flange two or three millimeters above the disc to form a receptacle for a piece of blotting paper, felt or other absorbent material cut to fit the receptacle exactly.

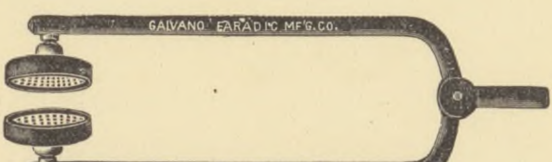


Fig. 52. Morton's Tong-Shaped Duplex Cataphoric Electrode.

The cataphoric electrode devised by me for use on the gums, as previously shown, consists of a pair of the above partially perforated discs mounted on a holder shaped like a pair of tongs, as in Fig. 52. This permits an application to be made on each side of the gum at the same time. Both discs have a ball and socket joint and are of the *same polarity.* The dispersing electrode may be held in the hand, or placed elsewhere, and both sides of the gum may be treated at the same time.

The double rubber cup electrode shown in Fig. 53 had been used by Westlake and others with each

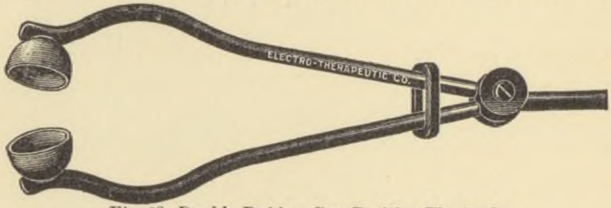


Fig. 53. Double Rubber Cup Positive Electrode.

cup connected to a different pole, and it proved inoperative except at one cup. This electrode has been recently modified in accordance with the principles incorporated in the electrode shown in Fig. 52 in the false hope of making it an operative device. Each cup has a platinum disc in the bottom and the cups may be changed for each patient.

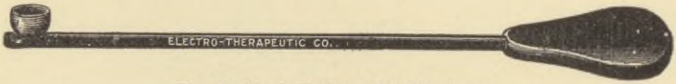


Fig. 54. Single Rubber Cup Electrode.

Fig. 54 is a single cup electrode made on the same general lines as the double electrode in Fig. 53.

The double cup positive electrode and the single cup electrode, Figs 53 and 54, are here reproduced solely for the purpose of expressing my absolute condemnation of them as working electrodes. They are constructed upon unscientific principles. The first requisite of successful cataphoric action is that the porous septum holding the absorbed medicament shall be as thin as possible—it should not be thicker than ordinary blotting paper, and the second requisite is that every portion of this septum of absorbent material should be in immediate contact with the metal back plate. In short, metallic conduction should end as near as possible to where cataphoric action is to begin. The faults of the cup electrode are that a very small metal plate is used, and that this plate is non-perforated, and that, finally, its shape invites a thick packing of porous material. As a result, the primal cataphoric action is expended in the porous material and not in the tissue ; the operator fails to benumb the gums, and thenceforward condemns the cataphoric method. With a proper electrode and some experience there can be no failure to anæsthetize the gums and deeper tissue, but in making an actual experiment of this kind before a class at the New York Dental College I found that the patient complained of some pain, due probably to the tearing out of abscess tissue back of the tooth at the moment of extraction. The electrode had not been applied quite long enough. I have found eight minutes to suffice, employing guaiacol and cocaine in an eight-per-cent solution, dilating it with almond oil, one half.

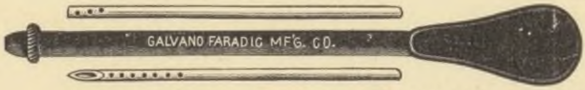


Fig. 55. Morton's Tubular Cataphoric Applicater.

Another modification of the reservoir idea as applied to an electrode is that illustrated in Fig. 55. This electrode is for use in operations on sensitive dentine. It consists of a heavy, stiff piece of platinum wire, tubular at its end, and perforated from the sides into the tube, so that it may hold an excess of the solution. The end of this "applicator" is applied direct to the pledget of absorbent cotton within the cavity. In place of the tube the applicator may be split one or more times, or otherwise arranged so as to hold the fluid by capillary attraction. This is important, as otherwise the pledget of absorbent cotton becomes dry, necessitating a renewal of the anæsthetizing fluid, and thus causing an unpleasant turning on and off of the current.

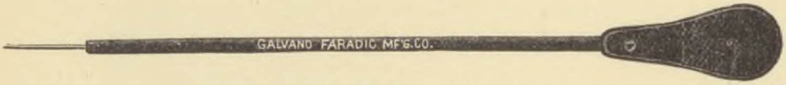


Fig. 56. Plain Platinum Applicator.

The usual form of "applicator" is that shown in Fig. 56. This is not tubular and possesses no reservoir capacity. The end of the platinum wire is roughened so as to retain, if desired, a pledget of absorbent cotton which may be wrapped about it.

Both of the applicators shown in Figs. 55 and 56 can be so changed in form as to reach spots which the straight applicators here illustrated could not reach.

To avoid the trouble of holding the electrode in place during a considerable time, as well as the chance of variable pressure, and therefore varying current, "spring electrodes" have been devised which, once placed within the mouth, retain their fixed positions.

Fig. 57 shows such an electrode (devised, I believe, by Dr. Van Woert), *in situ.* The illustration is taken from the manufacturer's circular.

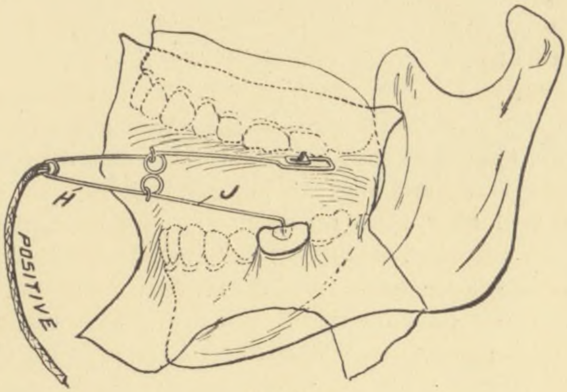


Fig. 57.

This shows the spring electrode in position, for anæsthetizing sensitive dentine pulps for extirpation, a shoe-like end resting against the rubber dam, and the point on the cotton, saturated with a medicament in the cavity.

And here a final word in regard to cataphoric electrodes of the "applicator" type for use in the cavities of teeth for anæsthetizing or bleaching dentine or for the introduction of any medicament. Sufficient attention has not been given by operators to the question of current density and its influence upon the rapidity of cataphoric absorption.

Current density is expressed in terms of the quotient of the current strength in milliamperes divided by the surface of the area of the electrode in square centimeters. If, for instance, a current strength of 15 milliamperes is flowing into the arm through an electrode of 5 square centimeters the density of the current at the point of application of the electrode to the skin is $\frac{15}{5} = 3$. But enlarge the electrode to 15 square centimeters and our quotient is $\frac{15}{15} = 1$. In other words, the larger the electrode at an equal current strength the *less* the current density, that is to say, the less the current strength at any given point beneath the electrode.

We will now take an electrode like the present type of applicator, assuming that its point of application is about 1 square millimeter, and that about 1 milliampere of current is flowing; our current density is $\frac{1}{1} = 1$. But supposing this rate of current flow under these conditions is giving pain to the patient and causing delay by its inefficiency in anæsthetizing the dentine. Let us as a remedy increase the size of the applied tip of the applicator to 3 square millimeters; our current density is $\frac{1}{3}$. The patient is now receiving the same total current as before but diffused over a larger area, so that it is reduced $\frac{1}{3}$ at any given sensitive point, and we may consequently give three times as much current as before and cause but the same amount of pain.

In this manner much more extensive cataphoric work would be accomplished.

The small cross-sectional area of the electrodes in common use as applicators therefore seems to me to explain the slowness of producing results and the unusual length of time consumed, reported by many operators. The cataphoric applicators constructed for me by the Galvano-Faradic Co. of New York, while retaining the feature of perforation described on page 97 are of sizes which as near as possible conform to the ordinary entire cross-sectional area of the cavity to be treated. These larger applicators furthermore fulfil a requirement which I have long insisted upon as essential to good cataphoric work and that is that the *entire* porous surface which holds the medicament must be in intimate contact with the metallic conductor at every point and that this same metallic conductor must be in as close contiguity as is possible to the tissue to be affected.

The slim needle-shaped applicator must therefore in my opinion be abandoned.

While the tubular and perforated applicator Fig. 55, will suffice for small cavities it is well to change its shape (retaining preferably the tubulation and perforation) for use in large cavities. And in this instance, since platinum is expensive, block tin or graphite may be substituted for a constructing material. Tin oxidizes but slightly and is a good conductor while graphite (gas carbon) does not oxidize at all. The applicators here referred to for

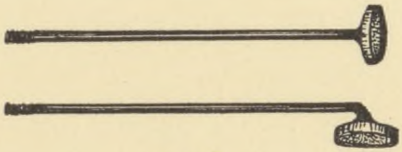


Fig. 58.

insertion into a needle holder, with or without a spring for retaining them in permanent position, are illustrated in Fig. 58. They may be made of any size.

Fig. 59 illustrates such an applicator in position. A modification of the wire brush electrode, Fig. 38, using a slide over fine platinum wires, might easily be made.

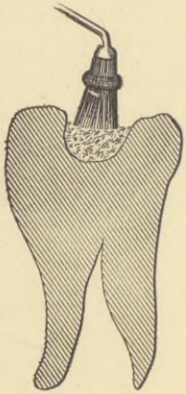


Fig. 59.

Of course the ingenuity of the operator will surmount any special difficulties if the general principle of current density be kept in mind. There is but one final precaution which seems almost unnecessary to state, and that is that in no event must any part of the metallic applicator come into actual contact with any part of the dentine to be affected. This might easily and thoughtlessly happen should the suggestion, made elsewhere, to pack in platinum, gold, or tinfoil over the porous material within the cavity and connect it to the battery terminal, be adopted.

In the sterilization of the pulp cavity and dentine as well as in the treatment of pyorhœa alveolaris, etc., the operator will do well to refer to the electrode termed the hypodermatic injection electrode and shown in Fig. 35.

CHAPTER IV.

BATTERIES AND CENTRAL STATION CIRCUITS.

To a person contemplating the installation of apparatus for the utilization of the cataphoric phenomena, the interesting question at once arises : What shall be my source of electricity ? If his office is equipped with electric lights, or if the electric light wires pass his door, he wonders if the central station current cannot be utilized. If he is not conveniently near electric light wires he wonders what variety of galvanic battery to use. These are important questions to settle and they should be settled properly.

We have seen in the chapter on "Sources of Electricity," in Part II. of this book, how currents of electricity are induced in the dynamos situated in the central stations, and that every dynamo is inherently an alternating current generator, but that by the application of a device called a "commutator"

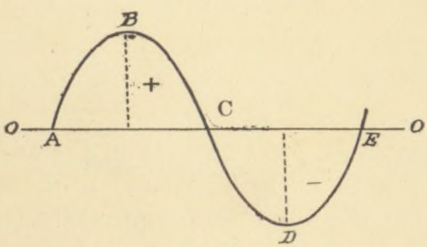


Fig. 60.

the alternating current impulses could be rectified or "commuted" into continuous currents. Let us consider what happens in a dynamo whose current impulses are commuted: If we imagine the "armature" of our dynamo to have but one coil it will develop an electromotive force which may be represented by the curved line in Fig. 60, where the horizontal line is the zero line or line of no voltage. For the first half revolution of the armature the current will flow through the coil in what we will call the positive (+) direction; it begins from zero, rises to a maximum and falls to zero again. Then, as the armature continues turning for its other half-revolution, another current is induced in the coil but in the opposite or negative (—) direction. This is indicated in our illustration by the curve below the zero line.

If, now, we put a commutator on this armature, we will so alter the conditions that the current impulses will all flow to the external circuit in the positive sense, as shown by Fig. 61.

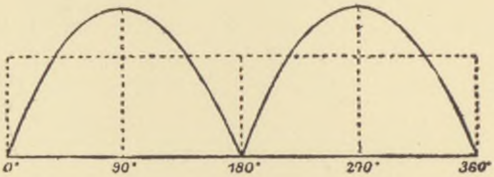


Fig. 61.

But suppose we put two coils on the armature, at right angles to each other, and connect them in series and at the same time commutate them. We will then have a condition like that shown in Fig.

62 where one electromotive force is superposed upon the other. By this is meant that the curve starting

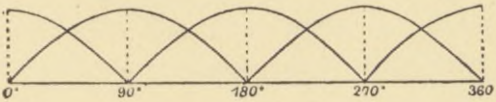


Fig. 62.

from 0^0 represents the voltage induced in one coil during one revolution and the curve starting from 90^0 represents the voltage of the other coil. But it will be seen that this curve does not truly represent the conditions, because at some points both coils are having current impulses induced in them ; as the two coils are in series the sum of the voltages in the coils should be taken and plotted out in another curve, as in Fig. 63. In this curve it appears that

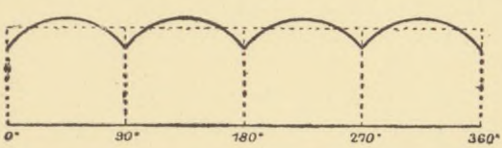


Fig. 63.

the points where there was a double voltage in Fig. 62 are now the highest points in the curve. With one coil we saw there were two waves or fluctuations per revolution ; with 40 coils there would be 80 waves or fluctuations. Each fluctuation in the latter case would be a small one but *it would be a fluctuation.* For the purposes of incandescent lighting such a current is called a "continuous" current and the fluctuations are not noticeable in the lamps or motors connected to the circuit but if we connect a telephone to such a circuit we can distinctly hear the hum or buzz produced by the fluctuations.

We can put a 10-pound weight on a man's head without inconveniencing him, but if we hit his head a smart tap with a 2-ounce tack-hammer we will injure him severely. So, a constant pressure exerted by a galvanic current on a patient will be tolerated where the rapidly pulsating rat-tat-tap of the central station current could not be tolerated.

Many practitioners are using the street circuit as a source of supply and are pleased with it, not appreciating that anything could be more desirable. There are, however, other dangers and inconveniences to be met with in the use of dynamo currents (such as lightning, accidental "grounding" of the patient and variations in the potential of the lines due to variations in load) which, in the opinion of the writer, makes it most desirable to use the battery. He has employed both and therefore speaks from experience.

If batteries are to be used, which is the best variety? There are three styles largely used, viz., the "red-acid," the Leclanché and the "Dry" batteries. The "red-acid" battery is one in which a solution of bichromate of potash and sulphuric acid is the active solution, with zinc and carbon elements. This battery, while giving a high voltage per cell, rapidly polarizes, especially when much used on a "short circuit," or circuit of low-resistance. The Leclanché battery is almost too well-known to need description, being the type of battery used for electric bells and similar purposes. Its solution is one of sal ammoniac and water; a porous cup containing a carbon plate and pulverized peroxide of manganese is placed in the sal ammoniac, forming one pole of the battery, while a zinc rod also in the sal ammoniac acts as the other pole. The "Dry" battery is a modification of the Laclanché and is very convenient, there being no solution to replenish or spill, or glass jars to break. When a cell of this class wears out or is used up (they will last about a year with ordinary usage), they are so inexpensive they can be thrown away with a clear conscience.

For general therapeutic work it is desirable to have about 40 cells of battery available for use, and for dental work at least 20 cells are needed, though it is best to have 40 cells for use in special cases. The constant aim of the manufacturers is, as it should be, simplicity of apparatus. Several are now in a position to supply very convenient boxes or cabinets with dry-cells all arranged and connected, and with special directions for use.

CHAPTER V.

RHEOSTATS.

REGULATORS of potential for purposes of cataphoric applications are a necessity, as has been abundantly shown. Such regulators should be so arranged that they will permit the current admitted to the patient to be easily controlled—made greater or less at will and by very small amounts at a time. This is particularly true in dental practice, as the nerves of the teeth are exceedingly susceptible to changes in current flow. Sensitive dentine is delicate material to operate upon, and it is absolutely essential that the regulators should be capable of admitting the current by very easy stages. The generic name for regulators is "rheostat," although they are often called by other names, such as "volt-selector" or "adapter."

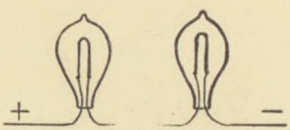


Fig. 64. Series Relations.

Broadly speaking, the rheostats on the market to-day belong to either one of two classes : (1) instruments comprising a resistance placed in *series* relation to the patient, or (2) instruments in which the resistance is in *shunt* relation to the patient. It will be understood that when a current of electricity

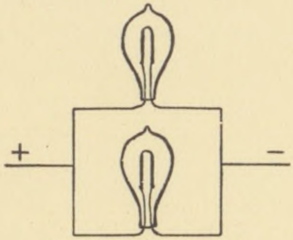


Fig. 65. Shunt Relation.

passes through two parts of a circuit, one after the other, those parts are in series, as are the lamps in Fig. 64, and when one part of a circuit is connected

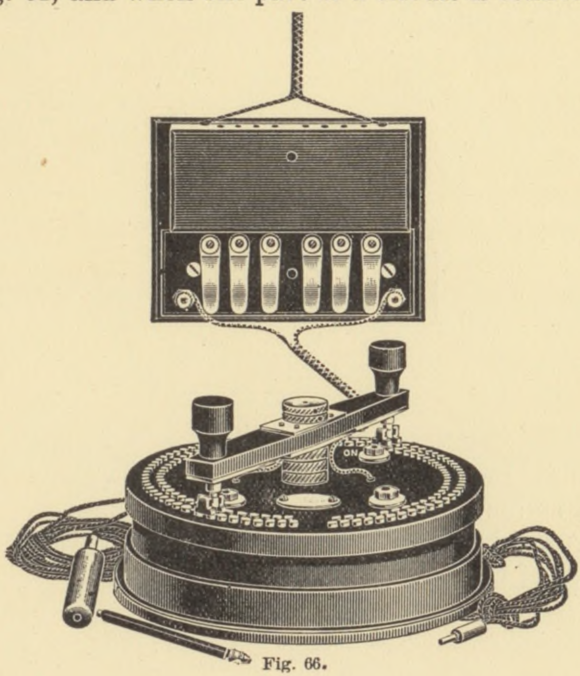


Fig. 66.

as a by-path to another part, so the total current is split, or divided, between the two, then the one part is arranged as a "shunt" to the other. (SeeFig. 65).

Both series and shunt rheostats have strong advocates, each of whom thinks his own arrangement is far superior to any other. It will be instructive to make a comparison between representatives of these two classes that we may draw our own conclusions.

1.—*The Clark & Mills Series Rheostat.* This instrument is shown in Fig. 66 and is made in Boston. It consists of an enormous resistance (several million ohms) divided up into a large number of steps. A diagram of the connections, furnished by the makers, is shown in Fig. 67 in connection with other apparatus deemed by them to be

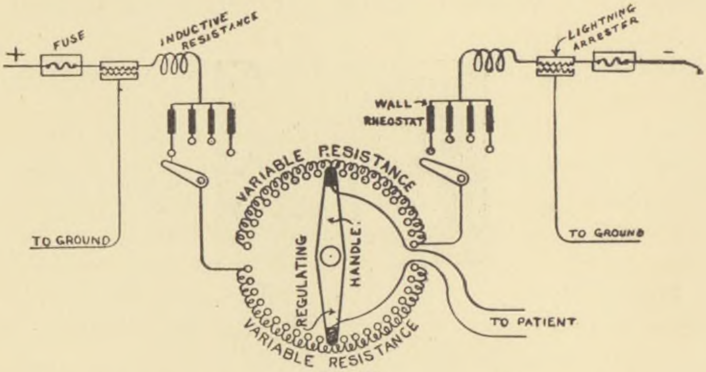


Fig. 67.

desirable when the rheostat is used on an electric light circuit.

It will be noticed that there is the same arrangement of resistances and apparatus in each side of the circuit, both positive and negative. This the makers term a "binary" arrangement and lay great stress upon it. As the same amount of current will go through the patient no matter which part of the series circuit he is put in, the only advantage of the "binary" method of connection (outside of a certain symmetry in the arrangement, pleasing to the eye) is appreciated if there should be an accidental ground connection to the patient; in such a case he might receive the full force of the total pressure as it took a short cut through him to the earth. In the diagram the fuses are intended to act as safety devices, cutting off the supply of current in case of an abnormal rush of current. The devices to which the ground wires are attached are lightning arresters—used when the central station wires are strung on poles in the open air, instead of being buried underground; the "inductive resistances" are to assist in the same operation. The "wall-rheostats" are resistances intended to absorb a certain amount of the total voltage leaving only a portion of the total to be varied by the operator. These resistances, as well as those in the variable portion of the apparatus, are made of graphite rods with metal tops upon which the necessary metal contact-shoes travel. At my request, Mr. Clark, one of the makers of this instrument, has written the following statement concerning it:

"We claim for our instrument that it is a simple series rheostat of high resistance having many fine gradations. The series rheostat is the simplest of all forms and is the most economical in the use of current. This latter point is of comparatively little importance when the commercial circuit is used as the current costs but little, but is of more importance in case a battery is used, as the battery is exhausted more quickly by using a shunt rheostat. A rheostat should have a high resistance, so that the resistance of the patient shall cut as little figure as is possible in proportion to the total resistance of the circuit. There are several reasons why this should be so. Take two cases :

"Case 1. Tooth resistance, contact resistance and body resistance is 50,000 ohms. With 10 volts applied to patient 0.2 milliampères will be flowing. Now, if better contact is secured at positive or negative terminal or if the cotton is dampened or if the tooth or body resistance should change so that the total resistance of patient should be lowered to 25,000 ohms, then the current would increase to 0.4 milliampères or by 100 per cent. The shock or pain might possibly be quite great.

"Case 2. Tooth resistance, contact resistance and body resistance is 50,000 ohms as before. Resistance in series with this is 450,000 ohms ; total resistance is thus 500,000. With a pressure of 100 volts the current flowing would be 0.2 milliampères or the same as in Case 1. If the body, tooth and contact resistance now decreases to 25,000 ohms the current would now become 0.21 milliampères or an increase of but 5 per cent and no shock or pain would probably be observed.

"If there is a movement of the applicator or when there is a poor contact in the circuit, a high voltage is of advantage in that it has a tendency to maintain the circuit. If from this reason the circuit is kept from being broken the patient is spared a shock. A circuit with a high resistance and a high voltage with a given current flowing will, when broken, give a somewhat greater shock than will be given when a circuit is broken that has a low voltage and low resistance and the same current flow.

"It is the current that does the work and not the voltage. A higher voltage may cause a greater shock at make and break than a smaller one, but with a given current flowing steadily it makes no difference to the human system whether there is a high resistance and high voltage or a low resistance and low voltage.

"To get a minimum current of 0.02 milliampères with a pressure of 110 volts a resistance of 5,500,000 ohms is required; with 220 volts a resistance of 11,000,000 ohms is required; with 500 volts a resistance of 50,000,000 ohms is required. These tremendous

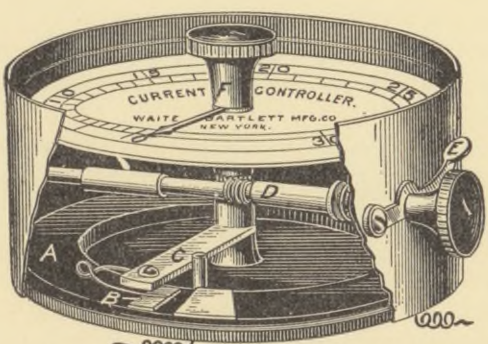


Fig. 68.

resistances are to be obtained only with graphite resistances which may be very reliable in some forms or very unreliable in other forms. About the only reliable form of these high resistances seems to be graphite rods. Secure metallic contacts should be made to them and the contact-shoe should move on these metal contacts."

1 *a. The Van Woert Current Controller.*—This is a type of the series rheostat and constitutes one part of the Van Woert Apparatus for Cataphoresis, with cells and a low voltage.

It is illustrated in Fig. 68.

The base is of slate, with a raised surface at A, the same being covered with a thin layer of graphite; the shoe B resting upon it, and connected with the arm C attached to the pinion F. The said pinion when turned to the right carries the shoe with it, which cuts down the resistance as it passes toward the opposite side of the circle, where the metal plate is affixed, and connected direct to the outlet. The wire shown under the worm-rod D is connected with the pinion F, and leads directly to the batteries. This worm-rod is for connection with a gear upon pinion F, which allows of a very slow and even movement of the shoe B. By pressing upon the lever E the worm-rod is thrown out of the gear, to allow of a rapid movement of the shoe by turning pinion F.

As I have elsewhere said, I am in favor of using cells rather than the street current and therefore advise any good assemblage of parts into a so-called Apparatus. Such an outfit must necessarily include a medical battery, current controller, milliampèremeter, rheophores and electrodes, and it certainly greatly adds to the convenience of the operator to have all these parts combined in portable form.

2.—*The Wheeler "Fractional Volt-Selector."*—This instrument is the invention of Mr. Geo. M. Wheeler of the Electric Therapeutic Co. of New York City, and a good general view of it is given in Fig. 69. The base is of solid mahogany, 7½ inches in diameter; the body is a metal cylinder 13

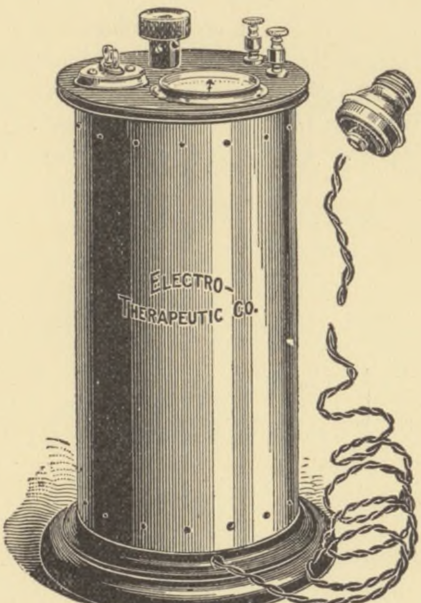


Fig. 69. The Wheeler Fractional Volt Selector.

inches high and 6 inches in diameter. On the top is a knob by which the regulation is effected, two binding-posts for the wires to the patient, a two-point switch for regulating the maximum voltage applicable to the patient, and a dial marked in *volts* with a pointer movable in relation thereto, moved by the turning of the knob. Thus, if this form of rheostat is used on a 110 volt circuit and the two-point switch is on the button marked 40 volts (the other button being marked 80 volts) the pointer on the dial can be moved—by moving the round knob—from zero to 40 volts. This means that a maximum of 40 volts can be applied to the patient, and if the pointer stands at 25 it shows that 25 volts are available for application to the patient. When the little switch is on the 80 volt button the readings of the dial must be doubled to get true results. This volt-indicating dial is not an electrical instrument but a mechanical device standardized

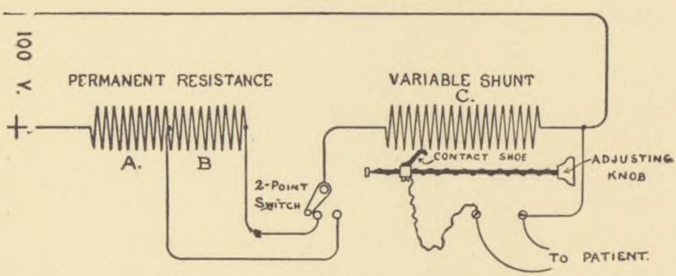


Fig. 70.

according to the known resistance of each step or change. The cord and plug on the right are for connection to the electric-light circuit, in this instance, although these instruments are also made for use with galvanic batteries.

The makers of this instrument have furnished the writer with a diagram of its interior connections, which are published for the first time, being given in Fig. 70.

The resistances are of german-silver wire wound on spools of fibre. Resistances A and B are wound on a spool placed inside another spool wound with the resistance C. It will be seen that if the two-point switch is on button No. 1, resistances A, B and C are all in series and are connected directly from + to — and there is a completed circuit without the patient being in circuit at all. If the two-point switch is on button No. 2 the resistances A and C are in series across the line from + to —. The total resistance from + to — being less than before, more current will flow through the instrument. And now for the chief characteristic of this instrument: Instead of placing the patient in series with the resistance, he is connected in shunt relation to the resistance coil C; thus, on one side he is connected to the negative (—) pole of the battery or other source, and on the other side to a travelling contact-shoe (moved back and forth by the knob or screw-threaded shaft), and the current instead of all going through the patient or all through the coil C, is divided, and only a portion will go to the patient. The coil C is wound in notches or spirally-cut grooves in its fibre spool, 63 to the inch; so the contact-shoe, in moving from one end of the coil to the other, touches successively between 700 and 800 different turns of the wire—in other words, there are between 700 and 800 different possible gradations in current flow. To understand clearly what this means, it

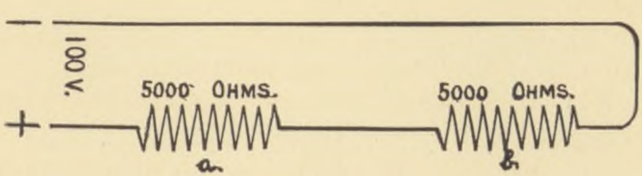


Fig. 71.

will be necessary to cite an example, in which Ohm's Law will be of great assistance.

If we have two resistances, *a* and *b*, each of 5000 ohms, in series, and apply a pressure of 100 volts at the terminals (see Fig. 71) there will be a current of .01 ampère,

$$\text{for } C = \frac{E}{R} = \frac{100 \text{ volts}}{R_a + R_b} = \frac{100}{5000 + 5000} = .01 \text{ ampère.}$$

If we now place a patient (whom we will call *c*), having a total resistance between contacts of 5000 ohms, as a shunt around the resistance *b* we will have the arrangement shown in Fig. 72.

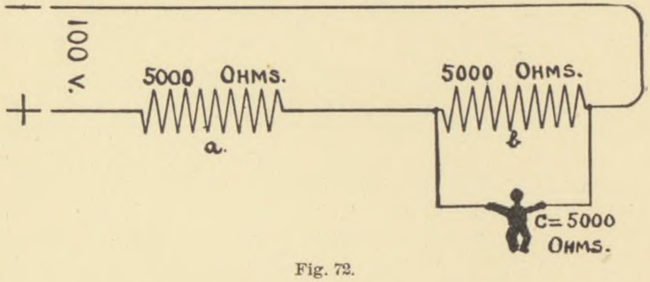


Fig. 72.

To determine the total current flow through the circuit as a whole under the new conditions we must apply a rule derivable from Ohm's Law and find the *joint* resistance of *b* and *c*. This rule is applied[1] in this way :

$$R_{bc} = \frac{R_b \times R_c}{R_b + R_c} = \frac{5000 \times 5000}{5000 + 5000} = \frac{25{,}000{,}000}{10{,}000} = 2500 \text{ ohms.}$$

[1] This rule is as follows: To find the joint resistance of two resistances arranged in shunt relation to each other, divide the product of their resistances by the sum of their resistances.

The total current flowing will then be:

$$C = \frac{E}{R_a + R_{bc}} = \frac{100}{5000 + 2500} = \frac{100}{7500} = .0133 \text{ ampère.}$$

Compare this with current flowing in Fig. 71.

How much current will flow through the patient (*c*) under these conditions? If the joint resistance of the shunts *b* and *c* is 2500 ohms and .0133 ampère is flowing through them jointly, the voltage being expended on this part of the circuit is:

$$E_{bc} = C \times R_{bc} = .0133 \times 2500 = 33.25 \text{ volts.}$$

Then the current in patient will be:

$$C_c = \frac{E_{bc}}{R_c} = \frac{33.25 \text{ volts}}{5000 \text{ ohms}} = \left\{ \begin{array}{l} .006 \text{ ampère or 6 milli-} \\ \text{ampères.} \end{array} \right.$$

What will happen is we shunt the patient around only a part of the resistance *b* instead of all of it? Let us see. If we shift the connection to a point

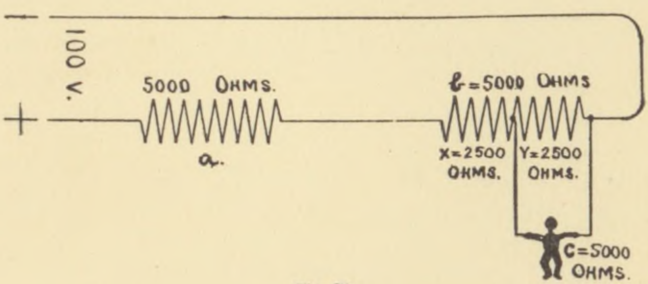


Fig. 73

half way along *b* (as in Fig. 73) so that *b* is divided into two parts, *x* and *y*, each of 2500 ohms, the joint resistance of *y* and *c* by the above-mentioned rule will be 1666 ohms. The total resistance of the circuit will then be: $R_a + R_x + R_{yc} = 5000 + 2500 +$

1666 = 9166 ohms. The current flowing will then be (in entire circuit) :

$$C = \frac{E}{R} = \frac{100 \text{ volts}}{9166 \text{ ohms}} = .0109 \text{ ampère.}$$

Knowing the current and the joint resistance of *y* and *c* we can find the volts expended in *y* and *c*: $E_{yc} = C \times R_{yc} = .0109 \times 1666 = 17.1594$ volts, and the current in the patient will be :

$$C_c = \frac{E_{yc}}{R_c} = \frac{17.1594 \text{ volts}}{5000 \text{ ohms.}} = \left\{ \begin{array}{l} .0034 \text{ ampère or } 3.4 \\ \text{milliampères.} \end{array} \right.$$

We thus see that by shifting the connection coming from the patient along the shunt coil in the Wheeler rheostat we get variations of voltage (and consequently current flow) in the patient's circuit, and that these variations of current flow are exceedingly small, being less than a quarter of a milliampère for each step.

Mr. Wheeler in writing to me about his instrument has this to say concerning the advantages resulting from its use :

"In applying electricity to sensitive dentine (and this also holds good for other applications) we find that the resistance of the dentine varies from the instant the current is applied, and it is to this great change of resistance in the dentine that the pain consequent upon using a series rheostat is due.

"The series control method causes pain because the aim of the operator is to keep the rate of current flow constant, for he knows that fluctuations of current flow cause pain to the patient. When the current is constant in a circuit the application of Ohm's Law shows that the voltage at the patient's electrodes varies, and varies in proportion to the changes of resistance in the patient. As the total energy dissipated in the patient (watts) equals the square of the current multiplied by the resistance of the patient, we see that when the resistance of the tooth or its contacts increase, the watts dissipated in that tooth increase ; as the operator cannot tell how the tooth-structure is varying in resistance it is practically impossible for him to maintain a non-fluctuating voltage."

He then shows by a series of calculations, not necessary to reproduce here, what is quite apparent after a little thought, namely, that by the *series* method the amount of energy (watts) dissipated in a tooth is doubled if the resistance of the tooth is doubled, while by the *shunt* method the watts are reduced one-half when the resistance of the tooth is doubled—if the volts at the electrodes are constant in each case.

In a previous chapter we have seen that the *watt* is the rate at which work is done or energy expended ; also that if the rate of expenditure of one watt is maintained for one second a *quantity* of work is done or energy expended which is called a *joule*. How is the energy expended in an electric circuit ? It is expended *or dissipated* in the form of heat. Incidentally certain effects are produced while the energy is being dissipated as heat. For example, when a current of electricity is passed through an electrolyte there is a transference of atoms *due to the passage of the current only*, and the energy dissipated during one second in producing that transference is dissipated as heat, and is equal to the square of the current passing through the circuit multiplied by the resistance of the electrolyte (joules, per second = $C^2 R$).

The electro-therapist must consider that the heat dissipated in the patient varies at a different rate from the variation in the cataphoretic effect. The heat dissipated varies as the *square* of the current flowing through the circuit, while the cataphoretic effect varies *directly* as the current.

Let us illustrate : If a current is flowing at the rate of one ampère through an electrolyte in which the terminals are silver elements and the resistance of the electrolyte is 10 ohms, there will be a transference of silver from one element to the other of 1.118 milligrammes per second, and the heat dissipated in securing this transfer will be $(1 \text{ ampère})^2 \times 10 \text{ ohms} = 10$ joules per second ; should the current rate be increased to 2 ampères there will be a transfer of 2.236 milligrammes per second and the heat dissipated in securing this transfer will be $(2 \text{ ampères})^2 \times 10 \text{ ohms} = 40$ joules per second.

From a careful consideration of the questions involved we may reach the following general conclusions :

1.—The physiological effect of a given rate of current flow through human tissue is the same whether high resistances and high initial voltages or low resistances and low initial voltages are used, *providing* there are no fluctuations in the current ; the heating effect and the cataphoretic effect will be the same.

2. When there is a fluctuation in the resistance of the patient the shock is much greater with high initial voltage than with low, and greater with a series rheostat than with a shunt.

3. A constant rate of current flow maintained through tissue will produce as much pain under changes in the resistance of the tissue, whether the series or shunt rheostat is used.

4. A wire coil resistance is much more convenient and cleanly than graphite in any form, and far more reliable for continued use.

5. A shunt rheostat uses more current than a series rheostat ; this is not important when a shunt rheostat is guaranteed not to run a battery down in less then a year with ordinary usage.

6. A shunt rheostat will permit a finer gradation in the steps or changes in current applied to the patient than in the series variety.

Because of conclusions 2, 4, and 6, my personal preference is for the shunt method of control.

CHAPTER VI.

MILLIAMPÈRE METERS.

We have seen from what has already been written that it was exceedingly desirable that the operator have some means at hand for determining the electrical conditions of his procedures. We have also seen that an instrument called a milliampère meter has been often referred to as the device which should be used for this purpose. A milliampère meter is an instrument for determining the rate of current flow through a patient, and in that manner obtain information as to what is going on inside of that patient. In Fig. 74 we have a diagram representing a shunt rheostat connected with one set of conductors to a source of electricity and with the patient *through a milliampère meter* by another set of conductors. We thus have the milliampère meter in series with the patient so that the current which goes to the patient must also go through the milliampère meter and thus make its presence known.

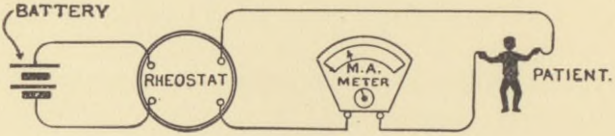


Fig. 74.

Some may not think it necessary to have any meter, believing that it is only a question of giving the patient *all he can stand.* It is possible that in a few isolated cases such a method of procedure might be permissible, but in the vast majority of cases it would be as unsatisfactory to administer electricity in this manner as it would be to feed a person drugs in as large quantities as he is willing to consent to, rather than give a measured dose calculated to produce a given result. In addition to measuring the rate of current flow the milliampère meter fills other important offices. Every variation in the resistance of the patient or of the electrode contacts is reflected by the meter in its fluctuating indication ; every cry of pain or expression of discomfort on the part of the patient finds an explanation from the milliampère meter's reading. Its use gives the operator the equivalent of a sixth sense, for he is able to see, mentally, what is going on beneath the surface. An ordinary incandescent lamp of 16-candle power burning on an electric circuit having a potential between its two conductors of 110 volts requires about one-half an ampère of current. But half an ampère, or 500 milliampères, is an enormous amount of current for an electrotherapist to use. In almost all classes of general applications of electro-therapeutic measures 100 milliampères is very rarely exceeded, and in ordinary practice 20 or 30 milliampères will be found more largely used. Some classes of work require very small currents, for if an application of, say, 5 milliampères is made, an evil may result which would have been escaped had only 2 milliampères been used. Again, in dental work, it is necessary to work with very minute currents—as low in some cases as 0.2 of a milliampère.

An instrument for use by either general medical practitioners, or by members of the dental profession, must therefore possess certain characteristics to be of value, and we will give a statement of these characteristics paraphrased from a report[1] of a committee which has given most careful consideration to the subject:

1. A good meter should have a clear, legible scale, fairly uniform over the range, and not crowded at different points.

2. The scale should be so clear that the operator can read it while working on his subject.

3. The internal resistance of the meter should be low.

4. There should be no tendency to overheat with the strongest current employed.

5. The instrument should be capable of indicating in all positions. This, however, is only possible in those meters *not* of the galvanometer type, and even then a change from the most favorable position is at the expense of delicacy of indication.

6. Any instrument whose indications depend directly upon the local magnetic force is objectionable, for the reason that its indications are liable to be affected by iron in the vicinity or other outside magnetic influences. This is true of all instruments of the galvanometer type, which is that type in which the current to be measured passes, not through an armature coil, but around the electro-magnet

[1] See Report of Committee on Meters of American Electro-Therapeutic Association in Transactions for 1893, page 18.

which influences the position of a magnetic needle suspended within its field of force.

7. The suspension system should be delicate and sensitive, and at the same time be unlikely of derangement in use or shipment. All purchasers of meters should demand a guarantee that an instrument should be delivered at its destination in good order.

8. It is an advantage for the meter to indicate with the current passing in either direction. However, this is not a consideration which should take precedence at the expense of accuracy. A little pole changing switch introduced in circuit with the meter will enable the operator to always have his current to flow in the right direction to his patient.

9. A meter should be portable and not readily broken or put out of order or adjustment.

A convenient meter for general use is one capable of indicating for two different rates of current flow. By this is meant the employment of *two scales* on the meter, either one of which may be used at the will of the operator. A very excellent arrangement is to have one scale read from 0 to 10 milliampères, in steps of tenths of milliampères and another scale to read from 0 to 100 milliampères in steps of 1 milliampère. All that is necessary is to turn a button and either scale will be in use.

In concluding this chapter I beg of each operator to use a milliampère meter in his operations and find what a comfort its use will bring; also, do not be led to believe that it is economy to use a very cheap instrument.

CHAPTER VII.

MEDICAMENTS.

THE following laws governing the absorption of medicine through the tissues regardless of electricity have been formulated (L'Union Pharmaceutique) by Professor Lewin, of Berlin :

1. Every healthy mucous membrane absorbs medicaments in direct ratio to the surface in contact therewith, barring modifications produced in the membrane by the chemical or physical action of the medicament. The only exception to this rule is the vesical mucous membrane, which has no power of absorption, even under the influence of irritant agents.

2. Each unit of mucous surface possesses an absorbing power in direct ratio to its own temperature.

3. The healthy skin does not absorb non-modifiable medicaments which do not irritate it, whether applied in aqueous solution or pomades ; under such conditions they can never penetrate to the blood. But absorption may follow either when the medicament is caustic and wounds the skin, or when it is dissolved in a volatile vehicle such as alcohol, ether, chloroform, etc. Certain agents, very finely incorporated in fat, may, after the application of prolonged friction, provoke redness of the skin and penetrate the circulatory apparatus.

4. The serous membranes, the muscles and the tissues of the parenchymatous organs, behave like the mucous membranes. The healthy corneal tissue does not absorb.

5. The respirable gases and the vapors are introduced into the blood through the lungs.

6. Wounds absorb just as do the mucous membranes; the same is true of corneal ulcerations.

MM. Linossier and Lannois[1] have studied experimentally the absorption of iodine by the skin, also without electricity, and have arrived at the following conclusions:

Iodine applied by bandages is absorbed by the cutaneous surface especially when one has taken the precaution to exclude the air from the region bandaged. Under these circumstances the quantity of iodine eliminated by the urine can reach almost a third part of the quantity placed upon the skin. Under the conditions of the experiment the pulmonary absorption is negligible.

The maximum absorption is at the beginning of the application and before the alteration of the skin occurs to any considerable extent.

Other volatile iodine combinations can be absorbed in very considerable proportions, and can even be employed in this manner for the purpose of general iodine medication.

For instance, following the application of 9 to 10 grammes of iodide of ethyl (every precaution being taken to prevent pulmonary absorption), a quantity of iodine corresponding to a gramme of iodide of ethyl may be found in the urine.

In using iodine cataphorically I prefer a solution

[1] "L'Echo Médicale du Nord," Lille, May 2, 1897, page 186.

of iodine in water to the tincture. Water ordinarily takes up but one part in five thousand of iodine, but by adding a little iodide of potassium aqueous solutions of any desired strength may be obtained.

LIST OF MEDICAMENTS.

A list of a number of the medicaments which have been found useful in cataphoretic applications is given below. As a general proposition it may be stated that all drugs which are themselves conductors of electricity, or which may be made conductors by combination with other drugs, can be used cataphorically.

Ether, Chloroform, Aconite, Strichnia, Hydrochlorate of Eucaine, Hydrochlorate of Cocaine, Guaiacol, Pilocarpine, Menthol, Aconitia, Onabain, Strophanthin, Carbolic Acid, Strychnine, Helleborin.

Iodide of Potash, Tincture of Iodine and Aqueous Solutions of Iodine, Bichloride of Mercury, Iodoform, Salicylic Acid, Salol, Antipyrine, Methyl Salicylate, Carbolic Acid, Alcohol, Glycozone, Hydrozone, Pyrozone, Nitrate of Silver, Chloride of Sodium, Borolyptol, Witch Hazel, Borine, Formaline, Chloride of Zinc, Trichloride of Iodine, Pentachloride of Phosphorus, Chloride of Potassium, Chloride of Platinum, Trichlorphenol, Lysol, Pyoktanin, Benzoic Acid, Thymol, etc.

This list may be indefinitely extended.

PART IV.—APPLICATIONS IN MEDICINE AND GENERAL SURGERY.

CHAPTER I.

SIMPLE CATAPHORESIS.

By simple cataphoresis we mean what is generally known as "Porret's Phenomenon," or what has been previously defined as electrical endosmose—the carrying of liquids through human tissues or other porous septa by the action of an electric current. This action has long been recognized, but it is only in late years that it has received any worthy attention—an attention mainly the result of laboratory experiments upon the lower animals and upon dead animal tissue.

Among such experiments, almost unique and especially worthy of mention are those of G. N. Stewart, physiologist, in Owens College Physiological Laboratory, Manchester, England. He showed that in all animal liquids when separated by a porous septum there was an immense transference of water from the positive to the negative compartment, also a distinct movement of pigments and proteids. In one experiment, in an hour and a half, with a current of only five milliampères the volume of a 3.6 per cent hæmoglobin solution had diminished 40 per cent in the positive compartment and increased to a corresponding degree in the negative. Another experiment showed that in a two hours' electrolysis of bile with a current of 65 milliampères, no less than 92 per cent of the water had disappeared from the positive compartment, which originally contained 10 c. c. of the liquid.

When 70 grams of rabbit's muscle with no porous septum was electrolyzed for 30 minutes by a current of 350 milliampères, the water in the cathodic half was found to exceed that in the anodic half in the proportion of 48 to 31 and the salts in the proportion of 48 to 23.

In a living rabbit Stewart passed a hollow metallic electrode into the vagina; when this electrode was a cathode, fluid was forced through it, while none appeared when it was an anode. In this case it might be queried if the flow was not due to increased secretion due to the stimulating effect of the cathode, but there was little doubt that cataphoresis was the main factor in its production.

These experiments are not cited to show the possibility of cataphoresis, for of this there is no doubt, but to show the very large amount of the transference of fluid which may take place in tissue. The fluid transfer also includes the removal of the substances dissolved in it, mainly salts. The importance of these latter to the maintenance of healthy nutrition is well known. Normally varying from one to two per cent. in muscle, nerve and other tissue, a decided change in the percentage produces a marked effect upon their vitality and their nutrition.

The importance of this fluid-conveying power and its concomitant deprivation of salts from the tissues, both by cataphoric removal and by electrolysis, is scarcely yet appreciated.

The hæmostatic and drying effect of the positive electrode may well be due to the removal of fluids, while the "liquefying" and "hemorrhagic" effect at the negative pole is equally due to cataphoresis. Granting the softening effect of the negative pole upon urethral stricture, is it not largely due to a liquefaction by the flow of fluids to it?

In a minor way it has long been noted that the eschar at the negative pole was soft and liquid while that at the positive pole was dry and hard, also that the negative needle in surgical electrolysis is loose and free in the tissue, while the positive needle, even though of unoxidizable material, was held firmly.

On a larger scale and in general, cataphoric accumulation of fluids at the negative pole is indicated in the resorption of tumors and of exudations. The application of the action to uterine fibroids and to inflammatory exudations is obvious. In the former case the continuous current produces a contraction of the uterus and diminution of the vascular supply of the tumor with a loss of its salts. Its nutrition becomes impaired and a reduction in size is accomplished. In the latter case the *starvation of its salts* alone is the most important element in causing absorption and dissipation.

The cataphoric action of the current is also indicated in chronic rheumatic affections of joints and in thickening of synovial membranes about the sheaths of tendons.

In short, in determining upon what action of the current to appeal to in order to accomplish denutrition and absorption, cataphoresis comes saliently to the front.

This well-known phenomenon of simple cataphoresis has long been recognized by the classical writers of electro-therapeutics, Erb, Remak, Lewandowski, and others, as an essential feature in the production of curative results of electro-therapy. But its nature was so obscure that it was impossible to differentiate it from other properties of the same current. For this reason Remak invented the term "catalysis" including under this heading cataphoresis and electrolysis, and incidentally effects upon the tissue due to dilatation of blood vessels and lymphatics and local increase of bulk in nerve and muscle fibres and cells, as well as finer molecular changes in vital structures beyond the present power of science to define. The sum total of such changes, however explainable, results in an alteration of nutrition of the tissue—in other words, modifies its metabolism.

CHAPTER II.

CATAPHORIC MEDICATION OR ELECTRIC MEDICAMENTAL DIFFUSION.

In the foregoing chapter the phenomenon of simple cataphoresis has been considered, and we have seen that whatever effect was produced, was due to the action of the current only and not to any drug which such a current was capable of transporting through the tissues.

That medicinal substances do penetrate the skin under the propulsive force of an electric current is now beyond doubt. To what extent this method of introducing medicine to the human system may become of practical utility in general medicine, becomes an important question. There are obvious reasons why the method cannot compete with the introduction of the same medicine into the stomach in some cases, and there is also some difficulty in measuring accurately the dose administered. But there are certain practical and theoretical advantages in its use, as, for instance, when the tissue to be affected is superficial and local. This is often the case in diseases of the skin, in ulcerations, lupus and cancer, and in superficially situated neoplasms like a syphilitic gummata. To avoid the action of the fluids of the stomach upon medicines is also sometimes to be desired, and there is a special efficiency in drugs introduced into the system in their nascent state.

The diffusive property of the current, taken advantage of in connection with human tissue, opens out to electro-therapy and general medicine an immense and fascinating field of study and practice and in many important directions points out entirely new treatments of a great variety of diseases thus far not commonly treated in this manner.

By cataphoric medication we mean the specific introduction of drugs or medicaments into living tissue ; this may be done in two ways, viz., by employing solutions in contact with non-oxidizable electrodes or by employing electrodes which are attacked by the chemicals formed at either pole by the action of the current upon the fluids of the tissue and upon the electrodes. The first method includes, whether in medicine or dentistry, the general introduction of drugs, electro-cocaine local anæsthesia, the anæsthetization of sensitive dentine or of the gums, the bleaching and sterilization of teeth, as well as incidentally the removal of drugs from the system, termed "cataphoric demedication." The second method comprises the electric diffusion from soluble electrodes into the tissue. It is thought best to speak of these various divisions in different chapters and to confine our attention here to medication from insoluble electrodes with non-anæsthetic drugs held in solution and projected from such electrodes into the tissue.

The fundamental principles upon which the introduction of medicine into the human tissue by cata- or ana-phoresis are based, have already been sufficiently dwelt upon in preceding chapters. It is sufficient to say here that I do not believe that the substances introduced are decomposed by electrolysis, and we may relieve ourselves of the confusion derivable from an appeal to ionization of the medicament. For these reasons we have refrained from quoting the numerous electrolytic theories lately advanced.

It is not, of course, denied that electrolysis occurs, as I have previously pointed out, but I would claim that electrolysis is incidental for purposes of current flow, and that this current carries with it free and neutral molecules subjected to no electrolysis.

Dr. Frederick Peterson early [1] published some experiments on the application of drugs cataphorically for the relief of neuralgias, and the following are given as characteristic examples in the hope that they may be suggestive to others.

"*Cataphoresis in a Case of Supra-orbital Neuralgia.*—Dr. E. C. Seguin kindly placed at my disposal an obstinate and severe case of right supra-orbital neuralgia. L. E., female, aged forty. Duration of neuralgia, a year and a half. Everything tried unavailingly. Suffering every few minutes with the usual agonizing pains of the disease. There was slight analgesia over right half of the forehead and right side of nose, but exquisite hyperæsthesia of the tactile sense in the same areas, so that a slight touch or breath of air was exceedingly painful. There was great tenderness on pressure. The two-ctm. square anode with a ten-per-cent. solution of cocaine was placed in the right supra-orbital

[1] "New York Medical Journal," April 27, 1889.

region over a painful spot, and the eight by twelve ctm. sponge and wire cathode in the right palm. Nine Grenet cells were used for three minutes, then raised to eleven cells for two minutes longer, which caused prickling but no pain ; and then raised to thirteen cells, which was too painful, and was reduced to twelve cells and continued for five minutes. The whole application lasted ten minutes without break of current. There was no neuralgic pain during this time and the hyperæsthesia had disappeared. There was the expected anæsthesia. The patient was completely relieved from pain for from four to five hours.

"A second similar application was made the next day in the same case by Dr. Seguin at his office with equally gratifying results.

"Same case and same electrodes as in No. 12. Seven Grenet cells, five milliampères current strength, ten-per-cent. solution of cocaine, six minutes' application. Equal relief.

"Same case and details. Eleven cells, ten-per-cent. solution of cocaine, six minutes. Equal relief.

"Same case. Application by Dr. Seguin. Ten-per-cent. solution of cocaine, fifteen milliampères current strength, twenty minutes' contact moving slowly over different parts of right supra-orbital region. Very great relief for five hours.

"Same case. Sixteen to twenty cells, ten-per-cent. solution of cocaine, five to seven milliampères current strength, nine minutes. Same relief. In this case aconitine pushed to its toxic effects did not relieve pain. The cataphoric application is still in use in this case, and always with the marked results mentioned. Latterly several applications of the anode with a twenty-per-cent. solution of cocaine have been still more distinctly beneficial. On one occasion she had eleven hours of perfect freedom from pain, the longest interval of relief in a year and a half. Whether any actual curative effect will be produced it is now too early to determine. The patient herself is so convinced of the efficacy of this method that she will now try nothing else."

"*Relief in a Case of Double Trigeminal Neuralgia from Cataphoric Use of a Mixture of Cocaine and Aconitine.*—E. B., female, aged thirty; excruciating double trigeminal neuralgia of a year's standing, upper two branches. Had tried blisters, electricity, and aconitine internally, and once had morphine habit. No day without pain. Twenty-eight chloride-of-silver cells. Water rheostat. Twenty-per-cent solution of cocaine on anode one centimeter in diameter to right temple over painful spot for twelve minutes. Cathode six by ten centimeters in right palm. Complete anæsthesia and analgesia and relief in that side. Same for five minutes to left temple with like beneficial result. Then four minutes over main trunk of nerve in front of right ear with a mixture of equal parts of twenty-per-cent. solution of cocaine and the solution of aconitine (gr. iv to 1 ounce), causing deep anæsthesia to touch and pain. With this last there was slight burning sensation at first, but it subsided in a minute or two. Relief from pain experienced for several hours."

"*Relief of Dorsal Neuralgic Pains in Locomotor Ataxia by Aconitine Cataphoresis.*—S. B., male; a case of locomotor ataxia suffering from intense neuralgic pains in the back at mid-dorsal region. Cathode on left side of abdomen. Anode one centimeter in diameter with aconitine as in No. 24 to region of greatest pain. Fourteen Leclanché cells, five to six milliampères current strength, four minutes' application. A white elevated disc larger than the area of anode was produced which was completely analgesic and anæsthetic for an hour, but in which there was a burning sensation for an equal length of time. The neuralgic pains were relieved for eight or nine hours. This was tried again a few weeks later with ten minims of tincture of aconite on the anode, with equal effect.

The most general form of procedure in securing medicamental diffusion is the electric bath. Bossi was the first to attempt to introduce medicines into the body by means of the electric bath.

Gärtner and Ehrmann employed the cataphoric introduction of mercury by means of the 2 cell bath of Gärtner.[1] He placed from 4 to 6 grams of bichloride of mercury in the bath employing about 100 m. a., for 15 to 20 minutes. An examination of the urine showed as much as 0.7, 0.3 and 1.3 m. g. of mercury present. Ehrmann employed this method in 34 cases of syphilitic diseases, the maximum number of baths being 54 in any one case. Toward the end of the treatments he employed the baths either every day or every other day, reducing the bichloride of mercury to 2 grains per bath.

In Prof. Lang's clinic Kronfeld made use of Ehrmann's bath in the manner described. He has

[1] "Elektrodiagnostik und Elektrotherapie," Lewandowski. Wien und Liepzig, 1892, p. 448.

published eight cases in which he cured syphilis. (See "Hedley" p. 99.)

Instead of using a full bath, tubs may be used for the feet and legs and basins or jars for the hands and arms. The tub employed should be of wood or porcelain and the medicated solution forming the body of the bath is made to constitute a positive pole by dipping into it a carbon plate connected to the battery. This may be protected by insulating material. The negative pole is a rod of brass several inches in diameter laid transversely across the tub around which may be placed wet towels, sponges, punk or similar substances which can be held in the hand and brought against the arms so as to gain a large surface of contact.

Those desiring to give extensive attention to this branch of cataphoric medication are referred to a recent and most admirable treatise upon the general subject of electric baths and hydro-electric methods in medicine by W. D. Hedley, M. D., of London.[1]

Further applications may be made with electrodes already described and will most naturally be of great variety according to the disease to be treated.

Cataphoresis has been mentioned as applicable in the treatment of consumption, by Dr Crotte. Formaldehyde is inhaled in a gaseous form and static electricity is at the same time applied to the chest. This would seem to be an initiative in a direction which may later be followed in a manner which will better appeal to our judgment.

In gynecological practice it is often desirable to introduce various remedies, for the purpose of

[1] "The Hydro-Electric Methods in Medecine," by W. D. Hedley, M. D., London, 1896.

causing their absorption into the pelvic organs or mucous membranes. For general applications no better apparatus can be suggested by the writer than that illustrated in Fig. 39. The mucous surfaces of the vagina readily absorb iodide of potash, iodoform, salicylic acid, salol, watery solutions of iodine, mercurials, salts of the alkaloids, etc. For more local applications, such as electro-cocaine, local anæsthesia of the cervix, the electrode shown in Fig. 33, should be employed.

In the treatment of diseases of the skin, cataphoresis would seem to be peculiarly applicable. In these diseases absorption is commonly promoted by emollients, but absorption would be greatly enhanced by the cataphoric power of the electric current.

For such cutaneous disorders as are commonly treated by painting with iodine the use of some of the iodine preparations, such as potassium, sodium or lithium iodide, iodol or diluted aqueous solution of iodine is called for.

Woodbury reports a case of cutaneous syphilitic neoplasm treated by the cataphoric application of iodide of lithium[1] and Shoemaker[2] has employed cataphoresis in general cutaneous affections.

I have employed the cataphoric introduction of drugs extensively in the treatment of rheumatic and gouty joints. The following case will serve to illustrate the general scope of many others.

April 13, 1894, Mrs. S. A. A., æt. 45. Gouty knuckles, deformity, pain, existing for about 10 years: the first and second joints of both hands about equally affected. Rubber "umbrella rings,"

[1] "Medical News," Philadelphia, June, 1890.

[2] "Sajons's Annual," 1890.

see Part I., Chap. IV., were passed on to each finger to cut off the circulation and the fingers dipped up to about the level of the rings into a solution of Bromide of Lithium. Fifteen milliampères of current was passed during fifteen minutes, positive electrode placed in the water. Great relief for 24 hours.

April 30, May 3, 5, and 7. Same treatment and continued improvement.

May 5. A saturated solution of piperazine was placed upon blotting-paper wrapped about the distal joint of the index finger (the joint most affected) and a piece of platinum foil wrapped about the blotting-paper made a positive pole, conveying 10 milliampères during ten minutes.

May 9. Patient reports that this joint feels very much better and softer and is smaller.

May 14. Both lithium and piperazine treatment as above described were repeated at intervals until June 2, when Tetra Ethyl Ammonia, a few drops on blotting paper, was substituted for piperazine. The knuckles now presented quite a creditable appearance and exhibited scarcely any traces of enlargement. In my experience I find that if the gouty enlargements of knuckles are soft and of recent formation they may be dissipated, while if hard and chalky they cannot be dispersed.

The chloride, benzoate and citrate of lithium are all very soluble salts and may be used with the positive pole in the above manner. The mercurial salts and aqueous solutions of Iodine are well adapted for cataphoretic purposes.

The rhinologist and laryngologist will find the method particularly adapted to the treatment of many difficulties of the upper air passages which may require the application of anæsthetics, astringents or antiseptics.

Among other interesting and useful applications is that by Dr. P. Aubert,[1] of Lyons, of pilocarpine as a sweat-producer. M. Aubert uses for a novel purpose the well-known fact that pilocarpine introduced into the system will induce perspiration. He applies a solution of pilocarpine at the positive electrode and produces *local sudation*, limited strictly to the area subjected to the treatment or beneath the electrode. Realizing that the sweat is rich in chlorides, and especially chlorides of sodium, he is able, by an ingenious method of procedure, to obtain what he calls "sweat prints" or a record of the points at which sudation has taken place or, in other words, the number and disposition of the sweat-glands. His method is as follows: He induces cataphoric local sudation and then applies a piece of clean white paper, free from treatment of any kind, to the region where this effect has been produced. Each orifice of the sweat glands leaves on the paper a minute drop of a chloride solution. When the paper is raised and brushed over with a weak solution of nitrate of silver the chloride spots are acted on and chloride of silver is formed at such points. An examination at the light reveals by the little black dots of chloride of silver the points where sudation has taken place.

Pilocarpine can only be introduced when in a solution with water, alcohol or glycerine. The question arises whether, in applying medicaments cataphorically, it would not be wise to add a little pilocarpine to the solutions and thus help to open up

[1] "Archives d'Electricité Médicale," Nov. 15, 1895, page 441.

the sweat glands and make better pathways for the introduction of the medicament.

Conversely to cataphoric medication I will make a brief reference at this point to cataphoric de-medication. The earliest hint as to the possibilities of this procedure was derived from the experiments of Vergnès described in Part I., Chapter II. But Vergnès's experiments related entirely to the removal of local metallic deposits from open lesions, like, for instance, an ulcer. It occurred to me that if metals could be introduced into living tissue that it should also be possible to reverse the process or remove them. This I have found to be true. The operation can be performed in cases of lead, copper, arsenic and other metallic poisoning. The patient is placed in a bath as already described, but in place of constituting the solution of the bath *positive*, it is made negative, while the positive electrode is a large sheet of carbon brought into generous contact with the arms and hands. Into the bath solution in the case of copper poisoning is allowed to dip a clean sheet of iron, say two square feet in dimension. Upon turning on the current up to about fifty milliampères and allowing it to flow for about half an hour, always within the limits of comfort to the patient, it will be found, after the cessation of the treatment, that a deposit of copper has occurred upon the iron plate. The water of the bath should be slightly acidulated with sulphuric acid.

This treatment of cataphoric de-medication must not be confounded with that of introducing iodide of potash cataphorically to serve as a solvent to the lead salts in the tissues. This of course is perfectly feasible, not only in the case of lead but in that of other forms of metallic poisoning and with other reagents.

In 1896, Dr. Van Marter, who had read of my experimentation along this line, brought to my attention a severe case of copper poisoning, being himself satisfied that the treatment was not only indicated but also likely to be successful. The patient was admitted to the Post-Graduate Hospital, Feb. 10, 1896. The case was as follows, and since there exists so little literature upon the subject I will cite Dr. Van Marter's notes, which include a good deal of original investigation on his part, in extenso.

"N. Greene, colored, worked eight years in fluxing room, Ansonia Brass & Copper Co., last three years didn't wear sponge, having gotten "used" to the fumes. Lost weight and strength steadily, had fever, green sweats, colics, chronic cough. Examination in Dec., 1895, showed no tubercle bacilli in sputum, general bronchitis; severe laryngitis. On examination the vocal chord showed plainly a green stain, quite dark and general, blue line on gums; metallic taste in mouth; hair stained bluish-green. His condition was bad, and every indication of tubercular laryngitis (of which he subsequently died) except tubercle bacilli. However, there being no question as to *cause*, and as he agreed to be experimented on, I sent him to the Post-Graduate Hospital for Dr. Morton's experiment, which conclusively proved the correctness of the "à priori" views in regard to the electric de-cataphoresis. The man was, however, so far gone and so weak that the experiments were discontinued, and he returned home to die slowly in peace.

" Chronic copper poisoning occurs in three forms : I. That acquired by copper miners and handlers of copper—a very mild and evidently harmless form. II. That acquired by those who are compelled to breathe the fumes of molten copper and its alloys—either in smelters or copper and brass foundries. this is a very severe and sometimes fatal form of poisoning. III. That acquired in the arts from brass filings—as seen amongst metal turners. This form is dangerous only on account of the mechanical irritation caused by the fine particles of brass (or similar) metals, inhaled—and deposited without change in the respiratory tracts.

" Form No. II., viz, that acquired in smelters and foundries from the fumes of molten copper " flux," zinc, and allied metals, is a very common form of poisoning. I have seen a large number in Ansonia, and Derby, Connecticut. It is often fatal—but I believe only indirectly so. In these cases, copper was the principal but not the only metal concerned : zinc, lead, tin, and traces of arsenic exist in the " flux " of the various alloys of copper. Clinically the symptoms of chronic copper poisoning are divided into three classes, sometimes each class is seen alone, sometimes together, the most common being : I. The form affecting principally the respiratory organs ; II. The form affecting principally the abdominal organs ; III. That affecting the central nervous system.

"*In Class I.* the symptoms are those of chronic Pharyngitis, Laryngitis, Bronchitis, Asthma and ultimately Emphysema, and very often followed by Tuberculosis, assisted by the local irritation.

"*In Class II.* the symptoms are usually metallic taste in mouth, epigastric pains, giddiness, headaches, wasting of body with a daily rise of temperature, colics quite frequent, cramps in extremities.

"*In Class III.* the symptoms are more obscure and insidious cramps are common; disturbances of sensibility, loss of muscular strength, burning, superficial pains, reflex activity of legs greatly increased, and often the "girdle" pains--in fact all the features of myelitis—this variety was first recognized and described by Schlockow, in 'Deutsche Med. Wochenschrift,' 1879, page 208.

Cataphoric medication, on the whole, is pre-eminently due to a diffusive effect exerted upon a medicament placed at the positive pole, but exceptions to this rule have already been carefully noted. In this connection I will refer to the conclusions arrived at by Prof. Simon Fubini and Doctor Pierre Pierina of Pisa, in a recent clear and exhaustive account of this entire subject.[1] As the result of these experiments, the authors conclude that:

1. The constant current determines the passage of certain elements through the skin, but for the introduction of some substances it is necessary that the current have one direction, and for other substances the opposite direction. Therefore the writers do not consider the statement that the passage of substances through the skin in cataphoresis is always in the direction of the current to be of universal application.

2. The iodine of potassium iodide, the salicylic acid of sodium salicylate, and of lithium salicylate penetrate the organism when the *negative* pole is in the aqueous solution of these salts; the strychnia of strych. nit., the atropine of atrop. sulph., the quinine of quin. hydrochl., the cocaine of cocain. hydrochl., the lithium of lith. salicyl. pass into the body when the *positive* pole is in the aqueous solution of these salts.

Dr. Max Aker-Blum of Wilmanstrand, Finland, has also recently written an excellent paper[2] on Cataphoric Medication and the theory of its electro-chemical action. Dr. Blum investigated especially the iodine salts and comes to the conclusion that the iodine salt solution should be placed at the cathode.

[1] Sur la Cataphorèse Électrique. Experiences faites sur homme et sur plusieurs espèces d'animaux. Archives d'Électricité Médicale, 15 Aout, 1897. See also Treatment, Rebman & Co., Publishers, London, 1897.

[2] See Electrochemishe Zeitschrift, Berlin, June 1, 1897, p. 49, for article by Rudolf Mewes founded upon Blum's paper.

CHAPTER III.

ELECTRO-COCAINE LOCAL ANÆSTHESIA.

If medicaments held in solution may be diffused throughout tissue by the action of a continuous electric current, and a drug is employed which when used hypodermatically will produce an anæsthetic condition, such a condition will be produced in the tissue penetrated by such current and solution.

The portion of this book devoted to the historical development of this procedure of electric medicamental diffusion treated in considerable detail of the cataphoric use of cocaine to relieve the pain of neuralgia. But to use cocaine cataphorically to produce a practical local anæsthesia sufficient for minor surgical operations is quite another matter, and for that reason this branch of the subject is here referred to separately.

Following in the footsteps of Richardson's Voltaic Narcotism of 1859 supplemented by Wagner's suggestion of 1886 to introduce cocaine by electricity, many no doubt have sought, but without success, this consummation. At each recurring lecture upon the subject of cataphoresis at the Post Graduate Medical School and Hospital, and as often as four times each winter, I have anæsthetized by electricity and cocaine a spot one inch in diameter upon a patient's arm and transfixed a thick fold of the skin by a needle without pain in order to point out the availability of the method in surgery. The first record of my own I am able to find, and I believe it is the earliest extant of the actual performance of operations during electro-cocaine anæsthesia, is as follows :

Case 1. Dec. 1, 1891.—A. D., servant, while scrubbing a rough floor a splint of wood about $\frac{3}{4}$ of an inch in length had penetrated the fleshy part of the thumb. I anæsthetized an area of one inch in diameter, using a block tin electrode, aqueous solution of cocaine, 10 per cent., on blotting paper, and electricity. Five to six milliampères of current were allowed to flow for 8 minutes. Dr Howard Lilienthal cut out the splinter without pain though the subject was of a highly excitable temperament. In a paper [1] read before the Medical Society of the State of New York in February, 1895, I stated that "there are few minor operations in surgery that I do not now perform under electro-cocaine local anæsthesia."

Illustrative of this practice I append a few cases, taken at random from my note-book, containing many other similar records.

Case 2. May 18, 1892.—E. S. Large vascular tumor on upper lip. Electrode one inch in diameter. Electro-cocaine local anæsthesia, aqueous solution, 10 per cent., 7 ma., 10 minutes. Anæsthesia complete. Several iron needle punctures, positive pole, caused no pain. Tumor cured.

Case 3. May 16, 1893.—M. H. H. Dermoid cyst. Electrode one inch in diameter. Electro-cocaine

[1] "New York Medical Journal," Apr. 20 and May 4, 1895.

anæsthesia, aqueous solution. Anæsthesia complete. Copper bulb positive pole within cyst, 15 ma., 15 minutes. Cyst cured.

Case 4. Jan. 28, 1894.—Mr. C. H. H. Warty growth at top of nose. Electrode one inch in diameter. Aqueous solution of cocaine eight per cent., 10 milliampères, 10 minutes. Zinc needle, positive pole.

Case 5. Feb. 13, 1894.—Mrs. R. Lipoma on neck. Electro-cocaine. Anæsthesia, aqueous solution, 10 per cent. solution of cocaine, 7 ma., during ten minutes. Incision with scalpel and copper bulb inserted, 25 ma., 23 minutes. Lipoma caused to completely disappear.

Case 6. Feb. 21, 1894.—Mrs. DeW. C. Fibroma of face. Electro-cocaine anæsthesia, aqueous solution, 6 ma, 10 minutes. Each fibroma punctured with a tenotomy knife and a very small copper bulb sunk into its middle. Each fibroma treated was obliterated.

Case 7. Dec. 3, 1895.—Mr. D. D. S. Lupus, extensive infiltration and sclerosis of tissue and ulceration involving the angle of the mouth on the right side over an area of about two inches across. Also separate nodule size of a bean on lower lip. Three applications guaiacol-cocaine, 8 per cent. solution, one inch electrode, 4 ma., 5 minutes, profound local anæsthesia. The entire affected area was treated with copper bulbs, positive pole, the bulbs sinking deeply into deep holes in the tissue. Size of bulbs, one-half of an inch long and one-third of an inch wide. Result, complete cure.

Case 8. April 15, 1896.—Mr. E. H. H. Sycosis parasitica. Electrode one inch in diameter. Guaiacol-cocaine anæsthesia. Five punctures copper needle, 2 ma. each puncture. Result, growth killed and no recurrence, nor no scar.

Case 9. May 5, 1897.—Miss G. L. B. Varicose vein on back of neck. Electrode three inches in length. Guaiacol-cocaine anæsthesia, two milliampères, four minutes. Zinc needle, positive pole, punctures within and along length of vein. Result, perfect, no remaining sign of the blackish disfiguring vein.

Case 10. May 6, 1897.—A. M. L. Protuberant nævus on forehead. Electrode one inch in diameter. Guaiacal-cocaine, anæsthesia complete. One milliampère four minutes. Zinc needle, positive pole to destroy nævus deeply. Result, no remains of nævus, no perceptible scar.

AQUEOUS SOLUTIONS.

Electro-cocaine, local anæsthesia by means of aqueous solutions of cocaine is then practicable. From four to twenty per cent. solutions may be employed—an eight per cent. solution is a fair average per cent. A piece of blotting-paper is fitted to one of the perforated electrodes already described, and the solution is filled first into the perforations and then dropped upon the blotting-paper, and the electrode, constituted positive, is put on the part to be affected, with the indifferent (negative) electrode placed elsewhere.

We will take for example the electrode, one inch in diameter. With a current strength of eight to ten milliampères (all that is easily bearable by the patient) and an eight per cent. solution, at least ten minutes will be required to produce local anæsthetization.

Before making the application the oil should be washed from the skin by soap and water.

GUAIACOL-COCAINE SOLUTIONS.

Taking again an electrode one inch in diameter let us drop into the perforations and upon the blotting-paper an eight per cent. solution of guaiacol and cocaine. Upon applying the electrode (no preparation of the skin is required), it will be found that on permitting one to three milliampères of current to flow, an anæsthesia more profound than by aqueous solutions is produced in from two to four minutes. This estimate of time and of current strength is a very conservative one. While in the case of aqueous solutions there is often a desire to force the current beyond the ability of the patient to bear the pain of its initial onset and first continuance, in the case of guaiacol-cocaine the patient is seldom aware that any current at all is in action. Thus the combination of guaiacol and cocaine renders the procedure much more convenient and effective. The recipe for an eight per cent. solution would read :

Guaiacol (pure) ʒ i,
Cocaine Hydrochlorate gr. vi.

The percentage may be increased to thirty per cent.

Among the many attempts made by the writer in conjunction with Mr. Wm. J. Evans, of McKesson & Robbins, to discover an efficient combination of guaiacol and cocaine two may be mentioned :

1. The first of these was termed guaiacol-cocaine, an apparently true chemical combination between cocaine and guaiacol.

2. Guaiacol sulphonate of cocaine, a combination of 61.5 per cent of cocaine alkaloid and 38.5 per cent of guaiacol sulphonic acid.

Finally, the following case from among others of its class, such as the incision of a felon, etc., is reported in full, since it serves to elevate electric medicamental diffusion up and out of a promiscuous mass of applications of various drugs for various purposes, and to place electro-guaiacol-cocaine local anæsthesia before the surgical profession as an entirely practical procedure for minor and even for major surgical operations.

Case 11. Dec. 17, 1897.—*Removal of a large pigmented nœvus.*[1]

In order to dispel any doubts concerning the efficacy of cataphoric procedures to produce local anæsthesia, both extensively and deeply, I anæsthetized in two applications (owing to the relatively small size of my electrode, which was only $1\frac{3}{4}$ inches in diameter) a skin area beneath the axilla of three inches in length and one and a half inches broad. The operation was performed at the New York Post-Graduate School and Hospital, by Dr. F. N. Wilson. The patient was Dr. F. P. Williams. Five minutes only were required to anæsthetize the area beneath the electrode; the guaiacol-cocaine solution was employed. Two deep linear incisions were made, each about three inches long and half an inch deep, in such a manner as to include the nævus and surrounding healthy skin, and the included piece

[1] Morton: "The Dental Cosmos," Jan., 1896, page 51.

then dissected up from the sub cutaneous tissues. A slight burning sensation of the knife was felt only at a certain part of the long incisions which were made outside of the anæsthetized area, but the dissecting out was absolutely without pain, as well also as the torsion of five small arteries and the insertion of ten deep stitches to close the gaping wound. No pain was produced in procuring the anæsthesia. Referring to the torsion of the arteries by the clamps, the patient, himself a physician, said, "It is funny I can bear that clamp, because they usually jump out of the chair," and "I knew what he was doing, but it gave me no pain," etc.

It is noteworthy in this case that the anæsthetic effects extended at least one-half an inch deep, and that there were no toxic effects of cocaine (a 16 per cent solution in guaiacol was used). The absence of toxic effects seems to me to be due to the fact that the guaiacol holds the cocaine in solution, thus localizing its action and preventing its diffusion into the circulation. This is of the highest importance, since the only objection which could be raised to the use of cocaine so extensively and of such strength as described in the above instance would be the danger of the absorption of a poisonous dose, especially in a highly vascular tissue such as the nævus operated upon. No reactionary hyperæsthesia followed the operation, and the wound healed by first intention.

In the chapter on electrodes some are illustrated as large as 6 inches in diameter and some 6 inches in length by 2 inches in breadth. With electrodes of this size I have successfully anæsthetized with the guaiacol solution correspondingly large areas upon the abdomen, back and legs. The time occupied was about six to eight minutes. The time, the size of the anæsthetic area and the depth to which it extends would seem to lead to the opinion that in this method we have a procedure superior from many points of view to the infiltration and older methods of hypodermatic injection of aqueous solutions of cocaine.

Among many experiments tried in December, 1895, I quote from one relating to erythrophleine hydrochlorate. This salt is readily soluble in water. It was introduced as a local anæsthetic some years ago by Dr. L. Lewin, of Berlin, for operations on the eyes. Solution placed on blotting paper in my perforated electrode one-third of an inch in diameter and electrode held upon the forearm : two milliampères of current was allowed to pass for seven minutes ; complete cutaneous anæsthesia beneath the electrode was established ; the reaction was, however, slightly painful, unlike that of cocaine.

Nothing has been said about experiments with eucaine and other drugs, because none of them has been found as effective as cocaine.

There is one further observation I would make, and this is that in many cases while the sensation of pain is totally abolished, the sense of contact or touch may yet remain intact. The patient often confounds the two sensations. The operator should be on his guard against this contingency.

Great as are the services of electricity to man, no service it has yet rendered will be more sympathetically appreciated than that of aiding in releasing him from the thraldom of pain. It is not impossible that this new era may arrive.

CHAPTER IV.

ELECTRIC DIFFUSION FROM SOLUBLE ELECTRODES.

THE destructive electrolytic action in human tissue of either pole of a continuous electric current is perfectly familiar. The electrodes are usually of metal, and care is taken that they be unoxidizable, as is, for instance, platinum or gold, if they are to be used at a positive pole, while, if used at the negative pole, they may be oxidizable or not. The positive pole electrode, when the current is in action, forms oxygen and acids out of the tissue itself ; the acids are mainly hydrochloric, sulphuric and phosphoric. The negative pole forms hydrogen and alkalies, the latter usually caustic soda and potash. Each pole is practically a little chemic workshop by itself—the one acid, the other alkalin ; the analytic and synthetic energy being furnished by the electric current and the materials acted upon being furnished by the tissue. The resultant and desired destruction of tissue is due to a number of factors, chief among which are that amount of tissue used to make up the newly formed and foreign chemicals, the secondary action of these newly formed products upon the remaining tissue, and the disruptive effects upon the structural composition of the tissue of the gases interstitially liberated. And the character of the artificially produced lesion and its resultant eschar is determined, to a great extent, by the second of these actions, whether it has been an acid or an alkalin corrosion or destruction. The lesion resulting at the negative pole is rich in fluids (by cataphoresis), and is slower to heal; it leaves, however, a smoother and less contractile cicatrix (an important consideration in the removal of facial blemishes). The lesion resulting at the positive pole is comparatively dry (also by cataphoresis), is quicker to heal and leaves a rougher and more contractile scar.

It will be observed that in this, the familiar form of electrolysis, no account is taken of the nature of the active electrode employed except that it be unoxidizable, insoluble, and therefore indestructible, and that as a consequence reliance for the electrolytic effect is based directly upon the characteristic effect of the current upon the tissue and not upon its effect upon the electrode. Any action of the current upon the electrode is, in fact, carefully guarded against.

But if we turn our attention to the nature of the metal which composes the electrode, be it the positive or (as I have demonstrated) the negative, an entirely new field of investigation and of results is opened out to our view. If our positive electrode be composed of a metal which is attacked by oxygen or by chlorin (formed at that pole out of the tissue), then a new chemic compound is formed at the point of the application, and we have no longer to deal with the effect of the liberated chemicals directly upon the tissue, but we are confronted with a new effect, viz., that of the newly formed chemic compounds (metallic salts) upon the tissue. And since, owing to the nature of human tissue, hydrochloric acid is pre-eminently formed at the positive pole, we shall find if copper, zinc, iron or other attackable metal is the metal employed at that pole, that we have formed respectively the oxychlorids of copper, zinc, iron, etc., double salts of the metal.

In this connection we may observe the further interesting fact that under the above circumstances the action of the current is almost entirely expended in decomposing the metal, and that as a consequence the undesirable destructive action of the usual electrolysis is avoided. For, as I have observed in practice and as will be seen upon reference to the cases in which this method of treatment is applicable and peculiarly efficacious, the destructive action of the current would be in the highest degree detrimental. The object is not to destroy tissue, as by actual cautery or by the application of caustics, but to implant within it and permeate it with the newly formed metallic salt. In fact, so distinctive is this new method, which is termed by Gautier, its modern author, interstitial electrolysis, from common surgical electrolysis, that it is unfortunate to use the term, electrolysis, at all in relation to it. The electrolysis is, as has been pointed out, principally of the metal, and but to a very limited extent of the tissue. A far more characteristic feature of the process is that the product of the electrolized metal permeates tissue, and it is for that reason that I feel compelled, in speaking of the method, to designate it as electric diffusion.

Another noticeable feature of electric diffusion of salts formed from soluble electrodes is that a remarkably low current strength suffices to set free a large amount of the metallic salt. Here, again, is a reason that very little of the usual electrolytic destruction of tissue ensues. Gautier, indeed, calls attention to this fact, and characterizes this method in its gynecologic applications as one of low current strength and long sittings, in contradistinction to the Apostoli method of high current strength and short sittings. In practical work, I have found that very low current strength, from 1 to 10 milliampères, gives much better results than from 10 to 50 milliampères. In this connection it should be noted that the electrode loses in weight. Gautier has found, as would be expected, that the loss in weight is proportional to the current strength and the duration of the current flow.

Again, the solution of the metallic electrode is not confined, as thus far supposed, to the positive electrode alone. I have found by experiment that soluble electrodes may also be employed at the negative pole. One of the best of the metals for this purpose is aluminium. The extension of metallic electrolysis to the negative pole greatly widens the field of this new method, since, while at the positive pole we have thus far been confined to the oxychlorids of metals, we now at the negative pole may apply to diseased tissue another class of metallic salts.

Electric diffusion, as the word, diffusion, indicates, possesses an obvious advantage over the ordinary topical applications of similar or other metallic salts of copper, zinc, iron, aluminium or other metals. For it is obvious that not only is the salt dissolved off of the metal, but by another and further property of the current it is forced into the tissue in a radiating direction around the metallic electrode.

In this respect, electric diffusion is remarkably unlike the application of the ordinary solutions by a brush, spray or injection, or their injection into tissue by the hypodermatic needle. The solution of the salt is not only applied but it is driven in. To use a homely simile, a wash or spray is like a nail held against a board, while electric diffusion plays the part of the hammer which drives the nail home.

The dissolving action of the electric current upon a metallic electrode, constituting a positive pole and applied within human tissue, had been noted by various authors in relation to the treatment of some diseases, particularly tumors, by electrolysis. Both Butler and Stevenson and Jones refer to this action upon zinc needles and point out the conjoint efficacy of the combined destructive action of the current and the newly formed chlorid of zinc.

Butler says : [1] "Electro-puncture is presumed to have been performed with needles made of unoxidizable material. Should the needle of the positive pole be made of material capable of being acted upon by the acids set free at this point, the results are modified to a great degree. For example, suppose the positive needle be made of iron, the needle becomes dissolved by the acids set free, and the phosphate, sulphate and chloride of iron are formed, principally the chloride. From this fact we would infer that iron needles would be useful where coagulation of blood is the result aimed at. And there is no doubt that they assist in the accomplishment of such a result to a considerable extent.* * * Another

[1] "A Text-Book of Electro-Therapeutics and Electro-Surgery," by John Butler, M.D., New York, 1880, page 213.

advantage of the operation is, that it is comparatively painless, in some cases entirely so."

Numerous successful cases have been published by French physicians, among whom are MM. Jouslain, Gautier, Larat, Imbert de la Touche, Delineau, Darier, Bergonie, and Bordier.

Onimus, of Paris, and Prochownick, of Hamburg, appear to have casually used soluble electrodes at the positive pole. The latter applied a copper sound with a current strength of from 80 to 100 milliampères in a case of gonorrheal infection of the uterine cervical canal.

But these isolated observations made almost no impression upon practice, and it remained for Dr. Georges Gautier, of Paris, to grasp the broad idea of diffusing metallic salts from soluble electrodes and to inaugurate by a series of experiments this new system of procedure.

I have already expressed a preference based upon much experience, for low current strength and prolonged time. It is difficult to lay down rules which shall apply in so many diverse diseases. In needle puncture (copper or zinc needles) I prefer to use no more than 2 milliampères applied at any one site for about three to five minutes. In a case of sycosis, reported later on this was quite sufficient to cure the disease. In lupus, ulcerations, pustules and acne this is also quite enough current strength. Gautier reports using 50 milliampères in a case of lupus, but I have found the high current strength seriously objectionable because of the consequent electrolysis of tissue and extension of the time of healing. In hypertrophic nasal catarrh with copper bulbs, I find about 4 to 8 milliampères sufficient. In ozena the same; in trachoma 1 to 2 milliampères and in intra-uterine applications from 10 to 20 milliampères; in gonorrhea 1 to 2 milliampères.

No positive rule can be laid down, since much depends upon the size of the electrode. In order to facilitate accuracy of dosage, I employ copper bulbs graduated according to the French scale of catheter or other electrodes whose surface area is a known quantity.

The operator may convince himself, if he desires, of the great rapidity of the electric diffusion of the copper salt by sticking the needle lightly into his own skin, or that of a patient, and watching the almost immediate formation of a small circular area of an apple green color. This is also well seen in a small wart or similar growth; the mass turns light green.

A practical point of importance is to thoroughly polish each electrode immediately before using it. This is easily accomplished by the aid of a piece of fine emery paper.

The adherence of the electrode to the tissue is a peculiarity and a danger. Even with a current strength of from 2 to 4 milliampères this adherence is noticeable. Therefore even when low current strength is employed as during the application of smooth metallic surfaces to mucous membrane, as in nasal and throat diseases, in trachoma, urethritis, etc., the electrode should be kept in slow movement, either longitudinal or rotatory. In the case of needles plunged into tumors and of sounds within the uterus this adherence can not be overcome by any safe manipulation; the needle must be loosened by reversing the polarity and using from 4 to 8 milliampères for about five minutes. The adhesion is due to the formation of an albuminoid salt of copper (where the electrode is of copper.)

Cases.—I present the records of a few illustrative cases. It is needless to say that much has been learned as to technique, precision and efficacy in securing results in individual diseases since my first cases were recorded.

CHRONIC TINNITUS AURIUM.

Probably there are few minor troubles more annoying to the patient than a chronic ringing in the ears; certainly there is no minor condition more difficult of cure. The cases as I have seen them are often associated with some degree of catarrhal trouble and commonly with tympanic vertigo and moderate deafness.

Case 1.—H. E., age 33; cured. Referred to me March, 1893, by Prof. D. B. St. John Roosa, to relieve him, if possible, of a most annoying and persistent ringing in both ears. Five years ago had a "dry throat"; had little saliva; mucous membranes cracked and bled; was treated by sprays for two years with no benefit; then used antiseptic washes. The uvula was elongated and had been cut off. Throat never ceased to trouble him. Two years ago had the grip, and about this time the ringing began. Present condition: weary, "nervous," depressed and irritable with much frontal headache and an almost continual ringing, worse in the left ear. The sound is like that of a distant cricket or like a sharp whistle; it worries him most when he is tired or when he lies down or after sexual intercourse. Sleep is often disturbed because he cannot get rid of the sound in his ears. As a rule it is worse at night. Has likewise much post-nasal discharge. Hearing in left ear considerably impaired; has some vertigo. The first treatment to the ears and throat was by the static induced current, then the sinusoidal, both followed by amelioration in the degree of the sound and by intervals when it ceased for a few hours. But the progress was not satisfactory to me, and I determined to treat the catarrhal condition first and cure it, before following up further applications to the aural region alone.

March 29.—Electric diffusion, copper bulb, throughout the post-nasal and pharyngeal region, 12 milliampères five minutes to each side.

March 31.—Discharges from nose anteriorly and posteriorly almost *nil*; ringing about the same.

April 3.—Ringing unimproved; headache better; slight nasal discharge. Repeated treatment.

April 4.—Raises slightly thick discharge from throat; watery discharge from nose; ringing same as ever.

April 5.—No discharge. Treatment repeated. Reports never felt so well for years, of the catarrhal symptoms. Ringing in ears ceased during the treatment.

April 7.—Headache; ringing in ears worse; no nasal discharge. Treatment five minutes, 10 milliampères.

April 8.—For a half hour after rising this morning was free from the ringing.

April 10.—Ringing ceases for long periods; no nasal discharge.

April 13.—Ringing continuous. Treatment same.

April 14.—Ringing very slight; no headache;

very little nasal discharge. Treatment, five minutes, 5 milliampères.

April 15.—Much ringing in left ear.

April 19.—Reports a discharge from the left nostril which colored the pillow in the night; a good deal of catarrhal trouble; bright yellow discharge and intense headache, also that his hearing was not so good. Discontinued treatment at the patient's request.

May 3.—Against the patient's desire I persevered with electric diffusion, applying the electrode freely to his hypertrophied tonsils and post-nasal region on the sixth, tenth and thirteenth. The ringing still persisted in a marked degree.

May 19.—Ringing the same; vertigo. Treatment same.

May 25.—Ringing and catarrhal troubles have ceased since last treatment. The throat presented an almost normal appearance; the narrowing and congestion of the fauces had disappeared; the tonsils were normal in size. One more treatment was given and the patient was allowed to cease, as nothing further remained to be accomplished. The treatment by electric diffusion from copper had occupied about two months and had been repeated about twelve times.

Jan. 30, 1894.—Patient reports that he has had no further ringing in ears and remains well of it, in spite of an attack of the "grip" during the winter.

TRACHOMA.

With the pathology and histology of this disease we have here nothing to do. It is merely a question of causing the absorption of the sago-like granulations or elevations in the conjunctiva, with the relief of the associate symptoms of pain, lachrymation and in the acute varieties the mucus discharge. The classical treatment is by operative or medicinal measures. The former removes the granulations by squeezing out their contents ; the latter attempts to cause absorption by setting up by various drugs a certain grade of inflammatory reaction. It is here proposed to treat this obdurate affection by another method, viz., the combined action of electricity and a nascent metallic salt caused to permeate the affected tissue by means of the diffusive property of the electric current. This method is very successful.

The use of electric diffusion in this disease first occurred to me in the case of an Italian woman under treatment for goitre at my clinic. The case briefly follows :

Case 1.—Jan. 4, 1892, R. P., age 50 ; trachoma both lids of both eyes. Extreme photophobia ; intense corneal vascularity ; excessive lachrymation ; trachomatous bodies ("sago grains") ; impaired vision. Treatment, electric diffusion from a copper electrode. An impromptu electrode was formed by bending a piece of copper wire into a suitable U-shaped loop. The loop was then passed *slowly* over the affected surfaces of the lids, while at the same time a current of 2 milliampères was flowing. The reader is referred to later cases for more typical results, for the reason that the treatment was inadvertently substituted at times by the use of the negative pole. But the cornea cleared, the trachomatous bodies became greatly reduced in number, the photophobia was much less, no lachrymation ; the vision improved ; the patient could see better and was able to read. This case simply initiated a method which was afterward carried out with more care and greater detail in my clinic, by myself and my assistants.

Care in manipulation is requisite. The eyelid should be everted as is usual in applications of the sulphate of copper or alum pencils, or the special protected electrodes devised by myself may be employed, without everting the lids. The electrode should be kept very slowly in movement or it will adhere to the conjunctiva and cause slight laceration upon removal, or at least compel the operator to reverse the polarity. Any metal, soluble at either pole may be employed, but copper and zinc are undoubtedly the best. The electrode without current will cause pain and with current somewhat more pain. To annul the pain, cocaine may be used in the usual manner.

Case 2.—Acute trachoma, first stage. March 22, 1893, patient age 11, had purulent conjunctivitis; upper and lower lids of both eyes trachomatous. Treatment: Electric diffusion from copper electrode, 2 milliampères, one minute to each lid. After the first treatment the photophobia almost entirely ceased and the granules diminished in size. The patient received six applications and was cured. April 29, 1894, about a year later, reports that he had remained well.

Case 3.—July 21, 1893. P., age 21; trachoma second stage. Referred to the clinic by Dr. Francis Valk, of the Ophthalmological Department of the Post-Graduate Medical School. During one year had suffered severely from photophobia, lachrymation and pain. Extensive ulceration of cornea and lids highly trachomatous. Treatment: Electric diffusion from copper electrode, 3 milliampères. July 24, patient much better; no pain; swelling of lid and ptosis of right eye much diminished. Less photophobia, soreness and lachrymation, trachomatous bodies very much softer and less gritty to contact of electrode. Electric diffusion from copper, 10 milliamperes from two to three minutes. July 26, edema of the lids has entirely disappeared; slight ptosis remains; no lachrymation; trachomatous bodies no longer isolated; cornea almost entirely clear. Same treatment. July 31, after the fourth treatment the trachomatous bodies had become entirely absorbed. Cornea perfectly clear. Dr. Valk stated that the result "was 50 per cent. better than he could have secured with the classical methods of treatment." Six more similar treatments completed the patient's cure, with the simple exception that some slight conjunctival redness remained as well as a moderate sensitiveness to bright sunlight. May 8, 1894, as the patient has never returned he presumably has remained cured.

Case 4.—July 21, 1893, A. D., age 8; trachoma, second stage. Purulent conjunctivitis with congestion and edema of the surrounding tissues; both upper and lower lids profusely covered with trachomatous bodies. Five treatments, electric diffusion from copper electrode, 3 to 7 milliampères; cocaine. The first treatment was followed by diminution of the mucus discharge; of the pain, lachrymation and photophobia; the trachomatous bodies softened and were gradually absorbed. Cured.

Case 5.—August 30, 1893, W. T., age 16; granular lids for seven months; pain; stiffness of lids; photophobia; morning adherence of lids; electric diffusion from copper, 3 milliampères. After twelve treatments, case cured by October 30. Applications were imperfectly made, owing to the refractory nature of the patient.

Case 6.—Jan. 15, 1894, K. S., age 17; native of Egypt; trachoma, third stage; always had weak eyes; began to be troublesome five years ago. Has photophobia, lachrymation, constant muco-purulent discharge and pain. Can only see as "through smoke." Palpebral conjunctiva scarred and white. Both lower lids, palpebral conjunctiva, adherent and dragging in the eyeball. Cicatricial conjunctivitis. Case "incurable." Treatment: Electric diffusion from zinc electrode, 5 milliampères to conjunctivæ of both eyes. March 9, 1894, reports both eyes better; now sees clearly; lachrymation has ceased; lids are no longer glued together in the morning by the mucus discharge. Repeated diffusion from zinc, 3 milliamperes to lids of both eyes. March 23, 1894, adhesions between the conjunctiva and the eyeball at the left lower lid were treated with negative electrolysis, 1 milliampère. April 18, 1894, palpebral conjunctivæ have assumed a more normal appearance. Circulation improved; less induration; patient regards herself as very well.

Case 7.—March 23, 1894, M. B., age 11; acute trachoma, first stage. Lids edematous; conjunctivæ injected; lachrymation, upper and lower lids of both eyes trachomatous. Treatment: Electric diffusion from copper, 1 milliampère. March 26, no edema; conjunctivæ lessened; sago grains have disappeared; treatment same. March 28, 1894, much better; slight redness of conjunctivæ; no mucus discharge, pain or photophobia; eyes clear and bright, 3 milliampères to both eyes. April 13, 1894, cured.

HYPERTROPHIC RHINITIS AND PHARYNGITIS.

The class of cases here referred to were of a chronic type and exhibited anterior and posterior nasal discharge, generally thick and purulent; the disturbed sensation of swallowing, due to retained secretions in the post-nasal space, narrowing of the rhino-pharynx and the characteristic symptoms of hypertrophy of the nasal and pharyngeal mucous membrane. Struck by the results obtainable in this disease by this method, I also called the attention of Dr. Clarence C. Rice, of the Department of Laryngology, Post-Graduate Medical School, to these results and he has, he writes, made trial of the soluble metallic electrodes in a number of cases which he has reported at a meeting of the American Laryngological Association in Washington.

Case 1.—Nov. 27, 1891, B. M., age 15. Ozena. One year ago patient contracted an acute catarrhal cold; it continued a month; since then has had a chronic catarrhal condition of the nasal passages. Odor began four months ago. There is a greenish muco-purulent discharge from the nose, post-nasal droppings and a slight irritative cough. Treatment: Electric diffusion from copper electrode. As in the first trial of this method in trachoma, so in this case the negative pole was also used. But experience soon taught me to confine the treatment to electric diffusion from the positive metallic electrode. By December 9, after four treatments the discharge was less, the odor less noticeable and the respiration freer.

January 8, examined by Dr. C. C. Rice, who reports deviation of septum toward right; left nostril twice the width of the right; middle turbinated bones covered with dry scaly secretions; pharynx dry with hypertrophied ridges on the sides. Further treatment by diffusion from copper was carried on, 1 milliampère for ten minutes. January 15 and 18, 5 milliampères each nostril, also same January 20, 22 and 27. Discharge diminished and less greenish. February 1, 3 and 5 same treatment. Patient, though not cured, is much better; less discharge, odor and headache. Improved.

With the present improvement in methods and electrodes I should expect to cure this patient should the opportunity present itself.

Case 2.—August 8, 1893, D. L. G., age 41. Ozena; post-nasal catarrh, atrophic. Has always "taken cold" easily. Had catarrh at 13 years of age; at 18 it had increased a great deal and he began to use salt water and a great many other nasal douches and "went to a great many doctors." His sense of smell became much impaired nine years ago, and has been growing worse ever since, until at present he cannot detect odors. The patient states, though I have had no opportunity of verifying his statement, that one year ago he had the antrum opened by Dr. Toeplitz, assistant to Dr. Knapp, and pus evacuated. This opening is still patent and must be plugged twice daily. Symptoms: Copious and most offensive anterior and post-nasal discharge; a great many crusts form; the nose bleeds easily; odor from patient's nose and mouth most offensive. Treatment: Electric diffusion from copper bulbs, Nos. 27 and 29 (Fig. 3) to naso-pharynx, 15 to 25 milliampères, occupying about five minutes. August 11, same treatment. Pharynx very much less congested; more discharge; patient says he feels very much better. August 15 and 23, crusts free themselves more easily; increased discharge from nose and slight bleeding after douching; treatment same. August 30, patient reports that his condition is very greatly improved; the incrustations remarkably diminished; very much less discharge, and that morning for the first time in eight years the sense of smell had returned to him and he had smelled paint and once more enjoyed eating; there was no offensive odor. The patient expressed himself as "50 per cent. better," and stated that no other treatment had ever accomplished as much for him.

Unfortunately, owing to unavoidable circumstances, this patient ceased treatment and has not since been heard from. It is to be regretted that the same treatment, as might easily be done, should not have been tried for the antrum.

Case 3.—Oct. 21, 1892, A. R., age 9, profuse muco-purulent discharge from the nose; nasal and pharyngeal obstruction of one year's duration. Treatment: Electric diffusion from copper electrode, about five minutes in duration and with a current strength varying from 5 to 10 milliampères. Symptoms began to improve at once, and after fourteen treatments, each several days apart, the patient was cured.

Case 4.—April 5, 1893, F. A., age 20; hypertrophic rhinitis. Had diphtheria in November, 1891. Ever since has had severe catarrhal trouble in frontal sinuses and nasal passages, anterior and posterior. Profuse, thick, yellowish discharge and much dropping of the discharge posteriorly. Feeling of intense fulness across forehead; upper lip and anterior portions of nose reddened and excoriated. Treatment: Electric diffusion from copper electrodes in anterior and posterior nasal passages on the left side. April 12, discharge not nearly so profuse nor as yellow on the side treated; less redness about the nose and lip. Right side treated in same manner as left; 10 milliampères for five minutes. Like many patients of this class he did not return and the case merely suffices to point out the immediately favorable effect of the first treatment.

Case 5.—Mrs. G. W. E., age 34; nasal catarrh, hypertrophic. Has had catarrh for three years with constant "dropping in back of throat," heaviness and dulness in head around eyes; used handkerchief constantly; good deal of nausea.

April 28.—Electrolytic diffusion to left nostril. Positive pole, 3 milliampères for fifteen minutes.

May 3.—Feeling of heaviness in head in morning gone; no nausea; application made to left nostril 5 milliampères, ten minutes; nose feels very much clearer; discomfort from application gone in half an hour.

May 5.—Same treatment to both nostrils; is feeling a good deal better; dropping in back of throat gone; scabbing in interior nostril does not occur, also diminution in amount of discharge.

May 9.—Until yesterday felt well; has taken cold and amount of discharge has greatly increased; large scab in left nostril; this was treated locally.

May 15.—Very much less discharge ; 6 milliampères to each nostril.

June 24.—About twelve treatments more of same strength ; application also made to pharynx and naso-pharynx, about 10 milliampères. Is very much better and is troubled but little. Went away on vacation at this time, and the last of September returned feeling well and nasal symptoms entirely relieved. Cured.

Case 6.—Miss H. J., age 48 ; post-nasal catarrh. About fifteen years ago affection began in left side ; had ringing in ears and heavy cold ; since has had constant buzzing on that side ; ticking of watch not heard ; right ear normal. Is not particularly susceptible to colds ; hearing is worse with a "cold" ; no pain ; has dropping of secretions into throat. Appearances, left side, pharynx atrophic ; right side, pharynx hypertrophic ; soft palate and entire isthmus dusky red. Treatment : Electrolytic diffusion 10 milliampères, applied positive pole about six minutes all over pharynx, also through left nares 10 milliampères five minutes. For a few minutes the amount used was 20 milliampères. Cured.

FOLLICULAR TONSILLITIS.

Case 1.—Oct. 18, 1893, B. G. A., age 15 ; throat began to be sore two days previously ; painful and swollen ; sense of malaise and nausea ; tonsils enlarged and grayish-white spots on both. Treatment : Electric diffusion from copper electrode to every spot.

October 20.—No more trouble with throat. Tonsils normal in appearance except for slight increase in their normal redness.

Case 2.—Jan. 18, 1894, F. D., age 18 ; shivering and hot flushes, malaise ; temperature 100 ; grayish-white spots on tonsil. Treatment : Electric diffusion from copper, 10 milliampères to every follicle as well as over entire tonsil. January 17. Patient reports that the throat was entirely relieved the next morning and to-day feels entirely well. Tonsils about normal in appearance.

URETHRITIS.

Case 1.—May 4, 1892, A. M., age 30 ; contracted disease in December, 1891. For ten months thought himself well. Discharge recommenced May 1, 1892 ; slight, free and painless ; no treatment.

May 1.—Treatment : Intra-urethral (from neck of bladder to entire mucous surface), 2 to 3 milliampères electric.

May 11.—Electric diffusion from copper electrode, 2 to 3 milliampères. A brass bulb of proper size and connected to an insulated stem was passed as far as the neck of the bladder, the current turned on and the electrode then slowly withdrawn, thus bringing under the influence of the cupric and zinc diffusion the entire urethral surface. The dispersing electrode was placed upon the abdomen.

May 13.—Patient reports that the discharge has entirely ceased. Later on he reported that it never returned and he remained cured.

Case 2.—A. M., March 19, 1893. One year later the patient referred to in Case 1, exposed himself to a new infection and contracted a severe attack of urethritis. Mindful of his previous cure he returned for the same treatment. The discharge was profuse, whitish and of the usual consistency ; there was pain upon micturition. Treatment: Electric diffusion from copper, 4 milliampères, the electrode slowly withdrawn. At one moment when the electrode temporarily adhered or "stuck," the current was reversed to negative to loosen it.

March 27.—Reports that he is much better.

March 29.—Reports to-day complete cessation of the discharge after the treatment of the 19th, but that he has now a slight relapse from "drinking too much." Treatment renewed.

March 31.—Reports that he is cured.

It may be noted here that extreme care to prevent adhesion of the electrode to the mucous membrane must be exercised in these cases. *A delicate milliampère meter is imperatively necessary,* as well as a good rheostat. From 2 to 3 milliampères of current is sufficient and the electrode must be kept in motion. At least this is the method of treating the urethra which has forced itself on my attention as essential. It is beyond question the great feature of this method, in contradistinction to that by injections, that the mucous membrane is electrically permeated with any given metallic salt, say the chloride of zinc or copper, rather than simply superficially washed by a solution of the same salt. There is an actual chemic union of the metallic salt and the deeper albuminous constituents of the tissue.

TUMORS, ETC.

Case 1.—May 18, 1892, E. S., age 60; vascular tumor on upper lip, nine years' standing, increasing in size. Three-fourths of an inch in diameter, bluish cast of color and can be partially emptied by pressure. Treatment: Electro-cocaine, local anæsthesia; first punctured by a platinum needle, positive pole, 15 milliampères for ten minutes. Upon withdrawing the needle, considerable hemorrhage ensued. It therefore occurred to me to insert an iron needle, positive pole, and secure the electric diffusion of the oxychlorid of iron—a styptic salt. This was done with 15 milliampères for five minutes. There was no hemorrhage upon the withdrawal of the needle and the tumor shrunk visibly in size.

May 20.—Tumor more compact; electric diffusion from an electrode 25 milliampères, twenty minutes. To withdraw the electrode without tearing tissue, the current was reversed at 15 milliampères for five minutes; no hemorrhage; needle almost destroyed by the action of the current. Tumor contracted.

May 23.—Tumor reduced one-third in size. This patient did not return.

Case 2.—Feb. 13, 1894, Mrs. R., age 30; lipoma, one and one-half inches long by one inch wide at base of neck. Patient was unwilling to take ether to have the growth removed and did not want to have a scar. Experimentally, since I knew of no previous fatty tumor removed by electricity, I consented to try and extirpate it. Operation: Electro-cocaine, local anæsthesia, 7 milliampères, 10 per cent. solution cocaine for ten minutes. A puncture was made with a microscopic trocar and the small piece of tissue sent to Dr. H. T. Brooke of the Post-Graduate School, Pathologic Laboratory, for examination. He subsequently pronounced it to be a lipoma. A copper electrode, three-quarters of an inch in length and one-sixteenth in diameter was inserted into the puncture made by the trocar, the skin being protected by the insulation of the stem of the electrode. The electrode thus sunk into the centre of the mass of the tumor was allowed to remain for twenty-three minutes, with a current strength ranging from 10 to 25 milliampères. The resistance to the current flow was great, owing to the fatty nature of the growth. At 25 milliampères the patient had violent palpitation of the heart and was upon the verge of syncope, owing to the presence of the electrode near the great nerve trunks. The wound being antiseptic no special dressing was applied.

February 28.—Patient reports that the tumor has entirely disappeared.

May 12.—Patient returned to New York from Chicago and presents herself for examination. No trace of the growth remains; a slight red spot, rapidly disappearing, marks the site of the puncture. Cured.

Case 3.—May 16, 1893. M. H. H., age 25; wen or dermoid cyst. Tumor began six years ago, about the size of a pea on the neck below and behind the ear. Two years ago it began to increase in size and to-day is about one inch and one-quarter in diameter. The patient decisively refuses to take an anæsthesia, wishes to avoid the scar from an incision, and asks to have the tumor removed by the aid of electricity. Tumor hard and movable. Treatment: Electro-cocaine, local anæsthesia to skin over tumor; puncture made, contents of sac mostly expressed and cavity injected with a saturated solution of iodide of potash—a non-soluble metallic electrode remaining within the sac with the solution; a current of 15 milliampères was allowed to flow for ten minutes, with the purpose of setting free the iodine and obtaining its effect in a nascent state upon the lining of the sac.

May 19.—No soreness. Tumor soft and pliable but hardening.

May 22.—Tumor about two-thirds of its former size.

May 23.—Tumor again filled and the operation was a most obvious failure. I resolved to try another method, viz., electric diffusion from a soluble metal. This was done with 20 to 30 milliampères of current for about ten minutes.

May 31.—Slight serous discharge of an orange-yellow color.

July 1.—Patient not seen again until this date, when he returned to state that the discharge had quickly ceased and that the tumor had entirely disappeared, leaving no evidence of the operation. Seen May 1, nearly one year later, there has been no recurrence. Cured.

SYCOSIS PARASITICA.

E. H., age 50. Disease began seven years ago. Patient stated that he had tried to pull out an ingrowing hair and it broke off. A papule formed here, and following this a diffuse redness began to spread itself in all directions from the site (the left side of the face just in front of the ear); at the same time papules formed, coalesced and spread outward. No pus was formed at first, but after a short time the tips of pimples became white and pus was discharged. This was followed by an exudation of serum from the excoriated surface and shortly before it was operated upon discharged in twenty-four hours one ounce of serum. He has been everywhere and tried every treatment to no advantage until last October, the 21st, when he was operated upon at the New York Post-Graduate Hospital by Dr. R. Y. Morris who removed the skin and subjacent tissue over an area in front of the ear about five and one-half inches long and two inches wide. Skin grafts were then applied which did well till one day about a week later he was out in the cold and a portion of the ears froze and had to be removed, which left when healed a scar two inches long and one inch wide in the centre of the wound. All went well and the part looked healthy till February last, when signs of the old trouble began to show themselves in the skin just outside of line of incision, and when he presented himself to me the characteristic papules had spread themselves over a surface of about three inches long by two wide; in places the tissue was covered with small blebs and had a boggy appearance, into which a needle could be thrust for a distance of one-quarter of an inch without producing pain or discomfort.

April 20, he began treatment, which consisted of electric diffusion from copper electrodes 1½ to 2 milliampères, ten to twenty applications, lasting in all ten to fifteen minutes, until the green oxychlorid of copper gave a distinct coloration to skin and tissue, using the positive pole, with the negative in back of neck. This was repeated eight times, the last one about May 10. The aluminium needle was used twice and the negative pole with equally successful results.

May 14.—He came with the skin over lesion showing a normal and healthy condition. Treatment ceased, with the injunction to return if there is the slightest evidence of recurrence.

NOTE.—The alternatives in this case were, I am informed by Dr. Morris, further incision or curetting, both of which were objectionable, because the cicatrix was already extremely tense and no further tissue could well be sacrificed. The effect of the electric diffusion method was remarkable. It left behind it almost no observable cicatricial tension, in this respect much unlike ordinary electrolysis, and unlike the effects from the knife or the curette.

I have employed electric diffusion from metals in a variety of cases not here enumerated. Its action upon hemorrhoids has been to cure them in the many cases in which I have tried it. I have used it in endometritis, cystic degeneration of the cervix uteri, in ulcerations of the rectum, in keloid growths, etc. I am at present treating lupus and epithelioma with thus far favorable results, and have even begun upon a case of sarcoma, but it is too early to make any report upon this later set of cases. Dr. Gautier has reported excellent results in a great variety of gynecologic procedures and conditions.

PART V.—SPECIAL APPLICATIONS IN DENTAL SURGERY.

CHAPTER I.

ANÆSTHETIZATION OF SENSITIVE DENTINE.

THE subject of cataphoresis, especially in its relation to local anæsthesia of the teeth, is now largely occupying the attention of the dental profession. Shakespeare says that few men, however great or courageous, are able to bear the toothache with philosophy. Anything which promises relief is welcomed, and cataphoresis in dentistry bids fair to be only second in importance to general anæsthesia; to annul the pain of the patient and to diminish the wear and tear upon the nervous systems of both patient and operator, is to disarm dentistry of half the dread which many of its operations inspire. Like the sure effect of slowly-dripping water upon the stone beneath it, so the prolonged suffering of pain, or the prolonged witnessing of such suffering, has a deleterious effect—perhaps greater than the sudden and soon-ceasing pain of a tooth-extraction for which patients now often appeal to general anæsthesia.

There is unquestionably an extensive field in dental practice for electricity when the principles upon which its employment is based are generally understood. It is already in familiar use for certain mechanical purposes exemplified in, for instance, dental pluggers and drills, and also for cauterization and interior illumination. And, as has been noted in an earlier chapter, much but unavailing effort has been expended in attempts to utilize the electric current alone, or upon Richardson's plan of voltaic narcotism to annul the pain of tooth extraction. Some of these efforts included even efforts to "obtund," by means of electricity alone, the pain of sensitive dentine when operated upon.

Many nostrums for use as local anæsthetics are on the market appealing to the dental practitioner, but the Dental Code of Ethics proscribes their use, for the general reason that the use of all secret preparations is wrong, and because they are likely to become a menace to life. A most hearty welcome has therefore been accorded to the cataphoretic method of producing local anæsthesia, and its users are already numbered by hundreds. Its applications are known to all, and a great good is being done by it.

Considerable attention was given to the anæsthetization of sensitive dentine in the first part of this book, and two cases were cited[1] illustrating the procedure and demonstrating its usefulness. In the second of these cases even the pulp was desensitized, the point of an excavator having readily entered into the pulp-chamber without any consciousness of pain on the part of the patient.

In these experiments and in all my later work of

[1] See page 42.

a similar nature I combined guaiacol with cocaine, for I have found that the time required is thus reduced two-thirds, and permits the reduction of the current strength about two-thirds; the most important feature of the combination is that the guaiacol holds on chemically to the cocaine and thus prevents any possible quick absorption into the general circulation with consequent toxic effects.

It is generally found that ten to thirty per cent. solutions of cocaine with guaiacol are best adapted for work upon dentine. As has been pointed out, guaiacol is perfectly bland in its action, and although it has a well-defined odor, it is by no means offensive; it is a colorless solution, and it leaves no undesirable after-effects. If, however, the operator does not desire to use guaiacol, but prefers to use aqueous solutions of cocaine, or, indeed, any other practical anæsthetic agent, what is here said applies with the same force.

In applying electricity to a tooth there should be careful discrimination as to the character of applicator employed. In small cavities the tubular and perforated applicator, whether straight or bent, or blunt or sharp at its end, is advised; in large cavities the spatulate form or some form of large applicator is essential. These applicators may be adapted to handles for the hand or to springs which automatically hold them in place. In this connection I would again call especial attention to the fact that the cross-sectional area of the applicator must nearly equal the cross-sectional area of the cavity to be treated.

It must be remembered that every movement of the electrode, and every addition of solution varies the resistance of the patient's circuit, and, therefore, varies the amount of current flowing through the tooth. Until anæsthesia is effected each such variation of current strength causes pain. I would suggest that in some cases it would be well to use very fine gold or platinum plugging packed lightly into the cavity over cotton which carries the medicament, with a clamp making connection between the metal filling and the rheostat.

When the current is first applied to the tooth it should be in the smallest possible quantity. As the patient can bear it the quantity should be gradually increased. If it is necessary to renew the medicated solution first reduce the current gradually, and apply the solution while little or no current is flowing and then increase the current flow. So extremely sensitive is a sensitive tooth that changes in rate of current flow must be made by very easy stages. Even when anæsthesia has been obtained a rate of two milliampères is considerable.

Different observers give very different reports as to the current strength employed in their cases. To the reports of those who give only the number of cells brought into action, or the number of volts indicated, we can give no advice, since this record is of no value for statistical and final deductions. The milliampèremeter is as essential to the electro-therapist as is the yard or rod measure to the surveyor. Some excellent practitioners report an inability to attain, for instance, more than a maximum current strength of $\frac{1}{10}$th of a milliampère. This indicates undoubtedly too low an initial voltage in their battery. Results as to the rate of flow will also vary according to the varying resistance of teeth and according to a similar variation in the resistivity of the medicinal substances employed. The chance of inaccuracy in some milliampère meters must also be taken into account. But the chief cause for the differences in the reported milliampère meter readings and indeed a chief cause of slowness in anæsthetization or even of failure to anæsthetize properly, is, in my opinion, the use of the fine, wire-like and small applicator which, according to the law of current density, explained in the chapter on Electrodes, fails to properly diffuse the cocaine into the dentine. This fault can be promptly remedied, as pointed out in the above referred to chapter, by employing an applicator the area of whose cross section very nearly equals that of the cavity to be anæsthetized. This point cannot be too strenuously urged, and has not yet been taken into account.

I would remark here that the matter of the first importance is to establish the general principle of Cataphoric Medication, namely, of cataphoric anæsthetization of sensitive dentine, and that time and further experience, together with the adoption of *standard* instruments and standard initial voltage, will harmonize results now only apparently contradictory by reason of insufficient information.

Dentine is anæsthetized primarily over the radius covered by the positive pole, because the current passes in the course of least resistance toward the apex of the root through the tubuli and pulp canal. Thus, the larger the surface covered by the positive pole the greater will be the surface anæsthetized and the better will be the results obtained.

The enamel is a non-conductor, so, to obtain an entrance for a medicament, it is necessary to place the electrode upon some exposed portion of the dentine.

Teeth whose dentinal structure is dense, are more tedious to anæsthetize than those whose structure is less dense, more time being required to produce the desired results ; renew the anæsthetizing solution from time to time. Watch the milliampère meter and see that so much current is not sent through the tooth that it will heat.

Do not break the circuit to your patient by removing the electrode from the tooth, with the current turned on ; such a procedure will cause an undesirable shock.

Considering the short time required to anæsthetize dentine it is advisable not to leave the patient during the administration, as an accident may occur by the patient interfering with the electrodes. Where teeth have been previously treated with creosote or carbolic acid, as satisfactory results should not be expected, as where such agents have not been employed, due probably to the fact that these substances have acted as coagulants.

Use a large negative electrode made preferably of punk or amadou over a piece of carbon. The punk remains moist for a long time and does not "burn."

Before making any applications to the mouth it is well to insulate the chair by placing linoleum or rubber under its feet ; it is also desirable to keep the patient out of reach of gas or water pipes, steam radiators or other metallic substances that would make a ground connection possible.

Apply the rubber dam to every tooth operated upon ; it is necessary to keep all saliva away from the tooth and the rubber dam serves to insulate it admirably.

Leakage of saliva means leakage of electricity, and may easily account for failure or delay. For this reason it is important to give careful attention to insulation.

Insulation with the rubber dam depends upon the method of application. It is often ineffective, however skilfully applied. Unless the dam hugs the necks of the teeth closely, leakage occurs, and sometimes it is impossible to effect this. As has been pointed out and illustrated diagrammatically by Dr. R. Ottolengui, a cross section of a malformed tooth shows leakage of saliva at the concavities.[1]

Such places can be dammed with punk, for filling, but this will not be sufficient for cataphoresis. For the latter they must be packed with soft gutta percha (temporary stopping)—, smoothing with cotton dipped in chloroform.

If the spaces are small, and it is perhaps best to do this in all cases, use chloro-percha around the neck of the tooth over the dam. Leakage through soft tissue is detected easily by the rapid rise of current flow as indicated by milliampère meter.

Any metal fillings which might come in contact with the electrode, or the wet cotton in the cavity, should be covered with chloro-percha or some other temporary stopping. If the cavity to be operated on is an approximal one, and a filling in the next tooth is too close to allow of its satisfactory insulation, the rubber may be applied only over the tooth to be worked on, thus insulating it; or, preferably,

[1] "Methods of Filling Teeth," p. 41.

the rubber being already in place, a second dam may be applied over the tooth to be worked on, which may be removed after anæsthetization.

In each case the polarity of the terminals should be tested with a piece of wet litmus paper or paper wet with a saturated solution of iodide of potash. Or if all connections remain unchanged the two electrodes may be brought into momentary contact and the proper direction of the movement of the needle of the milliampère meter be noted.

I would say, try a few cases on your least desirable patients at first, use solutions freshly made, and large applicators, and, if you will, guaiacol. With a brief experience, I believe you will find that in cataphoresis the members of the dental profession have acquired a procedure which will always survive.

The practical result of a great amount of experimentation which I have made to find a successful obtundent of sensitive dentine, either a simple medicine or combination of medicines, is this, that the best results are to be obtained either from a strong aqueous solution of hydrochlorate of cocaine or a solution of hydrochlorate of cocaine with guaiacol, which I was the first to propose. Either of these solutions should be freshly made on each occasion of use, for the widely known reason that all cocaine solutions deteriorate rapidly in anæsthetic power. The solutions should be anywhere from 10 per cent to 30 per cent for sensitive dentine and from 4 per cent to 10 per cent for mucous membranes. When used upon the latter the guaiacol solution should be diluted one half by the oil of sweet almonds.

What I would then advise in place of any fixed solutions is the following procedure. Keep on hand, for dental work, a bottle of cocaine crystals, a bottle of sterilized water and a bottle of pure, colorless guaiacol. When ready to operate take a small glass plate 3 or 4 inches square and place upon it a few crystals of cocaine ; add two or three drops of sterilized water or guaiacol as desired and heat gradually over a spirit lamp to a point short of the boiling point of the mixture. It is not necessary to heat to as high a point when the water is used as when guaiacol is employed. It is wise to apply the solution before it gets cold, as this may save a slight shock in a sensitive tooth. My preference, as has already been expressed, is for the guaiacol-cocaine, principally because of its greater rapidity of action, its sterilizing effect and its reduction of the chances of toxic effects from cocaine by preventing its diffusion to the general circulation ; its only disadvantages are its odor—which, with cleanly use, is trifling—and its softening effect upon the rubber dam.

A few cases are now introduced, interesting as to general technique and results, or instructive as to special points.

The following cases are contributed by Dr. M. L. Rhein. "*Case I.* Mrs. W., æt. about 32. Has had such a dread of dental operations that for ten years her teeth have been neglected, much to the patient's distress. Hearing that I was using cataphoric medication for producing desensitization of dentine, she applied to me in the spring of '96 to place her mouth in proper condition, with the understanding that cocaine cataphoresis should be used on all her teeth.

"Her nervous dread at the beginning of the first sitting can only be realized by the operator who has worked for such patients. The first tooth on which work was commenced was a superior central incisor with a large approximal cavity filled with loose debris of food mixed with carious dentine. The rubber having been adjusted, the contents of the cavity was so sensitive to the touch of an instrument that it was impossible even to remove the loose debris, which is always desirable. A freshly-prepared 50 per cent. aqueous solution of cocaine hydrochlorate was introduced and the positive pole introduced into the cavity while the cathode was conducted through the cheek by means of a sponge held securely under the rubber dam holder. The current was started with a voltage of $\frac{1}{25}$ through the 'Wheeler Fractional Volt Selector' and by $\frac{1}{25}$ gradation raised to 17 volts in the course of twenty-five minutes, at which time there was registered $\frac{1}{2}$ a milliampère of current. The application was entirely painless unless the voltage was raised too rapidly, when a restoration to the previous amount of voltage would remove every trace of sensation. At the lapse of 25 minutes it was found that I could remove the contents of the cavity in any manner desired without patient experiencing any sensation. The pulp was found to be exposed and also devoid of sensation, so that at the same sitting it was removed entire with a Donaldson nerve bristle without the patient feeling any sensation and without any second application.

"The patient was so pleased with the result that she was eager for appointment, not only to restore her teeth to a condition of usefulness but to rid herself of the odontalgia from which she was suffering in different parts of her mouth. In the course of this work six exposed pulps were removed in this way and over twenty teeth operated upon. In every case the cataphoric application gave the same measure of success as to anæsthetic properties. Some of the exposed pulps, however, did not come away so kindly, and were followed by hemorrhage which it was found difficult to control. This relaxed condition of the walls of the capillaries when cocaine is used is the one great objection to the removal of the pulp in this way, and frequently much time is lost in controlling this stubborn hemorrhage. In consequence I much prefer, after having cataphorically desensitized the pulp, to introduce the customary arsenical preparation which will produce its well-known effect without any perceptible irritation. To illustrate this I cite :

"*Case II.*—Mr. H., æt. about 40, presented himself with an aching third superior molar which was found to have a small pin-head cavity below the gum on the anterior approximal surface. The introduction of a bristle soon gave evidence of pulp exposure. It was Saturday afternoon and patient was to leave for Europe on Tuesday. The tooth was greatly valued for masticatory purposes. The rubber dam was carefully applied only to the one tooth, a clamp adjusted high up so as to expose the cavity. A solution of gutta percha in chloroform was then freely run around the neck of the tooth and over the clamp so as to prevent any possible leakage of current. After a 15-minute application of the current the cavity was painlessly enlarged and the pulp freely exposed. An arsenical application was introduced and cavity sealed. The patient returned on Monday having experienced no pain. The cavity was then extended so as to get on a direct line with the ends of the roots which were then cleansed of all the pulp tissue and filled at the same sitting. The patient experienced no sensation of any kind.

"*Case III*—Master R., æt 12 ; inferior first molar decayed on anterior approximate surface and crown. A fresh aqueous solution of cocaine hydrochlorate was prepared and current turned on. It was with extreme difficulty that the voltage could be increased, and even after this had become bearable it was necessary to increase the voltage to about 60 before a registration of $\frac{3}{5}$ of a milliampère was obtained. The resistance of the patient was so great that with 25 volts of current there was barely $\frac{1}{10}$ of a milliampère, and although the outer zone of dentine was found to be devoid of sensation there was no depth to the anæsthetic effect. This patient absolutely refused to allow the proper preparation of cavity to be made unless it was done painlessly. It required over one hour's application of the current with a final voltage of between 60 and 70 volts to attain the desired result. The tooth was, however, then thoroughly prepared without any objection on the part of the patient. The other three first molars were subsequently treated in the same manner always requiring about one hour's application before insensibility to pain was produced."

The following case reported by Dr. R. Ottolengui is of especial practical interest :

"The most satisfactory result with cataphoresis, within my experience, in a case which all dentists will recognize as affording a crucial test of the possibilities of this method of desensitizing sensitive dentine, is herewith described.

"The patient was a young woman, about seventeen, fully developed, large in stature, plethoric, cultured, highly educated, and very skeptical as to the possibilities of controlling the sensitiveness of her teeth by means of cocaine applied in any manner whatever. She had submitted to hypodermic cocaine on two or three occasions, with no anæsthetic effect whatever, and her faith in the drug had been completely shattered. The addition of the electric current, was an argument of no potency to her mind. These facts are worthy of note as indicating that neither suggestion, nor expectant faith, modified the result.

"The tooth was the right superior third molar. The cavity along the buccal surface, quite large, and filled with decalcified dentine of the most sensitive character. Furthermore, the caries extended superficially backward towards the posterior surface, a whitish line of decalcified enamel marking the limits to which the cavity must be extended. The sensitiveness was so extreme that the patient would not even tolerate having the cavity dried out with bibulous paper. She opposed treatment, and strongly urged extraction.

"After much persuasion she allowed me to proceed. With difficulty the dam was placed over the three molars, the holes being cut small enough to hug the teeth tightly, and far enough apart so that the gum septa between the teeth were well covered. As an additional precaution against possible leakage, the dam around the teeth was smeared with chloro-percha. Anhydrous crystals of cocaine dissolved in water, a highly saturate solution being freshly prepared, was placed in the cavity on a pellet of cotton. At first it was impossible to permit enough flow of current to obtain registration on the milliampère meter, but after a few minutes one-tenth of a milliampère was tolerated without discomfort. In ten minutes one fifth of a milliampère was flowing, and this was maintained for ten minutes longer, the current having been continued, in all, twenty minutes. Upon attempting to prepare the cavity, desensitization was so complete, that the leathery decay was readily removed, the bottom of the cavity thoroughly scraped, the margins perfected, the cavity extended backward around to the posterior surface, then up into the occlusal surface, where a large amalgam filling was met. This was removed, and that cavity fully prepared as a part of the original one. It will be recognized that now I had a most extensive operation before me, when I state that this thorough preparation of the cavity made me decide to fill with gold. I consequently dressed the tooth with oil of cinnamon, and filled temporarily with gutta-percha. At a subsequent sitting the tooth was found to be as sensitive as ever, but without difficulty a gold filling was inserted fully restoring all of the lost tooth bone. Four months later the tooth was comfortable, but responded to tests showing that the pulp was still alive and apparently healthy, despite the close approach to it made by caries."

Dr. Edw. C. Briggs, of Boston, Mass., makes the following interesting contribution to the subject. Dr. Briggs writes :

" I give you below a few cases which I have hastily noted down, and trust they will prove what you want.

" *Case I.*—Mr. W. H. B.—Was left superior, first molar, crown cavity. I used the G. M. Wheeler apparatus, and worked up to twenty volts in fifteen minutes, and allowed it to remain at that pressure for ten minutes, after which, the tooth was thoroughly prepared without any sensitiveness, and filled with gold. This was an exceptionally sensitive tooth.

" *Case II.*—Miss M. S.—This patient is of a very sensitive, nervous organization, and always was very difficult to operate upon, and many times I have been obliged to hypnotize in order to accomplish anything. The cataphoresis worked admirably, taking, however, twenty-five or thirty minutes.

" *Case III.*—Mrs. W. G.—This was a lower molar, and it took about fifteen volts fifteen minutes, which sufficed to anæsthetize the tooth ; and prepared and filled without sensation.

" *Case IV.*—Miss L. H.—In this case it was desired to destroy a pulp, and use the tooth for bridge work, and, after removing a small gold filling, the current was applied in the cavity for about thirty minutes, when I was able to drill down to the pulp and remove part of it, without any sensation; removed the remainder of pulp after an injection of cocaine in the syringe.

" *Case V.*—Mr. G. L.—This was an excruciatingly sensitive cavity in the crown of the molar. The patient jeered all the time the current was being used, having no faith in any relief. This was run extra long, fully half an hour, to make sure ; and the tooth was prepared and filled without sensation.

"I am giving these cases, as selected, at random, and might go on by the score—all pretty much of the same description. There is a very small percentage of failures, of which the case L. B. is a sample. In this instance, the patient seemed to be abnormally susceptible to electric current, and five volts gave so much pain that I was obliged to hold it at three volts, and after fifteen minutes, being unable to increase the flow of electricity gave it up entirely. Such cases are few and far between. As I wrote you before, it seems to be only a question of time to obtain absolute success, in every case; but it takes enough time to lead one to avoid using it, unless the case especially demands it. It is a great comfort to patients, however, to know that there is something that can be resorted to in time of need."

Dr. Henry W. Gillett, has reported numerous cases, of which the following examples may be given:

"*Case A.*—Mr. N., aged twenty-five; right superior second bicuspid, cavity quite sensitive. Treatment, cataphoresis for ten minutes with twenty-per-cent. solution cocaine, not quite one milliampère of current passing through the tooth at the end of treatment. Result, absolute freedom from sensitiveness to excavator or bur.

"*Case B.*—Mrs. H., aged forty; left superior bicuspid, large approximal filling, history and contemplated treatment such as had led to a decision to destroy the pulp. To do this it was more convenient to approach the pulp through the anterior cavity. The dentine was found too sensitive to permit drilling. Cataphoresis for fifteen minutes with thirty per cent. cocaine, then drill directly to the pulp, which was found much receded. The first notice that the pulp had been reached by the drill was from hemorrhage, and not from pain. In this case a further application was made and pulp removed painlessly.

"*Case C.*—Mr. C., aged thirty left; inferior second molar, very large corono-mesial cavity. The patient refused to allow shaping of cavity, because of sensitiveness. Cataphoresis for fifteen minutes with twenty per cent. cocaine. Result, entire freedom from sensitiveness, except in one corner near cervical margin.

"*Case D.*—Willie M., aged thirteen; mesial cavity in inferior first molar, very sensitive. Cataphoresis with thirty-per-cent. cocaine for ten minutes. Result, complete anæsthesia of dentine for some distance, but a second application for six minutes was needed for shaping the retaining grooves.

"*Case E.*—Mr. C. M., aged twenty, reports his teeth as very sensitive, and all cavities, even the smallest, prove so. Inferior second molar buccal cavity. Applied a twenty-per-cent. cocaine solution with electric current for twelve minutes,—seventeen volt current for the final third of the period. Result: entire absence of sensitiveness in the preparation of the cavity. For same patient at same sitting, right superior first bicuspid corono-distal cavity, twenty-per-cent. cocaine, current for ten minutes, reaching a maximum of seventeen volts. Result: complete absence of sensitiveness, except for final groove cutting. As the patient was anxious to be able to say that it had not hurt him at all, a second application was made about like the first, and the cavity completely anæsthetized. One of the most competent New York practitioners, in whose hands the patient had previously been, assured me afterwards that he had used every known remedy without success in the effort to even relieve the sensitiveness in this case.

"*Case F.*—C. Y., aged fifteen ; mesial cavity in right central incisor, very sensitive. Fifteen-per-cent. cocaine current for eleven minutes up to a maximum of twenty-five volts. Result : complete anæsthesia of the dentine during the preparation of the cavity. Same patient and same sitting. Similar cavity in left central ; same treatment, and similar results. The patient went to sleep during this second application, which, when we consider that this was his first experience, is good evidence that the process is not a painful one.

The following résumé of results quoted from a paper[1] by Weston A. Price, D. D. S., an able and indefatigable worker, will be read at this point with interest. He says :

I have observed the following results by applying the cocain solution as stated above : *First.* In nearly 1,500 cases, of which I have kept a record, the per cent of perfectly successful operations has been between 95 and 100, and of late, with the increase of experience, all cases have been successful on the second application, if not on the first. Of these fully 100 were cases in which the pulp was entirely removed at the time, and in about 200 more the pulp was drilled into and partly removed, and a devitalizing agent used to complete the destruction. *Second.* In almost all cases of single-rooted teeth the pulp was entirely removed at the time. *Third.* No sensation of pain was felt from the devitalizing agent applied after using cataphoresis. *Fourth.* Not a single case as yet of a dead pulp from the use of cataphoresis. *Fifth.* No difference has been noted in the time required for varying concentrations of cocain or any other agent. *Sixth.* The average time required for all cases was about thirteen minutes. *Seventh.* The amount of current tolerable is determined by the effect of

1. Read before the American Dental Association, August, 1897. Published—The Dental Digest, p. 460, 1897.

the cocain on the pulp tissue, and not in the dentin, in a case of unexposed healthy pulp. *Eighth.* The resistance through the wet dentin varies all the way from a few thousand to five hundred thousand ohms. *Ninth.* The amount of current tolerable has been found to vary from one two-hundred thousandths to two-thousandths of an ampere, the average being less than two ten-thonsandths at the beginning of the operation and four ten-thousandths at the finish. Of course, where pulps were devitalized a very much stronger current was used for the finish, though seldom more than that amount was used where the continued life of a pulp was expected. *Tenth.* There are no constant symptoms that will give any indication of the amount of current flowing. Each case has a different pain limit. Hence the absolute necessity of using a milliamperemeter. *Eleventh.* No effect has ever been noted in the tissues beyond the tooth, except where a very strong current was used, then slight periostitis.

The following cases are reported by Dr. F. T. Van Woert:

"FAILURES.

"*1st Case.*—Young woman, twenty-eight years of age, nervous temperament, with the right superior central pulp exposed. The current was turned on gradually from three dry cells, running through a saturated solution of cocaine about twenty-five minutes, after which four more cells were added, and the current standing $\frac{1}{5}$ milliampère against $9\frac{1}{3}$ volts for $1\frac{1}{4}$ hrs., after which the pulp was even more sensitive than when the operation was begun.

"*2nd Case.*—A little girl, twelve years of age, left inferior, first molar, large crown cavity, but no exposure of the pulp, current of three cells in the circuit, which caused intense pain upon the slightest movement of the current controller. Later it was tried with one cell, and with less than a 40th of a milliampere, the patient suffering severe pain nearly $\frac{3}{4}$ of an hour, using a saturated solution of cocaine, as in the previous case, the tooth was found to be more sensitive than when the operation was begun.

"SUCCESSES."

"Three cases of extirpation of pulp from the teeth of an adult female, at a clinic, before the senior class.

"1st :—Saturated solution upon full exposure, $\frac{2}{5}$ milliampêre of current, seven cells in the circuit, time $\frac{1}{2}$ hour, pulps removed without the slightest sensation.

"2nd :—Necrosis of the inferior maxilla, involving the outer plate from the second bicuspid, to the third molar, a suitable tampon was arranged and was moistened with a saturated solution of cocaine, over this was placed a piece of tinfoil for properly diffusing the current, which was turned on full from two dry cells, and maintained for twelve minutes, the end of that time there was complete anæsthesia, and the operation was proceeded with for ten minutes, when the application was renewed three minutes longer, and the operation completed."

The following cases have been reported by Nelson M. Chitterling, D. D. S., of Bloomfield, N. J., and may be found instructive :

"*Case I.*—Young lady presenting sensitive cavity in cervix of upper lateral incisor, so sensitive that the pressure of her tongue could not be borne. With two cells and the current controller at ten, thirteen minutes sufficed to render cavity absolutely without sensation.

"*Case II.*—Cavity in cervix of upper lateral was anæsthetized in *four* minutes by use of six cells, and excavated without sensation.

"This case was unusually sensitive, and the patient said that she was very susceptible to electricity.

" *Case III.*—Upper bicuspid pulp extirpated without pain after twenty minutes' treatment.

" *Case IV.*—Upper bicuspid pulp removed after ten minutes' treatment with eight cells."

PRESSURE LOCAL ANÆSTHESIA OF SOFT TISSUES AND OF DENTINE.

It has become a well established practice in dental surgery to introduce into the cavity of a tooth for the purpose of bleaching it, when the cavity admits of it, a twenty-five or other convenient per cent. of peroxide of hydrogen held on a pledget of cotton and sealed in. It is maintained that, in addition to the simple process of imbibition, the cocaine is forced into the substance of the dentine by pressure due to the evaporation of the ether. In this manner teeth can be successfully bleached to an extent not possible if the pledget of cotton holding the bleaching fluid is not sealed in, except when electricity is used.

It occurred to me that if this same principle could be applied to a sulphuric ether solution of cocaine that we should possess an extraordinarily simple method of anæsthetizing the soft tissues in general and sensitive dentine in particular,—a method so simple and sure that it would sweep away all the labor that has been expended in a certain class of cavities, upon the introduction of cocaine by electricity.

Since cocaine hydrochlorate would not dissolve in sulphuric ether, I dissolved it in guaiacol (making a 10 per cent. solution) and then found that I could add equal parts of sulphuric ether to the solution without precipitating the cocaine.

Experiment I.—June 23, 1897. Taking about twenty drops of the above solution I put it in a small test tube and inverting the tube I held its mouth firmly against the skin of my forearm. At the end of five minutes, removing the tube, I tested the area of skin comprised within the circle represented by the mouth of the tube and found that it was perfectly anæsthetized ; it remained anæsthetic for five minutes and then gradually recovered sensation without any hyperæsthesia to speak of and without injury to the skin.

Further experiments substantiated this result.

I have also made some experiments with air pressure by connecting to a rubber tube, itself in connection with a cylinder of compressed air and a gauge, a hollow needle having a shoulder near its extremity. Where the cavity permits of it, the solution of cocaine is introduced upon absorbent material, sealed in with plastic material and then the needle thrust through it as far as the shoulder will permit. At this point the air pressure is allowed to act. By the use of this instrument local anæsthesia is promptly obtained. Dr. M. L. Rhein has now an instrument of this description in his possession, and will as soon as possible make further experiments upon dentine and report some cases.

CHAPTER II.

ANÆSTHESIA OF THE GUMS.

UNDER this chapter falls the anæsthetization of the gums so as to permit of tooth extraction and implantation and other similar operations. The principles available for this purpose have already been enlarged upon quite fully, and it need only be said that the above operations may be successfully and painlessly performed by the use of the cataphoric method.

It is desirable to have the application made on both sides of the gum at the same time so as to get a perfect effect. If a tooth is to be extracted it is also desirable, when possible, to have an application made through the cavity of the tooth so as to reach the pulp and affect it measurably.

The two following cases are taken from an article by the writer which appeared in the "Dental Cosmos" for January, 1896. In the first case the patient, a Mrs. ——, was brought to me by Dr. Wm. J. Younger, of San Francisco, who was then (Dec. 11, 1895), in New York, that I might try guaiacol-cocaine anæsthesia and my new duplex positive pole electrode. (See Fig. 51). The lady was remarkably nervous and apprehensive and sensitive to pain, as she had that morning already undergone an implantation of a first right superior bicuspid.

"In this operation pain had been obtunded in the usual manner by hypodermatic injections of a solution of cocaine, requiring from fifteen to twenty minutes, and a succession of needle pricks. She had some after effects from the cocaine, particularly 'a bad feeling in the throat.'

"The tooth implanted at this second operation was a superior left first bicuspid.

"Adjusting the electrode to the gums at the spot devoid of a tooth, and packing in at one place (where good contact was not established) some absorbent cotton saturated with the guaiacol-cocaine solution, the current was turned on carefully. The negative electrode of the usual type was simply held by the patient in her hand. During the first three minutes the current strength registered was one-quarter, one-half, three-quarters and one and three-quarters milliampères. During the next three and a half minutes it was, in slow gradations, increased to two and one-half and finally to a limit of three milliampères. The electrical resistance of the patient's circuit varied during the operation between 6,700 ohms and 7,240 ohms, never remaining constant more than thirty seconds at a time. The current caused little or no pain, for, if slight sensation of pain was felt, the current strength was diminished a fraction and then again increased, without pain, as anæsthesia progressed. The electrode was removed in six and one-half minutes and the operation proceeded with and finished in an additional eight minutes. The operation need not be described, since it is a familiar one, nor need it be added that it was skilfully done ; during the deep incisions and drilling out of bone the patient experienced no pain whatever, except when, on one occasion, the knife for an instant cut into a region which had not been included within the area of action of the electrode.

"The success of the annihilation of the pain may be best expressed in the words of the patient : 'I never could have believed it could be so painless ; it didn't hurt a bit. This is very much easier than the syringe.' Dr. Younger stated that he decidedly prefered the cataphoric method with guaiacol-cocaine to the injection of cocaine solutions.

"It may be noted that the total current strength employed was very small ; that one half of the time was spent in avoiding pain by raising the current strength slowly to a fair working point (here the value of the 'fractional volt selector' was demonstrated) ; that no portion of the mouth was anæsthetized except that at the point of application of the electrode and that no after effects followed. The patient was examined the next day by Dr. Younger and the resulting conditions were found to be perfectly satisfactory."

A second case of tooth-implantation was also on one of Dr. Younger's patients. In my absence Dr. Edward C. Kirk made the anæsthetic application, and records and his notes of the case are as follows :

"The patient was decidedly an unsatisfactory individual for a test experiment in one respect, namely, that either naturally, or because of the physical and psychic impression produced by an implantation of the day before, he was in a condition of abnormally excited nervous sensibility. He gave expression frequently to exclamations which might easily be interpreted as expressions of pain actually felt, were it not for the fact that when at least 5½ milliampères of current were passing at 40 volts pressure, he called for more, when previously at 22 to 23 volts he complained of 'pressure' of the electrode, showing conclusively that the pain of the current was obliterated by the cataphoresis of the guaiacol-cocaine solution.

"The duration of the application to produce anæsthesia was six and one-half minutes; two and one-half minutes were occupied in raising the current strength in gradations from one-tenth of one milliampère to four milliampères; during the remaining three and one-half minutes the current strength was increased only from four to four and one-half milliampères. Twice the patient complained of a sense of compression due to the current. Upon removing the electrode there was noted a bleaching of the mucous membrane over the territory of contact (coagulation). There was no sensation in the part treated; anæsthesia was complete at the commencement of the operation. The patient remarked, 'It is nothing to-day to what it was yesterday' (*i.e.*, by the hypodermatic method)." The same solution and electrodes were employed in this case as in the other case above mentioned.

Many cases of tooth-extraction might be cited, but the method is the same as above stated except that at times it is wise to make an application to the interior of the tooth as well as to the gum. But I do not believe that a proper anæsthetization of the gums can be effected by aid of the rubber cup-shaped electrodes figured Nos. 53 and 54, an^d I consider that the numerous cases of failure reported are due to the use of these defective electrodes and to imperfect methods. The fault of the rubber cup-electrode, as has already been pointed out (see chapter on electrodes), is the smallness of the metallic plate within it and the thickness of the porous and absorbing material required to be placed within it. There is no escape in my opinion, if success is desired, from the employment of the form of electrode I have described in Fig. 51, namely, a perforated and feeding electrode of large metallic surface backing up a *thin* porous septum which holds the medicament.

CHAPTER III.

BLEACHING OF TEETH BY CATAPHORESIS.

WITH a view of ascertaining if discolored teeth could be actually and practically bleached by cataphoric medication, I performed the following experiments, assisted by Mr. Wm. J. Evans, of McKesson & Robbins.

The first point was to establish if solutions of $H_2 O_2$ would conduct electricity.

Experiment I.—$H_2 O_2$ twenty-five per cent., plus sulphuric ether seventy-five per cent. A few drops laid upon a glass plate, platinum wire electrodes placed one-half inch apart, forty cells equaling about sixty volts, gave only about one milliampère of current, a current strength too small for practical work.

Similar solutions of the same strength of $H_2 O_2$ in chloroform, glycerol, and distilled water give in the first two instances no current, and in the latter about two milliampères.

Experiment VI.—$H_2 O_2$ twenty-five per cent., plus sulphuric ether seventy-five per cent., plus dilute sulphuric acid a mere trace, gave twenty milliampères,—namely, sufficient for practical work if so desired.

Experiment VIII.—$H_2 O_2$ twenty-five per cent., plus sulphuric ether seventy-five per cent., plus solution of chloride of sodium, afforded electric conduction, but the solutions did not mix, and therefore were impracticable to work with in that form.

Experiment XI.—A molar tooth containing a large cavity, leaving half of its crown still intact.

The enamel of the crown was badly discolored by organic decomposition ; the central divisions of the dentinal tubuli were well exposed ; contrast was made by comparing it with another tooth to match the color, so that the shade could be determined. Cavity packed with absorbent cotton ; rubber dam adjusted, and the roots of the tooth imbedded in a piece of beef meat. Cotton was tightly wound about the platinum wire, constituting the positive electrode ; the negative was another wire inserted into the beef about one inch away from the imbedded tooth.

Solution of chloride of sodium two-fifths of a cubic centimeter, and one and three-fifths cubic centimeter of $H_2 O_2$ twenty-five per cent., water seventy-five per cent., made by shaking two parts of pyrozone twenty-five solution with one part of water and separating the fluids in a funnel, was dropped onto the cotton with a pipette ; the current was turned on and very quickly dried it, which was indicated promptly by the fall of needle of the milliampère meter, and more solution was continuously added. The darkened portion of the tooth bleached perceptibly white within a minute ; current strength twenty-five milliampères. Then about the same number of milliampères was employed during five minutes ; the enamel perfectly bleached. The bleaching action was also evident at the ends of the roots of the tooth, the $H_2 O_2$ having been conveyed there by way of the open pulp-canals. These latter, therefore, in actual practice, if exposed, should be closed by a non-conducting cement.

Experiment XII.—Two pieces of blotting-paper, 1 × 2 inches, each laid on a glass-plate and six bars of blue litmus-paper laid across the blotting-paper as shown in Fig. 75.

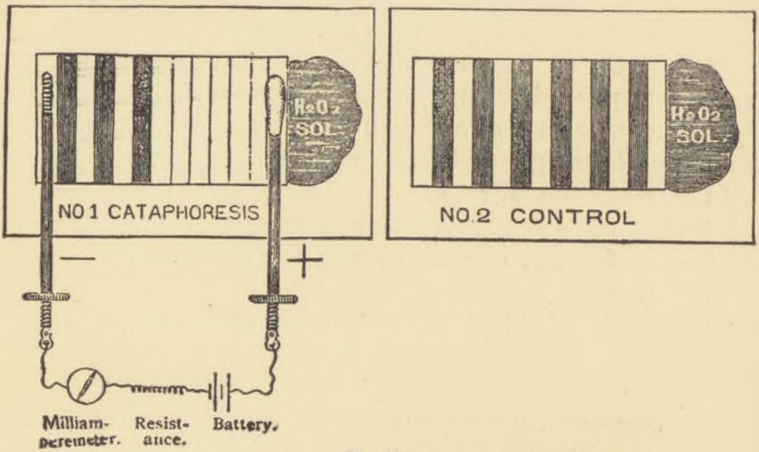


Fig. 75.

Two cubic centimeters of twenty-five per cent., aqueous solution H_2 O_2 applied on glass at end of blotting-paper; fifty milliampères current. Blotting-paper wet with a weak solution of chloride of sodium; current turned on. Almost immediately in No. 1 the litmus-paper at the positive end began to bleach, and this bleaching progressed in perceptible steps toward the centre until within four and one-half minutes the litmus-paper on the positive end (three bars of it) was completely bleached of its blue color. The control experiment showed no change proving that ordinary diffusion or chemical osmosis was not the cause of the result obtained in No. 1.

Experiment XIII.—Four pieces of blotting-paper, 1 × 2 inches, two pieces saturated with a decinormal solution of permanganate of potassium, U. S. P.—this stained them a chocolate color ; two pieces with

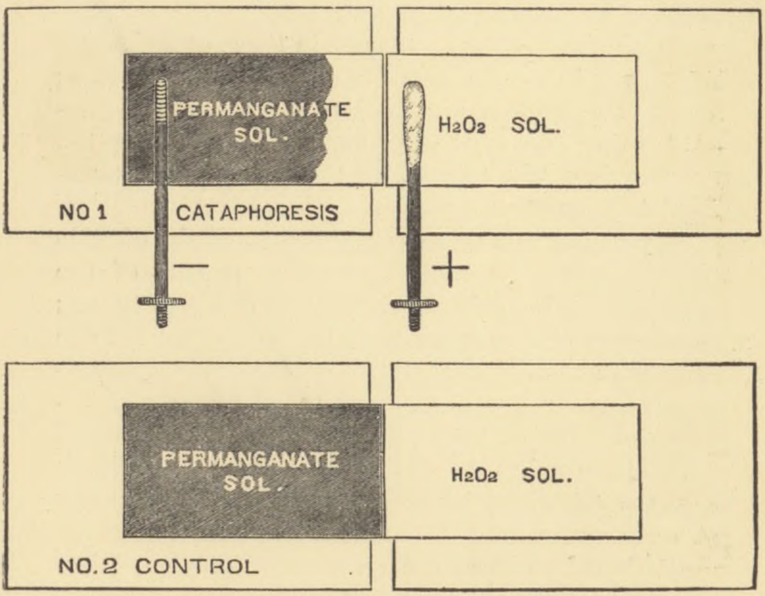


Fig. 76.

twenty-five per cent. aqueous solution of $H_2\ O_2$. Each piece of permanganate paper was brought into juxtaposition with each piece of $H_2\ O_2$ paper. No. 1 cataphoresis ; No. 2 for control. (See Fig. 76.)

The $H_2\ O_2$ pieces of blotting-paper were previously moistened with the solution of sulphate of soda ;

fifty milliampères of current strength were applied as indicated by the platinum-electrodes in the illustration. The encroachment of decolorization of the permanganate paper was noticed at once in No. 1; it progressed steadily, and at the end of five minutes had extended about one-third of an inch, thus proving cataphoric action, while the control, namely, No. 2, showed but a trifling decoloration at the point of immediate contact.

Current strengths were used in these experiments which would be excessive if applied to living dentine; but this is only a question of degree, and necessitates the same careful procedure in applying the current as would be used by the operator in anæsthetizing sensitive dentine.

To produce this effect cataphoretically the dioxide of hydrogen must come against some part of the tooth that is a conductor, and that is the dentine; so there should be a cavity in the tooth that is to be bleached; and, if there is, absorbent cotton containing a twenty per cent. solution of dioxide of hydrogen is applied there, and the current is turned on. If the pulp cavity is exposed the first effect is that the electricity will carry the bleaching agency at once down to the end of the root. The canal must therefore be sealed up, otherwise most of the bleaching agency will be carried down to the root-ends and the bleaching will all occur where it is not wanted.

On December 10, 1895, I read a paper before the First District Dental Society of the State of New York, which treated of this subject broadly. In this paper I showed that I had recently discovered a very important fact which bore vitally upon the procedure of tooth-bleaching. This was a method of preparing a twenty-five per cent. aqueous solution of "pyrozone," or dioxide of hydrogen, very easily. The method was as follows :—Take a glass tube and two cubic centimeters of pyrozone, twenty-five per cent. ethereal solution, and add to it a cubic centimeter of water. Mix it in the tube and put it in an evaporating dish in a warm place, and in three or four minutes the ether is entirely evaporated and there is left an active watery solution of pyrozone made very quickly. Otherwise such a strong aqueous solution could not be easily obtained. It does not retain its qualities any great time as the oxygen escapes. But why an aqueous solution? That is one of the important points. If the resistance of the fluid or medicine that is to be driven in cataphorically is too great, no current passes ; and if it is too small there is no cataphoresis. A certain degree of resistance is wanted to obtain a certain effect. An ethereal solution twenty-five per cent. dioxide of hydrogen is a bad conductor. If the applicator is dipped in a solution of sodium chloride or phosphate of soda and then dipped in the twenty-five per cent. ethereal solution, we can electrically get the pyrozone into the tooth where otherwise we could not ; but the aqueous solution is much better. There is a difference in this respect, that with an ethereal solution nothing can be dissolved in it that will make it a conductor and with the watery solution such substances can be added. The strong aqueous solution is offered as a great advance on the ethereal solution for cataphoric application, and as an opportunity of getting rid of the clumsy process of covering the applicator with cotton saturated with some foreign substance like sodium chloride or phosphate of sodium.

If a pledget of cotton be dipped into a solution of sodium chloride the chlorine will be set free and bleach the tooth, but there are reasons why chlorine has a destructive effect on the tissues of the teeth, and there are reasons why "pyrozone" is much safer and preferable to use. In the instance above given electrolysis occurs primarily and cataphoresis secondarily. Other applications of this principle will suggest themselves to the reader.

What is the actual method of procedure in applying the cataphoretic principle for bleaching ! We would take an aqueous solution of pyrozone twenty-five per cent., and add to it a little phosphate of soda to make it, if desired, a good conductor and then apply it by the positive electrode to the tooth which is to be bleached. The negative dispersing electrode being in place the current is turned on very gently and before the milliampère meter will indicate the passage of any current, the patient will probably say, "I feel the current and it gives pain." So it does at first, but by leaving the current where it is the pain dies away ; the current may then be increased and the application can be continued in that manner. Half a milliampère, or possibly a milliampère of current, will drive the "pyrozone" into the dentine of the tooth if the enamel is broken at any spot, and cause the desired bleaching effect.

In conclusion, a differentiation between the various stains which call for bleaching should be made.

The most perfect success is when this stain is purely from transfusion of blood. If perfectly fresh, as where an arsenical application causes rupture of the blood vessels in the pulp, the blood passing into the tubuli, the color of the tooth may be thoroughly restored by merely packing pyrozone, 25 per cent., into the cavity and sealing it in for 24 hours more or less. Older blood-stains require a more powerful agency ; such is supplied by electricity.

Metallic stains cannot invariably be removed from teeth by any method known.

Often, in attempting to remove an organic stain, a metallic stain may be produced,—hence the necessity for removing gold or other metal fillings before releasing any chlorine in the tooth, otherwise the chlorine will act on the gold and there will be thrown down a metallic purple stain.

There are of course numerous organic stains aside from those caused by blood transfusion. Putrescent pulp causes organic stains, which are removable by powerful chlorine liberations, provided no coagulants have been previously used.

Failures may be said to be due to two causes—First, the stain may be metallic—as from metal posts containing nickel ; this stain is green.

Copper amalgams produce a green copper-colored stain ; steel or iron —*i.e.*, rust—produces a brown stain. Gold, acted on by chemical agents, as for instance chlorine, produces a purple stain. Some amalgams may throw down a chloride of silver. Second, when organic stains have been made permanent by coagulants. In these cases this coagulation may be quite superficial—if so, remove mechanically a part of the tooth substance, after which the bleaching may be successful.

In cases when it is important not to remove the gold filling before bleaching, the gold should be coated with chloro-percha, especially if the gold filling protrudes into the cavity, as often occurs.

In this latter case the gold should be protected inside of the cavity as well as outside. This point as well as others relating to bleaching is exemplified in the subjoined case furnished to me by Dr. M. L. Rhein.

Mrs. S., æt. about 35. Superior left lateral incisor very much discolored, history of pulp removal 10 years prior in San Francisco, at which time root was filled and an anterior approximal gold filling inserted. This filling was found to be in perfect condition and tightly knuckled against the central. On either side of the cuspid a bicuspid had been permanently bridged into position and were in splendid condition. On this account, and taking into consideration the perfect condition of the gold filling, it was decided not to remove the filling. The rubber having been adjusted over the single tooth a new opening was drilled into the lateral at the palatal ridge until it entered the gutta-percha filling in the root. This was found contaminated with a slight odor, undoubtedly the product of decomposing organic matter in the tubuli. The new opening also exposed the gold filling on the inside of tooth. This was coated with chloroform and gutta percha, not only on the inside but on the outside, so as to avoid possibility of any direct action on the gold from the current. The cavity was then filled with an aqueous 25 per cent. solution of pyrozone, a little soft rubber tube slipped over the tooth, ligated at neck and ligated around application at cutting edge of the tooth, after this bag had been filled with pyrozone. The anode was then finally introduced into the root of the tooth. Eighty volts of current was used in this way without patient experiencing any sensation whatsoever. The milliampèrage amounted at the close to only $\frac{2}{5}$ and the current was kept on for 30 minutes. After one and a half years the tooth still retained its new color which closely matches the adjoining tooth.

The current has undoubtedly not only bleached the tooth but also made the entire interior of the dentine absolutely antiseptic.

CHAPTER IV.

ANTISEPSIS, OR STERILIZATION OF THE TEETH.

In an address delivered on March 24, 1896, before the Philadelphia Academy of Stomatology (at the solicitation of Dr. Edward C. Kirk, Editor of the "Dental Cosmos," whose interest in this subject is intense), I pointed out to the dental profession the importance of looking to the principle of cataphoresis as an aid in the sterilization of dentine. This would seem to be a field of usefulness quite as extensive, if not so striking to the imagination, as the anæsthetization of sensitive dentine.

There is considerable literature on the general subject of sterilization, showing that the protoplasmic fibrillæ which fill the dentine of the root after death of the pulp may undergo putrefactive changes and set up an irritative action with resultant pus formation about the root apex. The sterilization of the root is readily accomplished by cataphoresis and inflammatory results obviated. Present methods are only partly efficient.

The problem presents a number of phases. First, with regard to the sterilization of carious dentine in immediate proximity to the pulp. It has been a subject of much discussion whether it is a safe operative procedure to permit a layer of carious (infected) dentine to remain over the pulp as a protection to that organ and insert a filling over such a layer, or whether the carious process would still proceed, even though the cavity of decay was closed.

The desirability of permitting the carious layer of dentine to remain as noted grows out of the necessity for retaining the vitality of the pulp whenever possible. There is in the minds of many operators the belief that if the carious stratum of dentine covering the pulp can be effectually sterilized, such a layer affords the best protection possible for the pulp and should not be removed.

The eminent authority, Prof. W. D. Miller, of Berlin, believes ([1]) the integrity of the peridental membrane to be affected by the decomposition of organic matter remaining in the tubular structure of the dentine of the root after extirpation of the pulp and thorough filling of the canal. He says (p. 350): "We must bear in mind that the only decomposition which could take place in the dentinal tubuli is one which might be brought about by bacteria; in other words, putrefactive decomposition, or simply putrefaction. In the event of such a decomposition of the contents of the tubuli taking place, a great variety of substances might be produced, chiefly, however, ammonia ($N\,H_3$) sulphuretted hydrogen ($S\,H_2$), Hydrogen (H), carbonic acid ($C\,O_2$), a variety of acid and alkaline substances such as formic, lactic, acetic and butyric acids, carbonate of ammonia, propylamine, trimethylamine, etc., and finally the ptomaines.

"It must not be supposed, however, that all these substances would be produced in any one case. How

[1] See "Dental Cosmos," May, 1890, page 349.

many of them might be formed would depend upon whether it were a pure or a mixed infection—*i.e.*, whether the tubuli had been invaded by one or more kinds of bacteria."

This decomposition will naturally cause the generation of bad-smelling odors, and Prof. Miller says (p. 356): "The most probable and, I think, the only way in which gases might possibly be supposed to penetrate from the decomposing fibrils to the pericementum is by a process of diffusion. This, naturally, would apply only to such gases as are soluble in the fluids of the tubules. That an action of this nature does take place will be witnessed to by the fact that in drilling into a tooth containing a putrid pulp, *as we near the pulp-chamber*, the borings will sometimes be found to have an odor of putrefaction. I have not observed, however, that this odor could be detected from the more superficial layers of dentine, though Dr. Jenkins writes me that in chalky teeth he has noticed the odor soon after boring through the enamel. Now, it is quite possible that a similar action, in a diminished degree, may take place through the solution and subsequent diffusion of gases generated in the tubules themselves, though such an action would always remain insignificant when compared with the absorption of gases from the pulp itself."

While Dr. Miller's article on this subject is explanatory, he does not, however, deal with an important outgrowth of it, viz., in cases where death of pulp has occurred by natural causes and the whole dentinal structure is infiltrated with the products of pulp decomposition, ptomaines, mephitic gases, etc. In such cases, does not the sealing in of these materials in the dentinal tubuli by means of a filling in the root canal offer a menace to the future health of the pericemental membrane through the gradual osmosis of the tubular contents into the structure of the surrounding membrane? It would seem so, and that under these conditions a thorough sterilization of the dentine structure of a root is a *sine qua non* for the future usefulness of the tooth. The means so far placed at our command are embraced in the use of antiseptics placed in the root-canals and diffused by imbibition.

There are a large number of these antiseptics available for the purpose and in an article in the "Dental Cosmos" for May, 1891, Dr. Miller states that he had tested the following.

Chloride of zinc;
Bichloride of mercury, 5 per cent.;
Trichloride of iodine, 5 per cent.;
Pentachloride of phosphorus, 5 per cent.;
Double chloride of gold and sodium;
Double chloride of potassium and platinum;
Trichlorphenol;
Carbolic acid;
Lysol;
Peroxide of hydrogen;
Oil of cinnamon;
Oil of cloves;
Oil of peppermint;
Oil of wintergreen;
Pyoktanin;
Resorcin, 10 per cent.;
Benzoic acid, 10 per cent. alcoholic solution;
Absolute alcohol;
Thymol, 20 per cent. alcoholic solution.

In summing up his record of 354 experiments, Dr. Miller says: "The complete sterilization of cavities of decay, especially such as contain traces, or even considerable quantities, of carious dentine, requires much more time than we are accustomed to give it." Again, "The best results are obtained, as we should naturally expect, where rapidity of action is desired, by substances which are readily soluble in water."

Dr. Miller would be inclined to place at the head of the list of effective antiseptics for sterilization the trichloride of iodine were it not for its acid reaction; a five per cent. solution of bichloride of mercury is also powerful, but the use of this drug would seem to involve a slight discoloration of the tooth; peroxide of hydrogen is an agreeable antiseptic and will act efficiently, especially where the amount of carious dentine is small.

The ability to bleach a tooth-root throughout, *cataphorically*, by the use of peroxide of hydrogen, 25 per cent. solution aqueous or ethereal, or by any other so-called bleaching agent, is proof positive of the thorough chemical sterilization of the root so treated. Dr. Miller depended on imbibition for success in his experiments, but if cataphoresis is employed as a diffusing agent success will be more swift and sure.

There is, in addition to all this, the possibility of carrying medicaments into the peridental membrane for the treatment of acute infectious inflammatory conditions of that tissue. It seems to me that in the application of the cataphoric principle there is the promise of not only painless dentistry but of absolute thoroughness in the therapeutic treatment of pulpless teeth and the many disorders to which they are liable. We may then accept it as a fact, and one of prime and novel importance, that electricity by reason of its property of cataphoric action is a sterilizer of the tooth and of its surrounding tissue, and that in the case of a tooth thus sterilized alveolar abscess is not likely to occur. In this connection we will refer to further methods of procedure.

The hypodermatic syringe electrode, Fig. 35 will be found most useful. Zinc or other "soluble" hollow needles are introduced into the pulp cavity whose dentine is to be cataphorically sterilized and then a drop or more of a 2 per cent. solution of chloride of sodium or of bichloride of mercury is injected, a weak current turned on and the nascent oxychloride of the metal, formed gradually and on the spot where it is, electrically diffused. Or similarly, solid needles may be used if care is taken to previously inject a few drops of fluid into the pulp chamber, the object in both cases being to supply artificially for the corrosion, or solution of the metal, constituents of tissue like oxygen and chlorine not already in sufficient abundance in the dentinal tissue to be treated. The apical end of the root canal may be plugged by non-conducting material in the above procedures if sterilization is desired to be confined to the root alone. If, as I often do in practice, only a weak solution, 2 to 4 per cent., of hydrochlorate of cocaine be used as the injecting medium, the same result is attained together with the annulment of pain liable to be produced.

This entire branch of electric medicamental diffusion is treated most fully elsewhere. See Part IV. Chap. IV., and also the next chapter, Part V., Chap. V.

Antiseptics which promise the best results for electric sterilization from the point of view of both their germicidal and their conducting qualities are Peroxide of hydrogen (strong aqueous solution, see chapter on bleaching of teeth).

Peroxide of hydrogen (strong aqueous solution constituting also a two per cent. solution of chloride of sodium.

Chloride of Zinc.

Bichloride of Mercury.

Trichloride of Iodine.

Formalin.

And in short many other salts.

The choice of the antiseptic or medicament to be employed is greatly enlarged by using it as I have pointed out in Part III., Chap. I., in conjunction with a "fluid electrode" as I have called it.

CASE BY M. L. RHEIN.

The following is an account of an interesting and seemingly convincing instance of the efficacy of cataphoretic sterilization of a putrescent dentinal tract.

As the patient is a dentist, skilled in the accurate recording of dental data, I am enabled to give the history of the case prior to the time when it was given into my care, with a certainty which makes it reliable.

About twelve years ago, the right superior central incisor received a blow, which broke off the anterior corner. As the centrals were much longer than the laterals, both teeth were ground off with a corundum wheel, in order to avoid placing a gold corner.

The ground end of the injured central was exquisitely sensitive for the greater part of two years, which proves that the pulp did not immediately die as a result of the accident. It, however, did eventually die, because three years ago it suddenly developed an acute pericementitis.

Electric transillumination disclosed the fact that the pulp was dead, and an opening was made through the palatal plate of enamel, passing into the pulp canal. There was an effusion of bloody pus—affording temporary relief from pain.

The tooth was in such a condition at this time that it would not tolerate the presence of any of the medicated dressing used by the practitioner who had the care of the case, unless the outer opening was left unsealed.

These efforts to overcome the disease proved ineffective for several weeks, when the patient left town for the summer. About this time much was being said in favor of salol as a permanent root filling, and at the advice of a dentist residing at the summer resort, the patient permitted the root to be filled with salol and covered with gutta percha, which was tolerated, and the tooth was practically comfortable for over a year, though always responding painfully to percussion.

About this time the pericementitis returned in an acute form, and the case came into my hands. Upon removing the gutta percha, I found the entrance into the canal closed with a mass of salol, which, however, was easily removed ; this much wanted root filling, having dissolved away sufficiently to be loose in the canal, and entirely absent from the upper half of the root.

Bloody pus again escaped from the canal, and upon exploring, I became satisfied that some pulp tissue still remained near the root end, which being still attached through the foramen to the inflamed tissues beyond, responded so to the touch of a broach that it became necessary to use cocaine cataphoresis, before I could thoroughly cleanse the upper part of the root canal, which, however, was finally painlessly accomplished by this means.

The next step was to attempt sterilization of the dentine itself by cataphoresis.

The canal was thoroughly syringed with 1 to 500 solution of bichloride of mercury in peroxide of oxygen, and an electrode of chemically pure zinc was introduced, nascent oxy-chloride of zinc being thus forced into the dentinal tubuli, by the electro-chemical dissolution of the zinc electrode.

Usually when simple sterilization of the dentine is desired, the end of the root is sealed, so that the current cannot escape except through the dentine.

As there was unquestionably a dormant abscess at the end of the root, the electrode was made to touch the sides of the canal throughout and passed far up into the root, and the end of the canal was left unsealed, that medication might also affect the diseased tissues in the apical avea.

This was certainly accomplished, as considerable pain followed, increasing in force for several days, until it was so bad that $\frac{1}{8}$ of morphia was exhibited to induce sleep.

On the day following, the dressing of oil of myrtle which had been sealed it was removed for a few minutes to permit the escape of gas, and it was then replaced and tightly sealed again. At the same time an aqueous solution of iodine was applied cataphoretically on the gum.

From this time the tooth improved rapidly, and a complete cure was effected without further treatment.

CHAPTER V.

DIFFUSION FROM SOLUBLE ELECTRODES.

It will be recollected that in the chapter on electric diffusion from soluble electrodes in Part IV. there was an elaborate explanation of the principles involved in this method of treatment as applied in general medicine. It was shown that if the positive electrode is composed of a metal capable of being attacked by oxygen or chlorine (formed at that pole out of the tissue) then a new chemical compound would be formed at the point of application and that, this new compound would then be forced into the tissue. For example, if a copper needle should be the positive electrode the new compound thus manufactured will be oxychloride of copper and this compound is useful as a medicament.

The principle is applicable in dentistry as well as in general medicine, and many applications will suggest themselves to the practical dental operator. With zinc he could use an instrument and pass it to a certain spot and with the escharotic and destroying salt produced he could secure positive results. With copper less active salts are produced. Silver, if desired, can be used in the same manner and its salts are very active.

It is very probable that the procedure would be very useful as an aid in the treatment of pyorrhea alveolaris, that distressing and common trouble involving the formation of pus about the roots of the teeth and an attendant inflammation. As is well known the ordinary treatment is to remove thoroughly, where possible, all local possibilities for irritation and then apply a topical medication with astringent, detergent and stimulant drugs such as zinc chloride, zinc iodide, carbolic acid, caustic potash, dilute sulphuric acid and "pyrozone." In such cases there is a possible amelioration but always a probable recurrence of trouble.

If a zinc or copper needle insulated except at or near its point was made to penetrate the alveolar process and metallic electrolysis started by making the needle positive, there would be a diffusion of oxychloride of zinc or copper which would act favorably in allaying the inflammatory condition and dispersing the contents of an ulcer.

Dr. Rhein brought such a case to me and we made a copper spatula and passed it into the pocket that existed and passed into that tissue the oxychloride of copper staining the tissue green. This oxychloride of copper accomplished its mission and the result was most satisfactory.

In speaking of this experiment at a meeting of the First District Dental Society of the State of New York,[1] Dr. Rhein said : "When it comes to local anæsthesia we can make up our minds very easily ; but when it comes to the cure of chronic pathological conditions, as we find them in pyorrhea alveolaris and alveolar abcess, we know that a few ex-

[1] Meeting of December 10, 1895. See "Dental Cosmos," March, 1896, page 228.

periments are insufficient, and a few weeks' or a few months' experience is not enough to give us any reliable data or information. It opens up a field for the more thorough introduction of therapeutic agents to the seat we want to reach than anything that has been brought to our attention before, and I would especially call your attention to the point in regard to the use of chloride of zinc in this way. The application we get here is the freshly prepared zinc oxychloride in its nascent condition, where it unquestionably will be far more effective than chloride of zinc that has been lying about our offices.

PART VI.—APPLICATIONS IN MICROSCOPICAL WORK.

ELECTRIC STAINING OF TISSUE.

At the Fourth Annual Meeting of the American Electro-Therapeutic Association, held in New York in September, 1894, the writer presented a paper on the Electric Staining of Tissues, the principal points of which are given below. This paper is reproduced because it presents from another and fresh point of view general principles as well as a number of technical procedures which can be applied in actual practice.

Hitherto the staining processes essential to a differentiation of tissue elements by microscopic examination have been effected by direct staining actions and chemic reactions. The writer here presents a new method of staining, based upon the action of electric currents upon the tissue alone, and upon chemicals, or staining reagents absorbed by the tissue or within which they are immersed or brought into metallic or other contact. The chemicals may be initially staining or non-staining; the tissue may be in sections or in mass. This method thus opens out to histologic staining processes the entire field of electro-chemistry.

I have found that electricity acts to produce a differential stain :

1. By producing electro-chemic changes (which in themselves are stains) in the tissue itself.

2. By producing electro-chemic changes in tissue which give staining reactions to foreign chemic reagents.

3. By producing chemic decomposition of chemic compounds previously absorbed by tissue and capable of being decomposed by the current, and thus upon decomposition affording a stain consisting of one or more of the elements of the compound. (Example : iodide of potash, iodine stain) etc.

4. By a bleaching or by an intensifying reaction upon stains previously absorbed by tissue. Example : solutions of aniline colors ; methyl blue deepens at the anode, pales at the cathode ; congo red, deep blue at anode, pale or colorless at cathode ; phenolphthalein, gives violet stain at cathode in neutral solution of sodium sulphate. Many colors are bleached at cathode.

5. By producing decomposition of an electrolyte in which tissue is immersed and setting free a reagent which in turn acts upon tissue which has been otherwise untreated or which has absorbed another reagent or simply a stain.

6. By the electrolytic and cataphoric properties of the current upon metals kept in contact with tissue affording a direct or indirect stain. Example : oxychloride of copper (copper at positive pole) direct, same of zinc or other metals indirect invisible, but developed by reactions, or of silver salts developed by light, etc.

7. By the precipitation of finely divided metals

within tissue. Example : salts of silver and of gold, black and purple stains.

8. By the principle of electro-plating with solutions of metallic salts of copper, silver, gold, etc., and by other obvious methods which need not here be outlined.

The peculiarity and novelty in the electric staining processes here briefly outlined and all of which the writer has tested with success, is that, whereas most of the staining processes in practice act simply by chemic selection, or chemism, this acts under the directive influence of the flow of the electric current, and hence selects pathways dependent upon the respective conducting capacity for current, of the tissue components. That is to say, the electric conductivity of tissue varies according to its composition and the differential stain varies correspondingly. The parts of a tissue most saline are the best conductors ; they therefore are the most acted upon. An axis cylinder is, for instance, richer in salts than its medullary sheath ; it therefore will conduct the most current and will be the most deeply stained, or most completely bleached, etc., according to the method employed.

A newly formed connective tissue or a tissue formed of recent exudates will be more saline than a later stage of the same tissue, and therefore take more stain because it conveys more current. The same facts hold true of both in normal and in neoplastic growths. This variation of stain according to variation of conductivity of tissue affords a new basis for differential staining. As a general principle it holds good in any one of the eight methods outlined.

I am engaged in further investigations in two other directions of study which this method makes possible :

1. To trace fibrils, fibres, tracts of the same or of diverse tissues throughout a tissue mass, as in the differentiation of connective tissue, nerve fibres, etc. To locate cells and to trace gross tissue elements, as for instance, in a frog's leg the muscles, nerves, arteries, veins, etc., all of which conduct in a varying manner and stain in proportion to their conducting power.

2. To establish by the comparative depth of the stain, the relative conductibility of tissues, a question of great importance electro-physiologically and in electro-therapeutics. The muscle and the blood being the best conductors stain the most deeply.

A few minor points should be noted :

a. That when an electro-chemic decomposition is established within a tissue, saturated for instance by a binary compound like iodide of potassium, the staining element set free (iodine), is in its *nascent* state and hence more active.

b. That tissue acted upon by current is itself rendered more active to take a stain.

c. That the conductivity of the electrolyte or fluid in which the tissue is immersed must be carefully considered ; if it is too good a conductor the action is confined to the immediate neighborhood of the electrodes ; if a less good conductor, the action may extend even to a neutral centre.

d. That the voltage required to effect chemic decomposition varies greatly with the reagents employed. While 1½ volts is required to decompose water, copper salts may be decomposed by a small fraction of 1 volt.

METHODS OF PROCEDURE.

About a 30 cell battery (for the resistance is often high) a rheostat and a milliampère meter are the first essential requisites; fine platinum wire, absorbent cotton, a shallow platinum dish to connect to one or the other pole and the usual chemic and staining reagents are further requisites.

My most satisfactory preliminary experiments were made by placing a section or teased specimen of fresh tissue upon a microscopic slide beneath the usual cover-glass and watching the electric staining as it progressed; fine platinum wire or absorbent cotton wet with any required solution constituted the electrodes. By using this preliminary method, a drop of the staining fluid or of the chemical to be decomposed could be conveniently placed at either the positive or the negative pole and the reaction observed.

One of my first surprises and disappointments in thus watching under the microscope the deposition of what to the naked eye appeared to be deep green and black stains respectively from metallic copper and iron, was to find that the coloration was due in reality to amorphous granular mass deposited in the tissue, and not to a soluble salt which actually stained the tissue. The deposit appeared to be of green and black non-crystalline precipitates. This fact is interesting in relation to the treatment of tumors, ulcers, sinuses, mucous membranes, etc., by "metallic electrolysis," so-called, for it would thus appear that in this electro-therapeutic procedure, foreign substances in massive and not in soluble form set up irritative reactions.

Several examples, illustrative of many, of treating sections are here given.

The apparatus was as outlined. The prepared section was laid in the shallow platinum dish, connected to the positive or negative pole as desired, while the other pole was constituted of a tightly rolled tuft of absorbent cotton, cut off squarely at one end by scissors, about one inch long and connected to a platinum wire at the end farthest from the section. It will be seen that since the thin section rested upon the platinum, while the cotton interposed a considerable length between it and the next *metallic* conductor, the section would be in the field of the most intense electrolytic activity of the *electrolytic* circuit. That is to say, if, for instance, the action of the positive pole is required, it is gained as the platinum plate and the main action of the negative pole is removed to a distance, namely to the vicinity of the platinum wire ; or *vice versa*.

Experiment 1.—A section of spinal cord, preserved after the usual manner in bichromate of potassium solution, was washed in distilled water and laid upon the platinum plate, positive pole, cotton tuft negative pole. Diffuse chromic acid stain produced with 5 milliampères of current flowing five minutes.

Experiment 2.—Stain for amyloid. A section of amyloid liver, hardened in alcohol and soaked over night in a saturated solution of iodide of potash, was washed quickly in distilled water, placed upon the platinum plate, positive pole and the cotton tuft (negative pole) wet with a 1 per cent. solution of common salt applied to it. Current strength 10 milliampères, effect almost instantaneously a deep iodine stain. The specimen is again washed and preserved in glycerine.

Control experiments were made with the same specimens treated with solution of biniodide of potash (Gram's solution).

The specimens stained electrically were much superior ; they were translucent, like clear amber, while the others were comparatively diffuse, cloudy and "muddy."

Other binary compounds, easily decomposible, gave in the same manner instantaneous and clear stains. There can be no question about the superiority of the method in this and similar instances.

Experiment 3. — Similar sections to those in Experiment 2 were soaked over night in a mixture of iodide of potash and starch water and treated in the same manner. While the starch and the iodine reacted in the solution outside of the specimen, the specimen itself gave simply the iodine reaction.

Experiment 4. — Similar sections soaked over night in a mixture of iodide of potash, sodium chloride and starch water also gave simply the same iodine reaction.

Experiment 5. — Amyloid kidney, previously hardened in alcohol, was stained in an aqueous solution of methyl-blue about five minutes, washed and placed on the platinum plate *negative* pole ; the cotton tuft, positive pole ; current strength 10 milliampères during ten minutes. Examined microscopically, the capsule, connective tissue and Malpighian bodies are very intensely stained as compared with the rest of the section, which was of a brownish red color. Thus the connective tissue and the amyloid degeneration retained the blue stain, while the reticulum and lymphoid cells were not so deeply stained and were of another color. The pursuit of this electrolytic process is particularly interesting in relation to staining bacilli and some of the results are most promising. An anodal and cathodal compartment, separated by a porous diaphragm, is found useful in some cases.

I have every reason to believe that the introduction of this principle of electrolysis in staining specimens for microscopic examination will be the means of bringing to our view histologic relations now unknown to us, and it is in this hope and expectation that I venture to call attention to the method.

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